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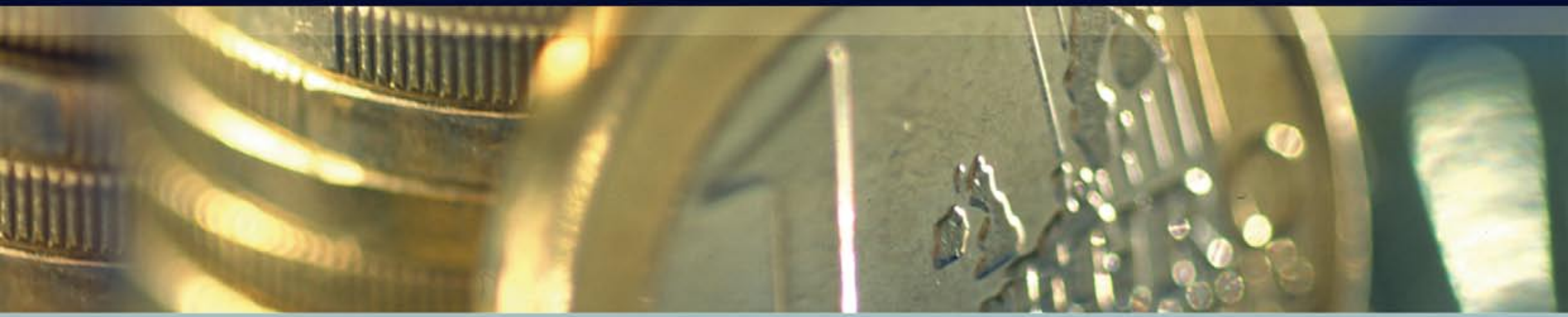

The Diffusion/Adoption of Innovation in the Internal Market

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The Diffusion/Adoption of Innovation in the Internal Market

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The Diffusion/Adoption of Innovation in the Internal Market

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Executive Summary

In the Lisbon Strategy, the Member States and the European Commission recognised that increasing innovation is a key to respond to the challenge offered by globalisation. When studying this innovation process, part of the literature understands the technological change process into three distinct phases: the invention process (whereby new ideas are conceived), the innovation process (whereby those new ideas are developed into marketable products or processes), and **the diffusion process** (whereby the new products spread across the potential market). The diffusion stage is where the impact of the technological change on the economy takes place and where it has to be evaluated.

In such a context, **public policies play an important role**. Among such policies, the full implementation and enforcement of internal market rules, the **Single Market Programme,** is essential to reap the benefits and the innovation potential of the large European domestic market. The impact that IM regulations may have on the adoption of innovation is likely to be channelled through the role that the Internal Market (IM) regulations have on some macroeconomic dimensions. For example, the IM EU regulations are aimed at fostering the free movement of goods and people and at increasing competition and cooperation across member states. These dimensions, which we will call **"transmission channels",** are those **directly affected by the IM regulations** which **will have an impact on the diffusion and adoption of innovation**.

In particular, reinforcing **cooperation** or **trade** is expected to positively impact the possibility that blueprints or innovation spill over from firm to firm as well as from country to country. At the same time, recent empirical and theoretical literature argues how more **competition** and neck-to-neck market structure may incentivize innovation and therefore also affect positively the possibility of diffusion of new innovations and technology across countries.

In this context, **the main aim of the present study** is to analyse the drivers of innovation adoption by developing proper measures able to proxy for innovation adoption and IM regulations, the identification of the channels through which innovation adoption takes place and the estimation of the main determinants of this adoption process in the IM.

More specifically, the aim of the study is fourfold:

1) Providing insights on the magnitude and nature of innovation diffusion at the EU level
2) Assessing the impact of IM on diffusion
3) Giving preliminary analysis of the impact of diffusion on productivity
4) Providing the reader with policy recommendations to foster innovation adoption.

Using innovation survey to account for innovation diffusion

The innovation surveys of the EU (Community Innovation Survey) provide us with three broad groups of measures:
- Innovation inputs: R&D, other expenditures related to innovation such as acquisitions of patents and licenses, product design, training of personnel, trial production, and market analysis
- Innovation outputs: introduction of new products or processes, organizational changes and market innovations
- Modalities of innovation: sources of information, perceived strength of various appropriability mechanisms, and the cooperation in research and innovation.

Main limitations are due to some statistical problems raised by the data: (i) answers concerning qualitative items can be subjective; (ii) quantitative items are not perfect (approximated); (iii) statistical secrecy limits sometimes the information precision.

Definition of innovation diffusion/adoption. In the CIS survey, the definition of innovation covers both the creation and the adoption of innovation. We consider that innovation adoption occurs as soon as the interviewed firm declares that its process or product innovations have been developed "Mainly together with other enterprises or institutions" or "Mainly by other enterprises or institutions". **Therefore, our definition refers to innovation adoption and does not allow to address all the issues associated to the process of innovation diffusion.** The magnitude of adoption is measured as the share of adopting firms among innovative firms. Innovative firms are those who innovate on product or process or both and who have ongoing or abandoned innovation activities.

Data base building

This research study is based mainly on two samples extracted from the CIS3 survey which concerns innovative activities carried out between 1998 and 2000. The micro dataset has been provided by EUROSTAT while the macro dataset have been downloaded from the EUROSTAT website.

There are significant differences between these two databases in terms of the number of countries represented and the sectoral disaggregation level. In order to have the best country coverage, the final database was built from micro and macro data following the availability of information according to countries. The use of micro data has been preferred for the countries for which data were available in the two datasets. This choice is due to the fact that, using the macro dataset, we face a double counting problem in the construction of the indicators of innovation diffusion/adoption.

Finally, the database contains 22 countries. The source is micro dataset for 15 of them. For the other 7 countries, the risk of double counting is present because of the use of macro dataset. For this reason, macro data have been rescaled. Comparisons of the rates before and after the rescaling procedure allows us to check the robustness of the method and to see that a substantial part of the gap between after and before rates comes from the figures of financial sector. We decided thus to drop it from the calculation of the indicators. In conclusion, **the database covers 22 countries and 6 sectors**.

Main statistics of innovation diffusion within the EU

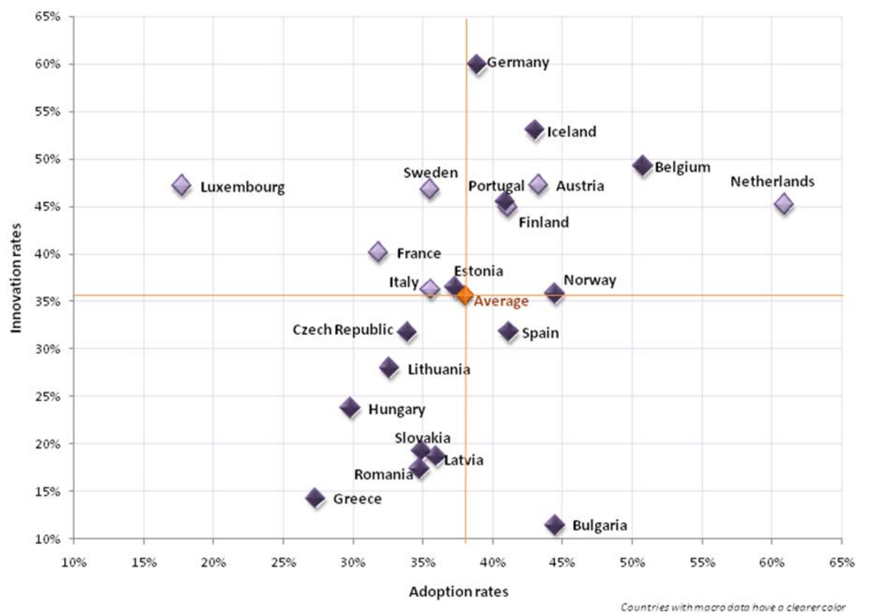
1. ***39% of EU innovative firms relies on innovation adoption, whereas the remainder "generates" internal innovation. However, this rate greatly varies according to countries and sectors*** [Figures 1 and 2].

At the country level, the maximum value of adoption is observed for the Netherlands with a rate of 61%, followed by Belgium with 51%. On the opposite, the minimum value is observed for Luxembourg with 18% which is particularly low if compared to other countries since all other values are between 27% and 44%.

Generally speaking, countries with the highest level of innovative activities are also those exhibiting the highest rate of adoption. It seems that fostering innovation activities may also be associated with spillover effects leading to higher levels of diffusion and adoption of innovation.

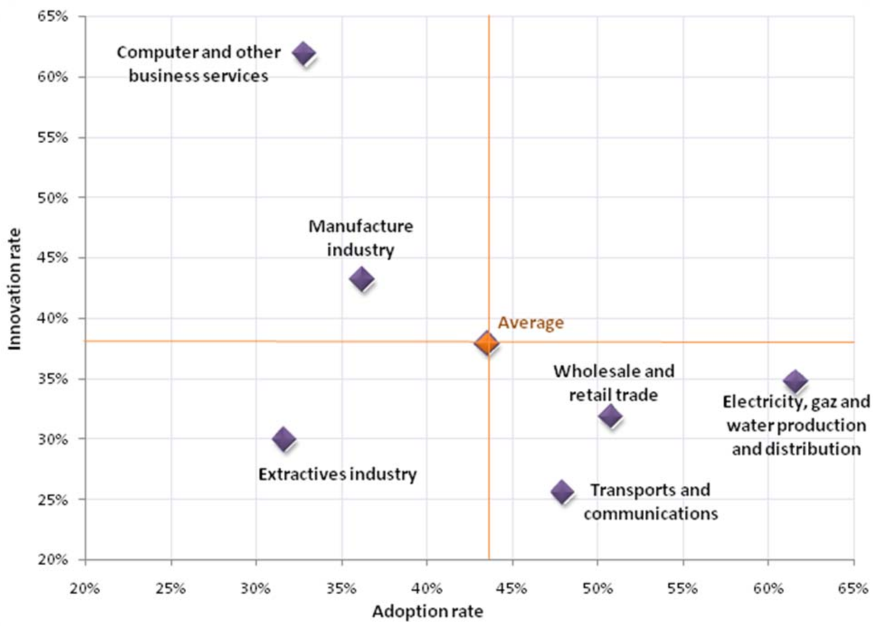
Innovation adoption is also far from being homogeneous across sectors ranging from 32% in Mining and quarrying and 62% in Electricity, gas and water supply.

Figure 1. Innovation and adoption rates by countries



Note: The average adoption rate given on the graph (and on all the following graphs) is computed as an average of the country rates and not as a global rate computed from the country and industry database.

Figure 2. Innovation and adoption rates by sectors



2. ***For all the countries, the adoption rate is higher for process innovation (41% on average) than for product innovation (28% on average). This contrasts with innovation rate which is more product oriented: 24 % of EU firms make process innovations whereas 28% perform product innovations*** [Figures 3 and 4].

Figure 3. Product innovation and product adoption by countries

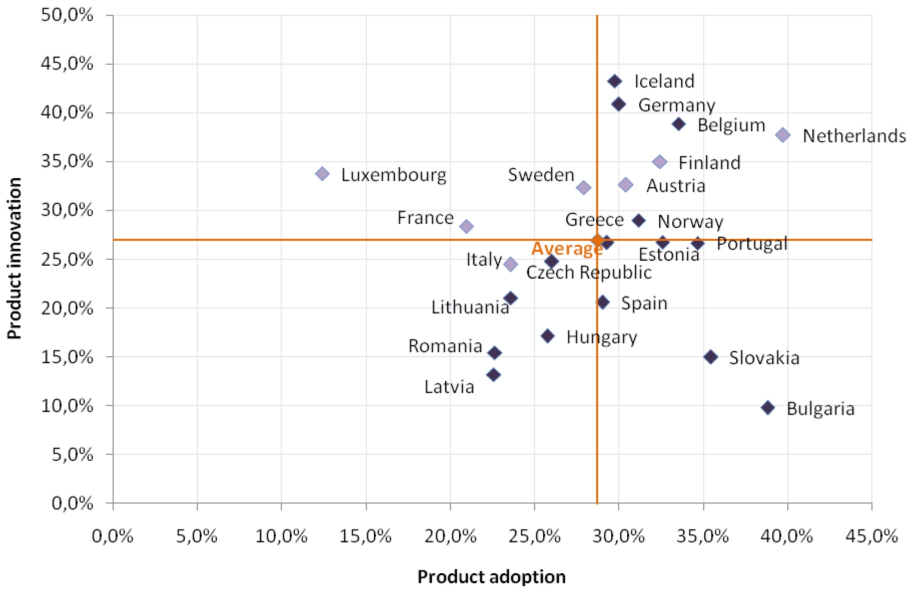
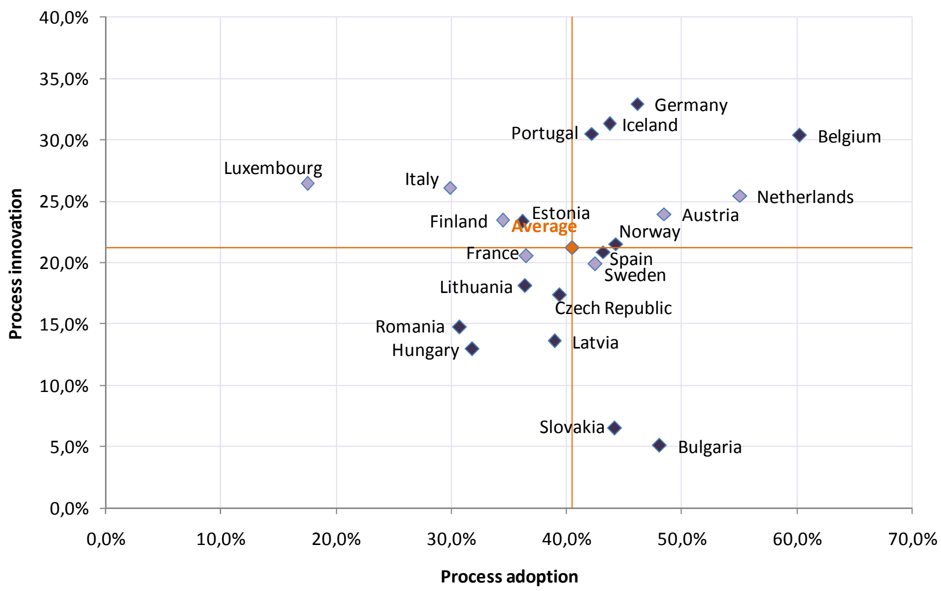


Figure 4. Process innovation and process adoption by sectors

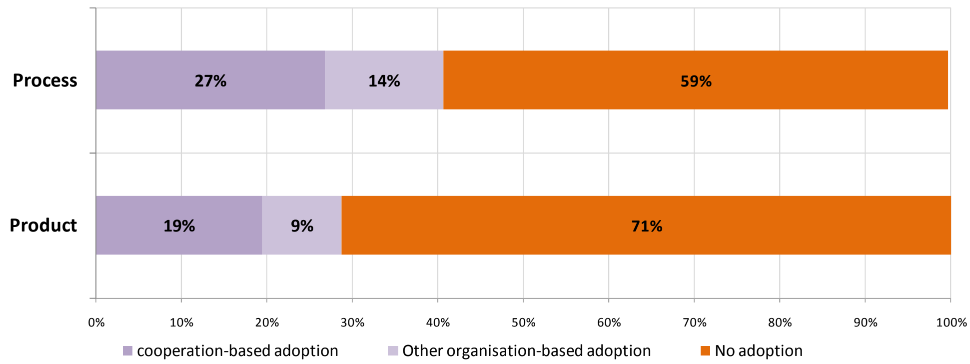


Such a result suggests that process innovations need interactions between the firm and its suppliers and/or clients to be successful. Moreover, process innovations are often the results of supplier or client needs. This would encourage cooperation or outsourcing strategies to develop this type of innovation.

3. ***Cooperation activities are driving innovation adoption at the EU level while the acquisition of innovations from external innovators is a less important source of adoption of innovation (both process and product)*** [Figure 5].

The nature of innovation adoption can differ according to the way adoption occurs. In particular, adoption may result from adoption of external technologies but it also relies often on the joint production of innovation. This last pattern is more frequent than the first one.

Figure 5. Innovation adoption rates in the EU



4. ***The comparison between two waves of the CIS (1998-2000 and 2000-2004) shows that the average adoption rate increases between the two periods.***

This is mainly due to process adoption that increases by 4.2 points of %. On the opposite, the product adoption remains stable (slight decrease of 0.1 point of %).

Moreover, it appears that **the increase in adoption is not necessarily associated with a global increase in innovation**. Process adoption growth does go together with an increase in process innovation (+6.3 points of %) whereas stability in product adoption is associated with a decrease in product innovation (-2.3 points of %).

This increase in the adoption rate can be observed in most countries and for several sectors. Among other factors, **the development of the Internal Market may at least partly explain this evolution**. The econometric investigations made in Part III of this report assess the role played by the different determinants, and the specific role of IM.

Assessing the role of Internal Market on Innovation Diffusion: Econometric study

From our literature review on innovation diffusion/adoption and based on a theoretical model of productivity, the causality among the variables we used for our empirical research on innovation diffusion goes as follows:

Internal Market reforms $\Rightarrow$ Channels (Cooperation, Competition, Trade) $\Rightarrow$ Innovation diffusion

In order to correctly disentangle the **direct effect** of the IM on the **transmission channels** (Cooperation, Competition and Trade) and the **indirect** one on the degree of innovation adoption we implemented a two-stage estimation procedure by using Instrumental Variables estimators. In a first stage we define the impact of some major IM regulations on cooperation and competition and trade across EU countries. The results of this first stage show how different IM regulations are important determinants of these three transmission channels. We observe that cooperation is, for instance, positively influenced by the IM proxies such as "regulatory and administrative opacity" which in turns are composed by sub-indicators referring to the degree of "communication and simplification procedures" and of the "licence and permit system" in each EU country examined. Also, human capital and trust are found to be drivers of cooperation across EU firms (both across countries and within the same country) pointing that **regulations leading to easier communication are going to boost cooperative innovation.**

Competition is driven by several IM regulations. We show how those members that implement more EU directives in the specific areas of competition are also experiencing lower markup levels and therefore stronger competition. Similarly, the reduction of public aids and subsidies as well as the improvement of the administrative procedures (in order to open a business in particular) foster competition.

Finally, trade flows are notably impacted by the **regulations which improve its easiness of trade as well as by a reduction of the intrusiveness of national governments in policy areas such as price controls.**

In a second stage, we address whether innovation adoption rates significantly depend on the degree of cooperation, trade and competition; the "transmission channels". Some control variables have also been included in the econometric analysis: legal structure and IPR as well as sectoral and country dummies. Estimations have been computed using an econometric model whose dependent variable is total innovation adoption as well as its possible disaggregation into sub-categories (product/process innovation adoption, made in cooperation or in isolation i.e. by direct acquisition of external innovations).

Results show that the impact of the transmission channels on innovation adoption is especially important for Cooperation, leaving Trade and Competition as apparently minor channels of innovation diffusion (and especially depending on the type of innovation adoption under examination). The overall result argues that **more cooperation across firms and countries is going to be beneficial to the process of innovation adoption**. Behind this result, however, lies a more interesting consideration to be done on the impact of IM regulations on the total innovation adoption share. In fact, for example, what we are measuring here is the indirect impact that IM regulations (those which foster and boost cooperation) are exerting on the level of total innovation adoption through the cooperation channel.

Hence, some *caveats* should be stressed. Whereas Cooperation, and all the IM regulations which boost it[1], seems to be the main determinant of innovation adoption whatever the type of innovation diffusion, the effect of the other two channels (Trade and Competition) varies according to the type of innovation adoption (made in cooperation *vs* in isolation or concerning product *vs* process).

In fact, the second channel which shows up to be statistically significant is that of competition[2]. This is only significant when we specifically look at the product innovation adoption made in isolation (directly acquired by the an external firm). The coefficient is negative implying that **more competition (lower markup) is going to foster more product**

[1] The IM regulations and other important factors affecting the Cooperation level across firms and countries are Trust, Communication and Simplification Procedures and Human capital.

[2] The IM regulation governing the first stage for competition are found to be: State control, Public Ownership, Sectoral and ad Hoc State Aid and other measures of Subsidies of the Govt. as well as the bureacratic quality of each member state.

innovation adoption on average. This result is consistent with empirical and theoretical models where neck-and-neck competition fosters innovation.

Trade seems to be of minor importance in igniting innovation adoption. In fact it shows to be statistically significant only for product innovation adoption made in isolation but with a negative coefficient. This may be due to the specific way we built the innovation adoption indicators as a ratio of adoptive firms over the total innovative firms. Hence, trade may be working both on creation and adoption of innovation making difficult to disentangle its partial effect.

Apart from these three macro-economic channels, micro-economic analyses have pointed out other determinants of innovation adoption: the innovative strategy of firms and especially, when they innovate, their choice to innovate on their own or to acquire external innovation.

Different specifications have also been tried where we inserted a considerable number of control variables. In particular, we find that **legal structure and protection of property rights, once we account for the transmission channels, reduces the speed by which innovation spills over across firms and countries**. However, this result should be considered within a broader context where the legal structure and the protection of property rights (especially of IPRs) may lead to an increase in the innovative activity and so, to a potential increase in adoption, which is not captured directly by the regression analysis.

The econometric results proposed in the report for a variety of variables are sometimes not statistically significant at conventional significance levels but still marginally significant. Hence, extra care should be used in the interpretation of these results even if, in many cases the coefficients seems to show the correct sign. Further analysis is indeed needed in order to get more robust estimates. This issue could be tackled by using more recent and complete databases such as the CIS4.

Empirical verification of the relationship between innovation adoption and productivity

The study aims also at **providing an empirical verification of the relationship between innovation adoption and productivity**, by means of descriptive statistics. The productivity indicator we use is labour productivity from Eurostat, that is, gross value added per person employed.

1. ***The average productivity level is positively and significantly correlated with the innovation adoption rate, although showing a moderate correlation coefficient of 27.1%. This confirms from an empirical point of view the theoretical link between innovation adoption and productivity.***

However, we do not observe such a clear relationship for the countries with low levels of productivity. It seems therefore, that **the adoption of innovation affects productivity in those countries that already experience high levels of productivity**, probably due to the presence of other intangible assets such as human capital, social capital and entrepreneurship, i.e. **absorptive capacities**[3].

2. ***When considering separately product and process innovations we observe a statistically significant positive relationship (correlation coefficient of 31.3%) for product innovation adoption vs productivity, whereas the relationship between productivity and adoption of process innovations is not significant*** *(correlation coefficient of 12.1%).*

3. The analysis at the sectoral level highlights that the only case where we observe a significant positive correlation between productivity and adoption rate is in the Manufacturing sector.

[3] The standard technology catching up framework would suggest that countries far away from the technology frontier should be those more relying on innovation adoption. However, recent empirical literature (e.g. Benhabib and Spiegel, 1994 , 2005) shows that the catch-up of follower economies is not immediate but it only works when also these economies are endowed with specific (and minimum) absorptive capacities. When, instead, they lack these caractheristics, follower countries are shown to diverge. This rationale may explain our result in the correlation analysis between productivity and innovation diffusion.

In the other sectors, the correlation between productivity and innovation adoption is not significant. Therefore, we could think that **an important part of the overall correlation obtained before may be due to the existence of national correlations between productivity and innovation adoption**, which vanishes once we take into account different countries with different productivity levels and behaviours.

With the information for all countries and sectors we also investigated the relationship between innovation adoption and productivity growth (for the years 2001-1004). Our results show a non-significant coefficient of correlation with a negative value of -2.5%, in contrast with the theoretical assumptions (which would instead point to a positive correlation between the growth in productivity and adoption rates).

If we carefully review this result, two differentiated patterns seem to be observed according to the productivity growth rates of two different groups of countries. Those with growth rates above the average (Czech Republic, Slovakia, Estonia, Lithuania and Hungary) present a low adoption of innovation (the exemption is Bulgaria, with a high rate of productivity growth and high innovation adoption levels). On the other hand, the rest of countries display productivity growth rates below the average but without a clear correlation with the level of innovation adoption, since some of those countries present innovation adoptions above the average (Spain, Italy, Austria, Finland, Norway and Belgium) whereas others are below the average (Sweden, France, Portugal, Romania, Germany and Luxembourg). Therefore, the global negative relationship is due to the existence of these two different patterns of productivity growth rates, whereas within each group such a negative relationship is not observed.

Main conclusions and related policy recommendations

Before summarizing the main conclusions and considering their implications for policy makers, it is important to recall that the results have been obtained through a statistical analysis which may suffer some limitations.

1) Our measure of diffusion focuses on adoption, and therefore does not allow us to cover the whole diffusion process.
2) The database used is of weak quality (due to double counting problems and missing observations).

Therefore the policy recommendations should be considered with the due caution.

1. The study stresses that the main determinant of innovation adoption is **cooperation**. The econometric study allowed us analysing what the drivers of cooperation are from an Internal Market point of view. In particular, a key role seems to be played by the level of trust among people within each country, by the improvement of communications and simplification procedures, as well as by high educational levels. Therefore, policies contributing to **reinforce social trust** within/across countries especially through "**communication and simplification procedures**" (within the broadest proxy for "regulatory and administrative opacity") are likely to develop **cooperation** among firms and consequently to achieve **higher levels of diffusion/adoption** and increase in the **efficiency of process innovation adoption. Strengthening Human Capital** also appears as an efficient way **to enhance cooperation and consequently innovation adoption**.

2. Along with cooperation, but to a much lesser extent, **competition has been identified as another factor likely to affect product innovation adoption directly acquired by external firms (in isolation)**. As a result of the impact of competition on product innovation adoption, also productivity levels seem to be affected by differences in the competition level (product, rather than process innovation adoption is shown to impact productivity levels). Econometric estimates of the main drivers of competition show that competition is negatively affected by the level of public ownership within each country, by the level of transfer and subsidies, as well as by the administrative burdens. As a consequence, **policies reducing unnecessary rents, administrative burdens and national government controls should be implemented at the EU level in order to achieve higher levels of competition** and eventually higher shares of innovation adoption of and eventually productivity.

3. The third determinant of innovation adoption which emerges as statistically significant in this study is the level of **trade**. Its negative impact on adoption seems rather small and limited to product innovation made in isolation. The result is however of difficult interpretation since this channel is probably affecting both innovation creation and adoption at the same time. Concerning the determinants of trade, we have shown that the higher the "price controls" and regulations within each country, the lower the level of trade. The composite index "Freedom to trade" (OECD) exerts on the contrary a positive impact on trade. Therefore, **policies reducing price controls or the national government controls on the transport sector** are likely **to foster international trade. This would however favor the "generation of innovation" more than the "adoption of innovation"**

4. As a result of the experience working with the CIS dataset in order to study the innovation diffusion process in the EU countries, we can offer some **suggestions for future implementation of CIS data and questionnaires:**

- It is important for policy makers to dispose of precise information about the diffusion/adoption of innovation. In spite of the important limitations of the CIS data in measuring diffusion and adoption, these data are still probably the most relevant tool that is available at the moment, and the only one likely to provide a general overview of these processes at the EU level. Some improvements in the survey may allow coping with the main limitations highlighted in this study. In particular, **collecting more quantitative information** about the way innovation is produced would be of great help in econometric and economic analysis. For instance, the shares (or the intensity) of innovation made in isolation, in cooperation or developed by others should be registered directly for each case. Moreover, the usefulness of the CIS data comes from the possible crossing of several items. Most of these crossing cannot be implemented using aggregated data available on Eurostat website while micro data are needed. **Increasing the availability of data at the micro level** (which for now is restricted to only few EU member states) would thus provide more tractable information and richer analysis of the adoption process and its determinants.

- A second suggestion would be that of **trying to eliminate the subjectivity in some of the questions of the CIS** questionnaire in order to be able to better define categories and quantify the answers. Some of the present questions, for instance, ask to define whether an innovation has been developed "mainly" by other firms of in collaboration. This subjectivity impedes to measure or consistently define the same processes across countries due to the possible biases related to the subjectivity of the answer. As suggested above, this subjectivity may be partly solved by asking the share of innovation that relies on each type of innovation and not as a result of the interpretation of the word "mainly".

- **In the present CIS questionnaire, the items allowing to deal with innovation adoption question, do not provide separated information about diffusion occuring within the country and across countries.** A revision of this question may solve directly this problem.

- **EUROSTAT should provide a technical annex on how the macro data** provided in their web-site **have been treated starting from the micro data**. Aggregation issues and different methodologies may be in fact a problem for researchers which have to know, first, how the statistical office treated micro data in order to obtain macro ones.

- So far in CIS we know if a firm has made innovation or adoption but not **the intensity of such processes**. Therefore, a firm making some innovation but at a very small scale and a big firm making a lot of innovation are, at the moment, considered equally. Both of them would answer yes, and this is all the information given in CIS. We have information about the share of turnover due to innovation. But this is only available for product innovations. This can hardly be asked for process innovations or other types of innovation (organizational, marketing, etc). **However a question (even qualitative) about the importance of innovation in the firm activity could be added**. This question should be asked for each type of innovation (innovation made in isolation/ innovation made in collaboration / innovation made by others).

- Finally, in addition to these marginal changes, it may be useful to constitute a working group to suggest improvements of the CIS in order to better account for innovation diffusion. This working group might suggest for instance a set of items, in order to explicit and validate the different channels of transmission between IM and diffusion of innovation.

Abstract

The implementation and enforcement of internal market rules, the Single Market Programme, is likely to foster innovation adoption, and to reap the benefits and the innovation potential of the large European domestic market. In this context, the main aim of the present study is to analyze the drivers of innovation adoption by (i) developing proper measures able to proxy for innovation adoption and internal market regulations, (ii) identifying the channels through which innovation adoption takes place and (iii) assessing the main determinants of this adoption process within the internal market (IM). An original model is derived from the theoretical literature on innovation diffusion. This two stages framework relies on the following assumption: the impact that IM regulations may have on the adoption of innovation is likely to be channeled through the role that the Internal Market (IM) regulations have on some macroeconomic dimensions. Special attention is put on three specific channels: cooperation, competition and trade. Results show that the impact of the transmission channels on innovation adoption is especially important for Cooperation, leaving Trade and Competition as apparently minor channels of innovation diffusion (and especially depending on the type of innovation adoption under examination). The overall result argues that more cooperation across firms and countries is going to be beneficial to the process of innovation adoption.

Introduction, objectives and outline of the report[4]

[4] AQR acknowledges the support provided by Esther Goya, Sandra Nieto and Diana Ordad for editing the document. CREUSET acknowledges the assistance given by Linda Bouhidel, Sylvie Chalaye and Jean-Pascal Guironnet.

Introduction, objectives and outline of the report

The “First Action Plan for Innovation in Europe”, launched by the European Commission in 1996, clearly states that, in spite of its excellent scientific capabilities, Europe's level of innovation is lower than that of its main competitors. At a time when **innovation is the main driving force in economic competitiveness** (as asserted also by the tradition of economic growth models starting from Romer, 1986), this has serious implications for employment and economic prosperity in Europe. Innovation has therefore become a priority of European countries in order to start and sustain the engine of economic growth.

In the Lisbon Strategy, the Member States and the European Commission recognised that increased innovation is a key to respond to the challenge offered by globalisation. Success in the global economy is determined by firms’ ability to give answer to changing views, needs and structures. Innovation is an opportunity that will enable Europe to create new markets and reinvent new ones. In such a context, **public policies play an important role**. Among such policies, the full implementation and enforcement of internal market rules, the **Single Market Programme,** is essential to reap the benefits and the innovation potential of the large European domestic market.

The Single Market Programme, as set out in the Commission White Paper of 1985, constituted a very ambitious supply-side programme with the aim of removing physical, technical and fiscal non-tariff barriers to the movement of goods, services, capital and persons inside the Community. The elimination of these barriers by 1st January 1993 aimed at creating a large integrated market for goods and services, allowing the realisation of economies of scale, and resulting in an increased **competition** in this internal market which would end up in efficiency gains. It was also aimed at providing increased incentives for European producers to invest in product and process innovations.

Indeed, as a result of the progress made from 1992 to 2006 in achieving an enlarged Internal Market (IM) of 25 Member States, the GDP increased 2.2% and the gain in total employment was estimated of around a 1.4%, which amounts to 2.75 million jobs (Ilzkovitz *et al*, 2007). However, implementation of Single Market liberalisation **measures are proceeding still nowadays,** and in fact, these gains could have been substantially larger if services market had been fully opened up to cross-border competition. In fact, certain measures have encountered problems such as technical barriers and public procurement. Policy instruments are not fully operational, barriers persist in certain sectors, and an internal market for knowledge is still missing.

It seems therefore that the efforts made to increase innovation have not been enough, but at the same time economic literature identify innovation processes as one of the driving forces in economic competitiveness. When studying this innovation process, part of the literature has understand the technological change process into three distinct phases, that is to say, the invention process (whereby new ideas are conceived), the innovation process (whereby those new ideas are developed into marketable products or processes), and **the diffusion process** (whereby the new products spread across the potential market). The diffusion stage, although apparently the less important phase of the process of technological change (at least, it has received less attention within research agenda and policy-makers), is where the impact of this technological change on the economy takes place and where it has to be evaluated. Indeed, the contributions made by technology to economic growth and development are determined by the rate and manner by which innovations spread through relevant population. Without diffusion, innovation would have little social or economic impact, albeit diffusion is also an intrinsic part of the innovation process.

In fact, for a long time in economic literature the major focus was on the process prior to the first attempt to commercialisation of a new idea (Fagerberg, 2006). It continues being an important issue but the importance given to access to external (to the firm, to the country) sources of knowledge and the view of knowledge as the outcome of learning processes implies the existence of knowledge flows. Knowledge flows include technology transfer and the flow of know-how, knowledge, and information, including both accidental spillovers and intentional transfers. There are many alternative routes for knowledge flows to materialize. They require a channel, such as for example an established collaborative link between two scientists from different firms, and a mechanism, that is a way in which communication can be achieved through the specific channel, such as co-operative research efforts, informal discussions, or the expressed ideas of a scientist. Such flows are not limited to the exchange of information between firms or institutions. As stated in David and Foray (1995) what characterizes and determines the performance of 'different systems of learning in science and technology' is not so much their ability to produce new knowledge as their ability to disseminate it effectively and allow it to become economically valuable to third parties. This is why in the last years there has been a transfer of interest from steady structures and absolute measures of innovative activities (such as R&D expenditure and patents) to the different types of interactions among actors within and beyond the boundaries of a national system.

Given the importance of innovation diffusion, it is of utmost importance to get to know **its main determinants**. According to previous literature (e.g. Hall and Khan, 2003), innovation diffusion results from a series of individual decisions to begin using the new technology, decisions which are the result of a comparison of benefits and costs of adopting the new invention (demand and supply-side perspectives).

- From the *demand-side* there are three main conditions for innovation diffusion: being aware of the new technology and being able to use and adapt the new technology (what is referred to in the literature as the absorptive capacity), and the profitability of adopting the new technology (depending on the price, on the expected returns, and on the level of risk). Therefore, from the demand side perspective, several factors are likely to affect these three conditions: user's investments in human capital and R&D, user's organizational innovation and size and market features, among the main ones.

- Based on the literature focusing on the *supply-side* factors we can identify two main drivers of innovation diffusion: Supplier's R&D and innovation (the capability of firms to improve their technology, provide users with complementary products as well as to reduce the technology costs) and supplier's financial means (to be able to adapt the new technology and to inform potential users).

Additionally, the *institutional dimension* is considered to be a highly important determinant of the adoption of innovation. Traditional economic and other regulations, such as competition and intellectual property rights protection, taxation, financing, education, national policies, EU-level policies and so forth can ease or block agents' interaction. This is particularly important when exploring the question of the emergence of the European Research Area and a European system of innovation since there are important differences in the ways public sector institutions and research facilities supporting industrial innovation have been set up and operate in each country.

In the present project we will focus on the impact of some institutional factors on innovation diffusion. Mainly, **we will analyse the role that the Internal Market (IM) may have on the diffusion of innovation, while controlling for some other determinants**.

With respect to the IM, **product market integration would theoretically stimulate innovation and its diffusion.** On the one hand, because the pressures of competition would stimulate innovation in firms in order not to be eliminated from a bigger market, retain their market positions and stay ahead of the competitors (Griffith et al, 2006). Also, because the creation of the IM would allow gaining scale economies, with fixed R&D costs distributed over a larger volume of production (Schmookler, 1966). And finally, because technology diffusion can be stimulated thanks to the increased FDI flows as a consequence of the functioning of the IM and because of a more intensified trade, among other reasons. However, despite these theoretical assumptions, **there is practically no evidence on the effect of the IM on innovation diffusion**.

Therefore, **the main aim of the study** is to analyse the drivers of innovation diffusion through the development of proper measures, the identification of channels through which innovation diffusion takes place and analysing the main determinants of this diffusion process in the European IM. In particular, we are interested in understanding the link between the strengthening of the IM and an improved innovative performance of the overall EU economy, with special emphasis on the role that the IM may have on the diffusion/adoption of innovation. Finally, we will analyse the effects of the innovation diffusion on growth.

To accomplish its tasks, **the study is divided into five parts**, as follows:

- Part I: Literature review and analytical framework to study innovation adoption and diffusion
- Part II: Descriptive statistical analysis of the innovation diffusion/adoption process in the EU
- Part III: Regression analysis in the study of the innovation diffusion/adoption process
- Part IV: Analysis of the effects of the innovation diffusion/adoption on productivity growth
- Part V: Policy recommendations

These five parts are complemented by a series of appendices that give some extensions to the content included in each of them.

Among the **main novelties of this study** we can stress the followings:

- In contrast to most empirical studies on innovation diffusion in which the determinants of the adoption of a specific technology is analysed, in this study we **analyse the determinants of general innovation adoption process across countries and sectors in the European Union**. Therefore, an initial important issue will be the **definition and design of the variable(s) proxying such innovation diffusion/adoption process.**
- A comprehensive **descriptive analysis of innovation adoption exploiting the Commnunity Innovation Survey (CIS)** data at the EU level (and not only a country case analysis) is done. This way we will be able to cover **most EU countries with a sectoral disaggregation and a temporal comparison CIS3-CIS4.**
- Although the main theoretical determinants of innovation adoption at the EU level are considered as explanatory variables in our analysis, our study focuses on the impact of some regulatory environment, specifically the **impact of the Internal Market on the adoption of innovation.** Our study considers therefore a wide spectrum of measures such as the ones covered by the functioning of the Internal Market and their impact on the rate of adoption of innovation.
- As a result of the project, we have **used a comprehensive database for most EU countries in** relation with the topic of **innovation adoption** as well as its **main channels of impact (trade, cooperation and competition).** In some cases, it has been necessary to homogeneize the information available from both micro and macro databases provided by the CIS.

PART I

Literature review and analytical framework to study innovation diffusion

I.1. Review of theoretical and empirical studies

Although it is widely usual in academic research to relate technological change with R&D investments or the generation of new technologies, needless to say that it is only when these new technologies are broadly introduced into the economy that their benefits will be realized. Thus, the diffusion stage of the technological change process becomes almost the foremost phase.

According to Stoneman (1986) technological diffusion is the process by which innovations, be they new products, new processes or new management methods, spread within and across economies. Diffusion involves the initial adoption of a new technology by a firm (inter-firm diffusion) and the subsequent diffusion of the innovation within the firm (intra-firm diffusion), being the later the process by which the firm's old technologies and facilities are replaced by new ones.[5]

Although these ideas are widely accepted, different theoretical approaches have been pursued to describe and give the rational behind the main characteristics of the diffusion process. This section will therefore review the main theoretical and empirical approaches to the diffusion phenomenon. Firstly, we will present some stylised facts in the process of diffusion of innovation, to focus later in the demand and the supply models and determinants.

I.1.1. Stylised facts in the process of diffusion of innovation

Technological change is often considered as the driven engine of the economy, which is divided into three differentiated stages, the well-known Schumpeterian trilogy (Schumpeter, 1939):

- the invention process (whereby new ideas are conceived);
- the innovation process (whereby those new ideas are developed into marketable products or processes);

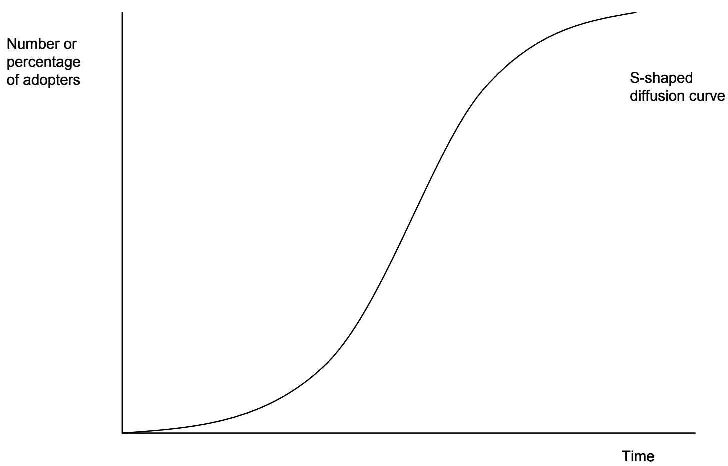
[5] As it can be seen in the definition by Stoneman, diffusion and adoption of innovation are not exactly the same process, although both terms have sometimes been used in the literature interchangeably. However, strictly speaking adoption would refer to the initial adoption of a new technology from another firm. Therefore, in the review of the literature made in this Part I we will refer to the process of innovation diffusion, the widest term, which besides is the one more commonly used in the literature.

- and the diffusion process (whereby the new products spread across the potential market).

This distinction is very important since, as it has been noted, every stage does not have the same impact on the economy. Thus, the diffusion stage, although apparently the less important phase of the process of technological change (at least, it has received less attention within research agenda and policy-makers), is where the impact of this technological change on the economy takes place and where it has to be evaluated, specifically where it has to be measured according to the change that exerts on the economy when a new technology has been introduced. Although many scholars have criticized the linear model that lies behind the division of innovative activity into three parts as oversimplified, it remains true that without invention, it would be difficult to have anything to diffuse, so the model serves us as an organizing principle, even if we need to be aware of its limitations (Hall, 2004).

New technologies tend to take time for being adopted by those who seem most likely to benefit from their use. This slowness has been considered in the literature as a stylized fact about innovation diffusion: diffusion rates first rise and then fall over time, leading to a period of relatively rapid adoption sandwiched between an early period of slow take up and a late period of slow approach to satiation. This fact is known as the **S-shaped curve of the rate on diffusion** when it is plotted over time.

Figure I.1. S-shaped curve of innovation diffusion



Apart from the widely spread notion of the S-curve, another commonality highlighted within academic research on innovation diffusion is **the importance of both economic and social**

factors. According to Hall and Khan (2003), diffusion results from a series of individual decisions to begin using the new technology, decisions which are the result of a comparison of benefits and costs of adopting the new invention. In their own words, "Diffusion can be seen as the cumulative or aggregate result of a series of individual calculations that weigh the incremental benefits of adopting a new technology against the costs of change, often in an environment characterized by uncertainty (as to the future evolution of the technology and its benefits) and by limited information (about both the benefits and costs and even about the very existence of the technology). Although the ultimate decision is made on the demand side, the benefits and costs can be influenced by decisions made by suppliers of the new technology. The resulting diffusion rate is then determined by summing over these individual decisions."

Taking into account these two stylized facts and regularities in technological diffusion, literature has been divided into demand- and supply-based studies. We will next review these theories.

I.1.2. Demand models: Demand-side determinants of the diffusion of innovation

I.1.2.1. Theoretical and empirical evidence based on the demand models

The so-called **epidemic model** states that what limits the diffusion is the lack of information available about the new technology, how to use it and what it does. Thus, this kind of model tries to answer why, if a new technology is a real improvement, some firms shift over to it more slowly than others. According to these models, consumers (or adopters) have equal tastes and the costs of acquiring new technology can be constant over time. But not all consumers are informed about the new technology at the same time. As time passes, more and more people adopt the technology, leading to an increasing rate of adoption. Eventually, the market becomes saturated and the rate decreases again, performing the S-shaped curve.

In this point, the distinction made by Rogers (1995) could be useful. According to the author, two features characterize every new technology: software and hardware. The later is explicitly the new tool or machine that will be used in the production process or sold in the market, which embodies the technology as a material or physical object. In turn, the former is the information to use it effectively, the knowledge base for the tool. Within this non-physical information, some could be transmitted through users' manual, but some becomes tacit and transmitted only person to person. Without good software knowledge, many potential users will not adopt the new technology, even aware of its existence. To pass on software knowledge, potential users need to be able to communicate directly with current users who have accumulated experience, following a "worth-of-mouth" information diffusion process. This is the reason why new technologies are not transmitted instantaneously, including when their existence is known by potential users. Moreover, within this kind of diffusion model process, people who know the software grow gradually, until a maximum where it is difficult to find someone without this software knowledge. To sum up, what arises of this kind of model is that it assumes that the use of new technology is constrained by the number of people knowing the existence of the new technology. However, as time proceeds, the experience of users leads to the spreading of knowledge on the existence of the technology to non-users who, in turn, become users.

Nevertheless, an important weakness arises from this kind of explanation of the diffusion process: it cannot explain the diffusion of an innovation from the date it is invented, but only from the date when some number of users used it. Thus, the epidemic diffusion can only begin when there exists a critical mass of users (Karshenas and Stoneman, 1995).

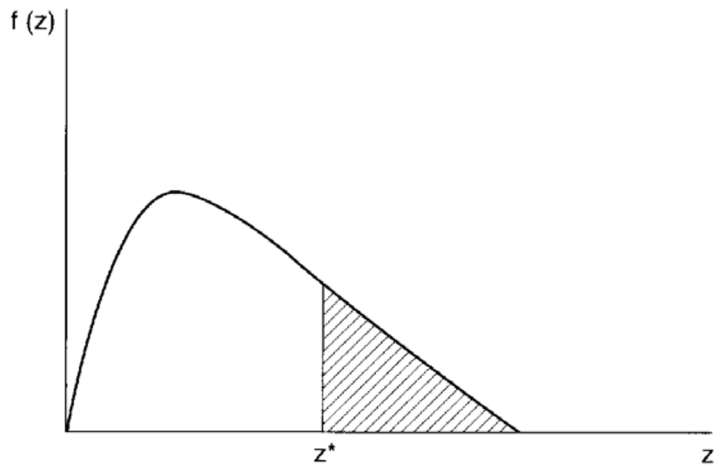
Among the main works on innovation diffusion within the epidemic area, a starting point was the pioneer one by **Griliches (1957)**, followed by those of Mansfield (1961), Bain (1962) and Bass (1969). All these papers performed empirical studies of the diffusion of specific technologies such as the diffusion of the hybrid corn seed in the Midwestern US (in the case of Griliches), 12 major innovations in the coal, iron and steel sectors (Mansfield), or the effect of the program independent television on the saturation level in each area (Bain). See Appendix I.1 for a review of their main contributions to the diffusion of innovation literature.

According to **the probit (or rank) and stock effects models** it is necessary to consider differences in the goals, capabilities or actions of individual members of the population as being determinants of the diffusion of information. In this framework, the decision to adopt is a choice made by a particular individual (or firm), so differences between individuals (or firms) may play an important role in explaining patterns of diffusion. In these models, individuals differ in some characteristics, namely z_i, which affect directly the profitability of adopting the new technology, and the model generates, again, and S-shaped curve. Its precise shape (that is, the time of the diffusion process that will be generated by this model) will depend upon on how z_i is distributed across the population, and on how z_i changes over time. Hence, information in the economy is perfect and knowledge about the characteristics and profitability of the new technology is widespread. The differences in adoption timing happen because potential adopters differ from each other. The heterogeneity is therefore represented by the key characteristics that are assumed to be important in determining responsiveness to the technology. This approach is known as probit or rank because its empirical application makes use of probit models, and it ranks firms by their significant characteristics.

As given in David (1969), suppose that the potential adopters of a technology differ according to some unspecified characteristic z that is distributed with a density function f(z) and a distribution function F(z) as in Figure I.2. At time t, a potential adopter i of a technology will be a user if his characteristic level z_i is higher than z^*, where z^* is a critical level of the characteristic. The proportion of the population who have adopted by time t will then be the shaded area in Figure I.2.

Thus, the key is to identify the relevant characteristics of the population. Among them, for instance, several scholars have suggested the firm size, the growth rate of industry demand, the age of existing capital equipment, the state of monopoly power in final product markets, the suppliers behaviour (since they are responsible for facilitating the flow of information about the new technology and for marketing it) and learning and search costs.

Figure I.2. Probit models of diffusion



Among this type of models, the Bonus (1973) work on consumers durable is the best known, although important contributions were made by David (1969, 1991) and Davies (1979). One clear gain of these models is that they enable one to generate a long and fairly impressive list of firm's specific determinants of diffusion speed, as it has been noted before. Moreover, the fact that they focus on individual decision making has helped to this bias in their use. Although this kind of papers are interesting to design the list of the main determinants of innovation diffusion from the demand side, the kind of empirical analysis performed in them can not be applied straightforward in our case since we will not work with individual decisions.

According to Karshenas and Stoneman (1995), **stock effects models** modify the probit models by introducing the assumption that the benefits from adoption are not independent of the number of users of new technologies (Reinganum, 1983). This way, as the number of users of new technologies increases, the gross benefits of adoption declines. Among the most interesting contribution of these models we find those of Reinganum (1981a, 1981b, 1983) and Quirmbach (1986).

I.1.2.2. Review of main determinants of innovation diffusion on the demand-side

Basically, we could point out that there are three main conditions for innovation diffusion:

- **being aware of the new technology,** which is stressed by epidemic models
- **being able to use and adapt the new technology,** which refers basically to demand models, although is also related to the supply side as we will see afterwards
- **profitability of adopting the new technology**: depending on the price, on the expected returns, and on the level of risk.

Therefore, from the demand side perspective, several factors are likely to affect the ability to be aware of the new technologies and the ability to use and adapt them (what is referred to in the literature as the absorptive capacity), as well as the expected returns of adoption: user's investments in human capital and R&D, user's organizational innovation and size and market features, among the main ones, as we analyse below in depth.

User's investments in human capital

The investments made by users in human capital play a crucial part in their ability to adopt innovations. This human capital is often a condition to be aware of the new technology and to be able to use it. Along with the specific institutional framework of each economy, the role played by human capital in the absorptive capacity of a firm or an economy is well documented. Nelson and Phelps (1966) argue, for example, how imitation and adoption imply an investment in human capital. Hence, the higher the human capital of a lagging economy, the faster will be its technological catch-up. Nelson and Phelps (1966) argue how "it is clear that the farmer with a relatively high level of education has tended to adopt productive innovations earlier than the farmer with relatively little education [...] for he is better able to discriminate between promising and unpromising ideas [...] The less educated farmer, for whom the information in technical journal means less, is prudent to delay the introduction of a new technique until he has concrete evidence of its profitability".

This is to say that, for example, “reverse engineering” on which a considerable part of innovation diffusion relies, is more likely to be performed by engineers than by low skilled workers. Instead, it is the physical production of the "replicas", used for production of the final good, to be carried out by unskilled workers. A more formal discussion of this hypothesis can be found in the works of Benhabib and Spiegel (2005) or Basu and Weil (1998) where the adoption of very different technologies may imply an increasing difficulty for the follower. In particular, it is sometimes assumed how the technological frontier may not be immediately appropriate for the follower to be imitated due to the large technical differences between the leader and the recipient country. Human capital may facilitate the absorption of these distant technologies acting as an enhancing factor for the diffusion of innovation.

User’s investments in R&D

Similarly, investments in R&D made by users can help adapting the new technology. The change in the conception of knowledge points out the role of R&D as an absorptive capacity (Jovanovic and Rob, 1989): the firms’ own commitment in learning activities and the ability of firms to recognise and appreciate the value of new information, ranging from generic science to new production equipment, assimilate it, and exploit its economic potential through commercialisation (Cohen and Levinthal, 1989, 1990). A firm’s absorptive capacity largely depends on the level of prior related knowledge owned by the firm. Also, the ability of a firm or an economy to use the results of research efforts made by other firms or other public and/or private research establishments depends on its ability to understand them and to assess their economic potential.

User's organisational innovations

Adoption of innovation often requires organisational innovation (example of ICT that requires organisational changes). Thus, the ability of users to make organisational changes may enhance their ability to use new technology, and therefore improve innovation diffusion.

Moreover, the kind of organizational structure is an important determinant of how knowledge flows inter and intra-firms. Lane and Lubatkin (1998) or Lenox and King (2004) analyze, for example, how the organizational structure of a firm influence the internal communication processes therefore shaping its absorptive capacity.

Size of the user's firm

Size may impact on the profitability of adoption. Indeed, it reduces the level of risk since it is distributed over a large number of products. It also reduces the financial constraint. User's financial means are required to be able to adapt the new technology and to lower the critical level of profitability. Imitation and adaptation of leading-edge technologies imply a cost for the technological follower. This determines the extent of technology flows from a best-practice technological frontier to the rest of firms or countries. The costliness of imitation is widely observed and acknowledged in theoretical and empirical literature. Maskus et al (2004), Mansfield et al (1981), Coe and Helpman (1995) or Behnabib and Spiegel (2005) point out how the cost of both the adaptation and imitation of technologies discovered at the frontier (or in other technological sectors) is usually positive but relatively lower than the cost of innovation. As argued by Maskus (2000), imitation usually takes the form of adaptations of existing technologies to new markets.

Mansfield et al (1981) point out for instance how, over 48 different products in chemical, drug, electronics and machinery U.S. industries, the costs of imitation lied between 40% and 90% of the costs of innovation. On the same line the empirical results of Teece (1977) estimated the cost of technology transfer across countries to be equal, on average, to 19% of total project expenditure. Therefore, the larger the firm, the higher the financial means devoted to the adaptation and imitation of technologies.

Moreover, the size of the firm is usually regarded as an important factor shaping the absorptive capacity. A good deal of empirical evidence seems to show how larger firms are more likely to exploit their existing internal knowledge in order to diffuse knowledge internally and increase their productivity (i.e. Levinthal and March, 1993; Dougherty and Heller, 1994). The process of full exploitation of the intra-organizational knowledge of each firm is usually called "inward absorptive capacity" (i.e. Gambardella and Giarratana, 2004). Smaller (or start-up) firms, on the other hand, seem to rely on what is called "outward absorptive capacity", that is, the use of knowledge produced outside their boundaries to rise productivity levels and to build their own knowledge stock. However, negative effects due to bureaucratic procedures in large firms may reduce the ability to absorb new technologies (Henderson and Clark, 1990).

User's market features

The main characteristics of the market faced by potential users are also likely to influence their propensity to adopt new technologies. The literature review has pointed out the role played by the market share of the user (Hall and Khan, 2003). The larger the market share, the higher the incentives to adopt, because a large market share increases the ability to appropriate the returns from adoption. In addition to market share, the market dynamisms may also imply higher rates of adoption. In probit models, demand growth is stressed as a positive factor of innovation diffusion, because it increases the expected returns.

Finally, based on epidemic models, we can state that the number of previous adopters on the market plays also a crucial part in innovation diffusion. The probability of being aware of one technology rises with the number of previous adopters. The information regarding how to use the new technology is also becoming more available, increasing the ability of potential users to adopt it. Moreover, the profitability may change along the diffusion path. Indeed, a high number of previous adopters may give rise to higher expected returns. This would be the case in particular if network externalities arise. Conversely, the risk of adoption decreases with the number of adopters.

I.1.3. Supply models and Technology characteristics: Supply-side determinants of the diffusion of innovation

I.1.3.1. Theoretical and empirical evidence based on the supply models

So far, we have focused on the influence of demand-side factors on technology adoption. Nevertheless, Rosenberg (1972) clearly argued that one of the reasons for the slow but eventually complete diffusion of new technologies was their relatively poor performance in their initial incarnations. In other words, the behaviour of the suppliers of these new technologies, both in improving them and in lowering their cost over time, was essential in ensuring their eventual acceptance. Specifically, he argued, successful diffusion relies on the capability of suppliers to adapt their innovation to the different contexts in which it can be adopted and to provide a large scope of complementary products and services. According to this author, on the supply side there are several important factors for the diffusion of innovation, for instance, **the improvements made to the technology after its introduction**, **the invention of new uses for the old technology**, **the development of complementary inputs** such as user skills and other capital goods, and the like.

Although in Rosenberg (1972) the author concentrated on certain supply side considerations, he recognized that alterations in relative factor and commodity prices also affect the rate of diffusion of new technologies. Since the diffusion process shows an apparent overall slowness and a wide variation in the rates of acceptance of different inventions, a better understanding of the timing of diffusion is possible by probing more deeply at the technological level itself. Even where it is possible to identify major inventions which seem to represent entirely new concepts and therefore genuine discontinuities, there are usually pervasive technological as well as economic forces at work which tend to slow down the impact of such inventions. Among others, Rosenberg (1972) points out the need for **improvements in inventions after their first introduction**, the development of technical skills among users and in machine-making and the characteristics of the institutional context and the regulatory environment. In Appendix I.2 we review some of these forces in line with Rosenberg's arguments in more detail.

I.1.3.2. Review of main determinants of innovation diffusion on the supply-side

Based on the literature focusing on the supply-side factors we can identify two main drivers of innovation diffusion:

- **Supplier's R&D and innovation**: New technologies are rarely commercialized in their very first version. They need to be improved and adapted to the specific needs of users. The capability of firms to improve their technology but also to provide users with complementary products is very important. Moreover, the price is often high at the first stage of innovation diffusion. In order to ensure a higher rate of diffusion, suppliers have to perform innovation in order to reduce the costs. For these reasons, the R&D and innovative capacity of new technology suppliers is thus essential.

- **Supplier's financial means**: They are of course important to be able to adapt the new technology (to cover the R&D costs) as mentioned above. But financial means play also a role to inform potential users, for instance as in Tonks (1986) who puts the stress on the advertising costs. The edition of users' guide may also generate important expenditures (in the aerospace industry for instance).

As stressed by the epidemic models, these different factors stemming from supplier features (cost reduction, complementary products, etc) are facilitated by the number of adopters already present on the market. In other words, innovation diffusion may be driven by suppliers and users interaction, as reviewed next.

I.1.4. Review of the literature and the main determinants of innovation adoption as a result of the interaction between supply and demand

A more formal modelling of the determinants of innovation diffusion from a supply-side point of view concerns to the adaptation of epidemic and probit models literature into interactions between demand- and supply-side influences. Thus, albeit most modelling frameworks use demand-side factors alone to explain diffusion paths, any diffusion pattern must be the result of interactions between supply and demand factors. Specifically, some of the supply issues under consideration refer to (Baptista, 1999):

- the nature of the cost function of suppliers and the way costs change over time.
- the market structure in the capital goods supplying industry.
- the way buyers (potential adopters) form their expectations about prices.

As it has been mentioned above, within epidemic models literature, Glaister (1974) was one of the first who allowed an influence on diffusion of the cost of acquiring technology and advertising, although supply-side factors were included in an ad-hoc fashion. Gould (1970) and Tonks (1986) used these kinds of models taking into account certain supply-side consideration, albeit it was Metcalfe (1981) who constructed a complete epidemic model including supply-side influences.

As said before, David and Olsen (1984), or Ireland and Stoneman (1985, 1986) explicitly use heterogeneous models to address the issue of expectations in the diffusion process, which was originally raised in Rosenberg's work concerning technology improvements. Thus, a technology that is expected to improve over time will tend to diffuse more slowly than one that is not. Concretely, Ireland and Stoneman (1985, 1986) concluded that, for a given number of suppliers, diffusion will be faster if buyers have perfect foresight rather than myopic expectations.

Concerning to the relationships between different technologies, Stoneman and Kwon (1994) point out that the adoption of any technology will be affected not only by variables relating itself, but also by variables relating to other technologies. On the other hand, Ayres and Ezekoye (1991) show that competition between technologies for the establishment of a standard in the market is observed, but also the existence of complementarities between different technologies (for instance, the dependent relationship between computer communications demand and advanced telecommunications demand).

An important result of this theoretical literature is that technology transfers do not happen spontaneously. The distinction made by Rogers (1995) on hardware and software indicates that some information is tacit, and requires interpersonal contact to be transmitted. Therefore, being aware of the technology and being able to adapt it requires **effective contacts between suppliers and users**. Interactions between users and suppliers are required for innovation diffusion to occur. These relationships support two distinct kinds of exchange between suppliers and users:

- **Exchanges of tangible assets**: Innovation diffusion may rely on flows of products and services. Imitation, reverse engineering, technology transfers increase with the openness of the economy. For this reason, **trade** is an important driver of innovation diffusion. Coe and Helpman (1995) and Coe et al. (1997) argue that international R&D spillovers are substantial and that trade is an important channel of such spillovers. Their effect on economic growth is also pointed out by Walz (1997). During the nineties, a great deal of empirical work has attempted to define the impact of foreign knowledge on domestic innovation and productivity. Markusen (1989), Verspagen (1997) and Keller (1999) analyzed initially the impact of trade (and in particular of the import of intermediates) on the diffusion of technology and innovation within and across countries. Empirical studies such as Syrquin and Chenery (1989), Wei (1993) or Sachs and Warner (1995) provided a solid evidence of the positive impact of trade on technology diffusion and growth.

A parallel strand of literature tried to shed some light on the specific mechanisms which act as channels of the international diffusion of technology. **Foreign Direct Investments** (FDI) are generally considered as the main one. One can think in particular at the impact of **multinational firms** (through their subsidiaries) on their local suppliers (backward linkages), on the customers (forward linkages) or on the competing firms (horizontal linkages). Kokko (1992) identifies different channels through which technology may be possibly transferred from Multinational Enterprises (MNEs) to other firms in the economy. These FDI channels rely, among others, on imitation effects, training effects or foreign linkages effects. Hence, an important question in the context of technology diffusion is under what conditions a firm would choose to service a foreign market through FDI activity.

- **Exchanges of intangible assets**: Ideas are not freely accessible to everyone. They are instead, at least partly, embodied into people (Lucas, 1988). Therefore, the diffusion of tacit knowledge and their absorption would rely on effective interpersonal interactions. Studies exploring this issue consider two main kinds of interactions: the face to face relationship, on the one hand, and the human capital mobility, from one institution to another or over space, on the other hand. We detail them below.

The more numerous opportunities of **face to face contact** can explain the highest labour productivity observed in large cities (Berliant et al, 2001; Charlot et Duranton, 2006). These interpersonal relationships would also explain knowledge spillovers from public research (Zucker et al, 1994).

The role played by **labour mobility** has also been highlighted. Almeida and Kogut (1997) and Breschi and Lissoni (2003, 2006), for instance, indicate that the higher the mobility of scientists, the better knowledge diffuses. Much intelligence remains embodied tacitly in knowledge agents and is potentially mobile, as originally envisioned by Marshall. Once (potentially) mobile, agents are no longer simply knowledge agents employed in some organization; they are the “knowledge spillover agents” (KSAs) who are increasingly able to appropriate and profit from at least some embodied knowledge through mobility. Audretsch and Keilbach (2003) express the incentive as follows: “When the lens is shifted away from the firm to the individual as the relevant unit of observation, ….the question becomes “How can economic agents with a given endowment of new knowledge best appropriate the returns from that knowledge?” They go on to argue that the most rational appropriation is the entrepreneurial route, i.e. spinoffs and startups originated by university scientists. Clearly, those who possess such talents and abilities are able to appropriate and capitalize on them to the benefit of themselves and often to their surrounding localities.

Moreover, mobility needs not to be considered transitive among future employers, as mobility could indeed re-circulate KSAs among a sub-set of likely institutions. Indeed, Rallet and Torre (1999) argue that infrequent mobility of corporate researchers to other sites is often sufficient to transfer key tacit knowledge inputs at critical R&D stages. Impediments to elective mobility among European knowledge workers are far less frequently encountered in the U.S. Strong cultural and linguistic preferences are of course important factors that bind people to organizations and locations everywhere.

Following these studies, more recent research suggests that, beyond direct relationships, the **integration within networks** is a key factor for knowledge diffusion. Empirical studies based on scientific or technological collaborations (Singh, 2005; Sorenson et al, 2006; Gomes-Casseres et al, 2006; Autant-Bernard et al. 2007) confirm the impact of social proximity as a channel of knowledge diffusion.

Therefore, whatever their nature, interactions between suppliers and users favour the exchanges of tangible and intangible assets that are at the root of innovation diffusion. In addition, three factors are likely to improve these interactions between supply and demand:

- **Information and Communication Technologies**: They ease interpersonal relationship and they give a better access to information, thus facilitating awareness about the new technology.

- **Market structure**: Information and technology flows are favoured by vertical and horizontal integration. This latter increases effective contacts and the flows of both tangible and intangible assets.

- **Geographical concentration**: the spatial organisation may be more or less favourable to innovation diffusion. The literature points that concentration facilitates for suppliers to adapt the technology to potential users (see Lundvall 1992). Spatial concentration also facilitates for users to be aware of the new technology, and reduce the risk –local trust.

I.1.5. Regulatory environment determinants: Emphasizing the role of IPRs, integration and competition

Another important issue regarding the main drivers of innovation diffusion refers to the regulatory environment. This dimension is introduced in some models of innovation diffusion (Baker 2001, Cutler and McClellan 1996 for instance), but it also refers to a literature that does not develop models of innovation diffusion. For instance, the regulatory environment and governmental institutions can have an impact on technology adoption and therefore diffusion via the ability of a government to sponsor a technology with network effects. Several empirical studies in the healthcare sector have stressed the role of regulation in this sector on diffusion. As highlighted by Baker (2001), providing reimbursement for the use of advanced and costly procedures, a generous insurance system often fosters adoption of new techniques and methods of treatment. Also, Cutler and McClellan (1996) found evidence of a positive effect of a generous insurance environment on adoption decisions. Specifically, they obtained that the insurance environment along with state regulations related to the use of new medical technology and the interactions between physicians and hospitals are the most important factors determining the use of an advance heart attack treatment procedure called angioplasty. Adoption and diffusion of innovation can also be impacted by other types of regulations, such as environmental regulations that may even prohibit or require the use of certain technology or production methods. For instance, Gray and Shadbegian (1998), using annual data from 1972 to 1990 obtain that firms respond to the policy environment they function in. They find that newer plants are more likely to use technologies that produce less

Table I.1. Innovation diffusion models

	Issues	Authors		Issues	Authors
Demand side			***Supply side***		
	Lack of information on new technologies slows the diffusion	Rogers (1995)	*Improvements in inventions after first introduction*	Capabilities of the supplies to adapt the innovation to the market	Rosenberg (1972)
	Population of adopters is constant and homegenous			Upgrades of the innovations speed up the diffusion	
	Population of adopters does not seek for information on new technologies (passive agentes)		*Development of technical skills*	Development of skills in the users helps the diffusion (learning effects)	
	Nature of technology is unchanged over time			Development of complementary products increases the speed of diffusion among users	
	Economic analysis of diffusion:	Griliches (1957)	*Diffusion and institutional context*	Market structure study: Larger firms:	
Epidemic models	Profitability for the users			Adopt more than small firms	Hall and Khan (2003)
	Innovation location			Have less financial constraint	Dorfman (1987)
	Use of a logistic diffusion curve			Are able to diversify the technology	
	Empirical analysis: study of diffusion of hybrid corn			Enjoy economies of scale, imperfect capital markets	
				Downsides:	
	Information constraint	Mansfield (1961)		Bureaucratic problems	Henderson and Clark (1990)
	Word-of-Mouth diffusion				
	Uncertainty about the profitability of the innovation slows its diffusion				
	Slower initial learning as the cause of the S-shaped diffusion curve			Regulation and institutions	
			Regulatory environment	Government can sponsor a technology and create network effects	Baker (2001)
	Other empirical studies:				Cutler and Mclellan (1996)
	Television diffusion	Bain (1962)			
	Empirical models of diffusion with analysis of the users' rate of acceptance	Bass (1969)		Environmental issues may push to the adoption of specific a technology	Gray and Shadbegian (1998)
			Mixed model		
	Differences across firms and population (heterogeneity) play a role in the diffusion	Bonus (1973)		Insert in demand side model some feature of supply side models:	Glaister (1974)
Probit models	Analysis of the differences in profitability related to heterogeneity	David (1969, 1991)		Costs of adquiring technologies	Gould (1970)
	Characteristics analyzed:	Davies (1979)		Advertising costs	Tonks (1986)
	Firms size, age of equipment, growth rate, industry demand, monopoly power, suppliers behaviour, learning costs			Reciprocal influence across different technologies	David and Olsen (1984)
				Competition between technologies	Ireland and Stoneman (1985)

pollution and that new plants in stricter regulatory environments are more likely to use technologies that produce less pollution.

Though it is not integrated in the main stream literature of innovation diffusion, this approach is important to understand the mechanisms of innovation adoption, and especially when it comes to consider the role played by structural reforms such as the one associated to the Internal Market.

The regulatory environment displays several factors likely to influence innovation diffusion. Firstly, the role played by **normalisation and standardisation procedures** can be stressed. Normalisation reduces uncertainty and creates network effects that increase the profitability of adoption (David, 1985 and David and Greenstein, 1990) showing that compatibility standards constitute a factor likely to favour innovation diffusion. Secondly, as pointed out in our literature review, the **insurance system** may also reduce the risk, at least for some sectors like medicines. Other drivers of innovation diffusion that can be of more interest from our perspective of analysing the role of Internal Market measures are those related to the **competition environment** in which firms operate as well as the **integration level across the countries** in which such firms work. Finally, considered as the main driver of innovation diffusion stemming from the regulatory environment we find certainly the **IPR regime**. Indeed, it has an impact (not always positive) on all the conditions of the innovation diffusion: it produces positive effects by improving awareness about the new technologies, it also gives incentives to suppliers to improve the technology or to develop complementary technologies; but on the opposite, it generates negative effects on the price, since royalties have to be paid. Therefore, its impact on innovation diffusion is not unidirectional. For this reason, we give more details below to better understand the specific effects of competition, integration and IPR regime on innovation diffusion.

I.1.5.1. The role of IPR regimes

Knowledge, technology and the outcomes of the innovative activity are typically non-excludable and non-rival goods. The non-excludability implies that once a blueprint, a design, an idea or an organizational procedure is discovered it is very difficult (if not impossible in some cases) to prevent other economic agents to take advantage of the new discover and to appropriate (at least in part) some of its benefits. The non-rival issue means that once a new idea or blueprint has been created its benefits would be maximized if each economic agent could access these “goods” at their marginal costs. Setting the price of a new technology equal to its marginal cost, however, would result in a severe damage to the incentives to innovate and therefore lead to a decrease of the innovative activity which, in many economies, represents the major engine of economic growth.

From a general point of view, intellectual property rights (IPRs) are legal mechanisms designed to represent a barrier to the possibility of free riding and imitation of new ideas, blueprints or technologies by agents which did not incurred in the costs of producing these innovations. Maskus (2000) argues how "absent such rights, economically valuable information could be appropriated by competitive rivals". It is straightforward to understand, therefore, how IPRs are aimed at ensuring the innovator with an adequate monetary compensation for the investment in R&D.

Hence, as pointed out by Maskus (2000) IPRs may encourage new business development by stimulating technology innovation and compensating innovators for incurring in the fixed costs of R&D. The artificial creation of a temporary monopoly power for the successful innovator compensate for the fixed costs incurred during the risky process of technology and knowledge creation (Maskus, 2000). Additionally, IPR may facilitate the creation of a market for ideas and mitigate disincentives to disclose and exchange knowledge which might otherwise remain secret (Merges and Nelson, 1994).

However, strong IPRs will create market distortions through the creation of monopoly power for the innovator (see for example Deardorff, 1992). At the same time, IPRs work on the imitators side by prohibiting free imitation and, therefore, rising the relative costs of copying a new blueprint and inhibiting the flow of ideas and technology, and therefore the ability of researchers to cumulatively build on each other’s discoveries (Heller and Eisenberg, 1998; Murray and Stern, 2005).

Also, Gilbert and Newberry (1982) show how, granting sufficient monopoly power to the successful innovator, will allow the monopolists to delay the entry to the markets to possible competitors by “sleeping patents” long enough and impeding technology diffusion. Deardorff (1992) shows, also, how the returns of strengthening IPRs decrease as more and more countries apply the highest IPRs standards. This is because the extra market that can be covered (as well as the extra innovation that can be stimulated) by the application of stronger IPRs is finite.

Also, Rodrik (1994) argues how the enforcement of IPRs irrespective of the market structure of an economy (for example when an economy lacks a developed R&D sector) may end up shifting resources and welfare from the least developed countries (LDCs) to the industrialized and developed countries which perform innovation at the technological frontier. A similar reasoning can be done when looking at the relative costs of performing technology innovation and technology acquisition (imitation).

All in all, ceteris paribus within the same economy, the enforcement of IPRs implies a trade-off between the positive incentive given to the R&D sector and the negative effect coming from an increase in the cost of imitation. If, on the one hand, increasing the protection of IPRs theoretically ensures the innovator to be rewarded for its investment in R&D it is argued, on the other hand, how strengthening IPRs protection significantly rises the costs of imitation. Levin et al. (1988) and Gallini (1992), for instance, argue how "patents raise imitation costs by about forty percentage points for both major and typical new drugs, by about thirty percentage points for major new chemical products, and by twenty-five percentage points for typical chemical products". Also, Helpman (1993) and Lai (1998), among others, link negatively the speed of imitation to the extent by which IPRs are enforced in the follower country. Sakakibara and Branstetter (2001) and Lerner (2002), instead, find that domestic patent applications seem not to respond significantly to changes in patent policy.

Branstetter et al (2004) assess empirically the impact of tighter IPR on the technology flows from the country undertaking FDI to the host country. The impact of IPR should then not be disconnected from the innovation-diffusion which relies on FDI, since it can impact on the local efforts on R&D, not only in local firms but also through FDI of transnational companies and relationships linking the agents of innovation system. Indeed, IPR, as well as interpersonal relationship and absorptive capacity affect diffusion both within and between countries.

Finally, as pointed out by Barro (2000), "the economic effects of secure property rights and a well-functioning legal system are reasonably straightforward. Since people are, to a considerable degree, self-interested, they tend to undertake hard work and investments only if they have a reasonable probability of enjoying the fruits of their efforts. Thus, if property rights are insecure - for example, because of high crime rates or high rates of taxation or high chances of government expropriation - people tend to work less and invest little". Recent empirical and theoretical works, therefore, point to the protection of property rights (and among of these of IPRs) as essentials for long-run economic growth. Acemoglu (2004), Barro (1998), Hall and Jones (1999), Knack and Keefer (1995), Aghion and Howitt (2005) are only some among the authors who claim property rights enforcement to be crucial for a country's economic performance.

Table I.2. Effects of IPRs on economic growth and innovation diffusion

Positive effects	Encourage new business development	Acemoglu (2004)
	Compensate fixed costs of R&D and incentivize innovation	Barro (2000)
	Ensure FDI and increase trade flows	Hall and Jones (1999)
		Knack and Keefer (1995)
		Maskus (2000)
		Schneider (2005)
Mixed effects	IPRs impact differently countries at different stages of their development	Helpman (1993)
		Acemoglu, Aghion and Zilibotti (2006)
		Aghion and Howitt (2005)
		Connolly and Valderrama (2005)
	It can create distortions to the market	Deardorff (1991)
	It may inhibit technology diffusion in LDCs by distorting the incentives to imitation	Helpman (1993), Lai (1998)
	It may shifts resources from profitable imitation to non-profitable innovation depending on the specific country characteristics	Levin et al. (1988)
		Gallini (1992)
Empirical Studies	Positive effect of IPRs found on economic growth (panel studies)	Chen and Puttitanun (2005)
		Rapp and Rozek (1990)
		Gould and Gruben (1996)
	Mixed effects	Thompson and Rushing (1999)
		Smith (1999)

On the other hand, Helpman (1993) suggests that tighter IPR can, under certain conditions, decrease global welfare. The analysis of the impact of IPRs on the growth and welfare of the technological innovators and that of the imitators, has therefore provided ambiguous policy making insights. For a deeper insight on how IPRs'impact depend on the development of the country and the endowment of other factors see Appendix I.3.

Despite the mixed arguments in the relationship between IPRs and innovation diffusion, it is common sense to think that the European Union would benefit from a faster diffusion of cost-effective production technologies supported by better developed Internal Market for knowledge. If Europe is to become a region in which innovation and ideas can circulate without being impeded by national barriers, there is a clear need for harmonisation of European administrative and legal practices in the area of a common system of IPRs. However, at the same time a better balance between the need to provide incentives to innovators and the goal to encourage the diffusion of innovative technologies and business practices is needed. This implies to develop a transparent, inexpensive and uncomplicated IPRs system. Although this goes beyond the objective of this project, see Ilzkovitz et al (2007) for a review of the main aims that such a kind of system should pursue.

I.1.5.2. The role of integration and competition

From our perspective, other driver of innovation that is of utmost importance is the role played by **economic integration** across countries. Specifically, product market integration such as the **Internal Market** may have an impact on the incentives to innovate and to adapt innovation through different channels:

- Firstly, the creation of an Internal Market implies a **greater market size** which in turn increases profits and allows writing off the fixed R&D costs over a larger volume of production and sales (Schmookler, 1966). In Arrow (1962)'s words "competition leads to more innovation, because competition means more production, and therefore more units to spread the fixed costs of innovation".
- Secondly, the creation of a single market should lead to increased knowledge spillovers because of **more intensified trade and investments**. Indeed, the reduced barriers to cross-border flows of products and factors favours trade and investments across countries belonging to the same economic area so that innovation can be more easily transmitted and adapted.
- Thirdly, the integration of economies makes them a more attractive location to do business. By attracting inward FDI, integration would encourage the diffusion of new

technologies developed elsewhere. Therefore, the Internal Market stimulates technology transfer and diffusion via the **increased FDI flows**.

- Fourthly, a higher integration of the market implies a **higher productive specialisation**, so that the presence of MAR externalities[6] would lead to higher innovation diffusion. Following Arrow (1962) and Romer (1986, 1990) it is claimed that geographical agglomeration of industries produces knowledge externalities which can have positive effects on the rate of innovation (MAR-externalities) since agglomeration describes efficiency gains from the existence of technological spillovers due to the existence of a pool of specialized labour, the location of customers and suppliers, and physical and institutional infrastructures, and arise from the collocation of firms of the same industry. In the EU case, following Midelfart-Knarvik et al (2004), the single market has led to specialised regions and an uneven distribution of manufacturing industries in Europe. Thus, allegedly, integration leads to specialization and, therefore, to more innovation.
- Internal Market can imply an increase in the **standardisation of products and processes**. The question which is not so clearly answered is whether setting internal EU standards promotes the diffusion and development of technologies or, on the contrary, by pre-empting competition among standards, slows down improvement of existing standards and the development of more efficient alternatives.
- In integrated economies, the **mobility of labour is higher**. Labour mobility is a source of knowledge spillovers, which are a diffusion mechanism of innovation (Crespi, 2004).
- Finally, firms operating in a more integrated market are therefore exposed to **higher competition**, having stronger incentives to innovate in order to retain their market positions and stay ahead of the competitors (Aghion et al, 2005; Griffith et al, 2006). Since integration and competition go hand by hand, we go deeper in this last channel in the rest of this section.

Within an integrated area, such as the Internal Market, competition is expected to increase due to the removal of non-tariff barriers which is targeted to creating a large integrated market for goods and services, allowing the realisation of economies of scale. Indeed, integration generally changes the conditions of competition by facilitating market entry by new firms and

[6] Marshall-Arrow-Romer externalities

by reducing the ability of firms to segment national markets geographically. In the case of the European Internal Market, empirical evidence shows that on average, price-cost margins of the sectors most affected by the Single Market Programme declined (Ilzkovitz et al, 2007). European companies reacted to this decline in profit margins by reducing their costs and obtaining efficiency gains through an increased presence on the markets of other Member States (increased multinationality) and a concentration of activities on the core businesses of companies (reduced sectoral diversification). Additionally, the on-going process of liberalisation in the network industries, while taking account of the need to provide services of general economic interest, implies a stepwise opening up of the telecommunications, postal services, energy and transport sectors to competition. Also, the creation of the EMU has reinforced the integration and the competition effects of the Internal Market by reducing the costs of cross-border activities (elimination of the costs of managing multiple currencies and of exchange rate risks) and by increasing the transparency of prices.

The consequent fiercer competition in integrated markets is expected to result in (allocative and productive) efficiency gains. This would stimulate innovation because the risks of being eliminated from the market are higher, providing increased incentives for producers in such an area to invest in product and process innovations, improving the dynamic efficiency of the economy.[7]

According to economic literature, Porter (1990) argues that local competition encourages innovation by forcing firms to innovate or fail. In this view, for any given set of industrial clusters, competitive pressure enhances innovation and productivity. In Gilbert (2007)'s view, competition can promote innovation by reducing the value failing in R&D, but with no-exclusive IPRs, competition can decrease innovation incentives by lowering post-innovation profits. Also, Aghion et al (2001, 2005) defends the existence of the "escape-the-competition" effect, where the market is indeed competitive. According to their arguments, competition

[7] Although the theoretical reasons behind the argument that internal market implies higher innovation and innovation diffusion are several, the evidence suggests that the Internal Market in the EU does not seem to have been a sufficient catalyst for innovation and resource reallocation towards technology intensive activities despite the observed reduction in mark-ups and evidence pointing to a reorganisation of production activities. While the effect of the Internal Market on R&D and innovation has been positive, it has not been strong enough to significantly improve the innovation and productivity growth performance of the EU. The innovative performance of the EU as a whole and of most EU countries lags significantly behind that of top performers such as the US and Japan. European companies are not sufficiently encouraged to innovate and, in this respect, the Internal Market has been an insufficient driver of innovation. See Ilzkovitz et al (2007) for some explanation behind this result.

discourages laggard firms from innovating, whilst encourages neck-and-neck firms to innovate.

With the emphasis on the impact of competition on innovation adoption, Reinganum (1981) stresses the **double edge**, that is, on the one hand, one might expect that competitive pressure accelerate the adoption of innovations in order to be more productive and achieve its own monopoly. But on the other hand, each firm will capture less of the post adoption of the innovation, and so may have less incentives to adopt.

According to Geroski (2000) the net effect of competition on the rate of diffusion is ambiguous. Not all of the statistical results point in the same direction, and most suggest that measures of competition like concentration ratios of counts of the number of firms in an industry experiencing diffusion are not all that important as a driver of diffusion. There is an extensive case study literature which suggests that incumbent firms are often very slow to adopt new technologies when entry barriers are high, and this suggests that it may be that it is competition from entrants or threats of entry which matters most in stimulating diffusion. "Initially competition is between the old technology and different variants of the new technology. When ''the'' new technology has been legitimized, competition is between the various firms who use the new technology to serve the market. In short, competition probably does speed diffusion rates, but the degree of competition felt by adopters and non-adopters at any time probably depends on the rate and extent of diffusion which has occurred up to that time".

Redmond (2004) also stresses that competition among firms frequently involves product innovation, and sometimes telecommunication technologies. This in turn would increase the telecommunication infrastructures of the society, which facilitates information flows, and therefore, the diffusion of innovations. Additionally, as Gruber (2000) stresses in a study analysing the diffusion of mobile telecommunications in Eastern Europe, the speed of diffusion increases with the number of firms. The argument behind this stresses that telecommunication technologies increases the potential subscribers that can be served, and the market potential therefore increases. The argument in such technological fields is the same as Redmond (2004), that is, more technological progress support the existence of firms in the market and their entry, then increase the market competition and therefore the speed of the diffusion of a certain technology. According to his results, competition has a positive impact on diffusion. As the World Bank (1994) points out for the case of the telecommunication market, the entry of new firms is the single most powerful tool for encouraging telecommunications development because monopolies rarely meet all the demand. More competition, moreover, attracts capital, especially foreign capital, which carries a high degree of technological knowledge. Therefore, the results of his investigation provide support to the view that competition accelerates the diffusion of innovations.

I.1.6. How innovation diffusion is formalised in empirical literature

So far, we have reviewed the main theoretical and empirical literature on innovation diffusion/adoption so as to identify its main determinants. Now we turn to the analysis of how innovation diffusion has been formalised in such empirical literature.

Innovation diffusion in the explanation of economic growth. Based on the paper in 1966 by Nelson and Phelps, many empirical researchers afterwards tried to provide evidence on the certainty of their hypothesis to explain economic growth: while the growth of the technology frontier reflects the rate at which new discoveries are made, the growth of total factor productivity depends on the implementation/adaptation of these discoveries, and varies positively with the distance between the technology frontier and the level of current productivity. Applied to the diffusion of technology between countries, with the country leading in total factor productivity representing the technology frontier, this is a formalization of the catch-up hypothesis that was originally proposed by Gerschenkron (1962).

Therefore, much empirical literature on innovation adoption has focused on its impact on productivity or productivity growth. In one set of papers, if R&D of firm j is positively correlated with TFP in firm i, all else equal, this is consistent with technology spillovers from firm j to firm i (e.g., Keller, 2002). A variant of this approach replaces TFP by the number of patents (e.g. Branstetter, 2001, and Peri, 2002) presents a hybrid approach by relating patents in region i to patents in other regions, where the latter is instrumented by R&D expenditures.

According to Hall and Khan (2003) there are two alternatives to this basic approach, a generalization and a simplification. In the former, a particular channel of technology diffusion is added to the analysis. Coe and Helpman (1995), e.g., analyze the relationship between productivity and foreign R&D conditional on imports from that foreign country, finding that R&D abroad benefits domestic productivity, possibly through the transfer of technological know-how via trade. Nadiri and Kim (1996) suggest that the importance of research spillovers across countries varies with the country: domestic research seems important in explaining productivity in the US but the contribution of foreign research is more important for countries like Italy or Canada. Additionally, the role of human capital in facilitating technology adoption is documented by Welch (1975), Bartel and Lichtenberg (1987) and Foster and Rosenzweig (1995). Benhabib and Spiegel (1994), using cross-country data, conclude that technology spillovers flow from leaders to followers, and that the rate of the flow depends on levels of education. The other alternative to the international R&D spillover regressions, a simplified one, is to relate productivity not to foreign R&D, but to other measures of foreign activity: Aitken and Harrison (1999), for instance, study the correlation of inward FDI and domestic firm productivity (so-called FDI spillover regressions).

Determinants of innovation diffusion. In contrast to the empirical literature on the analysis of the impact of innovation diffusion on economic growth, the literature analysing the determinants of innovation adoption at an empirical level is more micro than macro-oriented. As argued in Hall and Khan (2003), the review of the literature on adoption of new technologies has focused to a great extent on microeconomic determinants, in part because these have proved to be the most important in explaining the broad patterns of technology diffusion, especially within a single country or economic system. This is the reason why most empirical papers on the determinants on the adoption of innovation focus on a specific technology and analyse some specific determinants that can be behind the adoption of such technology. Although many of them have already been named in the sections above, we just review now a few of them to provide an idea of how they formalise innovation diffusion.

In Hannan and McDowell (1984) for instance, using a failure time estimation procedure, it is found that market concentration, bank size, whether or not the bank is owned by a holding company, and market conditions like prevailing wage levels all significantly affected the adoption of Automated Teller Machine (ATM) by U.S. banks during the period 1971-1979. Through the estimation of a logistic model of diffusion, by Gruber and Verboven (2001), these authors explained variations in the rapid diffusion of mobile telecommunications in Europe using two factors: the market structure of mobile phone providers, and the improvements in mobile telephony technology achieved by the transition from analog to digital technology. The impact of technological improvements was obtained to be the most important factor, but they also found that the concentration of mobile telephone suppliers was negatively correlated with consumer adoption of mobile phones providing support for the idea that competition increases adoption by lowering prices. Similar results were found in Parker and Röller (1997) for the diffusion of mobile telecommunications in the United States during the 1984 to 1988 period using also a logistic model of diffusion.

However, of more interest for our project is to have an idea of how to formalise the study of the determinants of innovation adoption at a macroeconomic level, and specially to analyse the impact that the regulatory environment may have. In this respect, when looking across countries, other factors such as the level of economic development, geography, or culture may play an important role. For example, the relatively rapid diffusion of "wireless" or "trackless" technologies such as mobile telephony or air travel in developing countries may be largely attributable to their relatively late development and to geographical constraints that increase the cost of physical networks.

As for the regulatory environment and governmental institutions, as surveyed above, it can have an effect on technology adoption, although at an empirical level, the impact has been studied for specific regulations and for specific technologies. In many cases, the impact goes via the ability of a government to "sponsor" a technology with network effects. The exact effects observed will depend partly on the particular price-setting mechanisms chosen by the regulator. For instance, several empirical studies in the healthcare sector have highlighted the role of regulation in this sector on diffusion. Baker (2001) studied the effects of the provision of health insurance on the adoption of new medical procedures with information for American hospitals in the period 1983-93. He argues that by providing reimbursement for the use of advanced and costly procedures, a generous insurance system often fosters adoption of new techniques and methods of treatment.

Adoption of new technology is impacted not only by regulations about market structure or the insurance environment, but also by other types of regulations, such as environmental regulation. Environmental regulations directly affect adoption because in many industries regulations will either prohibit or require the use of certain technology or production methods. Gray and Shadbegian (1998) use a regulatory shift in the US to estimate the effect of regulation on investment strategies of firms in the paper industry, where environmental regulations could have encouraged adoption of new production technology if they required replacement of older, more pollution-creating machines or methods. However, they might also have reduced overall investment and therefore the diffusion of new innovations if it was costly for firms to purchase pollution abatement technologies or remodel older plants. Using Census data for individual paper mills from 1972 to 1990, Gray and Shadbegian find that firms indeed respond to the policy environment they function in. They find that new plants in stricter regulatory environments are more likely to use technologies that produce less pollution. Third, they show that regulation-driven investment and productive investment crowd each other out, i.e., more investment in pollution-abating technologies has led to a decline in investment in production technology. Mowery and Rosenberg have argued in a 1981 study that rapid diffusion of technological innovations in the U. S. commercial aircraft industry to U. S. airlines during the mid-twentieth century was due in part to actions of the regulatory agencies, first the Post Office and then the Civil Aeronautics Board. Because price competition was limited during some period, airlines focused on the rapid adoption of new types of aircraft in an effort to compete on quality.

Therefore, as we have surveyed above, both micro- and macro-economic analyses of the determinants of innovation adoption refer to specific technologies. The same is true for the study of the impact of regulation measures on innovation adoption since most studies analyse the effect of one measure of regulation on a specific innovative technology. In our study, though, we will consider a wide spectrum of measures such as the ones covered by the functioning of the Internal Market and we will consider their impact on the rate of adoption of innovation in general terms, without specifying any particular technology.

I.1.7. Conclusion

Based on the theoretical and empirical literature several drivers of innovation diffusion have been highlighted (see Table I.3 for a review). Their impact on innovation diffusion relies on the fact that they increase the awareness about the new technologies, the ability of adopters and suppliers to adapt and use the technologies as well as the profitability of the adoption of new technologies.

Table I.3. Determinants of innovation diffusion

Demand side:

- Users' investment in human capital (increases ability to adopt innovations)
- Users' investment in R&D (increases ability to adopt innovations)
- Level of prior related knowledge owned by the firm adopting the innovation
- Balance between specialisation and diversity in order to absorpt external knowledge
- Organisational innovation, ability of users to make organisational changes, kind of organisational structure
- Size of the user firm
- Market characteristics of potential users; share of the market; market dynamism; demand growth; number of previous adopters in the market

Supply side:

- Suppliers' R&D and innovation capacity of new technology suppliers
- Suppliers' financial means (advertising costs, users' guide, …)
- Interaction between users and suppliers:
    - Exchanges of tangible assets: trade, FDI,…
    - Exchanges of intangible assets: face to face contacts, labour mobility, …
    - ICT facilitates awareness about the new technology
    - Market structure: horizontal integration favours flows of tangible and intangible assets
    - Geographical concentration facilitates the awareness of the new technology

Regulatory environment determinants:

- Role played by normalisation and standardisation procedures
- Insurance system
- IPRs (see table I.2 for a more detailed discussion)
- Competition
- Integration of the economies

Some of these drivers result from the user features or from supplier features. But innovation diffusion also relies on the interaction between users and suppliers, and on the regulatory environment. The Internal Market aims at modifying the functioning of the European markets. Therefore, it is likely to produce changes in the user and supplier features or in their interactions. For these reasons, the Internal Market may impact on innovation diffusion, as we will analyse in detail in the next subsection.

I.2. Internal Market and innovation diffusion/adoption

Internal Market (IM) may impact on some of the drivers of innovation diffusion. But it is not obvious which determinants it impacts on, and through which channels. In order to understand it, we first come back to the objectives and nature of the IM.

I.2.1. The IM objectives

The IM is one of the European Union's most important and continuing priorities. Its main target is to benefit the Union's citizens and businesses by granting them with:

- greater European market integration,
- removal of obstacles to the free movement of services and capital and
- freedom of establishment.

Hence, the IM Directorate-General designs and delivers policies of economic reform that make the Union's economy dynamic and competitive. Some areas of direct interest when coming to the implementation of the European IM are:

- regulated professions, services, company law and corporate governance,
- public procurement and
- intellectual and industrial property and postal services.

In the area of financial services, it aims at establishing the legal framework for the integration of the Union's capital markets and the creation of a single market for financial services.

Therefore, the IM cannot be simply defined by an indicator such as GDP or consumption indexes. This is due to the fact that the IM is a "**set of rules of the game"** which has to be put in place for the EU citizens and firms in order to be able to freely move, locate, compete and exploit market potential wherever within the European boundaries.

Within the framework offered by the IM, and more specifically related to the innovation area, it was possible for the Commission to propose the **European Research Area (ERA)** in January 2000, as the major research policy debate in Europe (Commission of the European Communities, 2000). The development, at European level, of an area for the coherent and coordinated pursuit of research activities and policies, and an area in which researchers and knowledge move freely was supposed to encourage the expression of European excellence in several ways:

- First, by making it possible to establish a 'critical mass' of potential excellence, by networking the capacities present in different Member States, particularly through intensive use of information and communication technologies.
- Second, by releasing people and teams from the protection of national barriers, thus introducing competition and increasing the general level of excellence.
- Third, by attracting to Europe the best researchers from the rest of the world, in the same way that American campuses are currently attracting researchers.

Related to it, the Lisbon European Council Summit held on in March 2000 set an objective to 'make the European Union the most competitive and dynamic knowledge-based economy in the world by 2010'. This has since then been interpreted as requiring focused community-wide investment in research, and the improvement of innovation and entrepreneurship. In comparison with the IM, the Lisbon Strategy was much wider in scope, reforms in product, capital and labour markets as well as measures to stimulate R&D and innovation. Additionally, it pursued to exploit the synergies between the different structural policy areas, among others the area of the knowledge-based economy. In other words**, the IM strategy can be seen as an important element of the Lisbon Strategy.**

Therefore, the **objectives pursued by the ERA and the Lisbon Strategy are therefore supposed to improve not only the generation of innovation but also its adoption, generating a good environment for it.** In the next sub-section **we try to analyse why IM may impact on the drivers of innovation diffusion**.

I.2.2. Why IM may impact on the drivers of innovation diffusion?

It is important to define accurately the channels by which IM may affect innovation diffusion. The creation of an IM has possibly many effects on the innovation diffusion across countries and firms. This is because it sets up new (better) conditions (legal directives) which should encourage movement of goods, people and services, a better allocation of resources and therefore increases in productivity.

The channels by which the set up of an IM affects innovation diffusion, therefore, are indirect in the sense that the IM influences and affects other macro-magnitudes such as competition, trade, labour mobility or mergers and acquisitions possibilities, firm easiness of location within the EU boundaries and so on.

All these above mentioned macro-magnitudes influence the speed and extent by which innovation diffuses both within and across countries and firms. A better functioning job market (one which allows workers to move freely and find the best job opportunities as well as for firms to find the more suitable human capital) is achieved by permitting the free movement of people as well as setting a common legal framework on a EU basis giving similar incentives (or at least decreasing the barriers to the entry) to work in all Member States. The same reasoning goes with all the norms and legislations regulating, for example, the weight of each national government on the functioning of its market. If the national government is heavily present in the markets by transferring resources or subsidies or by participating in the markets with Government Enterprises, less incentives are given to firms (and especially European firms) which may want to enter those heavily regulated markets. One of the goals of the IM is to reduce the burden (direct or indirect) that firms have to face when entering a EU market. So, reducing State intervention is likely to make European markets more attractive for FDI, trade, firms' investment location since it increases competitiveness. All these factors are fundamental in promoting innovation diffusion.

Hence, we can identify how IM may impact on the three main conditions of innovation drawn from the theoretical literature, namely, (i) being aware of the new technology, (ii) being able to use and adapt the new technology, and (iii) the level of profitability of the adoption of the new technology. For each, the channels by which the IM may impact on innovation diffusion are highlighted.

I.2.2.1. IM and the awareness about new technologies

Firstly, the IM is likely to improve the potential awareness about new technologies. Four main channels drive this effect.

- **Labour reforms associated with the IM**, based not only on active labour market policies but also on portability of pension rights, recognition of qualifications, and eligibility of pensions, among others, aims at providing higher mobility, better job-matching and more even distribution of skills and resources across countries. Human capital and its mobility have been identified as key factors in order to be aware of the new technology and to be able to assess its economic value. Therefore, labour reforms constitute a first channel through which the IM may impact on the awareness about new technologies. An homogeneization of these reforms at the European level would then imply the possibility for workers to cooperate and move across national boundaries and therefore ignite the technology diffusion mechanism.
- **Trade policies associated with the IM** are also likely to play a part. Awareness about new technologies increases with flows of goods and services within which these technologies are embedded (i.e. reverse engineering). Promoting trade, IM may enhance awareness about new technologies and thus innovation diffusion.
- The IM may also result in an increase in **cross border mergers and acquisitions**. As pointed out in the previous section, the industrial structure, the size of the firms as well as the competition between them influence the ability to be aware of new technologies. The way foreign firms can compete and possibly acquire other firms in non-EU markets is likely to affect innovation diffusion.
- Finally, **FDI resulting from the IM** may also favour awareness about new technologies. Capital market policies associated with the IM facilitate FDI, by giving access to foreign capital markets. Of course, FDI may take several forms and sometimes involve only financial flows. But, as demonstrated by the empirical literature, when they are associated with the creation of new plants or labour mobility, technology transfers may occur.

I.2.2.2. IM and the ability to use and adapt the new technology

A second set of channels may drive the impact of the IM on innovation diffusion, by influencing the ability of users and suppliers to use and adapt the new technologies.

Labour reforms associated with the IM do not only affect the ability of potential adopters to be aware of the new technology. They may also improve the level of human capital that is necessary, in both demand and supply-side, to be able to adapt the new technology and to introduce complementary organisational innovation.

Financial means have also been stressed as crucial factors to adapt new technologies to the users. Capital market reforms insure a better access to financial means, and are therefore likely to improve innovation diffusion.

I.2.2.3. IM and the profitability of adoption

Finally, the IM is likely to enhance innovation diffusion by **increasing the profitability of the adoption of new technologies**. Indeed, the reforms associated with the IM aim at reinforcing **competition**. As stressed in the previous section, competition between potential adopters but also between suppliers are drivers of innovation diffusion. Market structures faced by users affect the expected returns of adoption. Competition between suppliers may give them incentives to improve their technology and to reduce its price.

The IM may also **reduce the price of technology** thanks to the enlargement of the market. The size of the market faced by supplier influences the price at which they are going to sell their technology. From a theoretical point of view, the larger the market, the lower the price.

From a demand-side perspective, the **market size** can also impact on innovation diffusion by increasing the expected returns. The demand growth faced by potential adopters has been identified as a positive determinant of their propensity to adopt, because it increases the profitability.

In a more indirect way, profitability of adopting new technologies may also be affected by the **reforms of the IM on the labour market**. As mentioned in the previous sections, the risk of adoption is an important driver of innovation diffusion. This risk can be limited by the establishment of trust between agents. In this sense, providing the EU countries with higher worker mobility, labour market reforms resulting from the IM can favour more trustful relationships, likely to enhance adoption profitability.

Finally, IM regulations may lead to the **normalisation and standardisation productive and innovative procedures**. **Cooperation will be then enhanced** since workers will be able to apply similar frameworks (software, methodologies and so on) interchangeably across European countries without the cost of adapting their work to that already carried out in other

EU countries. Therefore, the EU directives regarding normalisation and standardisation are likely to boost cooperation effects and ultimately the diffusion and adoption of innovation.

It is difficult to categorize all these concepts under univocal definitions. However, even if with shortcomings, it is possible to define the types of IM regulations which may affect specific "innovation transmission channels" such as (i) trade, (ii) cooperation and (iii) competition. These channels, and their effect on innovation adoption, will be analyzed in more detail throughout the rest of this report. For a review of the main ideas on how IM affects innovation diffusion see Table I.4.

Table I.4. How IM affects innovation diffusion

Awareness about new technologies: ("Trade Channel")

- Trade policies
- Increase in cross-border merges and acquisitions
- Capital market policies, which facilitates FDI, giving access to foreign capital markets

Awareness to use and adopt new technologies: ("Cooperation Channel")

- Labour reforms
- Facilitation of the mobility of workers,
- Normalisation and standardisation procedures

Profitability of adoption: ("Competition Channel")

- Reforms reinforcing competition
- Capital market reforms
- Enlargement of the size of the market (increasing the expected returns)
- Labour market reforms

I.2.3. Conclusion

As we have highlighted above, the EU reforms associated with the IM may act on innovation diffusion through several main channels: **Trade** (implying larger markets), **higher competition, FDI, labour mobility and cooperation and cross-border merges and acquisition.**

The model and the empirical strategy that we will derive in the next subsection have therefore the following novelties if compared to the previous empirical literature we have surveyed:

- Contrary to most empirical studies on innovation diffusion in which the determinants of the adoption of a specific technology is analysed, in our theoretical and empirical model we analyse the determinants of general innovation diffusion across countries and sectors in the European Union. Therefore, an important issue will be the definition and design of the variable proxying such innovation diffusion/adoption process.
- Although the main determinants of innovation diffusion at the EU level are considered as control variables, the model focuses on the impact of some regulatory environment, specifically the reforms followed to achieve the Internal Market.
- The model aims at catching the role the IM has on innovation diffusion through the analysis of two dimensions: on the one hand, the impact of the reforms on some specific channels of innovation adoption (trade, competition and cooperation), on the other hand, the impact of these channels on innovation adoption itself.

I.3. Theoretical model and empirical strategy

The model we propose to use aims at describing the diffusion of innovation both from a cross-country and inter-firms perspective. To do so we are going to formalize the diffusion of innovation by means of a S-shaped curve. As in other standard models which rely on a logistic diffusion curve (surveyed in section I.1), which is the most widely used to analyse the innovation diffusion/adoption process, this is initially a slow process but, as the number of adopters increases, also the speed of adoption of innovation rises. Crucial to our analysis will be the role played by the functioning of the Internal Market as a driving force shaping the different paces at which innovation is adopted across/within countries and firms. To do it we control for the main determinants of innovation adoption that have been analysed in section I.1 (firm size, human capital, R&D activity, among others) and focus on the impact that the regulatory environment set up by the IM may have on the diffusion/adoption of innovation.

I.3.1. Setup of the basic model

Let us first assume that the aggregate production function for each country is a standard Cobb-Douglas production function with constant returns to scale as follows:

$$(1) \qquad Y_i = F(K, AL) = K_i^{\alpha} (AL)_i^{1-\alpha}$$

where Y_i is output produced by country i (where $i = 1...I$)[8], K_i is capital while $(AL)_i$ represent labor-augmenting technological progress. We choose to formalize the technical progress as of being "labor augmenting" following the standard growth literature. As pointed out by Acemoglu (2002) and Jones and Scrimgeour (2005) this assumption allows us to have a model where factor shares are stable in the long-run and balanced growth is ensured[9]. Also, expressed in its intensive form, we can define the output along the transitional dynamics path as a function of time:

$$(2) \qquad y(t) = A(t)\left(\frac{s}{n+g+d}\right)^{\frac{\alpha}{1-\alpha}}$$

where $y = \frac{Y}{AL}$.

I.3.2. Endogenous technology

We innovate on the standard Solow-Swan framework, which we have been using up to now, by endogenizing the behavior of $A(t)$ along the transitional dynamics path. The idea is to define the evolution of productivity ($A(t)$) over time as a function of the diffusion of innovation.

The underlying hypothesis of our theoretical model is that the productivity level of each economy in any point of time (again, $A(t)$) will be a positive function of the extent by which

[8] For easiness of exposition we drop the *i* subscript and use it only when a comparison across countries is made in the text.

[9] The Steady State Growth Theorem (which is usually known as the Uzawa (1961) theorem) states that if a neoclassical growth model exhibits steady state growth then it must also be that technical progress is labor augmenting.

this same economy is able to adopt the outcomes R&D[10] activity and transpose them into productive activities. The rationale is simple and goes as: the more the number of innovations adopted/diffused into the economy, the higher will be the productivity level of this same economy[11].

The endogenous level of productivity for each country at time t is then expressed as follows:

$$(3) \qquad A(t) = \gamma A(t-n) - \left[\omega^{-1} + \left(1 - \frac{1}{1+\exp(\Delta^{-1} - \varepsilon)t} \right) \right] \qquad \gamma > 1$$

where with γ we denote the productivity augmentation term related to the adoption of the new technological paradigm. This is to say that $\gamma A(t-n)$ represents the maximum productivity level attainable with any given technological paradigm. The arrival of new technological paradigms over time continuously shifts this value upwards.

$A(t)$, therefore, represent the productivity level given by the difference between the maximum productivity level and the amount of new blueprints that have not yet been adopted in the productive process (the term in square brackets).

Let us now analyze the variables which define the amount of blueprints not already adopted in the square brackets. With ω we denote the effort exerted in the R&D sector by each economy whose result is a flow of blueprints[12]. Δ is the number of already adopted blueprints (innovations) for production in each economy over the total pool of blueprints available in each point in time. The parameter ε is the speed by which innovation diffuses within the economy. It is easy to notice how, increases in the value of all these three parameters (ω, Δ and ε) imply an increase in the number of already adopted blueprints in each point in time

[10] As regards to **innovation**, this is taken to be the result of R&D effort in each economy. The outcome of R&D takes the form of new blueprints or ideas (from an empirical point we may assume them to be proxied by patents for example).

[11] **Productivity** is the result of the adoption of these innovations (blueprints, patents and so on) discovered in the R&D sector which then translate into productive activities. Hence, for example, the discovery of a new blueprint may not imply a corresponding productivity increase for a long time. The invention of personal computers did not immediately increase the productivity of developed economies until their diffusion reached a critical mass. The time which elapses in between the invention of a potentially profitable blueprint and the increase in productivity will be a function of the speed of innovation diffusion.

[12] The arrival flow of blueprints may be formalized by using a Poisson arrival rate as in the model of Aghion and Howitt (1992).

(i.e. a higher level of innovation diffusion), and therefore a lower value of the term in square brackets and a subsequent higher productivity.

The parameter σ instead, represents peculiar spatial effects attached to each economy. This parameter captures whether a firm (or a country) is operating within a industrial or technological cluster or not. We will describe this point more in detail in the Appendix I.4.

As in the model of Aghion and Howitt (1996) we assume that blueprint creation is the outcome of research and that these are assumed to arrive discretely with a Poisson rate $\lambda\varpi$ where $0<\varpi<1$ is the fraction of population employed in the R&D sector while the overall result of the R&D sector is then given by $\omega = \lambda\varpi$.

To be slightly more precise, as the R&D effort increases, the number of available blueprints will increase accordingly and so the variable Δ (the number of blueprints already adopted in each point in time) will decrease. More formally we suggest:

(4) $$\Delta = f(1/\omega)$$

Hence, the productivity level of each economy in equation (3) is a function of the effort exerted by each economy in the R&D sector (ω). Similarly to other standard endogenous growth models (see Romer, 1990), an increase in the effort in the R&D sector implies (under some weak conditions) an increase in the **long run** technology stock of the economy. This result is also consistent with a large empirical evidence which we already treated in the review of the literature in section I.1.

I.3.3. Innovation diffusion/adoption and the role of the IM

In our model, the effect of innovation diffusion is captured by the S-shaped diffusion function $\left(1-\frac{1}{1+\exp(\Delta^{-1}-\varepsilon)t}\right)$. The second term into the parenthesis represents the logistic diffusion curve and the amount of blueprints which are adopted in each point in time within an economy[13]. The parameter ε plays the crucial role of defining the speed by which the innovation is adopted within an economy.

As an identifying assumption of our theoretical formalization, and differently from other endogenous growth models, we propose to analyze the behavior of the diffusion of innovation by linking it to the functioning of the IM and other institutional country-specific characteristics. In particular, we relate the speed by which innovation diffuses throughout an economy with the functioning of the Internal Market within its boundaries. In more analytical terms, we assume the following:

(5) $$\varepsilon = f(\theta)$$

where $f(\cdot) > 0$ and θ represent the degree/quality by which the IM of each economy works. Higher values of θ are associated with a better functioning of the IM. In principle the relation in eq. (5) states that better functioning of the internal market will lead to a faster rate of innovation adoption. However, as we will point out in the econometric part III of this report, the IM regulations are usually aimed at affecting some macro-magnitudes (trade flows, cooperation or competition) and not the adoption of innovation directly. This is because we have to think of IM regulation as a set of rules put in place by the EU whose aim is that of allowing freer trade, more competition and cooperation across firms and countries.

However, as we pointed out in the literature review, trade, competition and cooperation are the "transmission channels" through which innovation adoption takes place and is facilitated. Hence, there is a substantial indirect effect of IM regulations on innovation adoption mediated through the direct effects that such regulations have on the transmission channels, trade, competition and cooperation.

More formally we may re-write eq. (5) as follows:

(5.1) $$\varepsilon = f(\tilde{\theta})$$

and where

[13] Hence the overall quantity within the parenthesis can be thought as being the amount of blueprints still available for adoption, that is, the "amount to be learnt".

(5.2) $$\tilde{\theta} = f(IM)$$

$\tilde{\theta}$ proxies here for the effect that IM have on the transmission channels of (i) trade, (ii) competition and (iii) cooperation. In the empirical specifications which we are going to present in part III we will estimate eq. (5.1) and (5.2) by means of a two stage least squares estimation where eq.(5.2) will study the impact of IM regulations on the transmission channels and eq. (5.1) the effect that these channels (and indirectly of IM) on the rate of adoption of innovation.

In Appendix I.4 we leave a broader description of other features of the theoretical model and of the different paths for the diffusion of innovation.

Table I.5. Summary of Equation (3)

$$A(t) = \gamma A(t-n) - \left[\omega^{-1} + \left(1 - \frac{1}{1+\exp(\Delta^{-1} - \varepsilon)t} \right)^{\sigma} \right]$$

Variable	Explanation	Expected sign
$A(t)$	Endogenous productivity level : it represents the actual productivity level of the economy at time t.	
γ	Productivity augmentation term: it proxies for the technological paradigm positive shift in between (t-n) and t. The higher γ and the bigger the difference between the old technological paradigm and the new one.	γ is constrained to be >1
$\gamma A(t-n)$	Maximum productivity level attainable with a given technological paradigm.	The sign is expected to be positive.
$\gamma A(t-n) - \left[\omega^{-1} + \left(1 - \frac{1}{1+\exp(\Delta^{-1} - \varepsilon)t} \right)^{\sigma} \right]$	Difference between the maximum attainable productivity level and the actual productivity achieved in each moment starting from the date of the technological paradigm shift.	Positive and in the limit equal to zero.

$$\left[\omega^{-1}+\left(1-\frac{1}{1+\exp(\Delta^{-1}-\varepsilon)t}\right)^{\sigma}\right]$$	Amount of innovations available but not yet adopted into productive processes in each moment in time. It is a function of the blueprints (innovations) which are introduced/adopted into the productive process.	The sign is expected to be negative on total productivity.
$$\frac{1}{1+\exp(\Delta^{-1}-\varepsilon)t}$$	Logistic diffusion function. It shapes the slowly process of adoption of new innovations into productive processes for each economy.	The sign is expected to be positive.
$\varepsilon = f(\theta)$	Speed by which innovation diffuses (or it is adopted) within a given economy.	Function is positive in its argument. The sign on total productivity $A(t)$ is expected to be positive.
θ	Internal market directives	Sign on the speed of innovation diffusion, ε, is expected to be positive. Overall sign on producitivity is positive.
ω	R&D effort exerted. It proxies for the expenditures of each economy in Research and Innovation.	The sign on total productivity $A(t)$ is expected to be positive.
$\Delta = f(1/\omega)$	Number of already adopted innovation into the productive process relative to the overall pool of innovations for each technological paradigm across time. As the effort on innovation increases, Δ decreases since the pool of available innovation for any point in time is a positive function of R&D effort (see above).	The sign on total productivity $A(t)$ is expected to be positive.

I.3.4. Empirical Approach

I.3.4.1. On the IM approximation

The theoretical model we developed above is aimed at providing a theoretical background on the main relationships between the variables which are likely to affect the process of innovation diffusion/adoption. As commented before, an identifying assumption of our theoretical formalization, and differently from other endogenous growth models, we propose to analyze the behavior of the adoption of innovation by linking it to the functioning of the IM and other institutional country-specific characteristics. In particular, our theoretical model relates the speed by which innovation is adopted within an economy with the functioning of the Internal Market within its boundaries. This linear relationship, as shown in equation (5) will be the basis for our empirical model.

From an empirical point of view, however, it is necessary to clearly define what kind of variables we intend to use in order to proxy for the IM. In the strand of other recent works (Griffith and Harrison, 2004, or Nicoletti and Scarpetta, 2003) we believe the best approximation of the IM is to make use of available data on political and structural reforms which have the aim to create such IM. This is to say that the IM can only be approximated by making use of variables/categories which **proxy** for the objectives the IM directives want to achieve (i.e. greater European market integration, the removal of obstacles to the free movement of services and capital and freedom of establishment). Some of the variables (which we are going to detail in Part II) that we are going to use to proxy for the IM will be, for example, openness and competition in product markets, business environment and entrepreneurship in product markets, regulatory trade barriers, access of citizens to foreign capitals markets and others with the idea of proxying the most relevant reforms enacted at the EU level in order to achieve the goals of the IM.

All the variables proxying the IM have economic effects. We identify some of the channels through which these reforms affect economic performance and, especially for our case, innovation diffusion/adoption. We identify these economic dimensions as channels (trade, competition, cooperation, for example) which then will affect, as pointed out in the literature review, and in equation (5) the speed by which innovation diffuses across countries and firms. The same applies to various types of labor reforms which ultimately will affect the degree of labor mobility and job matching across regions and countries (and increasing cooperation, therefore understood as a channel).

For the sake of exposition, therefore, we will refer with *IM proxies* to those variables directly representing and proxying the structural reforms aimed at achieving the desired goals of the Internal Market. Instead, with *channels* we will refer to those economic dimensions (Trade, Cooperation, Competition and so on) which are directly affected by the structural reforms (that is by the IM proxies) and that then influence the extent and speed by which innovation diffuses across countries. Here below we detail the empirical strategy we are going to use.

I.3.4.2. Estimating the impact of the IM on innovation adoption[14]

From an empirical point of view, we are going to estimate two stages which allow us to link the effect of IM directives on the speed of innovation adoption. This dynamic is captured by the relationship between the parameter ε and θ as detailed in eq. (5). The relation is assumed to be linear such that an increase in the quality of the IM will imply a direct positive effect on the extent and speed by which innovation diffuses across the countries and firms operating within the internal market itself.

Therefore, the causality within the variables we are going to use for our empirical research goes as follows:

IM reforms $\Rightarrow$ ***Channels (Trade, Competition, Cooperation)*** $\Rightarrow$ ***Innovation adoption***

Hence, our empirical strategy has to take into account that the variables proxying the IM are not used as direct explanatory variables of the adoption of innovation but as indirect ones through their impact on the *channels*. And the c*hannels* have to be considered so, in the sense that they are the way through which the IM has its impact on the adoption of innovation. Thus, the channels are not considered to be exogenous when explaining the adoption of innovation but to be approximated by their own determinants.

There exists an evident problem of simultaneous causality between the variables which we define as channels of innovation adoption (Trade, Competition, Cooperation, among the main

[14] As it will be shown in Part II of the report, the variables we use for the diffusion/adoption of innovation refer more specifically to the adoption process of technologies. Therefore, in the presentation of the empirical strategy we refer to adoption of innnovation in order to make it more connected to what it will be presented afterwards in Part II.

ones) and the degree of innovation adoption itself. From an econometric point of view it would be impossible to directly disentangle the causality (and therefore to estimate the coefficients) between the "channels" and the degree of innovation adoption due to the fact that innovation adoption is very likely impacting trade, competition and cooperation and the other channels through its impact on the overall economic performance of each country and firm.

Hence, we propose a Two Stage Least Squares (TSLS) estimation where in the first stage we estimate the impact of IM reforms on the possible channels of innovation diffusion and then, in the second stage we disentangle the effect of these channels (Trade, Competition, Cooperation and so on) on the speed and extent of innovation adoption. This would go as follows[15]:

Stage 1: *Trade = f (IM Reforms implementation in each State)*
Competition = f (IM Reforms implementation in each State)
Cooperation = f (IM Reforms implementation in each State)

Stage 2: *Innovation Adoption=f(Trade (fitted),Competition (fitted),Cooperation (fitted))*

The relation to be tested is given below in the structural model:

(6)
$$Trade = \mu_1 + \delta_1 IM_1 + Z_1\theta_1 + \eta_1$$
$$Competition = \mu_2 + \delta_2 IM_2 + Z_2\theta_2 + \eta_2$$
$$Cooperation = \mu_3 + \delta_3 IM_3 + Z_3\theta_3 + \eta_3$$

(7)
$$InnovAdop = \alpha + \beta_1 Trade + \beta_2 Competition + \beta_3 Cooperation + Z_4\,\theta_4 + \varepsilon$$

where *InnovAdop* is going to be our measure of innovation adoption. *Trade, Competition and Cooperation* proxy for the channels by which the IM indirectly affects innovation adoption and that we put as explanatory variables in the 2nd stage of the TSLS estimation. Notice that

[15] From now on, the equations in the first stage will cover just three equations, one for the channel related to Trade, another one for Competition and one for the channel of Cooperation, since these are the channels through which we believe the IM has most of its impact on innovation adoption. However, the same idea could be extended to others channels if considered to be important and if good statistical information was available for them.

for simplicity we name IM the vector of Internal Market Reforms which, on the other hand, we will suggest in Part II.

Since we are interested in the specific partial effect of each of the channels in eq. (6) on the adoption of innovation, our empirical strategy is to estimate the equations in the first stage (in eq. 6) and then use the fitted values obtained in the 2nd stage (eq. 7 as correct instruments once cleaned from the possible correlation that they may experience with the error term ε. Thus, the basic assumptions we are concerned with are the possible non orthogonality of the explanatory variables in the second stage w.r.t the error process (the endogeneity of the channels w.r.t. the innovation adoption).

(8) $$E\{\varepsilon\, Trade\} \neq 0,$$
$$E\{\varepsilon\, Competition\} \neq 0,$$
$$E\{\varepsilon\, Cooperation\} \neq 0$$

If this condition is verified (as there are theoretical arguments for it), then the partial effect of the channels of adoption (Trade, Cooperation and Competition) will not be correctly estimated by OLS estimation. If so, it would be impossible to define the causality between explanatory and dependent variables[16].

To solve this endogeneity problem, therefore, we make use of the variables that we believe to be truly orthogonal to the innovation adoption (that is the measure of IM) for which we do not observe reverse causality. That is, our identifying assumption is that IM structural reforms do cause innovation adoption (through the above mentioned channels) but that innovation adoption does not cause IM structural reforms.

Hence,

(9) $E\{IM'\varepsilon\} = 0$ orthogonality condition of the excluded instruments.

We propose a more detailed analysis of the empirical model in Part III of this document.

[16] This is to say that if conditions in (8) are not violated, then the explanatory variables in eq.(7) are endogenous and therefore the generic OLS estimator is inconsistent.

PART II

Descriptive statistical analysis of the innovation diffusion in EU

A first empirical analysis will be carried out in this part. The aim of Part II is twofold. Firstly, it analyses, from a descriptive point of view, the dependent variable (the adoption of innovation) which will be then used in Part III for the econometric estimations. Hence, the descriptive analysis will help us to shed some light on the behaviour of innovation adoption both from a cross-country and cross-sector point of view. Indeed, the estimation of our model raises the question of the data. The first issue deals with the measure of the dependent variable, eg. innovation adoption itself. This is the aim of the first part. Secondly, comes the evaluation of its determinants. Although this point will be addressed in more detail in Part III, we give a first assessment through preliminary descriptive statistics.

Regarding the evaluation of the dependent variable, previous empirical studies on innovation diffusion are mainly based on monographic studies. They quantify innovation diffusion by looking at the adoption of a specific technology (ICT, seed, medical technologies for instance). However, our aim is to provide a general picture of innovation diffusion/adoption in EU, in order to analyse the impact of the EU Single Market and to assess the effect on global performances. Therefore, databases covering all EU countries and a wide range of sectors have to be used. Regarding innovation, global dataset allowing international comparisons are not numerous. Countries started only recently to collect systematically information on this topic, and the issues covered by the surveys remain restricted. Most empirical studies rely on three main data sets.

Thirty years ago, countries started conducting **R&D surveys**. These surveys are structured and administered in a possibly comparable way in more and more countries. They provide us with statistics on innovation input (R&D expenditure, research staff, software, etc.). This information is useful to weight R&D effort in each country and sector (industries or services) over time. However, it does not inform about the mechanisms of innovation and about the outputs of the innovation process. Therefore, R&D surveys cannot be used to address the issue of innovation diffusion.

Data on **patents** are also available over long time periods and for most countries. At the EU level, Eurostat provides patent statistics at national and regional scale. Such data have been widely used since the 1990s to proxy knowledge diffusion by looking at patent citations (Jaffe, Trajtenberg and Henderson, 1993). They can also be used to observe innovation diffusion through patent applications (Schneider, 2005 on U.S. patents applications). However, they do not inform us on the mechanisms driving this diffusion.

In the early 1990s, the Oslo manual set out the guidelines for a new type of survey, the **innovation survey** (OECD, 1992). Such surveys are now conducted in many developed countries, including emerging, transition and developing countries. On the whole, over 50 countries have carried out at least one innovation survey (the US being a notable exception).

In the EU countries under the coordination of Eurostat, the statistical office of the European Union, a common core questionnaire was agreed upon and surveys were launched under the acronym of CIS (Community Innovation Surveys). These surveys have been repeated every four years. Up to now there exist four waves of CIS (CIS 1 for 1990-1992, CIS 2 for 1994-1996, CIS 3 for 1998-2000, and CIS 4 for 2002-2004).

The different parts of the survey allow us to deal with most of the issues addressed in this study. Information is available on the use and adoption of external sources of knowledge and innovation, the location of partners (within the same region, the same country, the rest of Europe, US or other part of the world), etc. For this reason, we are going to use it as our main source of information.

The remainder of this part is organized as follows. The first section discusses the main characteristics of the innovation survey. The second section shows how innovation survey can be used to measure innovation diffusion/adoption, by distinguishing among innovation activities, generation of innovation and adoption of innovation. Section 3 gives us descriptive statistics on innovation adoption obtained from the third Community Innovation Survey. The fourth section analyses the potential determinants of adoption, focusing especially on innovation inputs, market features, and regulatory environment. Finally, the last section provides some insights on the evolution of adoption rates over time, by confronting CIS3 and CIS4.

II.1. Using innovation survey to account for innovation diffusion/adoption

As Mairesse and Mohnen (2008) report, the innovation surveys provide us with three broad groups of measures: innovation inputs, innovation outputs, and modalities of innovation.

The **innovation inputs** encompass besides R&D, other expenditures related to innovation such as acquisitions of patents and licenses, product design, training of personnel, trial production, and market analysis.

Four types of **innovation outputs** are distinguished in the version of CIS3, namely the introduction of new products (which can be new to the firm or new to the market), the introduction of new processes, organizational changes and marketing innovations. Whereas patents and bibliometrics measure the technical, scientific, inventive side of innovation, the innovation output items, contained in the innovation surveys, measure the development, the implementation, and the market introduction of new ideas. Namely they refer to the introduction on the market of new products or services and the introduction of new ways of organizing production and distribution.

The modalities of innovation are the sources of information that lead to an innovation, the effects of innovation or the reasons for innovating, the perceived obstacles to innovation, the perceived strength of various appropriability mechanisms, and the cooperation in research and innovation.

Several econometric analysis have been performed with the innovation survey data. The next part briefly reviews them. Then we enter more deeply into the presentation of the survey.

II.1.1. Innovation survey: a review

Following Mairesse and Mohnen (2008), we can divide studies based on innovation survey into four main groups. A first set of studies (Blundell et al. (1999), Hollenstein, (1996) Raymond et al (2007) among others) examines the **determinants of innovation** (sources of information for innovation, cooperation for innovation, obstacles to innovation). Their main findings can be summarized as follows:

- The probability to innovate increases with firm size
- The intensity of innovation is unaffected or even decreases with firm size
- Incumbents tend to innovate more
- Demand pull is often significant and positive
- Technology push is also positive, but less often significant
- R&D, especially continuous R&D, matters.

These studies also provide sectoral taxonomy for innovation based on principal components analysis (Hollenstein, 1996) or on probability tests of model of innovation determination (Raymond et al., 2007). Few studies so far have estimated dynamic models using panel data from successive innovation surveys. Peters (2005), Duguet and Monjon (2002), Cefis (2003), Raymond et al. (2007) highlight the persistence of innovation. Enterprises that innovate in one period tend to innovate also in the subsequent periods.

A second set of studies tests the existence of **complementarities between different innovation strategies**. There are complementarities between innovation strategies when two strategies tend to be adopted together rather than in isolation because their joint adoption leads to better results. Some studies have tested the joint adoption, others have tested whether indeed joint adoption leads to higher performance (super-modularity: the whole is more than the sum of its parts). This issue has been investigated for various aspects of innovation: complementarities between different types of innovation, e.g. product and process innovation (Miravete and Pernías, 2006) or between internal and external technology sourcing (Cassiman and Veugelers, 2006). Complementarities between different types of cooperation strategies have also been highlighted (Belderbos, Carree, Lokshin, 2006) as well as complementarities between internal skills and cooperation (Leiponen, 2005).

A third set of studies explores the **effects of innovation**, looking at productivity level or growth, exports, patenting or employment. For instance, Crepon-Duguet-Mairesse (1998) revisit the relationship between R&D and productivity. They estimate a model composed of three equations: first, an equation explaining the amount of R&D; second, an innovation output equation where R&D appears as an input, and, finally, a productivity equation, in which innovation output appears as an explanatory variable. Their results confirm the rates of return to R&D found in the earlier studies of the 80s and 90s, as long as proper account is taken of selectivity and endogeneity in R&D and innovation output.

Finally, a last set of studies relies on innovation survey to deal with **innovation policy issues**. See Arundel et al. (2008) for a summary of the findings regarding government support for innovation in various innovation surveys. Linking government support and firm performance, most studies find additionality (instead of crowding-out) of government support for innovation. Complementarities between innovation policies also occur (Mohnen and Roller, 2005) calling for a policy mix.

In spite of interesting information provided by these studies, our understanding of the innovation process is still far from perfect. In the Mairesse and Mohnen (2002) model, the unexplained residual is very high, especially in low tech sectors. Though the magnitude of the residual may partly result from the nature of the survey, it also highlights our ignorance in matters of innovation, as noted by Mairesse and Mohnen (2002) themselves.

An important issue that remains relatively unexplored is **innovation diffusion/adoption**. To our knowledge, nothing has been done to derive an analysis of innovation diffusion/adoption on the basis of this survey. This latter provides statistical data on the modality of innovation and the effects of innovation on economic performance. Therefore, innovation survey can be used to address the question of innovation adoption. However, we should be careful in building indicators of innovation adoption from the CIS. Firstly, innovation adoption is not assessed directly. There is no specific item to account for it. We have to deduce it from several items. Secondly, CIS faces several problems, due to the target population, data collection and methodological specificities. These latter are discussed in the next sub-sections, while section II.2 suggests different indicators and considers the pros and cons of each design. As mentioned by Arundel et al. (2006) in the Trend Chart Methodology report, technology diffusion is among the indicators that have to be developed. Our approach can thus be seen as a first attempt to quantify these phenomena at the EU level.

II.1.2. Target population of the CIS

The target population is the population of enterprises related to market activities, with 10 employees or more. The CIS3 database covers the three-year period from the beginning of 1998 to the end of 2000[17]. However, the CIS3 does not cover all NACE market activities. A core target population is observed. "Non-core" activities can be included as well. Activities belonging to each population are listed below.

The following 9 sectors shall be included in the **target population** of the CIS 3:

- mining and quarrying (NACE 10-14)
- manufacturing (NACE 15-37)
- electricity, gas and water supply (NACE 40-41)
- wholesale trade (NACE 51)
- transport, storage and communication (NACE 60-64)
- financial intermediation (NACE 65-67)
- computer and related activities (NACE 72)
- architectural and engineering activities (NACE 74.2)
- technical testing and analysis (NACE 74.3)
- research and development (NACE 73)

This specific focus on some sectors may create an important limitation to make comparisons between sectors. In particular, CIS covers only few service sectors. Major service sectors such as retailing or hotels are excluded from the CIS on the grounds that innovation is too infrequent in these sectors to be efficiently surveyed using the CIS. Then, the comparison between industry and services must be made very carefully.

[17]Micro data from CIS4 were not yet available at the EU level in the time of developing this project. This is why we focus on CIS3, although we have used CIS4 macro database for comparative temporal analysis.

II.1.3. Data collection in the CIS3

Countries can use census or samples or both. For instance, UK and France use a census of large firms and sample selection for SMEs. The selection of the sample should be based on random sampling techniques, with known selection probabilities, applied to strata. It is recommended to use simple random sampling without replacement within each stratum. Member States are free to use whatever sampling methods they prefer, as long as the quality thresholds for the results are achieved. As usual, this data collection leads to non-response problems. More precisely, two kinds of non-response problem arise: unit non-response and item non-response.

II.1.3.1. Unit non-response: sampling issues

The units that do not respond to the CIS 3 survey questionnaire may have different characteristics than those that do respond. Therefore, a simple random sample of at least 10% of the non-respondents is selected (necessary if non-respondents, as an unweighted percentage of all relevant enterprises in the sampling frame, exceed 30%). However, in nearly all sectors SMEs were more likely to respond than large firms.

The form to be used for this non-response survey includes some of the questions of the standard CIS3 questionnaire, in order to determine if the non-respondent is an innovator or not. Then, several methods can be used to calibrate the data. They rely on a stratification by NACE and firm size and, more recently, by region in some countries like UK and Denmark. Each stratum is calibrated using turnover and number of firms. If non-response is not equally distributed across strata, Member States may use a stratified non-response sample.

On this basis, a set of weights is applied to the raw data, to make inferences about the whole population. There are two potential sets of weights that can be used, namely business weights and employment weights, to adjust estimates in order to account for firms not included in the sample. For CIS1 and CIS2, data have typically been weighted using business weights, which are calculated as the inverse sampling fraction of the number of firms in each cell of the stratification. Using business weights, each firm in the population carries an equal weight. This can provide basic measures of population performance, but does not correct for differing firm sizes. Using employment weights, which are calculated using the inverse sampling fraction of employees in each cell of the stratification, allows data to be grossed up and corrected for firm size. So the greater the size of the firm, the larger the weight it carries in the employment weighted results. Employment weighted data provide a more robust means of estimating whole economy performance.

II.1.3.2. Item non-response

If some items are not filled in, the information is searched elsewhere (firm annual census, R&D survey, etc.). If it cannot be found, then imputation is done: a value is attributed according to the answer given by the other firms in the same stratum (e.g. same size and same NACE). As for metric variables, a weighted mean is calculated and applied as a ratio to the enterprises with the missing values, within the stratum concerned. As for ordinal, nominal and percentage variables, the technique used is nearest neighbour imputation. This technique consists in copying the missing data from a donor (with a record not violating any error check). This latter is chosen in such a way that the distance between the donor and recipient is minimised.

Unfortunately, this imputation has not been made systematically. Some missings are therefore present in the database we have got from Eurostat. A preliminary work has been done to identify these missing observations. The database has then been cleaned. The procedure is detailed in point II.1.5.4 below.

II.1.4. Characteristics of the data

Some characteristics of the data are likely to raise **some statistical problems**. Firstly, the CIS data are mainly **qualitative and subjective data** ("new", "new to the market"). Consequently, the quality of these variables is not always very good. The quantitative data are also imperfect. Innovation expenditures are rather approximate. They do not correspond with the information registered in the R&D surveys (R&D typically higher in innovation than in R&D surveys). The share of innovation in total turnover is also estimated by the respondent and does not come from vouchers. As Mairesse and Mohnen (2008) report, innovation output statistics are noisier than other statistical sources like R&D statistics for instance. They need to be instrumented to correct for errors in variables.

Secondly, innovation survey provides **only cross sectional data**. Some studies (Duguet and Monjon, 2002, Peters, 2008, Raymond et al. (2007) use several waves of innovation surveys. However, such a panel analysis has not yet been done for many countries because it requires the existence of multiple observations per firm across successive waves of innovation surveys, with a sufficient amount of overlap of sampling across successive waves. At each wave of CIS, additional questions are asked to include new dimensions of innovation (like questions on knowledge management in CIS3 or marketing innovations in CIS4) and some questions are removed, reformulated or their order is modified. For example, between CIS2 and CIS3 the objectives of innovation were replaced by the impacts of innovation, making it impossible to continue examining the role of innovation objectives on innovation behaviours (Mairesse and Mohnen, 2008).

In addition to temporal comparisons, **international comparisons are still difficult** to perform. All the EU countries do not follow the same sampling and calibration method. Therefore, differences between countries may appear that do not result from differences in their firm innovation behaviour, but that come from methodological differences. These biases have to be corrected to make comparisons between countries (in particular to compare performances across countries), by using the information given by countries on the method they used[18].

Moreover, innovation survey **does not allow us to provide comparison with the American case**. Indeed, the United States is one of the major countries with no innovation survey, although the U.S. National Foundation conducted a pilot innovation survey in 1985.

Finally, **some variables are censored data**. Indeed, the European Community Innovation Survey questionnaire is set up in a way that gives rise to a selection problem. First, firms are asked some general questions on their identity, their total sales and number of employees, their sectoral affiliation, and whether they belong to a group. Then comes a set of questions which define innovating firms versus non-innovating firms. Only innovating firms have to fill out the rest of the questionnaire and provide information on their innovation outputs and inputs, as well as on various modalities of their innovative activities. Therefore, we have very few information on the "non-innovating" firms (turnover, export, number of employees, in

[18] We will talk about these corrections in the remainder of part II.

level and growth rate, the main industry they belong to, and their potential affiliation to a group). This allows us to correct only partially the selection biases that arise when only innovators are considered. We will come back to this selection bias issue in the econometric part (Part III).

II.1.5. The database building

This research work is based on two samples extracted from the CIS3 survey which concerns innovative activities carried out between 1998 and 2000. The first has been provided by the European Commission as a micro anonymized dataset whereas the second is a macro-aggregated dataset available on Eurostat website.

- The micro dataset contains 49761 firms belonging to 15 different European countries and several different NACE2 sectors.
- The macro-aggregated dataset covers 26 EU member state countries as well as Iceland, Norway, Turkey and provides information for Core sectors aggregated into 7 sectors.

Before pursuing with the descriptive analysis, a preliminary comparison analysis will allow us to underline some main limitations of these datasets (section II.1.5.1). Then we will explain how we built the database (II.1.5.2).

II.1.5.1. CIS3 Macro and Micro data comparisons

The data at the macro and micro level show significant differences in two specific dimensions:

- the number of countries for which the CIS provides data
- the sectoral disaggregation level

The number of countries available

The data at the macro level would be available for "*all **25 EU Member States** plus Iceland and Norway as well as Turkey and Romania. Furthermore other European and non European countries also carried out surveys equivalent to CIS3. The survey in Poland is mainly based* *on CIS2, but many variables are also comparable with CIS3*".[19] However, when analysing the availability of data more carefully, many missing observations are present for some of the relevant countries to our research which, *de facto*, constraints some cross-country comparisons and a full exploitation of the data. In particular, the innovation adoption items are available only in the CIS3 version for 14 countries. The countries for which data are available at the macro level for this CIS3 item are: Belgium, Germany, Greece, Spain, France, Italy, Luxembourg, Netherlands, Austria, Portugal, Finland, Sweden, Iceland and Norway.[20]

When instead we analyse the data availability for the proposed indicator of innovation adoption at the firm level (CIS3 "micro" level) data are available for the following 14 countries: ***Belgium***, Bulgaria, Czech Republic, Estonia, ***Spain***, ***Greece***, Hungary, ***Iceland***, Lithuania, Latvia, ***Norway***, ***Portugal***, Romania and Slovakia (in bold the ones available in both the micro and the aggregated databases).

When we compare the micro CIS3 data with the macro ones some important "core countries" are notably missing in the micro database: Germany, France, Italy, Austria, Sweden, Finland and Netherlands. It is important to stress that these countries are probably the most important ones when the analysis focuses on the adoption of innovation, as they are those with a higher level of innovative activity. Table II.1 recaps the countries in the two databases.

Sectoral disaggregation issues

The CIS3 macro data are normally available for the following sectors:

1. Mining and quarrying (NACE 10-14)
2. Manufacturing (NACE 15-37)
3. Electricity, gas and water supply (NACE 40-41)
4. Wholesale trade (NACE 51)
5. Transport, storage and communication (NACE 60-64)
6. Financial intermediation (NACE 65-67)

[19] See methodological notes to the CIS3 in the Eurostat web-site: http://epp.eurostat.ec.europa.eu/portal/page?_pageid=1996,45323734&_dad=portal&_schema=PORTAL&screen=welcomeref&open=/science/inn/inn_cis3&language=en&product=EU_MAIN_TREE&root=EU_MAIN_TREE&scrollto=288 .

[20] Notice, these countries are available under the definition: type of innovation breakdown "*innovative activities*" and "*Product/process, developed by the enterprise together with other enterprises or institutions or developed mainly by other enterprises and institutions*".

7. Computer and other business activities (NACE 72, 73, 74.2 and 74.3)[21]

Table II.1. Countries' presence in macro and micro datasets

	CIS3 macro	*CIS3 micro*
Austria	X	
Belgium	X	X
Bulgaria		X
Czech Republic		X
Estonia		X
Finland	X	
France	X	
Germany	X	X
Greece	X	X
Hungary		X
Iceland	X	X
Italy	X	
Latvia		X
Lithuania		X
Luxembourg	X	
Netherlands	X	
Norway	X	X
Portugal	X	X
Romania		X
Slovakia		X
Spain	X	X
Sweden	X	
Obs.	14	15

In bold the core countries missing in the CIS3 micro dataset

This said, some countries have missing data for some sectors normally available in the CIS3 macro dataset. This implies that some sector cross-country comparisons will not be possible even if the aggregated data at the country level can be actually computed for the 15 countries.

The CIS3 micro dataset allows a much higher disaggregation level than the macro data source. However, this level of disaggregation is uneven across countries. Aggregation by

[21] computer and related activities (NACE 72), research and development (NACE 73), architectural and engineering activities (NACE 74.2), technical testing and analysis (NACE 74.3)

sector is not the same according to the countries under consideration (see Appendix II.2 for more details on this point).

II.1.5.2. A database built from Micro and Macro data

In order to obtain the best country coverage, a database was built from micro and macro data following the availability of information according to countries (see Table II.2). The sectoral classification is as presented above, that is to say, in 7 domains.

Micro data have been favoured for the countries for which we have the two datasets. This choice is due to the fact that, using the macro dataset, we face a double counting problem[22] in the construction of the indicators of innovation diffusion/adoption (see Appendix II.1). This latter prevents to cross some information. As we will see below, this problem constrains a lot in the set up of the innovation adoption indicators.

Concerning the micro dataset, we also face difficulties because micro databases are not harmonised between countries. In particular, this concerns such areas as the data type, the code for non-response, etc. Once more this is likely to constraint some cross-country comparisons and a full exploitation of the data.

Moreover on the micro database, some missing or inconsistent observations have lead to a reduction of the size of the sample. For example, because of individuals answering ”yes” to the items “product and process innovation” and giving no answer to the item “innovation mainly developed by others or in collaboration with other firms”, 622 observations have been dropped from the sample. So, the dataset contains 49139 firms after cleaning. Deleting missing and inconsistent observations has a very weak influence on the spatial and sectoral characteristics of the sample.

[22] We detail this issue in Appendix II.1. However, briefly, this refers to the fact that at the macro level we are not able to verify whether a firms is replying yes to two specific items of the CIS3 data used in the construction of the innovation adoption indicator and, therefore, we may double count it.

Table II.2. Database source according to countries		
	CIS3 macro	***CIS3 micro***
Austria	X	
Belgium		X
Bulgaria		X
Czech Republic		X
Estonia		X
Finland	X	
France	X	
Germany		X
Greece		X
Hungary		X
Iceland		X
Italy	X	
Latvia		X
Lithuania		X
Luxembourg	X	
Netherlands	X	
Norway		X
Portugal		X
Romania		X
Slovakia		X
Spain		X
Sweden	X	
Obs.	7	15

Finally, the database contains 22 countries. The source is micro dataset for 15 of them. For the other 7 countries, the risk of double counting is present because of the use of macro dataset. This problem is dealt with as explained in Appendix II.1. However, in order to keep in mind that potential differences may arise between the two sources of information, different colours are used in the descriptive part for countries coming from micro and macro sources.

Regarding the sectoral coverage, as mentioned above, only seven sectors are available from Eurostat website. This is therefore the smaller breakdown we can use once micro and macro data are merged. In addition to that, due to the double counting problem, the finance sector must be dropped out. Indeed, because of an important number of firms with both product and process innovation in this sector, the computation of our adoption rate is strongly biased (the explanation on this point is detailed in Appendix II.1). **Thus we finally end up with 22 countries and 6 sectors.** A more detailed analysis by sector is provided in appendix, focusing on the micro database information (see Appendix II.2).

As a means to develop the descriptive analysis in this Part II of the report as well as the regression analysis in Part III, we have developed a database with considerable information, not only on the topic of innovation and innovation diffusion/adoption, but also on the different determinants of this innovation adoption and on the Internal Market proxies. Therefore, a first deliverable of this project is the database that has been constructed as homogeneous as possible for all EU countries and sectors finally included in this project.

II.2. Measuring innovation adoption

In the CIS survey, the definition of innovation covers both the generation of innovation and the adoption of such innovation. Therefore, it can be used to analyse the process of innovation diffusion, by identifying innovation that relies on an adoption process. We first explain how we proceed to distinguish adoption and generation of innovation. Then, we discuss the choice of an indicator of the magnitude of adoption. Finally we suggest indicators likely to characterize the nature of adoption.

II.2.1. Definition and magnitude of innovation adoption based on CIS3

For each firm, the CIS gives information on the way the product and process innovations have been developed. Firms have to choose between three answers:

- innovation developed mainly by the firm
- innovation developed mainly together with other firms or institutions
- innovation developed mainly by other enterprises or institutions.

Therefore, we will consider that **innovation adoption occurs as soon as the firm declares that its process or product innovations have been developed "Mainly together with other enterprises or institutions" or "Mainly by other enterprises or institutions".**

Two kinds of limitations are associated with this definition:

- A first set of limitations is due to the fact that only part of the innovation diffusion process is accounted for by CIS. **Our definition refers to innovation adoption and does not allow us to address all the issues associated with the process of innovation diffusion.**

In addition, the CIS survey does not allow us to address the question of the diffusion among countries. This issue would be of great interest in the context of the EU. However, the items of the CIS regarding the way innovation is made do not provide any information about the location of the organizations by which or with which the innovation has been developed[23].

Another drawback is that such a definition prevents us to study organisational or marketing innovation for which these items do not appear. This kind of innovation concerns numerous enterprises. Indeed, more than one European firm over two (58.8%) has introduced at least one organisational or marketing innovation between 1998 and 2000. However, this kind of innovations is not yet considered in the official definitions. Eurostat measures innovation rate in the state members through product and process innovation activities only.

- The second set of limitations is due to the inaccuracy of the information contained in the CIS. Our definition does not strictly account for adoption in the sense that innovation developed together with other enterprises can rely on knowledge sharing more than on innovation diffusion. However, as mentioned in the literature review (part I) most studies stress the importance of effective collaboration to adapt the technology and make it suitable for the adopter. This is thus relevant to consider that in many such cases, innovation diffusion occurs.[24]

Moreover, we do not have, for each firm, the number of innovations that fits with the definition. This is a strong limitation to account for the extent of adoption.

[23] As we will see in sub-section II.4, questions are ask to the inventor about the location of their partners. But these questions is not related to the items regarding the way the output of innovation has been made, but to the items regarding the use of R&D cooperation. In the CIS, this information refers more to innovation inputs than to innovation output. Therefore it can hardly be used to assess the innovation adoption processes. Firms that mainly innovate by themselves (and thus are not considered as adopting firms according to our definition) may have established R&D cooperation links. We will use this information about location of partners in the analysis of the determinants of adoption, but it cannot be used to assess innovation diffusion between countries.

[24] Therefore, the indicator we suggest to use accounts more accurately to innovation adoption than to innovation diffusion. This is why we will use this concept of innovation adoption from now on for the results of the analysis made with our database.

Finally, firms are asked about their "main" way of innovation. Therefore, some firms are excluded from the definition above while they do rely on innovation adoption, but this is not their main way of innovation (some firms answering that their innovations have been developed *mainly* within the enterprises or the group may be at the same time adopters of innovation developed elsewhere). We are therefore driven to consider that adoption/diffusion is done by the firms whose product or process innovations are developed mainly together with other firms or mainly by other enterprises, and that all the information they provide regarding inputs and outputs concerns this kind of innovation.

In spite of these limitations, the definition we suggest is the one that covers most enterprises. According to it, on average, **39% of the innovating firms adopted a product or a process innovation in Europe between 1998 and 2000**. This represents **less than 14% if we compare to the whole sample (and not only to innovating firms).**

A more accurate definition of adoption should be built, by adding an additional restriction. In the CIS, firms have to indicate whether their product innovations are "new for the market" or "only new for the firm". Focusing on *product that are new to the firm only* will be more efficient to account for "*pure" innovation adoption*, since it considers only firms that adopt existing technologies, developed outside the firm. In other words, adding the "new for the firm only" item would ensure that the innovation already existed. This definition would also provide us with additional information, namely the turnover associated to innovation. Indeed, firms have to indicate the distribution of their turnover due to "new to the market" and to "new to the firm" innovations. This distribution gives interesting information. It allows us not only to identify innovation adoption but also to quantify innovation adoption. This would lead to alternative indicators of the magnitude of adoption. They are discussed in the Appendix II.3.

However, this definition accounting for more pure innovation adoption faces **several drawbacks**:

- Firstly, it obliges us to focus on **product innovation only**. In particular, the second item does not exist for process innovation (except in some countries: UK for instance). This is a serious problem since the share of process innovating enterprises is quite as high as the share of product innovating enterprises (respectively 24.4% and 28.8% of the CIS3 enterprises).

- Secondly, it requires having information at the firm level, in order to cross several items. As detailed in the Appendix II.1, **this cannot be done with the macro data** available on the Eurostat website.

For these reasons, the remainder of the study focuses on the definition given firstly: **firms are considered as adoptive ones if they declare that their process or product innovations have been developed "Mainly together with other enterprises or institutions" or "Mainly by other enterprises or institutions".**

Even though imperfect, this instrument built from the CIS is the only systematic information available to measure innovation diffusion/adoption within the EU. It will allow us to provide a first assessement of the innovation adoption in the Internal Market, and to think about how the CIS could be improved to better account for these phenomena.

II.2.2. Magnitude of innovation adoption

On the basis of the definition given above, the magnitude of adoption will be measured as the share of adopting firms. Two different ratios could be considered:

(a) Adopting enterprises / Total number of enterprises

Problems of interpretation will arise with this indicator when comparing countries and industries. Indeed, the differences between countries or NACE could come from differences in the magnitude of adoption but also from differences in the intensity of innovation (activities or countries with higher level of innovation will exhibit higher ratio). So, we suggest to use a ratio based on innovative enterprises only:

(b) Adoptiong enterprises / Number of innovative enterprises

This will ensure that cross country or cross sector differences in adoption magnitude are not due to differences in innovation intensity. It also provides us with more tractable data. Indeed, the percentages are higher than with the first indicator and its variance is higher as well. Therefore, the inference made on this basis will be more efficient.

Two alternative definitions of "innovative enterprises" can be considered, with different scope:

- If we strictly follow our definition of innovation adoption, we can refer to product and process innovative enterprises only:

  Indicator 1: Number of adopting enterprises / Number of process and/or product innovative enterprises

- However, one can also use a broader definition, including "ongoing or abandoned innovation activities" (process or product). This latter is the "official" definition used by the EU to measure the share of innovation within countries or NACE. For this reason, we recommend to focus on this definition.

  Indicator 2: Number of adopting enterprises / Number of enterprises with process and/or product innovation or with ongoing or abandoned innovation activities

One can also imagine adding "organisational and marketing innovation" as well. However, we will use this item for other purpose later on. For this reason we should avoid to include it at this stage. Therefore, our indicator of the magnitude of adoption will be the last indicator above **(indicator 2).**

II.2.3. Nature of innovation adoption

The nature of innovation adoption refers to two different questions. **The first one can be summarized by the following question: what kind of innovation is adopted. The second one refers to the way innovation is adopted.** It is important to get indicators of these characteristics, since the determinants of innovation adoption can differ according to them.

The first question will be studied by looking at the distinction between product and process innovation. The innovation adoption presented above can be different according to the nature of innovation (product and process).

Indicator 3: Number of firms identified as actors of innovation adoption *and* introducing **product** innovation / Number of **product** innovative firms.

Indicator 4: Number of firms identified as actors of innovation adoption *and* introducing **process** innovation / Number of **process** innovative firms.

This will inform us about the nature of the innovations (product or process) that diffuses over the industries in the different countries. However, due to the subjective nature of the definition of innovation adoption ("mainly"), this indicator must be considered carefully. We will not be able, for firms introducing both product and process innovation, to know if innovation diffusion occurs for both or for one kind of innovation only. The bias should not be neglected. According to the information recorded in the CIS3 micro aggregated database, firms introducing both kinds of innovation represent 19% of the adopting enterprises. But for some countries or industries this may be more important (see Appendix II.1).

The second kind of characteristics deals with the nature of the adoption process, in reference with the channels it relies on. The nature of innovation adoption can differ according to the main drivers of adoption. In particular, adoption may result from adoption of external technologies. But it **also** relies often on the joint production of innovation.

One item of the CIS allows us to address this question. Firms indicate whether their innovations are developed mainly in cooperation with others or mainly by others. Two indicators can be derived from this information.

Indicator 5: Number of firms declaring that their **process or product innovation** has been developed "mainly **together** with other enterprises or institutions"/ Number of innovative firms.

Indicator 6: Number of firms declaring that their **process or product innovation** has been developed "mainly by **other** enterprises or institutions"/ Number of innovative firms.

II.3. Descriptive statistics of innovation adoption in the EU

Based on the definition and measures of innovation adoption given in section II.2, this third part will characterize innovation adoption in Europe. We put the stress on three kinds of comparisons:

- **Nature innovation-based comparisons**: Since the adoption process may differ significantly according to the type of innovation under consideration, a distinction will be made according to the nature of innovation: in particular, product vs process innovation and collaboration vs external sources of innovation will be analysed.
- **Geographic comparisons**: Comparison across European countries in relation to the main variables characterizing innovation adoption.
- **Sectoral comparisons**: For the indicators available at a sectoral level, comparisons will allow us to identify some differences across industries in the adoption process and barriers to innovation adoption.

II.3.1. Descriptive analysis of adoption rates: General strategies

As previously mentioned (section II.1.5.2), the computation of a global adoption rate (at country or sectoral level) raises some difficulties. Because micro aggregated data allows the crossing of different items, an exact count of the number of adopting firms is possible. This is not the case with macro data, for which double counting of product and process innovation occurs (see Appendix II.1 for a detailed explanation on this point). Therefore, the values from macro database are higher than those from the micro database. In order to cope with this issue, **a rescaling procedure** has been used to make the two databases information compatible. This rescaling procedure and its limitations are explained in Appendix II.1. In the following graphs, the clearer colour given to the countries observed from the macro database will help us to keep in mind that the global indicator of adoption computed from macro data may be affected by this procedure.

Overall, our empirical evidence shows that the **percentage of adoptive firms is equal to 39%.** This rate varies a lot according to countries and sectors**,** but this will be analysed afterwards.

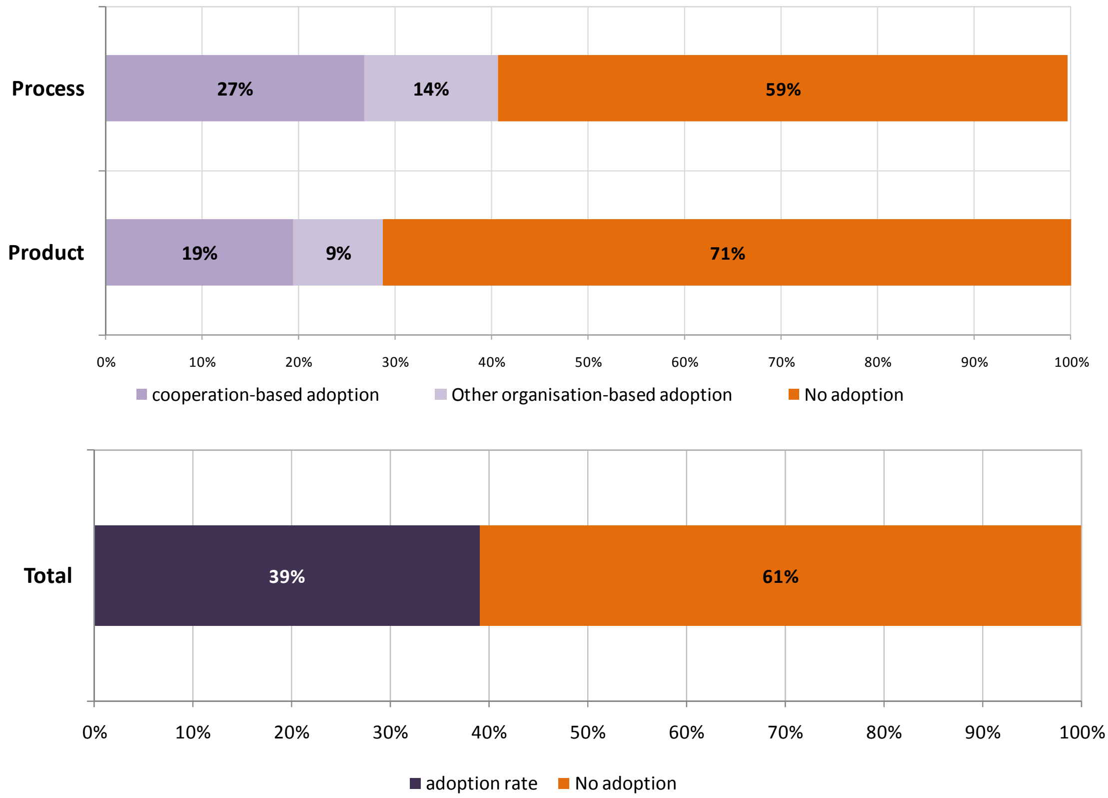
Now, we turn to analyse the general pattern of the use of adoption made by firms that are product innovators and those that are process innovators, to study whether their adoption intensity varies as well as the way it is adopted. In this sense, we distinguish two modalities of adoption. The firms can:

- either develop their innovation mainly in cooperation with other enterprises or institutions
- or rely on innovation developed mainly by other enterprises or institutions.

Is innovation adoption more important for *process* or *product* innovations and is this adoption the result of *Cooperation activities with other firms* or innovations are acquired directly from *other innovative firms*?

1) **Innovation adoption seems to be more important for Process innovations than Product innovations.**
2) **Cooperation activities are driving innovation adoption at the EU level while the acquisition of innovations from external innovators is a less important source of adoption of innovation (both process and product).**

Figure II.1. Innovation Adoption rates in the EU



MAIN INSIGHT: For all the countries, the adoption rate is higher in the case of process innovation (41%) than product innovation (28%). **So, innovation adoption is more process-oriented** (even if innovation on its own is more product-oriented, 24 % of EU firms make process innovations vs. 28% which perform product innovations). It is not surprising that process innovations appear highly adopting. Indeed, there is a close relationship between process innovation and machinery investment (Conte and Vivarelli, 2005). In turn, such embodied technology represents a very tradable component compared to i.e. intangible assets.

These results may seem surprising because process innovations are more often kept secret than product innovations. In this context, we could think that firms are more reticent about collaborating or entrusting other organisations for innovation development. However, our results seem to suggest that **process innovations need interactions between the firm and its suppliers and/or clients to be successful. Moreover, process innovations are often the results of supplier or client needs. This would encourage cooperation or outsourcing strategies to develop this type of innovation.**

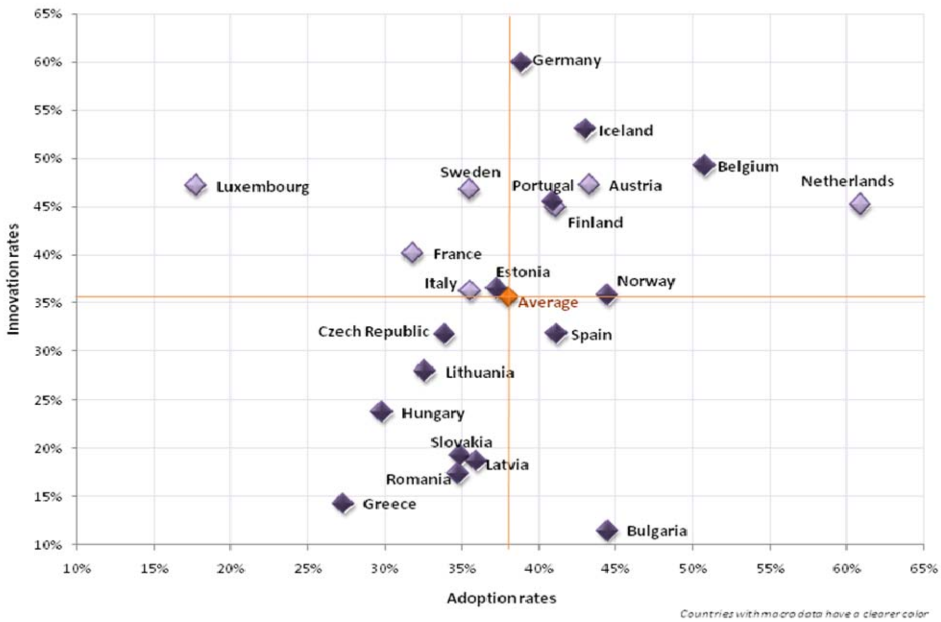
II.3.2. Descriptive analysis of innovation adoption by countries

We will organize the description by firstly analysing the heterogeneity of adoption rates across EU countries, and then present the main correlations of innovation adoption vs. the total innovative effort with the idea of understanding whether differences can be actually observed among countries which "produce" innovation and those which, instead absorb or "adopt" this innovation. This task will be carried out, also, by disaggregating innovation adoption by its main "characteristics", that is of being product or process innovation or that of being performed jointly with other innovative firms or as a result of a direct acquisition from another (external) firm.

Are innovation adoption rates homogeneous across EU countries and are they correlated with innovation rates?

1) **No, innovation adoption rates vary substantially across EU member states**
2) **Yes, highly innovative countries seem also to be those which are more engaged in adoption activities.**

Figure II.2. Innovation and Adoption rates by countries



Note: The average adoption rate given on the graph (and on all the following graphs) is computed as an average of the country rates and not as a global rate computed from the country and industry database.

MAIN INSIGHT: Although our empirical evidence shows that the **average percentage of adoptive firms is equal to 39%, this rate varies a lot according to countries.** The maximum value is observed for the Netherlands with 61%, then for Belgium with 51%. On the opposite, the minimum value is observed for Luxembourg with 18%. This percentage is low if compared to other countries since all other values are between 27% and 44%.

Also, countries with higher level of innovative activities seem to be also those more dynamic in the context of innovation adoption. It seems that **fostering innovation activities may also be associated to** some extent to spillover effects (which take place through "adoption mechanisms") leading to **higher levels of diffusion and adoption of innovation**. It is also interesting to note that **the rates of innovative firms are similar to those of adopting firms** (in this respect, we should take into account that the adopting rates are calculated over innovative firms).

Generally, countries with low innovation rate also record a low adoption rate. This concerns Greece and a majority of Eastern Europe countries (Romania, Latvia, Slovakia, Hungary...). On the opposite, countries with high innovation rates have higher adoption rates (like Belgium, Netherlands, Iceland, Germany, Austria).

Some countries have **specific positions**:

- **Luxembourg** has a high rate of innovation but the adoption rate is very low. This report can also be observed for France and Sweden but in lower proportion.
- **Bulgaria** has a very low innovation rate but an important adoption rate.

The analysis of Pearson correlation rates between innovation and adoption shows that:

- These two variables are not significatively correlated if all countries are included in the calculation (Pearson correlation = 0.277, p=0.201).
- **These two variables are significatively associated at a significance level of 5% if we exclude Luxembourg** (Pearson correlation = 0.449, p=0.036).
- These two variables are significatively associated at a significance level of 1% if we exclude Luxembourg and Bulgaria (Pearson correlation = 0.569, p=0,007).

<u>Are Innovation Activities correlated with Adoption both in the case of Product and Process Innovations or do we observe differences in both types of innovations across EU members?</u>

EU countries with higher rates of Product Innovation are also experiencing higher rates of Product Adoption (apart from the specific cases of Bulgaria and Luxembourg). The same is true for Process Innovation activities: those countries innovating more on process are also those which seem to benefit from process innovation adoption.

Figure II.3. Product innovation and product adoption by countries

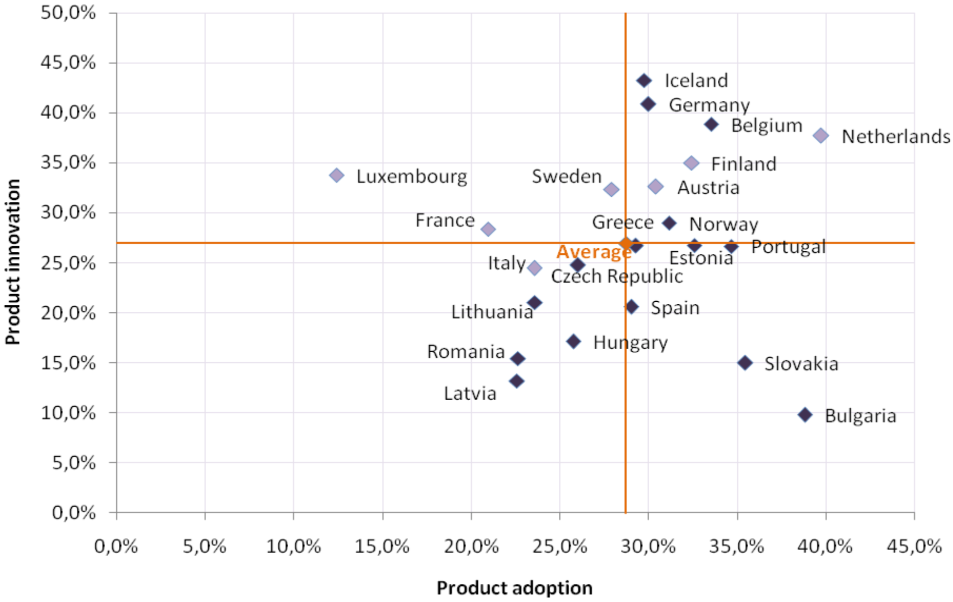
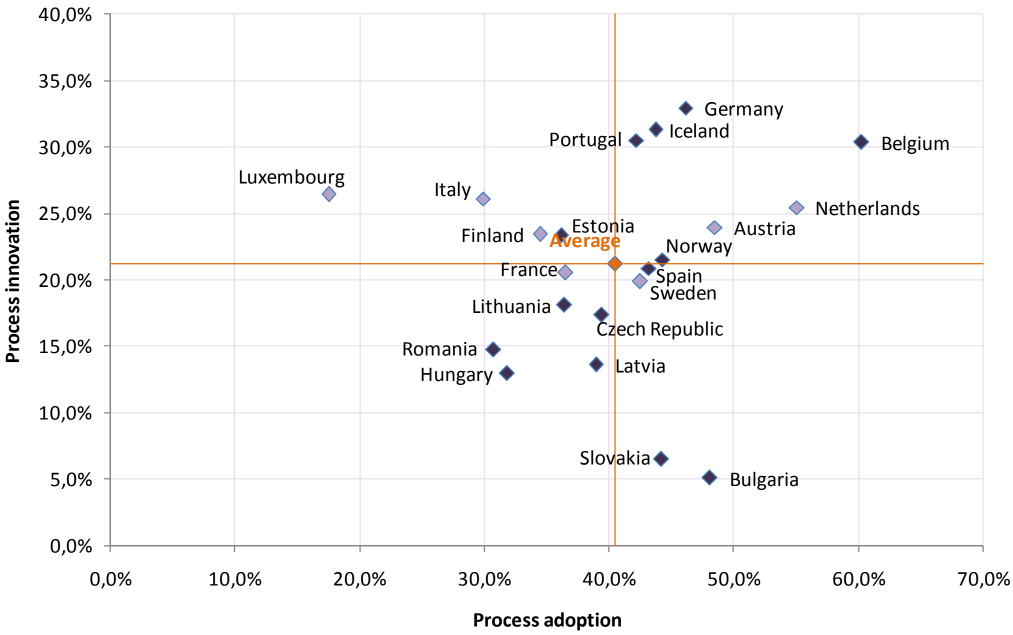


Figure II.4 Process innovation and process adoption by countries



MAIN INSIGHT:

Product innovations: We find evidence of a **positive correlation between being Product Innovators and being also Adopters of product innovations** across EU countries. This result seems to be in line with the overall observation that fostering Innovation activities (this time leading to product innovations) will also be associated to higher rates of adoption. Interestingly again, **the rates of product innovative firms are similar to those of product adopting firms.** If we exclude Luxembourg and Bulgaria when computing correlation for product innovation and product adoption, the relation is significant and positive (Pearson = 0,460; p-value = 0,041).

Process innovations: Countries for which innovation activities are more process oriented (those with high process innovation rates) are also those in which the same processes are more adopted (supposedly by closest firms). Again, **being innovators (this time process innovators) seems to be associated to higher rates of process adoption**. Countries which do not make process innovation, instead, are also stuck to low levels of adoption. However, in this case, it is interesting to note that the rates of process innovative firms is much lower than those of process adopting firms, that is, **firms tends to rely on process adoption more proportionally than on making their own process innovations**. When we drop out Slovakia and Bulgaria, we obtain a significant positive correlation (Pearson correlation = 0.6515; p-value = 0.0019) among both variables.

Are there any differences in the nature of adoption when we look at product and process innovation in EU countries? Is more important cooperation or other organizations-based adoption and is this pattern consistent across EU countries?

Both the cooperation-based and other organization-based adoption rates are higher for process innovation than for product innovation. And similar adoption strategies are followed for product and process innovations since cooperation and other organisation-based adoption rates for product are positively correlated with the ones of process across EU countries.

Figure II.5. Adoption nature by country for product innovation

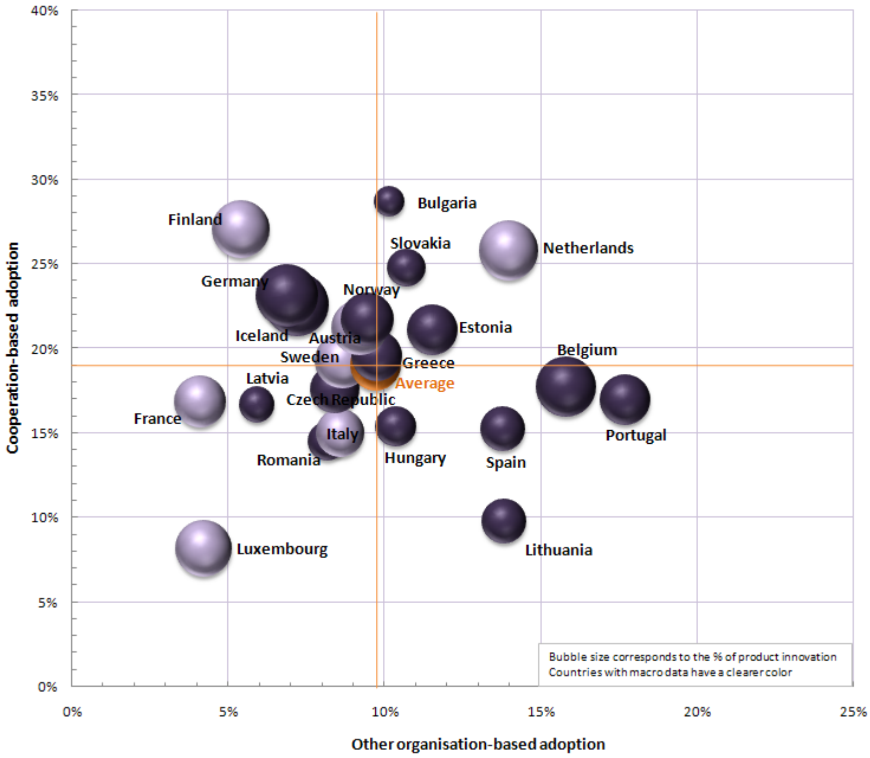


Figure II.6. Adoption nature by country for process innovation

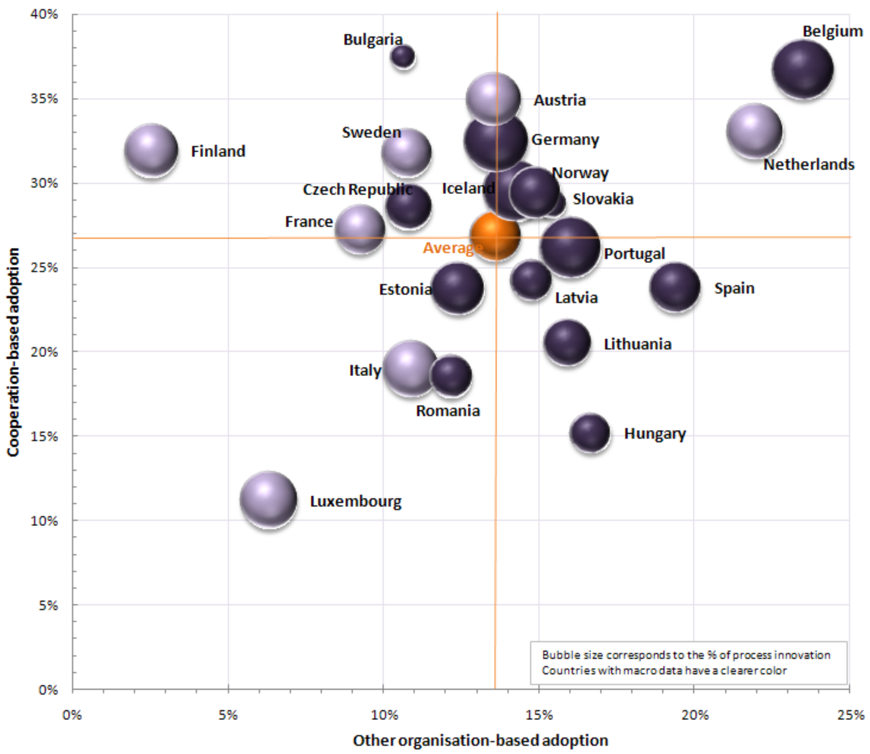


Table II.3. Pearson correlation Matrix

		Rates related to PRODUCT				Rates related to PROCESS			
		Cooperation	Other organization	Adoption	Innovation	Cooperation	Other organization	Adoption	Innovation
Rates related to PRODUCT	Cooperation	1	-0,002	0,821**	0,154	0,788**	-0,026	0,588**	-0,112
			0,992	***0,000***	*0,482*	***0,000***	*0,909*	***0,004***	*0,619*
	Other organisation		1	0,568**	-0,076	0,181	0,753**	0,528*	0,100
				0,005	*0,730*	*0,420*	***0,000***	***0,012***	*0,659*
	Adoption			1	0,083	0,751**	0,408	0,785**	-0,035
					0,705	***0,000***	*0,059*	***0,000***	*0,876*
	Innovation				1	0,321	0,024	0,258	0,867**
						0,145	*0,915*	*0,247*	***0,000***
Rates related to PROCESS	Cooperation					1	0,189	0,861**	0,083
							0,400	***0,000***	*0,713*
	Other organisation						1	0,662**	0,112
								0,001	*0,620*
	Adoption							1	0,121
									0,591
	Innovation								1

** The correlation is significant at 0.01 level.
* The correlation is significant at 0.05 level.

MAIN INSIGHT: According to Fig II.5 and II.6, **both the cooperation-based and other organization-based adoption rates are higher for process innovation than for product innovation.** In terms of level, **differences between countries are lower for product innovation than for process innovation**. Indeed, the gap between minimum and maximum rates is larger for process innovation.

For process innovation, Belgium and Netherlands strongly appear to be countries with high level of adoption based both on cooperation and entrusting to other. Some countries seem more cooperation oriented like Finland, Bulgaria, Sweden contrary to Hungary, Spain and Lithuania where the other organization-based adoption rate is higher.

For product innovation, even if country differences are smaller, various profiles can be identified. Profiles observed for process innovation are often the same as those for product innovation. Countries that strongly rely on cooperation for product adoption also strongly rely on cooperation for process adoption.

From Pearson correlation matrix (see table II.3), we can see that both the cooperation and other organization-based adoption rates for product are significant and positively correlated with the ones of process, which means **similar adoption strategies are followed for product and process**.

II.3.3. Descriptive analysis of innovation adoption by sector

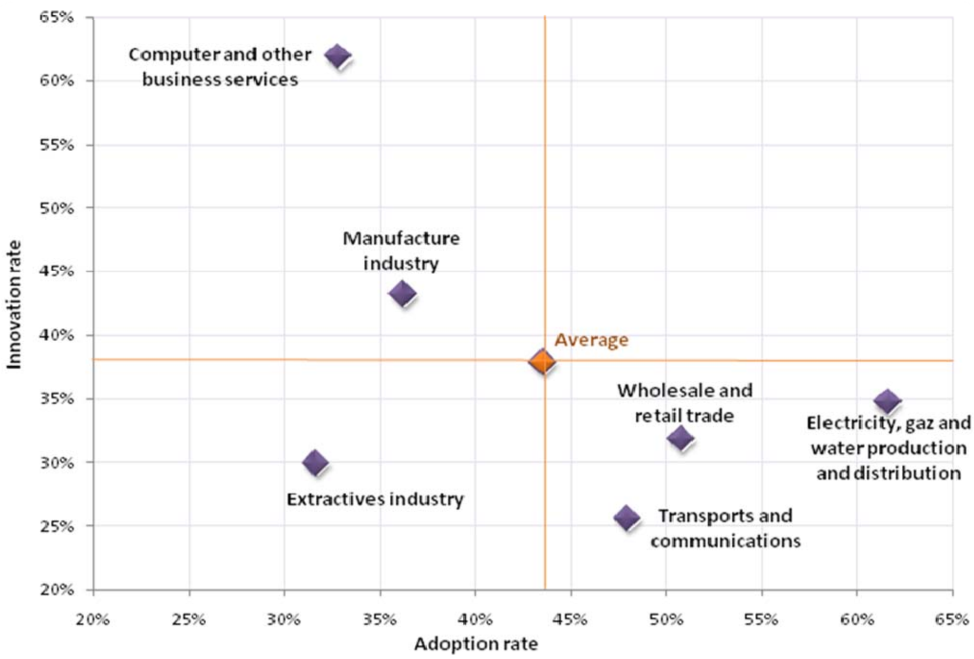
The descriptive analysis of innovation adoption is next carried out by productive sector in order to provide evidence of whether the innovation adoption patterns evidenced in the country analysis are also observed at the sectoral level. Then, we will try to answer questions such as if innovation adoption is an activity mainly performed in highly innovative sectors or, instead, mostly performed in low-innovative sectors. Are there any differences in the way innovation is adopted when we focus disjointly on product rather than process innovations?

Are adoption rates homogeneous across sectors and do they present any correlation with innovation rates?

1) Innovation adoption is far from being homogeneous across sectors ranging from 32% in Extractive industries and 62% in Electricity, gas and water supply.

2) No, surprisingly we find a negative correlation between innovation activities (those sectors which innovate more) and the adoption of innovation at the sectoral level. Innovation adoption seems to be weak in those sectors which instead are the most innovative ones.

Figure II.7. Innovation and Adoption rates by sectors



MAIN INSIGHT: Sectors for which the **adoption rates are the most important are Electricity, gas and water supply (62%), then Wholesales trade (51%) and Transport and communication (48%).**

If compared to the country case, the correlation between innovation rates and adoption rates is negative. Sectors with high adoption rates (Wholesale trade, Transport and communication, Electricity, gaz and water supply) are the ones with low innovation rate. Conversely, sectors recording high innovation rates (Manufacturing and Computer and other business services) show small adoption rates. Extractive industry has a specific position with both low innovation and low adoption rates.

The lack of correlation between adoption and innovation at the sector level may highlight the occurrence of inter-sector technological flows. Generation of innovation would be mainly driven by some sectors (namely Manufacturing and Computer and other business services) and then adopted in other sectors.

Is innovation adoption relying on Cooperation activities or on External innovative activities when focusing on sectoral dynamics?

For both Product and Process innovations, Cooperation is the channel through which innovations are mainly adopted. The direct acquisition of innovation by the outsourcing to other organizations is a minor adoption strategy regardless of the sector taken into consideration and of its relative adoption rate.

Figure II.8. Adoption nature by sector for product innovation

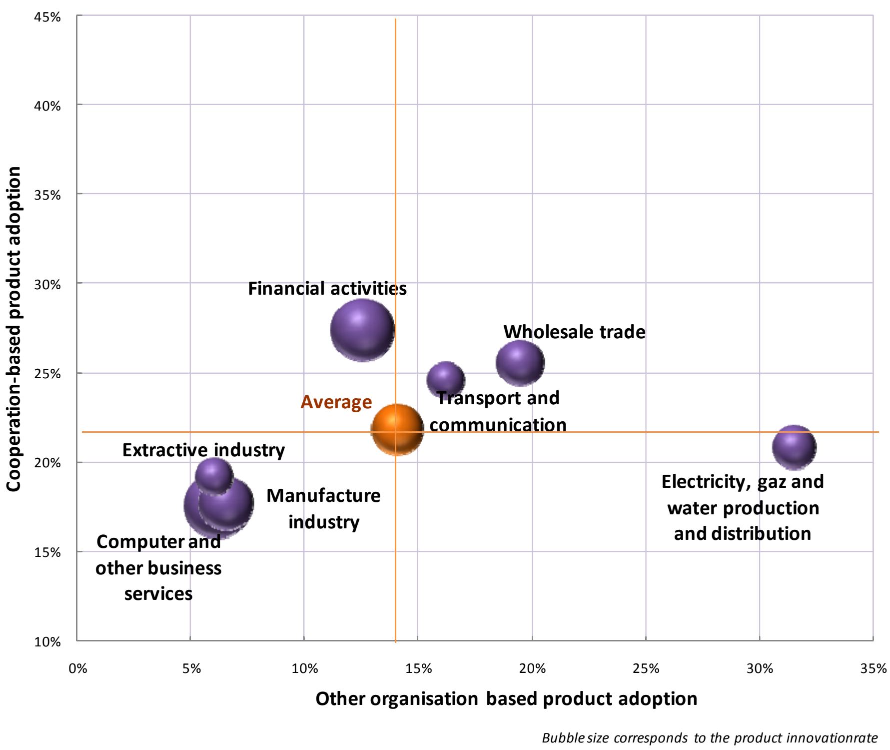
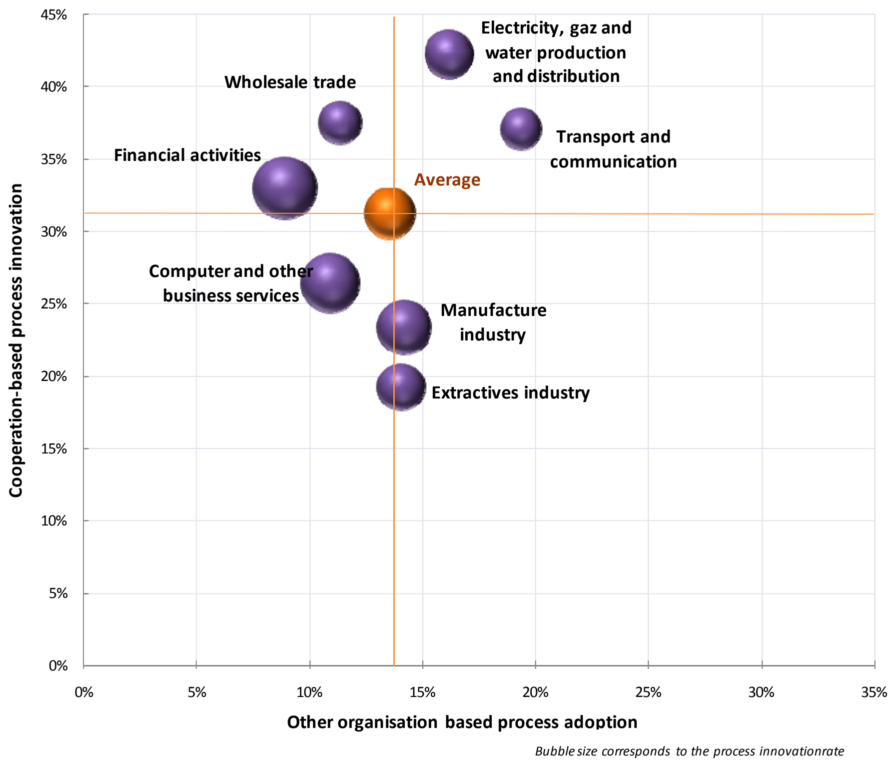


Figure II.9. Adoption nature by sector for process innovation



MAIN INSIGHT: Adoption is more cooperation-oriented than relying from outside resources, whatever sector is analysed.

Concerning adoption behaviour in the sectoral case, we can relate the following facts:

- Both for product and process innovations, **cooperation rates are particularly high for Wholesale trade, Financial activities and Transport and communication** (and Energy only for process innovation adoption). On the opposite, Manufacturing and Extractive industry record lowest rates.

- Whatever the sector and the nature of innovation (product/process), **cooperation is more frequent than outsourcing to other organisation** (except for Energy production and supply in the case of product innovations).

- The **adoption is more cooperation-based for process innovation** than product innovation whatever the sector (except for Extractive industries for which the rates are similar).

- Concerning the **share of innovative firms entrusting with other organisation, this share varies a lot according to sector**. It is the highest for Energy and Transport (for both product and process) and also Trade (for process only). It is the lowest for Computer and other business services, Manufacturing, Extractive industry and in lower proportion for Finance.

II.3.4. Sector composition and country's overall performance

Crossing the descriptive statistics obtained by country and those obtained by sector, one can wonder to what extent sector composition impacts on the country's performances in term of innovation and adoption. Countries specialized in highly innovative (resp. adoptive) sectors would be indeed more likely to exhibit high rates of innovation (resp. adoption) and conversely.

In order to explore more deeply this issue, appendix II.7 gives the detailed descriptive statistics by country and sector. This allows to highlight the specialisation of some countries, and to see to what extent this specialisation may be at the root of the country's overall performances. Three main conclusions arise.

- In some cases, the sector composition may explain the country overall performance. For instance, the high adoption rate recorded for Belgium may result from its specialisation in Wholesale and retail trade and in Transport and communications (see fig. A.II.7.1 in appendix). Indeed, these two sectors are among the most adoptive ones (see fig. II.7 above). Conversely, the low adoption rate registered for Greece might be explained by its specialisation in Manufacturing activities (see fig. A.II.7.1 in appendix), a sector in which the adoption rate is relatively weak.

- For some countries however, specialisation is not the only explanation of innovation performances. In particular, the German specialisation in Computer and other business services only partly explains its high rate of innovation. This sector does record the highest innovation rate at the EU level (see fig. II.7) and therefore influences positively the overall innovation rate in Germany. However, beyond this positive impact of its specialisation, Germany also benefits from a positive innovation dynamism: the innovation rates in Germany are higher than the EU rates in every sectors (see fig A.II.7.2 in appendix). In the Netherlands, the two same phenomena explain the overall high adoption rate: this country is specialized in two highly adopting sectors (Wholesales and retail trade and Transport and communication) and at the same time, for every sectors, Deutch firms exhibit higher adoption rates than the EU average (see fig. A.II.7.3 in appendix). Conversely, the weak performances of Slovakia and Latvia in terms of innovation may results from their specialisation in a low innovative sector, Wholesale and retail trade, and at the same time from an overall low propensity to innovate. Their innovation rates are lower than the EU ones in every sectors (see fig A.II.7.2 in appendix).

- Finally, in some other cases, the high level of innovation or adoption cannot be explained by the country specialisation. For instance, Austria has no strong specialization in strongly innovative sector (see fig. A.II.7.1 in appendix), but it is characterized by high innovation and adoption rate. Moreover, some countries specialized in sectors with low innovation and adoption performances registered high rates of innovation or adoption. For instance, in spite of their specialisation in Wholesale and retail trade and in Transport and communications (two sectors characterized by low innovation rates), Belgium and Iceland exhibit high innovation rates. Conversely, the low innovation rate observed for Greece cannot be explained by the country specialisation. Althought specialized in a relatively highly innovative sector (Manufacturing), this country faces very low rates of innovation.

Therefore, the country industrial specialisation only partly explained the strong differences in innovation adoption rates. Using descriptive statistics tools, the next section explores the determinants that may drive these differences. A more comprehensive analysis will then be provided in part III, using econometric tools.

II.4. Descriptive statistics of the potential determinants of innovation adoption in the EU

As detailed in Part I of the report, several factors are likely to influence the innovation adoption rates of firms. Some of them rely on the innovation inputs carried out by both adopters and innovators. Other potential determinants are related to other firm and market features. Finally, a third set of determinants refers to institutional environment (especially IPR regime and Internal Market regulations). In this subsection of the descriptive analysis, we study to what extent these three kinds of determinants are related to the innovation adoption rates in the EU countries. In Table II.4 we offer a list of the specific determinants of innovation adoption for which we will analyse their correlation with adoption rates.

Table II.4. Potential determinants of innovation adoption analysed in the descriptive

DETERMINANTS OF INNOVATION ADOPTION

A. Innovation inputs

- Sources of information for innovation
- Innovation expenditure
- Human capital resources
- Organisational changes
- Cooperation in joint R&D

B. Market features

- Competition
- Barriers to competition
- Trade
- Barriers to trade

C. Regulatory environment

- **Protection methods for inventions**
  - Patenting
  - Other legal and informal protection methods
  - Security of property rights
- **Internal Market regulations**
  - Transposition Deficit
  - Product Market Regulations by EFW
  - Product Market Regulations by OECD

II.4.1. Innovation inputs and adoption

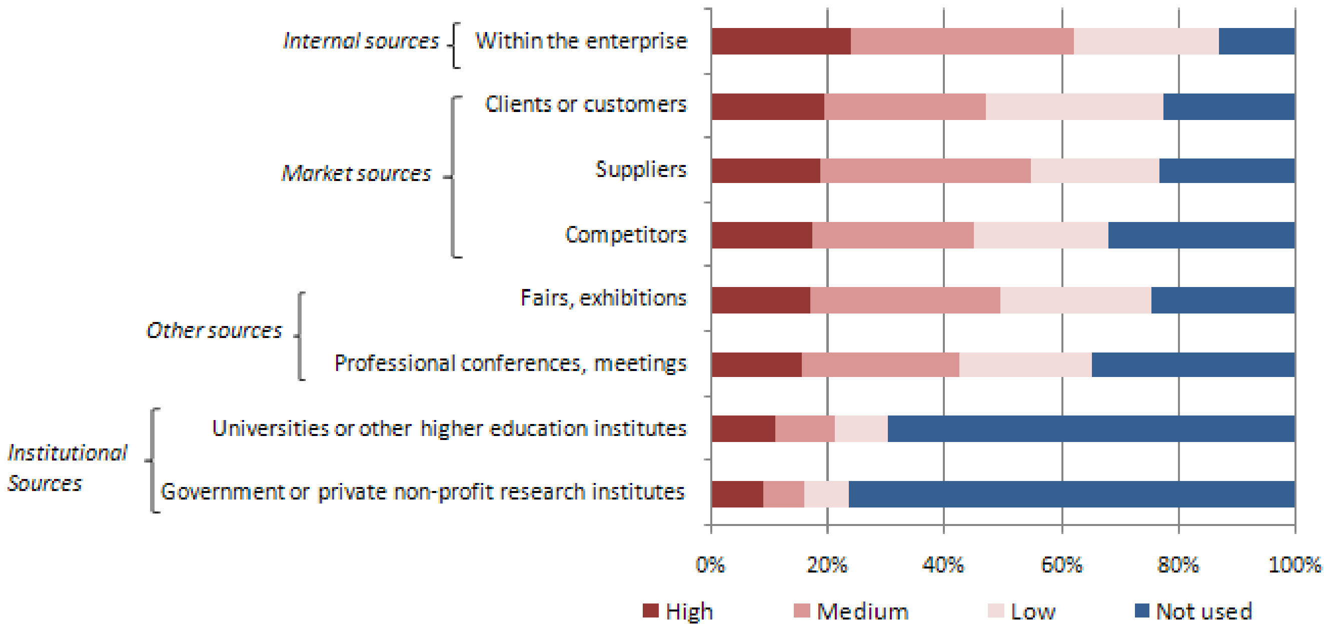
The literature review provided in Part I of this report highlighted that both demand side and supply side determinants are likely to impact the firm ability to adopt new products or new processes. We cannot address separately the demand side and supply side factors. Indeed, the CIS macro aggregated data from Eurostat website does not allow us to distinguish the features of firms that mainly adopt innovation from the one of firms that generate innovation. Therefore, the issue of the relationship of innovation inputs with innovation adoption is considered as a whole. The five types of innovation inputs studied in this section (sources of information, R&D inputs, human capital, organisational changes and cooperation activities) can thus reflect both suppliers and adopters' investments.

II.4.1.1. Sources of information for innovation: Different country profiles clearly identified but not significatively related to the level of innovation adoption

The CIS survey includes interesting information regarding the main sources of information used by firms in their innovation activities. In particular, a distinction can be made between sources of information that are internal to the firm or to the group, and the different external sources. As stressed in Part I of the report, the way information circulates among agents is an important channel of diffusion. This sub-section aims at analysing whether the different sources of information are associated with different level of innovation adoption. With this aim, we first characterize the EU countries according to their type of information sources (internal sources, market sources, institutional sources, etc.). We then study to what extent these different informational profiles are correlated with innovation adoption.

In terms of sources of information for innovation, sources within the enterprise are the most used (Fig.II.10). Information from market sources (from clients as much as from suppliers or competitors) or from other sources (like fairs or professional conferences) is also frequent. Indeed, between 65% and 87% of innovative firms exploit these different sources of information. But only between 15% and 20% of firms use them with a high importance. On the contrary, the institutional sources, that is to say, information from universities or government or private non-profit research institutes are weakly exploited: respectively by 30% and 23% of innovative firms. However, the percentages of firms using them at a high level are relatively high (11% and 9%).

Figure II.10. Sources of information for innovation for all the countries[25]



In order to analyse correlations between various variables about sources of information for innovation and to describe European countries according to the importance of these different sources and its relationship with their level of innovation adoption, a Principal Component Analysis (PCA) was carried out[26]. Here below we give the main results.

Is there a link between the use of sources of information for innovation and innovation adoption rates?

The link between the type of information sources used for innovation and the level of adoption is not really obvious. However, 4 groups of countries can be identified according to the primary source of information used when making innovation.

[25] The modality internal sources from other enterprises within the enterprise group is excluded because of the importance of missing values (39% of the total). Iceland is also excluded for the same reason.
[26] For technical details (eigen values, correlation circle and matrix), see appendix II.4.

Figure II.11. Sources of information for innovation according to countries and adoption rates

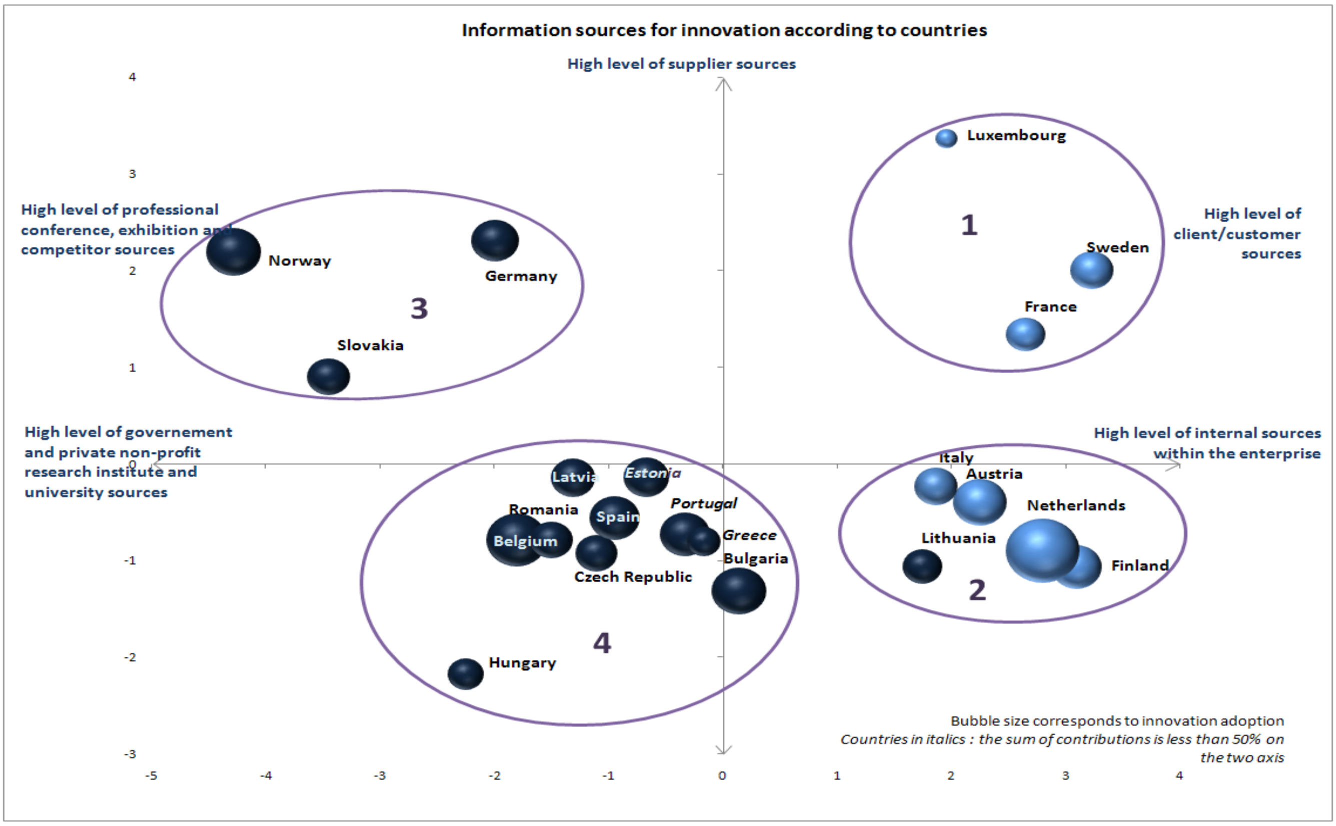
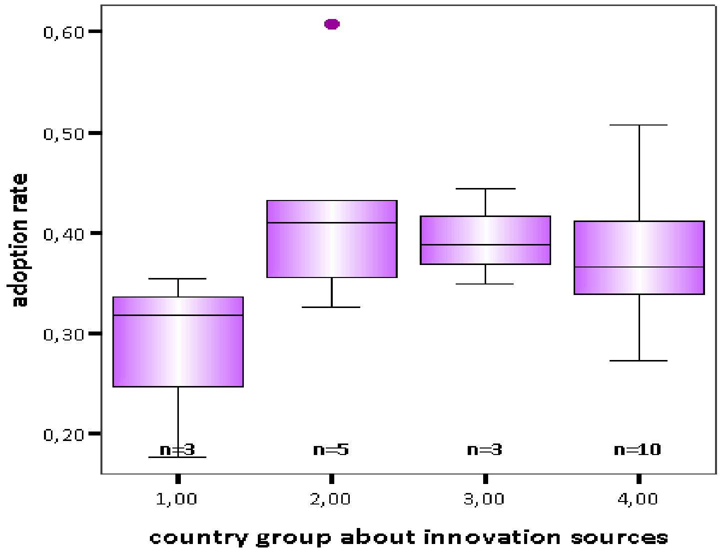


Figure II.12. Box plot : Main statistics for adoption rate according to information sources group



Statistics represented in this graph are:
- *the minimum (lower line out of the box)*
- *the first quartile (lower line of each box)*
- *the median (line inside each box)*
- *the third quartile (upper line of each box)*
- *the maximum or far value (upper line out of the box)*

MAIN INSIGHT: The factorial map (Figure II.11) clearly shows **4 groups of countries**:

- The first group (Luxembourg, Sweden and France) mainly exploits internal sources and market sources related to clients and suppliers. The use of institutional sources is comparatively low (high level use rates varies from 2% to 7%).

- The second group (Italy, Austria, Netherlands, Finland, and Lithuania) is generally characterized by a high level of use of information produced within the enterprise. Compared to the first group, the use of market sources is low. Only Finland and Austria have a high level of use for client sources. For these countries, the exploitation of institutional sources is as low as in the first group (the maximum rate is 6%). But it is also the case for competitor and other sources.

- The third group (Norway, Germany, Slovakia) is very specific due to:
  - a high level of institutional sources (rates are above 20% except for Germany with 18% for universities and 13% for the second institutional source)
  - a high level of professional conferences, exhibitions and competitor sources.

  So, this third group is positioned on innovation sources that are currently encouraged in technological policies, that is to say, based on relationships between firms and public research activities and cooperation between enterprises within the same industry. The level of other market sources is also relatively high.

- The fourth group (Belgium, Romania, Latvia, Spain, Portugal etc.) is close to the average situation for institutional sources (except for Hungary for which the two rates are very high: 30%) and for professional conference, exhibition and competitor sources. The client and supplier source rates are limited and internal source rates are very low compared to other countries.

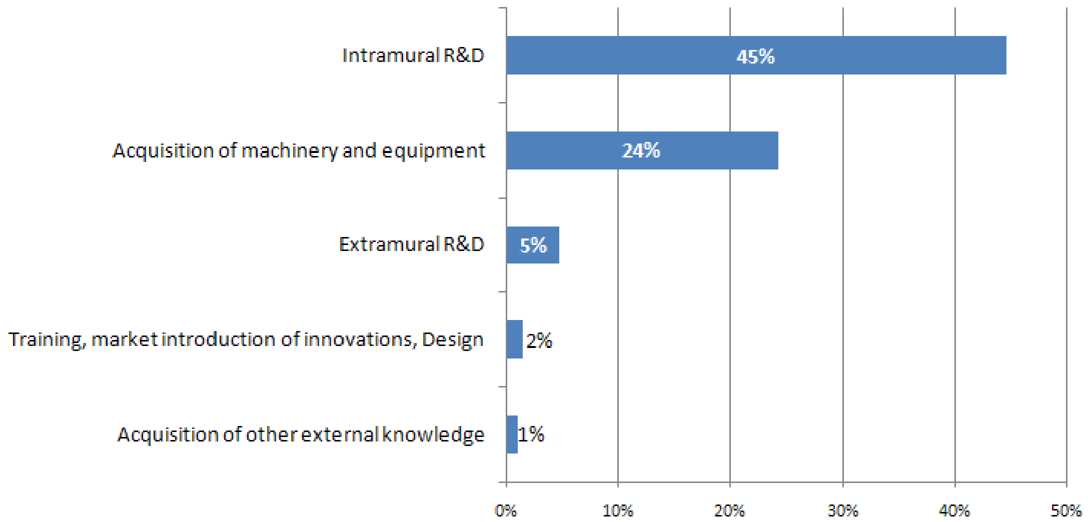
More interesting for our purpose of relating the sources of information with the adoption rates of the different countries, the box-plot (Figure II.12) shows that for the second, third and fourth groups, the different quartiles of the adoption rates are close. Additionally, a one-way analysis of the variance confirms that **average adoption rates are not significantly different according to groups** (F-statistic being equal to 1,962 and the significance value of the F-test being to 0,158). According to the box-plot, only **the first group (composed of France, Sweden and Luxembourg, which mainly exploit internal sources and market sources related to clients and suppliers) present lower adoption rates than the rest**.

II.4.1.2. Innovation expenditure nature and the adoption rate are not significantly associated

The amount of expenditure associated with innovation activities has been stressed in the literature as an important condition of innovation diffusion. Indeed, the R&D and other innovation expenditure made by both the innovator and the adopter are needed to improve the technology, to reduce its price, or to adapt it to the adopter needs. The CIS survey contains detailed information about these expenditures. The total level of innovation expenditure can be observed, but also its distribution among different types of activity. Therefore we can analyse the impact on innovation adoption rates of both the global level of innovation expenditure and the different natures of this expenditure. Three countries however contain missing values for these items (Luxembourg, Austria and Sweden). They are thus excluded from this analysis.

Figure II.13 shows that innovation expenditure is mainly devoted to intramural R&D (with 45% of expenditure) and to the acquisition of machinery and equipment (24%). The other types of innovation activity concern a small part of total innovative expenditure. The acquisition of other external knowledge which contains purchase of rights to use patents and non-patented inventions, licenses, know-how, trademarks, software represents only 1% of European total innovation expenditure.

Figure II.13. Innovation expenditure distribution according to the nature of activities[27]

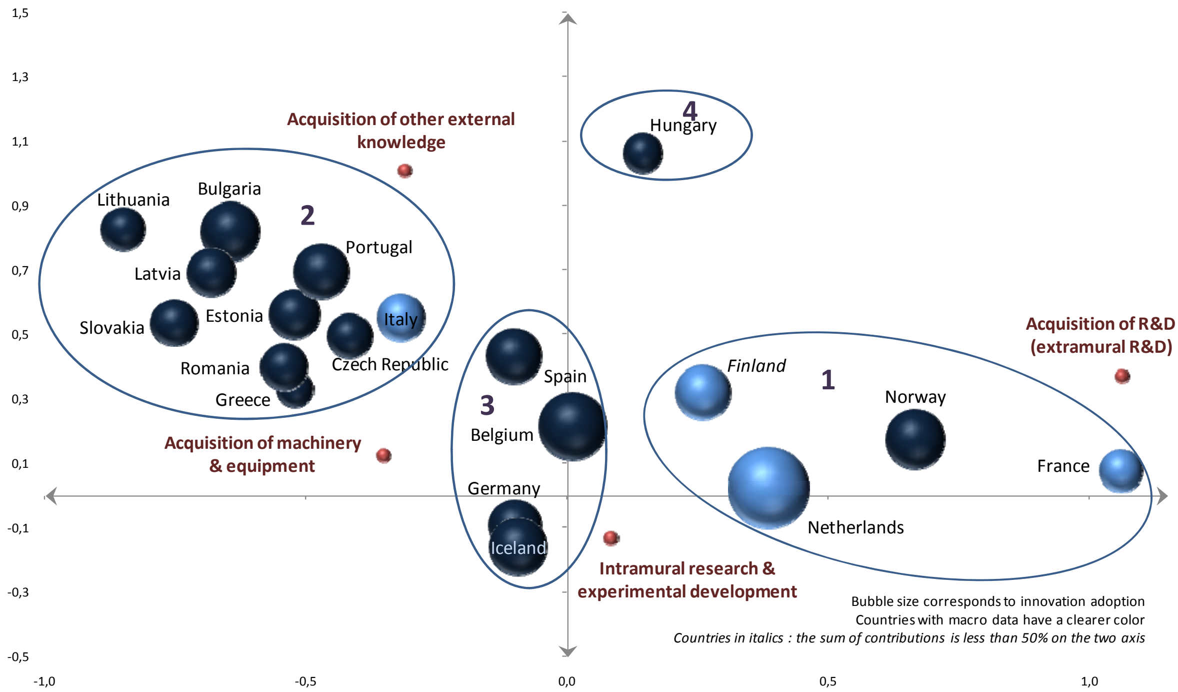


In order to analyse the correlations between various variables about innovation expenditures and to describe European countries according to the importance of these different resources, a Factorial Correspondence Analysis (FCA) has been done[28]. The factorial map (Figure II.14) clearly shows 4 groups of countries:

[27] In this calculation, Austria, Luxembourg and Sweden are not included because of missing values.
[28] We use here and FCA (and not a PCA) because we work on R&D expenditure. This allows us to use a contingence table since the sums of rows and columns have a direct interpretation. The variable "Training, market introduction of innovations and design" is not included in this analysis because it gathers different modalities of innovation expenditures. These 3 modalities are three different questions in terms of engagement (yes or no modalities) but unfortunately they are gathered in only one question in terms of expenditure. For more details, see Appendix II.5.

- The first group of countries (France, Norway, Finland and Netherlands) is characterized by an important share of both intramural and extramural R&D expenditure. For example, for France, the internal expenditure share is equal to 70% and the external one to 29%, that is very high compared to all the countries (Figure II.14 below).
- The second group has an opposite profile. Indeed, it is characterized by low internal and external expenditure rates but by high rates in terms of acquisition of machinery and equipment (the share varies from 55% to 86% according to countries) and in lower proportion in terms of acquisition of other external knowledge (from 2% to 7%; except Slovakia for which the rate is equal to 0). This group essentially gathers Eastern European countries and Southern states like Italy, Greece and Portugal.
- The third group has an intermediary position. It contains Spain, Belgium, Germany and Iceland.
- Finally, Hungary belongs to a distinct single country group. This country has a specific profile: the share of acquisition of other external knowledge is very high (14%).

Figure II.14. Innovative expenditure modalities by country



Are higher innovation expenditures related to more innovation adoption across EU member states?

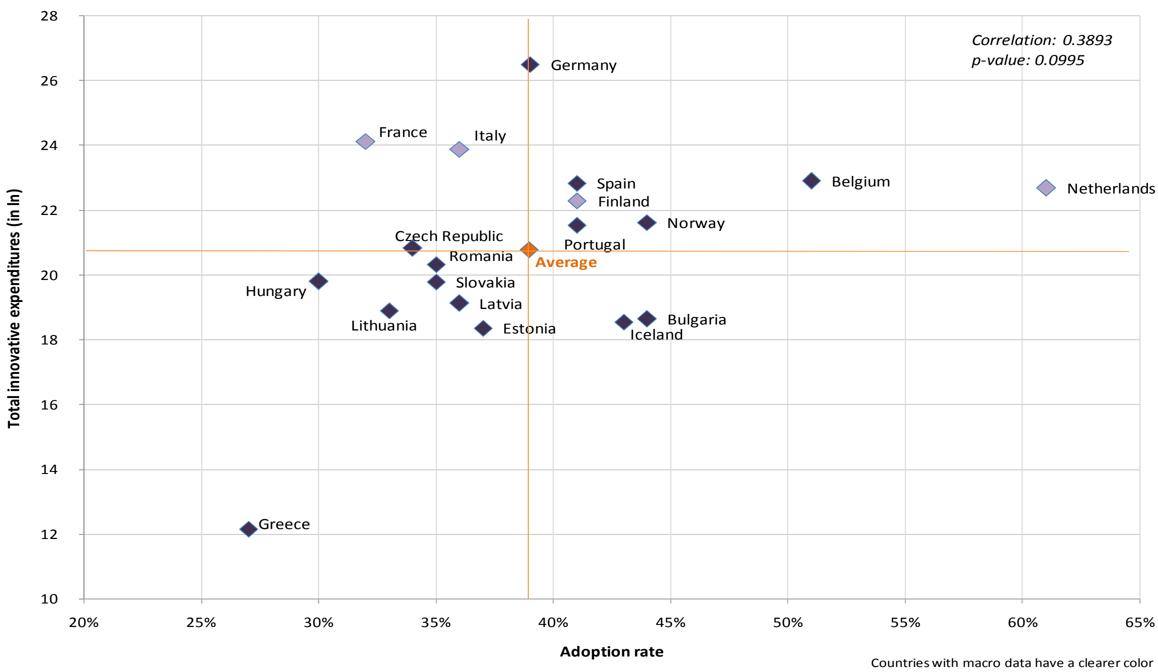
Evidence seems to point to a positive link between innovation expenditures and total adoption of innovation, although it is not significant in most cases (only with the modality of Intramural R&D the relationship is weakly and significantly positive).

Table II.5. Pearson correlation Matrix

	Adoption rate	Intramural R&D share	Extramural R&D share	Acquisition of machinery and equipement share	Acquisition of the other external knowledge share
Adoption rate	1	.409	.134	-.349	-.211
		.082	*.586*	*.143*	*.387*
Intramural R&D share		1	**.551***	**-.956****	-.212
			.014	***.000***	*.384*
Extramural R&D share			1	**-.749****	.098
				.000	*.691*
Acquisition of machinery and equipement share				1	.016
					.949
Acquisition of the other external knowledge share					1

* The correlation is significant at a 5% threshold. ** The correlation is significant at a 1% threshold.

Figure II.15. Total innovative expenditure (in logs) and adoption rate by country



MAIN INSIGHT: From Figure II.14, **we do not clearly see any correlation between adoption rate (represented by the bubble size) and the relative importance of the different modalities of innovation expenditure.** This is confirmed by the Pearson correlation matrix: the adoption rate is not significantly correlated with any kind of innovation expenditure (only in the case of intramural R&D it is significantly positive at a 10% level). Instead, if we test if total innovative expenditure are significatively correlated with the innovation adoption rate, we also observe that:

- The amount of total innovative expenditure presents a 0.3% correlation (not significant) with innovation adoption rates, that increases to a value of 39%, significant at a 10% of significant level, when the total innovative expenditures are taken in logarithms
- The share of total innovative expenditure in turnover in innovative firms offers a correlation level of 22% with adoption rates, which is not significant.

Therefore, we can conclude that evidence seems to point to a **positive link between innovation expenditures and total adoption of innovation, although it is not significant in most cases (only with the modality of Intramural R&D the relationship is weakly and significantly positive**, Table II.5).

The positive link between innovation expenditure in logs and adoption of innovation can be seen in Figure II.15. Countries with high total innovative expenditure have, by and large, the highest adoption rates (except for France and Italy) and, on the opposite, countries with low expenditure have the smallest adoption rates (except for Bulgaria and Iceland).

This relatively low level of correlation may result from the impact of R&D expenditure on the overall innovation level. In our indicator of adoption, the denominator is the number of innovative firms. Therefore, the positive impact of R&D expenditure on the propensity to innovate may reduce the impact observed on the rate of adoption. The correlation coefficients between the different R&D expenditure variables and the innovation rate are indeed positive and significant. For instance, the correlation between the total innovation expenditure variable and innovation rate is 0.63 (p-value: 0.004). R&D expenditure influences at the same time innovation adoption and overall innovation performances. The absence of a significant impact on the adoption rates points that **R&D expenditure do not impact very significantly more on innovation based on adoption than on innovation mainly developed by the firm itself.** The micro econometric part of the report (section III.5) will examine this possible effect of R&D on the overall innovation, in order to disentangle the impact on innovation adoption from the impact on "generation" of innovation.

Moreover, if looking at innovation adoption disaggregated by product and process, we can detect that, among the many innovation expenditure CIS proxies, only "total innovation expenditure" shows to be significantly correlated to process innovation adoption[29]. It seems

[29] Results are detailed in Appendix II.10 for both product and process innovation adoption separately.

therefore that more investments in innovation may actually boost number of process innovations which are ultimately adopted.

II.4.1.3. Human capital resources and adoption rate: a positive but non significant correlation

The education level can be a fundamental input in adoption behavior. Indeed, in order to assimilate knowledge produced out of the firm or in cooperation with partners, the firm needs qualified human resources. The internal absorptive capacity (Cohen and Levinthal, 1990) appears as a necessary condition to adopt external knowledge. This question can be addressed using both CIS and non CIS variables. Specifically, we are going to use two different proxies for human capital: the average number of employees with high education in innovative firms obtained from CIS3 and the percentage of Human Resources in Science and Technology[30] in labour force in each country in 2000 obtained from EUROSTAT. In the next Figures we cross the adoption rates with these two variables.

Is Human Capital directly correlated to Innovation Adoption rates?

The link between different measures of Human Capital and Innovation Adoption rates seems to be non-significant even if positive.

There is no correlation between the adoption rates of innovation and the skills of the observed workforce. As noticed previously for R&D expenditure, the absence of a strong correlation between adoption and human resources can be explained by the positive correlation between Human Ressources and innovation. Indeed, as our adoption index is divided by the number of innovative firms, the positive impact of Human Resources on overall innovation increases the denominator and therefore reduces the rate of adoption. The correlation coefficient between innovation rate and human resources in S&T equals 0.49 (with p-value: 0.024). In other

[30] HRST is defined according to the Canberra Manual as a person fulfilling at least one of the following conditions:

- Successfully completed education at the third level in a S&T field of study
- OR not formally qualified as above, but employed in a S&T occupation where the above qualifications are normally required.

We have also crossed adoption rate with the core of HRST that is to say people who have:

- successfully completed education at the third level in a S&T field of study
- AND are employed in a S&T occupation

In this case, the correlation is smaller than with the total HRST (pearson correlation = 0,1898 ; p-value=0,3976).

words, human capital influences positively adoption, but also the other types of innovation. **The impact of human resources on innovation adoption is not significantly stronger than its impact on the "generation" of innovation**. This potential direct impact of human resources on overall innovation performance will be more deeply dealt with in the econometric estimations provided in part III of the report (see in particular the estimations made on the microdataset, in sub-section III.5).

Figure II.16. Average number of employees with high education in innovative firms and adoption rate by country

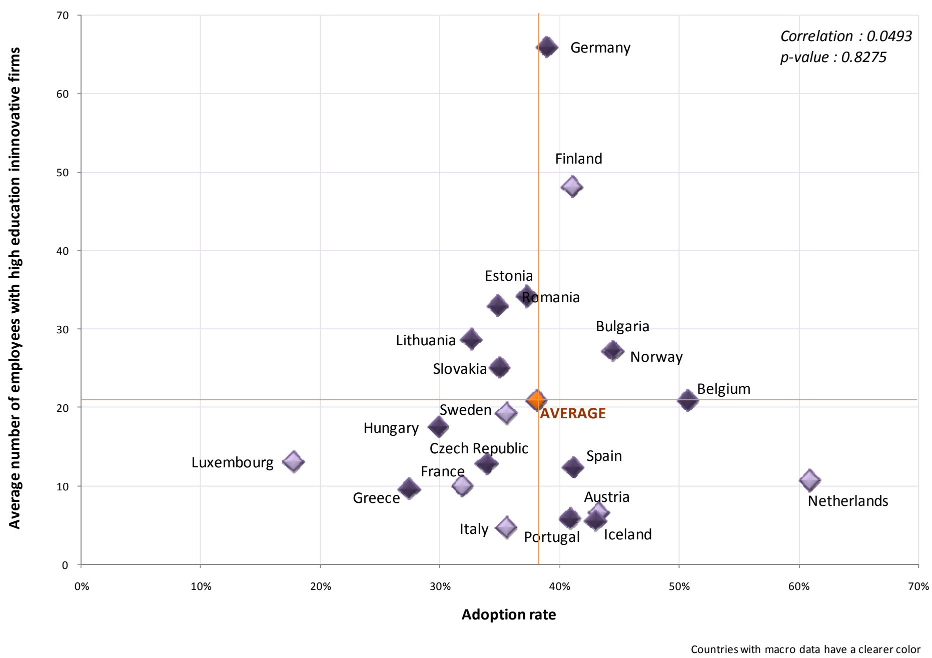
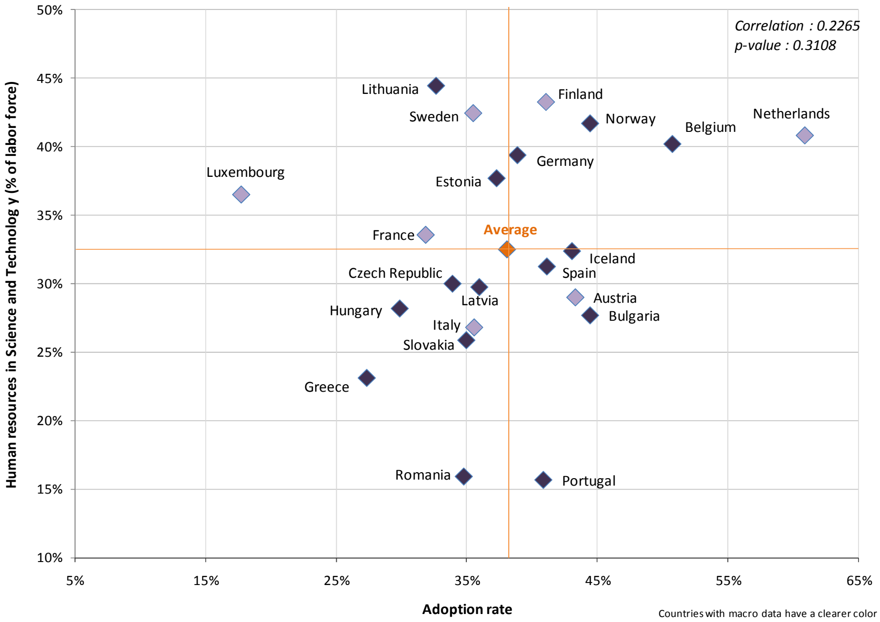


Figure II.17. Human resources in S&T (% of labour force) and adoption rates by country



MAIN INSIGHT: We observe that, for the countries we have available in our sample, there is no correlation between the adoption rates of innovation and the skills of the observed workforce.

However, it is possible to notice how many countries with a low percentage of HRST also have a low adoption rate. It is the case for a majority of Eastern countries (Czech Republic, Hungary, Slovakia, Latvia Romania) and Southern countries (Greece, Italy). By contrast, some countries with a high HRST rate display high adoption rate. It is essentially the case for countries located in the North of Europe such as Netherlands, Belgium, Norway, Finland and Germany. But some countries have a disproportioned adoption rate compared to the level of HRST. For Portugal, Bulgaria and Austria, the adoption rate is relatively high compared to HRST rate. We have the opposite situation for Lithuania, Sweden or France.

Figure II.16 does not show a significant correlation between adoption rates and the number of employees with high education level (Pearson correlation = 0.0493; p-value=0.8275). Among countries for which the average number of highly educated employees is below the average, some have a low adoption rate (like Luxembourg, Greece or Hungary…) but some have, on the opposite, a very high adoption rate (like Netherlands or Belgium). Moreover, countries recording the highest average number of highly educated employees have a medium adoption rate.

When crossing adoption rate with the percentage of Human Resources in Science and Technology in labour force in each country (Figure II.17), the correlation is higher but it is still not significant (Pearson correlation=0.2265, p-value=0.3108). This correlation turns however to be significant at 10% threshold if Portugal is removed.

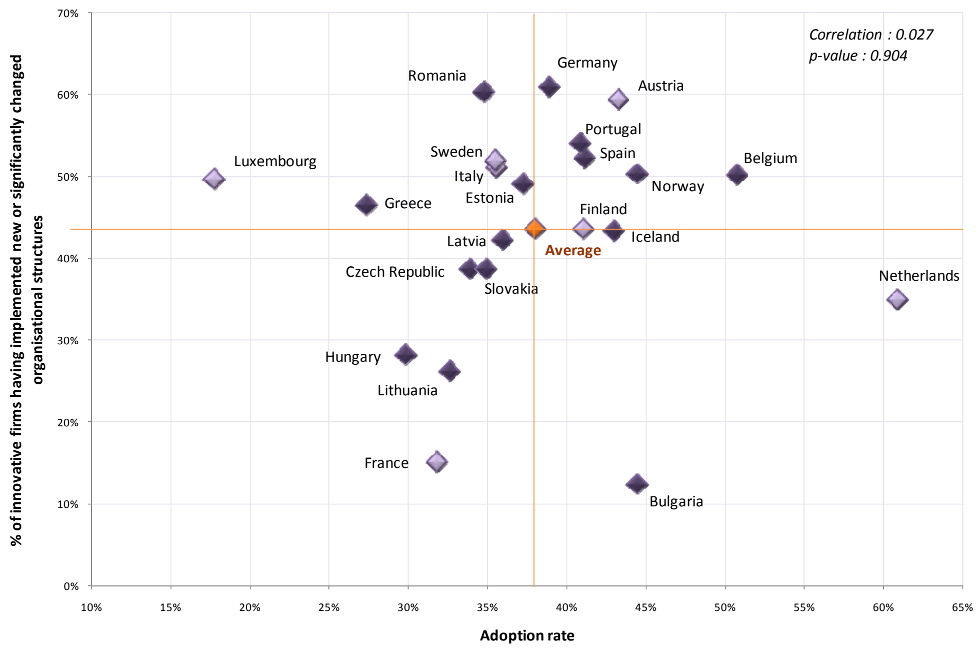
II.4.1.4. A weak positive relationship between adoption rate and organizational changes

Leading innovation adoption strategies can require changes in organisational structures. CIS data allows us to know if firms have implemented or not new or significantly changed organizational structures.

Are changes in the organisational structure correlated to Innovation Adoption?

There does not seem to be much evidence that organisational changes is related to more Innovation Adoption if all EU countries in the sample are considered. However, if we drop the Netherlands and Bulgaria (with high adoption rates and low organisational structures) and Luxembourg (the opposite situation), the relationship becomes significantly positive.

Figure II.18. Organizational changes and adoption rates by country



MAIN INSIGHT: We can see that the percentage of innovative firms with organizational changes varies substantially according to countries. Bulgaria and France record very low percentage (respectively 12.4% and 15.1%) whereas Romania, Germany and Austria have the highest rate (close to 60%).

According to Figure II.18 we observe that **the adoption rate increases generally with the percentage of firms with organizational changes.** The correlation computed from all countries is not significant but three states appear as specific: Luxembourg, Bulgaria and the Netherlands. The correlation becomes significantly positive at 5% if we drop them out (correlation = 0.490, p-value = 0.033).

II.4.1.5. A non significant correlation between adoption and cooperation in joint R&D

From the CIS survey, it is possible to know the number of firms that are engaged in innovation cooperation, that is, active participation in joint R&D and other innovation projects with other organisations (either other enterprises or non-commercial institutions). In addition to the general information about R&D cooperation activities, the CIS survey provides the distribution of these cooperations according to the location of the partners. Thanks to this information, two additional variables can be built, in order to assess the relationship between cooperation among EU countries and cooperation within EU countries[31]. In the context of the internal market, a key issue concerns the impact of the diffusion of innovation across EU countries. Focusing on R&D cooperations that take place between EU countries might give first insights about the potential flows of knowledge that arise between firms that belong to different countries.

The overall rates of cooperation in EU countries are given below on Figure II.19. On average, only a little more than one innovative firm over four cooperate for its innovation activities. Not surprisingly, countries that are most involved in R&D cooperation are Scandinavian and Baltic States. Hungary and Luxembourg are also strongly relying on cooperation for their innovative activities, with respectively 55% and 38% of their innovative firms engaged in R&D cooperation. Conversely, Spain and Italy, but also Germany and Portugal do not rely strongly on cooperation for their innovation activities.

Is there any correlation between cooperation activities and the rates of Innovation Adoption across EU member states?

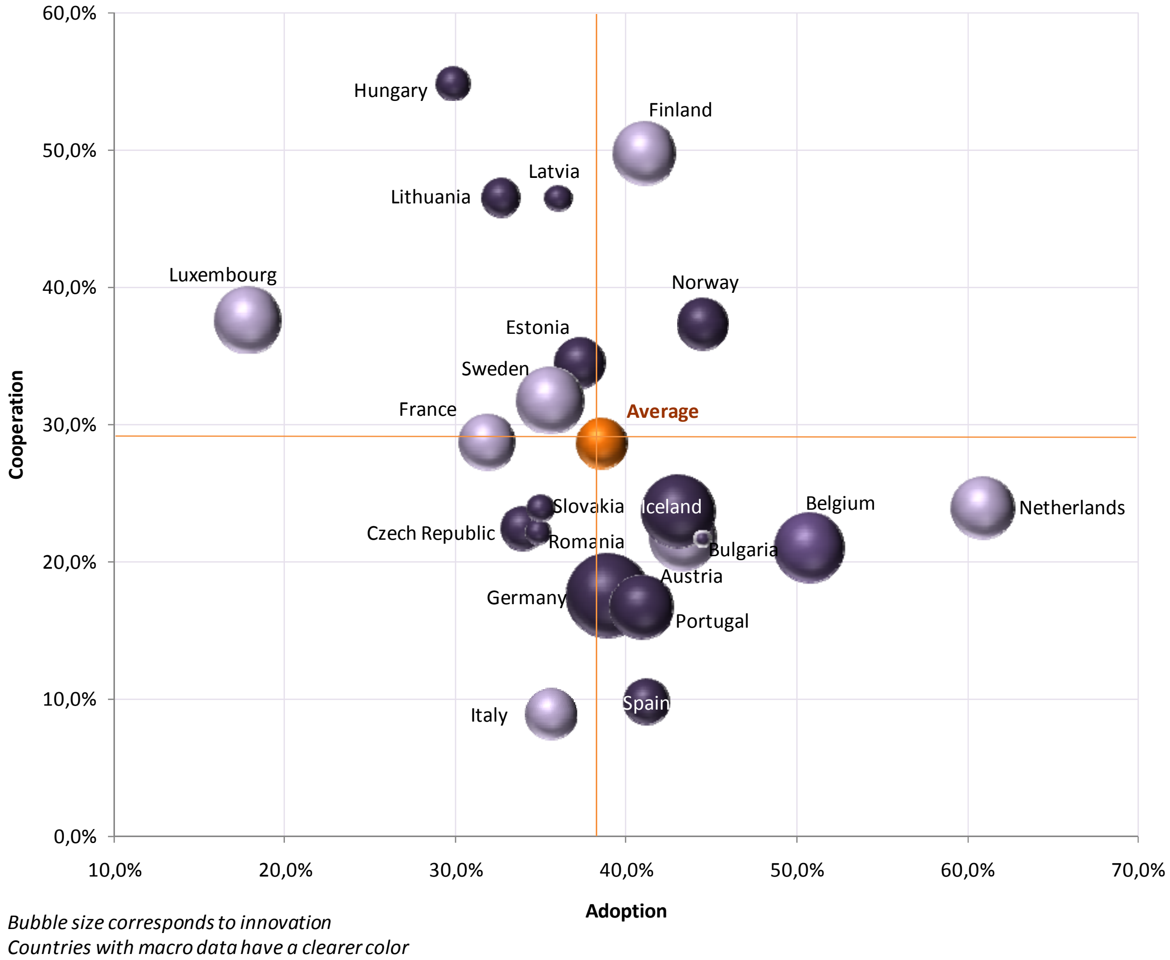
Correlation between these two measures seems to be (surprisingly) weak and therefore non significant.

The correlation with innovation adoption is not significant, and the coefficient is even negative (correlation coefficient: -0.32, p-value: -0.14). One can think that this could be due to a positive impact of cooperation on the overall level of innovation. This would increase the denominator of our adoption rate and counterbalance a positive effect on adoption. But this is not the case: the correlation rate between cooperation and innovation is not significant (it

[31] The micro database contains however missing values for some countries (in particular Belgium, Spain and Greece) regarding the detailled information about location of partners. In order to overcome this problem, missing values have been replaced by using the macro data available on Eurostat website.

equals to -0.20, with p-value: 0.39). This result may seem surprising since the adoption rate notably contains information about cooperation in product and/or process innovations. This non-significant correlation may result from country aggregated data and from the fact that the question about cooperation focuses on R&D only.

Figure II.19: Cooperation and adoption rates by country



If we turn to consider R&D cooperation activities according to the location of partners, we can observe from figures II.20 and II.21 that national cooperations are, not surprisingly, much more frequent than European cooperations. The average percentage of national cooperation is 23%, against 14% for inter-EU cooperation.

The share of innovative firms engaged in EU and National cooperations differs significantly from one country to another, with a stronger dispersion for national cooperations than for EU cooperations. However, the picture is nearly the same as the one observed for the overall cooperation rate, whatever the location of partners: Countries registering cooperation scores above the average are exactly the same in the three graphs, except Luxembourg. In this country, the high overall cooperation rate is mainly due to cooperation with partners located in other countries. This appears clearly on figure II.21. Luxembourg is the EU country that exhibits the highest rate of European cooperation. One innovative firm over three collaborates with a partner located in other European countries. Conversely, its national cooperation rate is below the European average.

Figure II.20: National cooperation and adoption rates by country

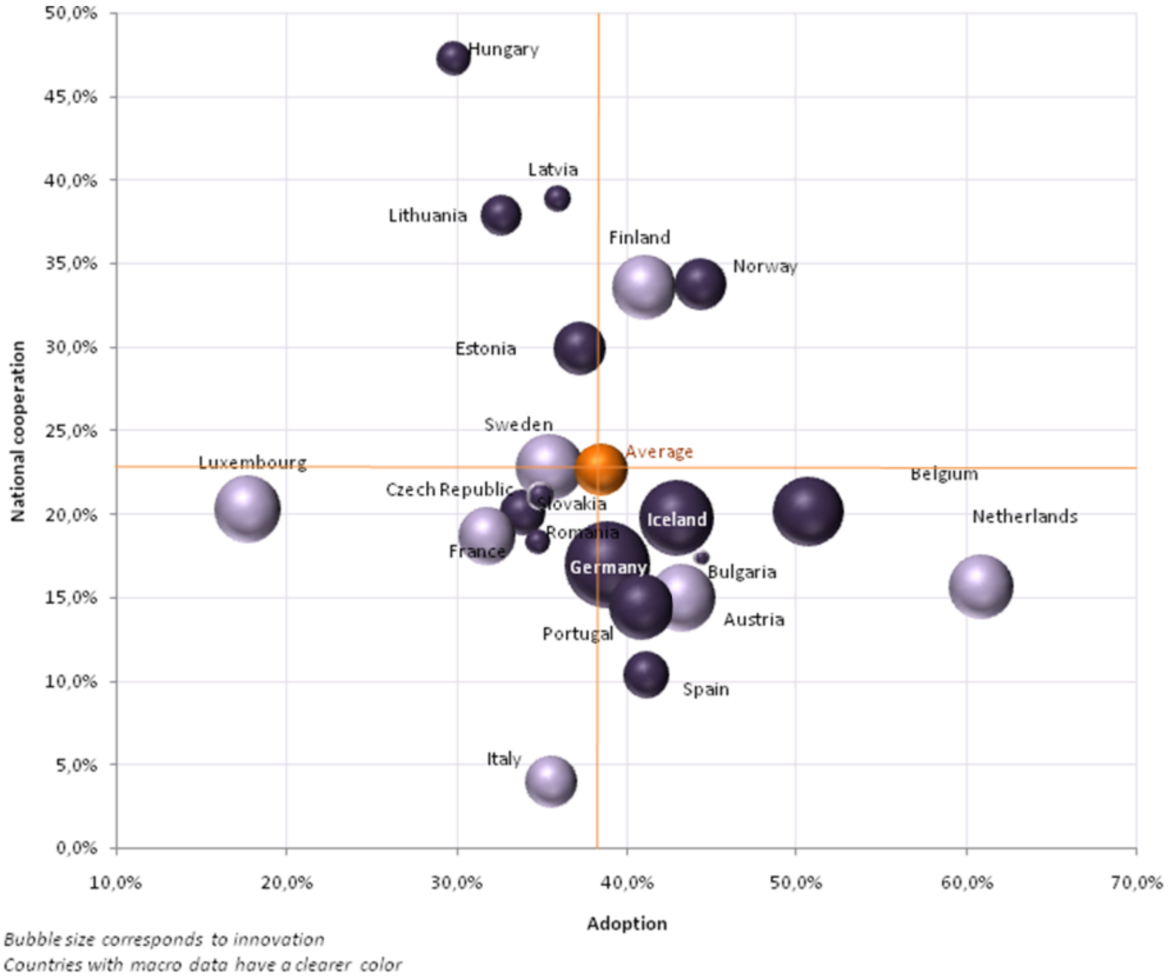
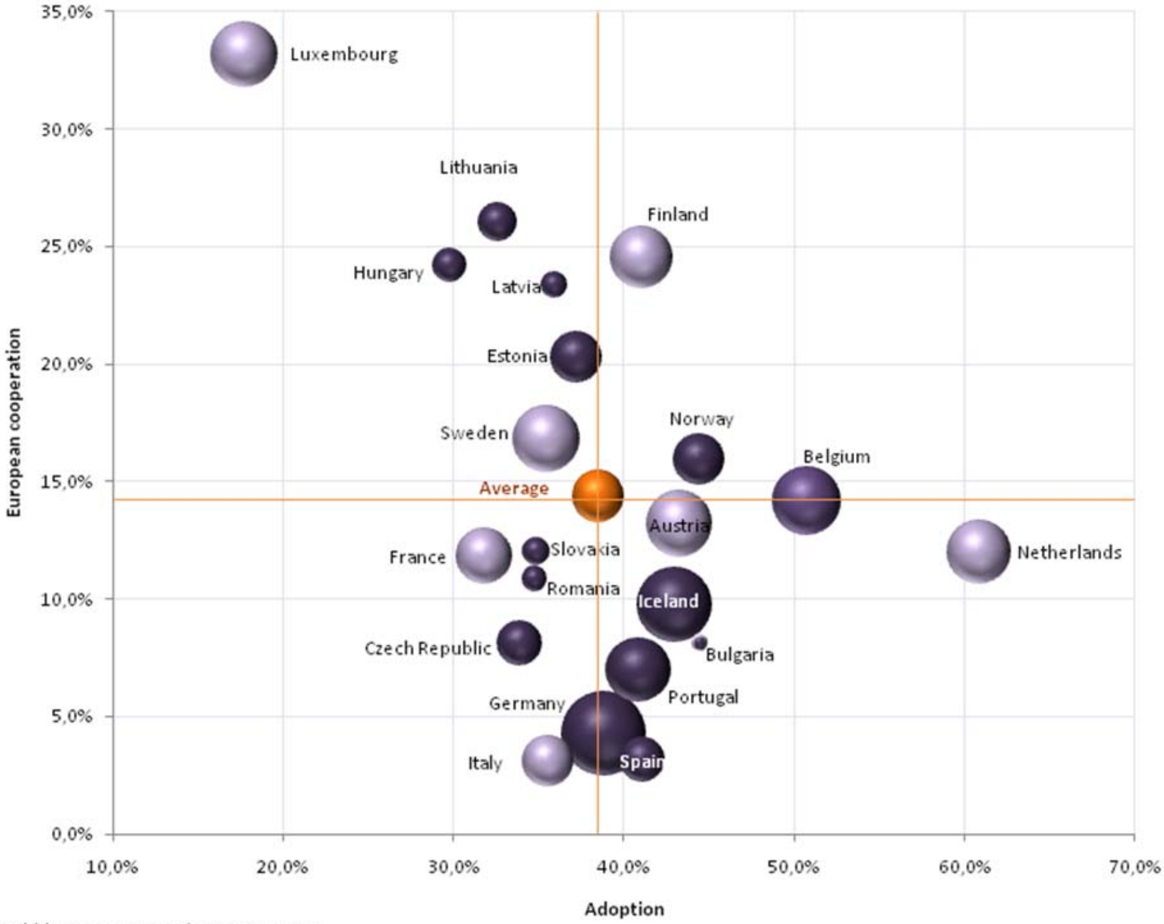


Figure II.21: European cooperation[32] and adoption rates by country



Bubble size corresponds to innovation
Countries with macro data have a clearer color

MAIN INSIGHT: Specific profiles arise in term of cooperation. Not surprisingly, countries that are most involved in R&D cooperation are Scandinavian and Baltic States. We observe **no significant correlation** between the share of innovative firms engaged in cooperation and the adoption rate (p-value: 0.144). This result may seem surprising since the adoption rate notably contains information about cooperation in product and/or process innovations. This non-significant correlation may result from country aggregated data and from the fact that the question about cooperation focuses on R&D only.

[32] European Union countries include Belgium, Denmark, Germany, Greece, Spain, France, Ireland, Italy, Luxembourg, Netherlands, Austria, Portugal, Finland, Sweden and the United Kingdom while European Free Trade Association countries includes Iceland, Liechtenstein, Norway, Switzerland.

II.4.1.6. Conclusion on the relationship between innovation inputs and innovation adoption

From all the descriptive analysis in this sub-section, one can conclude that **there is a very little correlation between innovation adoption rates and the different variables proxying innovation efforts such as sources of information, R&D expenditures, human capital and the fact of doing organisational changes and cooperation in research.** It seems therefore that although from a theoretical perspective these variables would influence the absorptive capacity of firms and therefore their ability to adopt innovations, the empirical evidence for the EU countries do not support such theories.

When we look at innovation adoption disaggregated at process and product level, our results show how, among the many "sources of information" CIS proxy only two of them show a significant correlation with product innovation adoption[33]. These are "Government or private non-profit research institutes" and "Suppliers". The correlation is however negative indicating how these sources of information do not seem to lead to the spill over of innovation for firms relying on them.

II.4.2. Market features and innovation adoption rates

In this sub-section we analyse to what extent the data we have on innovation adoption rates are related to several issues concerning market features such as competition and the level of barriers to trade.

II.4.2.1. Competition and innovation adoption rates: no significant correlation

Competition can be assessed only indirectly through proxy variables and in our study we follow the one given in Griffith and Harrison (2004). The markup is measured as the average level of profitability at the country-industry level. Specifically, our measure of average profitability (or markup) is value-added as a share of labour and capital costs –in country i, industry j and year t):

$$Markup_{ijt} = \frac{ValueAdded_{ijt}}{LabourCosts_{ijt} + CapitalCosts_{ijt}}$$

[33] Results are detailed in Appendix II.10 for both product and process innovation adoption separately

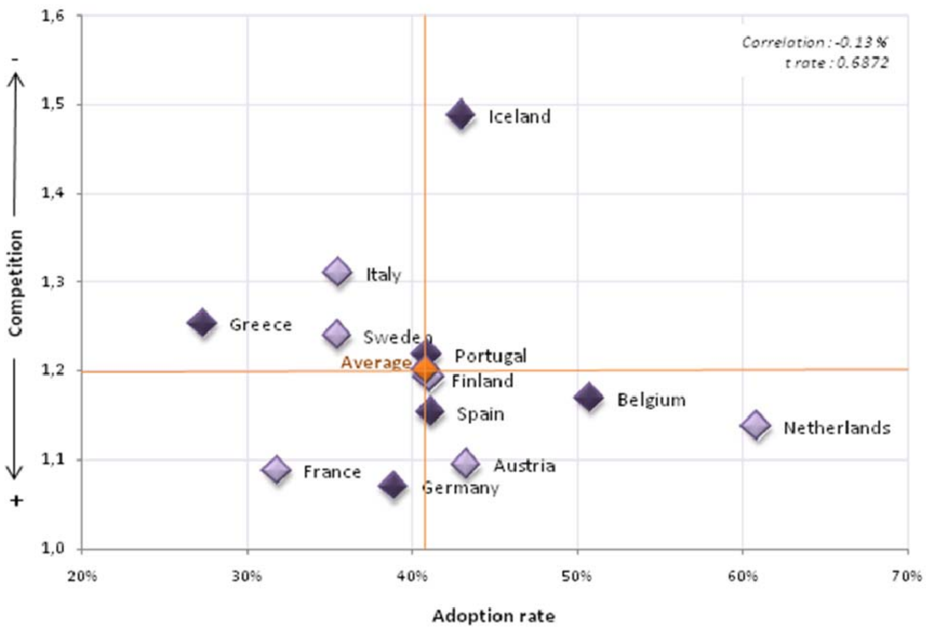
This profit level is obtained for manufacturing industries using the OECD STAN database, which provides information at the two-digit industry level on value added, labour and capital stocks. The higher the profit or markup (above the value of 1), the less the competition achieved in the market under analysis since more profits can be extracted by the distortion/absence of competition. On the opposite, perfect competition would imply a markup with a value equal to the unity. Therefore, the higher the indicator, the lower is competition.

As noticed by Griffith et al. (2006), Boone (2000) shows that this measure of competition is preferred to most other commonly used measures. It is more theoretically robust, particularly than those based on market concentration and market shares, and it is the only commonly used measure of competition that is available across countries. In our case, this indicator is available for only 12 countries.

Are higher levels of Competition in each EU member state related to more Innovation Adoption?

No, more competitive markets do not seem to be positively correlated to higher rates of innovation adoption.

Figure II.22. Adoption rate and competition index



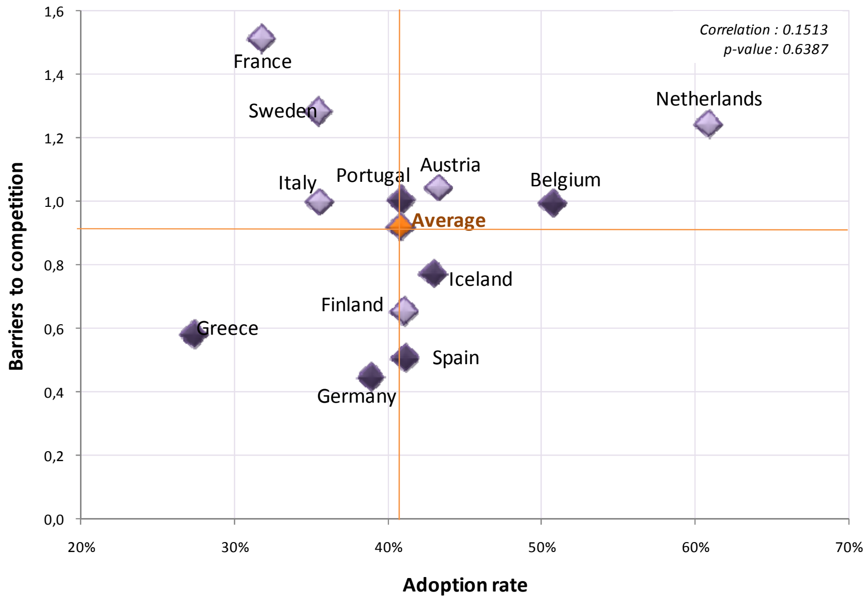
MAIN INSIGHT: We can observe that **countries with low levels of competition (and thus high markup values) are generally the ones with the lowest adoption rates**: Italy, Greece, and Sweden. On the opposite, the most adoptive countries like Belgium and Netherlands have the smallest markup index (e.g. the highest level of competition). **However the correlation rate is not significant**. Even if we drop Iceland, which seems to be an outlier (high adoption rates with low competition levels) the correlation remains non significant (correlation=-0.164, p-value=0.629) indicating that higher levels of competition are not significantly associated to higher innovation adoption rates

The absence of significant correlation cannot be explained by a positive impact of competition on the overall level of innovation, that would reduce the denominator of our adoption rate. The correlation coefficient between mark-up and innovation rate is not significant. The correlation coefficient equals -0.09 (with p-value: 0.77). Higher competition is thus not associated to higher innovation

Although it is not a measure of competition, there is an indicator from the OECD Product Market Regulation indicators database called "barrier to competition" which is expected to be highly influencing competition. From this point of view, we think it can be of interest to analyse the relationship it maintains with the innovation adoption rates. This indicator can be interpreted as follows: "*In general, domestic barriers to competition tend to be higher in countries that have higher barriers to foreign trade and investment, and high levels of state control and barriers to competition tend to be associated with cumbersome administrative procedures and policies that reduce the adaptability of labour markets*".

As already obtained above, the correlation analysis in Figure II.23 shows a non significant relation between this variable and adoption rates (correlation: 0.1513, p-value: 0.6387). **Countries with high levels of barriers to competition can have low adoption rates (France, Sweden and Italy) as well as high adoption rates (Netherlands and Belgium).** However, we should bear in mind that this indicator of barriers to competition should be understood as an explanatory variable of competition, as it is done in the regression analysis of Part III. The divergences between this indicator and the competition index presented on figure II.22 should also be noticed. This is due to the very different criteria entering into each of these index. This illustrates the subjectivity that arises in defining such variables and the necessary caution that is required for their interpretation.

Figure II.23. Adoption rate and barriers to competition index



II.4.2.2. The innovation adoption rate seems to be not correlated with the level of trade and negatively correlated with the barriers to trade

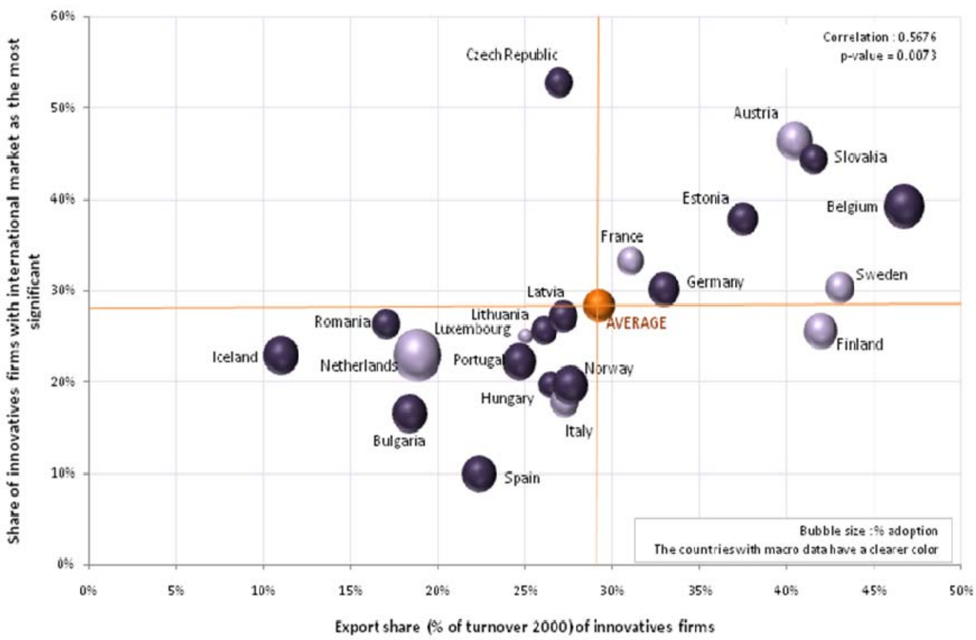
In this part, we assess to what extent the adoption rate in each country is associated with international trade and trade barriers. We wonder if the more opened countries record also the highest adoption rates. To this aim, we firstly rely on CIS variables and then we turn to consider "trade barriers" measured in the Global Competitiveness Report.

Two items of the CIS can be used to proxy the level of trade. The first one is the information relative to the most relevant market of the firm (regional, national or international). We can assume that the firms with mainly international market are more exposed to international pressure and opportunities. Therefore they would be more likely to adopt innovations. The second CIS item gives the total amount of exports. The indicator used is then the share of export with respect to turnover. Figure II.24 relates these two variables. Not surprisingly they are strongly correlated with a rate of 0.5676 (and a p-value of 0.0073).

Is Trade in each EU member state related to Innovation Adoption and do barriers to trade have an impact on it?

1) **No, it seems that trade is not significantly related with innovation adoption**
2) **The higher the barriers to trade, the lower the innovation adoption rates in the EU countries.**

Figure II.24. Export and international market in innovative firms and adoption rate



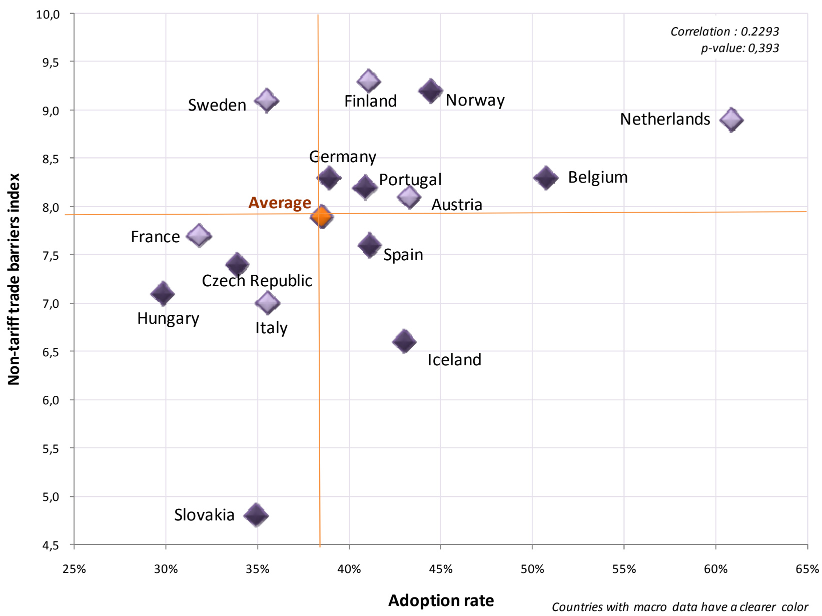
MAIN INSIGHT: The bubble size in Fig II.24 allows us to cross the adoption rate with the trade openness degree of the country in terms of share of exports in innovative firms' turnover and of share of firms for which the international market is the more significant. We can see that countries with the highest adoption rates are not systematically the ones for which the market openness is the most important. For instance, Netherlands and Belgium for which the adoption rates are the highest have inverse positions on the Fig: for Belgium, the trade openness degree is very important (notably for export share) contrary to Netherlands. Countries with low adoption rates are close to the average.

To sum up, the two proxies for trade are not positively correlated to innovation adoption. The correlation between the adoption rate and the export share is equal to -0.017 (p-value = 0.762) and between the adoption rate and the share of innovative firms with international market as the most significant is equal to -0.075 (p-value = 0.812).

The relationship between trade and adoption will be explored more deeply in the econometric part. In particular, the absence of bilateral correlation may result from the impact of trade on overall innovation, which is the denominator of our adoption index. Therefore it is likely to lower the correlation observed between trade and adoption rate. As we will see in the micro econometric part (sub-section III.5), trade exerts a positive impact on overall innovation, but this impact is mainly due to "generation" of innovation and not to "adoption" of innovation. In other words, highly exporting firms are more likely to innovate, but they have also more incentives to innovate by themselves than to adopt existing innovations.

Additionally, although not measuring trade but proxying for regulatory variables that may affect trade, we find an indicator named "Regulatory trade barriers" and more specifically "Non-tariff trade barriers" from the Economic Freedom World report. This variable is based on the Global Competitiveness Report's survey question: "*In your country, tariff and non-tariff barriers significantly reduce the ability of imported goods to compete in the domestic market.*" The index varies between 0 and 10. It is high if a country has low non-tariff trade barrier, that is to say, if the freedom of exchange across national boundaries is important. Unfortunately, these data are missing for five countries[34].

Figure II.25. Adoption rate and non-tariff trade barriers index

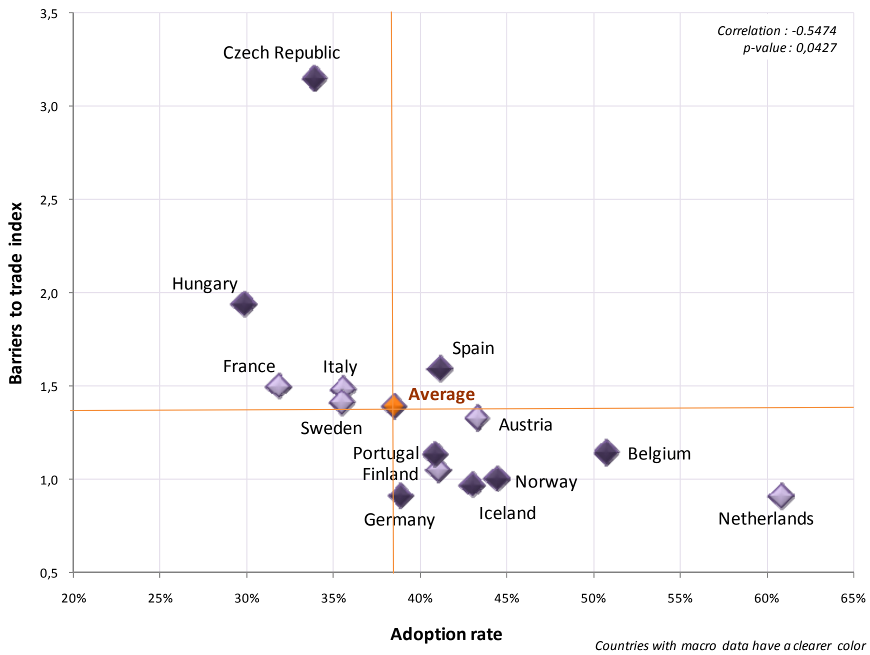


[34] Bulgaria, Estonia, Lithuania, Latvia and Romania.

Figure II.25 shows a positive link between this variable and innovation adoption rates. In most cases, countries with low values for the index (so, with high non-tariff trade barriers) record low adoption rate. It is the case for France, Hungary, Italy and Czech Republic. On the opposite, countries with high exchange freedom like Netherlands, Norway, Belgium, record higher adoption rate. Nevertheless, the correlation between these two variables is not significant (correlation: 0.2293 ; p-value: 0.393).

Finally, we cross with adoption rates a last variable that we find more general but missing for seven countries[35]. This variable named "Barrier to trade and investment" comes from the OECD Product Market Regulation indicators database. This synthesis variable contains information about ownership barriers, discriminatory procedures, regulatory barriers and tariffs[36]. Figure II.26 shows a negative and significant correlation between the two variables. The correlation is significant at 5% level. We can see that countries with high barriers to trade record the lowest adoption rate. As above, we find among them, France, Hungary, Italy and Czech Republic. On the opposite, Netherlands, Belgium and Norway are confirmed to be countries with low barriers to trade and high innovation adoption levels.

Figure II.26. Adoption rate and barriers to trade index



35 Bulgaria, Estonia, Lithuania, Latvia, Romania, Luxembourg and Slovakia.

36 For more details, see P. Conway, V. Janod and G. Nicoletti, 2005, Product Market Regulation in OECD Countries: 1998 to 2003. Economics department working papers n° 419.

We can therefore conclude that, **no matter which is the indicator for the barriers to trade, the higher they are, the lower the innovation adoption rates in the EU countries**. The negative correlation found for the overall innovation adoption indicators is shown also in the case of the disaggregated item "product innovation adoption"[37]. This result is consistent with the idea that especially product innovation adoption is affected by barriers to trade due to the fact that innovation in products is embodied in tradable goods and when Trade is made more difficult (by any kind of barrier) then also innovation spills over less rapidly.

II.4.3. Regulatory environment and adoption rate

As shown in the review of the literature (Part I), another important issue regarding the main drivers of innovation diffusion/adoption refers to the regulatory environment. In this sub-section we present how some of these regulations can be measured and make a preliminary descriptive analysis of the relation they maintain with innovation adoption. Specifically, we firstly consider patents and other protection methods and secondly we refer to several indicators about the functioning of the Internal Market.

II.4.3.1. Patents and other protection methods and adoption rate

Intellectual property rights (IPR) appear as an important issue for innovation diffusion/adoption, although without a consensus on the direction of the impact. On the one hand, we have shown in the literature review that IPRs can improve diffusion. Innovators are obliged to reveal the content of their invention which increases the potential of related innovations. It also gives incentives to improve existing technologies, which is likely to facilitate their adoption. On the other hand, IPRs may prevent adoption by forbidding external agents to use the technology (except if they pay for a licence). In order to address which of these effects are preeminent, we aim at providing the correlation that IPRs maintain with innovation adoption. Several items of the CIS may be used to proxy for IPRs. We first consider the patenting activity through the consideration of the number of patent applications made by the firms in each country (A). Then, we make some comparisons with the information on other legal and informal protection methods also given in the CIS (B). Finally, we provide a different view about IPRs, using data on the index on "Security property rights" from the Economic Freedom of the World (C).

[37] Results are detailed in Appendix II.10 for both product and process innovation adoption separately.

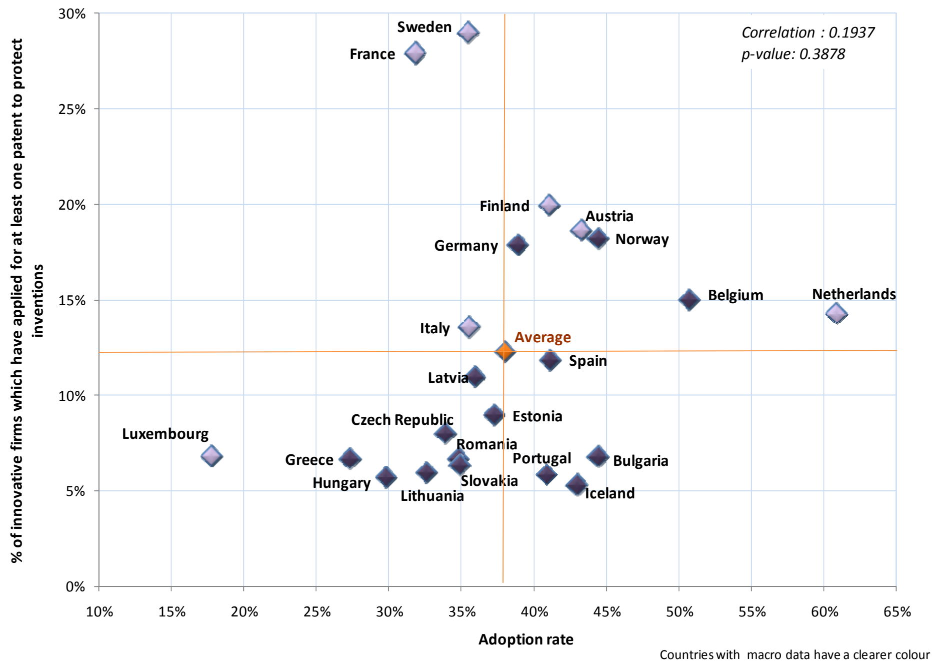
A. Patenting is the main legal protection mean for firms. But the number of patent applications can be very different according to the sector and the nature of inventions. By country, we can observe large differences in terms of percentage of innovative firms having applied for at least one patent. As shown in Figure II.27, for the majority of countries, this percentage varies between 5% (for Iceland) and 20% (for Finland). Nevertheless, two countries have a specific position due to their very high patent application rate: France and Sweden, with a patent application rate of almost 30%.

According to Figure II.27, we can observe that many of the countries with low patenting rate are also those with low adoption rate. It is the case of many Eastern European countries (Hungary, Lithuania, Slovakia, Romania, Estonia, Latvia, Czech Republic) and Southern countries (Italy and more specifically Greece). One possible explanation of this low patenting and adopting activities may be that in these countries firms may be very cautious in their strategy not to diffuse information. In this context, they can prefer to internalize R&D activities and to choose other protection methods than patenting. On the opposite side, we find the countries of Belgium, the Netherlands, Norway, Austria, Finland and Germany with adoption rates over the average as well as high patenting activities. These two patterns (low-low and high-high) would point to a positive relationship between adopting innovation and patenting. However, the Pearson correlation calculated from all data shows a positive but not significant correlation (coefficient = 0,1937 ; p-value=0,3878). This is due to the presence of some countries which have a specific profile:

- Portugal, Iceland and Bulgaria with low patenting rates but high adoption rates
- and, above all, France and Sweden where a low adoption rate is combined with a very high patenting rate.

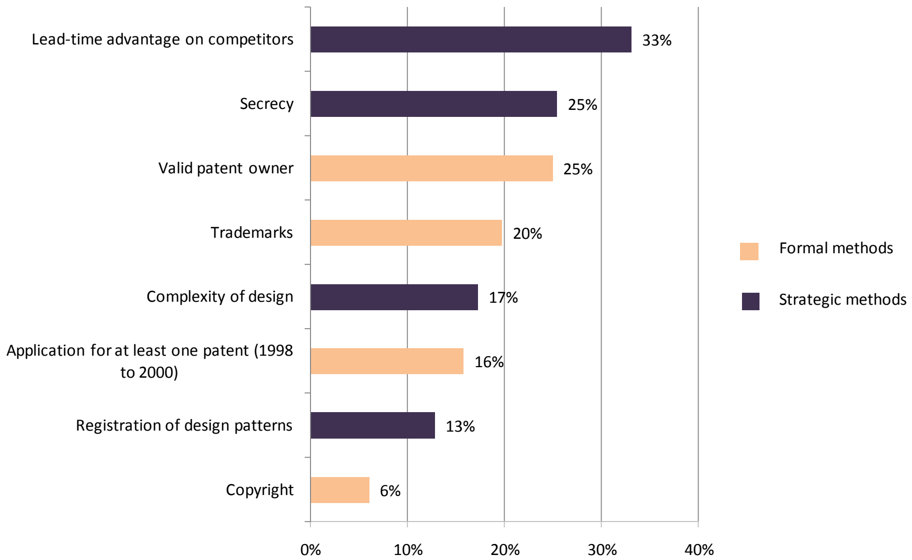
Therefore, if France and Sweden are dropped because of their particular position, the correlation between adopting innovation and patenting becomes significant at 5% level (coefficient = 0,4856 ; p-value=0,03). Therefore, we can conclude that, **in general terms, high levels of patenting activities are associated to high levels of innovation adoption.**

Figure II.27. Adoption and patents application to protect inventions



B. Other legal and informal protection methods. From the CIS database, we can observe that patent application is not the most used method to protect inventions (Figure II.28). Indeed, lead-time advantage on competitors and secrecy, which are more strategic than formal methods, are the most frequent. Respectively, they are used by 33% and 25% of innovative firms. On the opposite, copyright (6%) and registration of design patterns (13%) are the less used by EU firms.

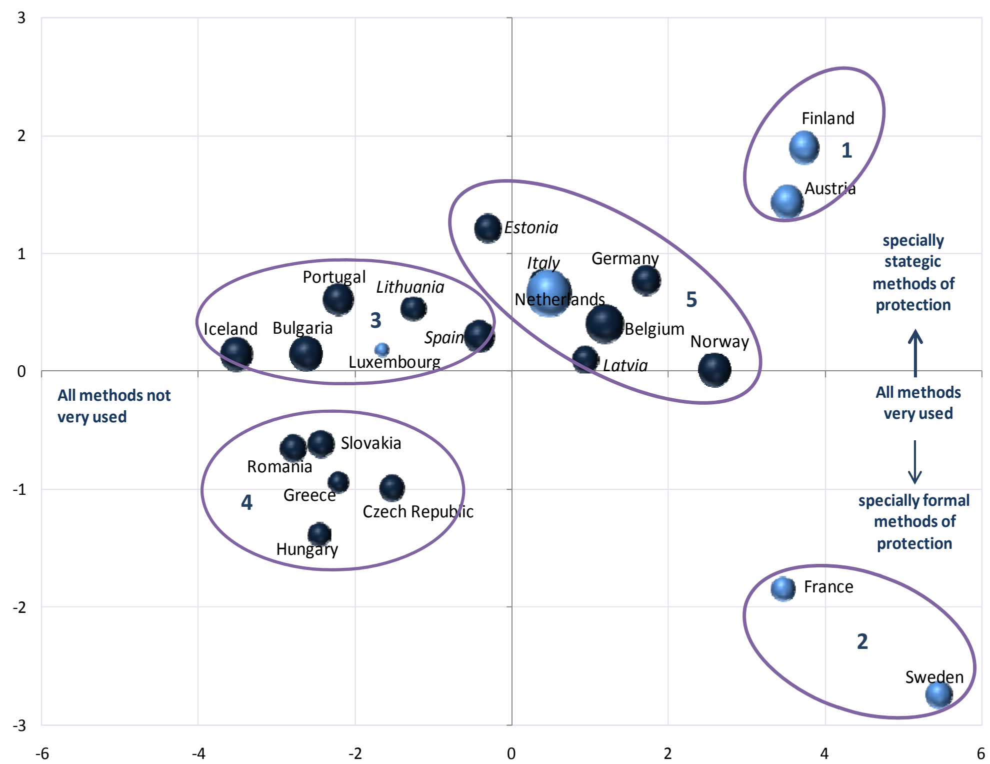
Figure II.28. Percentage of innovative firms using intellectual protection methods



Which is the relationship between the use of different innovation protection methods and innovation adoption in EU member states?

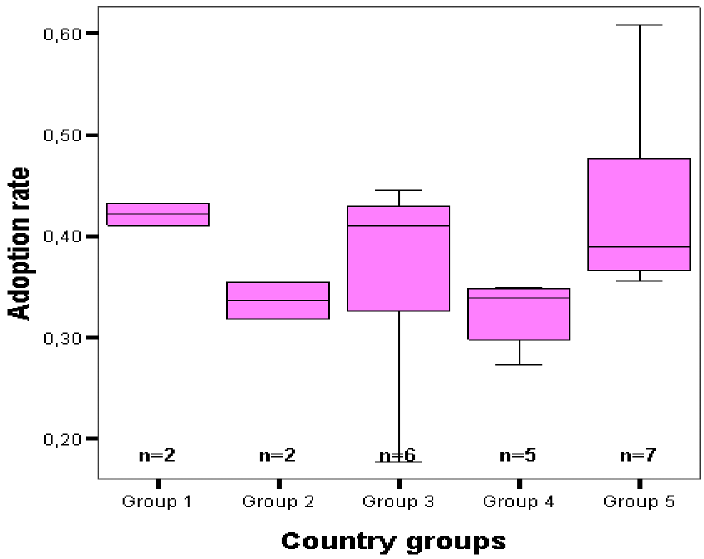
It seems that highest adoption rates are shown in countries in which the recourse to protection of invention and more specifically strategic methods is frequent. However, statistically we obtain that average adoption rates are not significantly different according to the different groups identified according to different profiles in the use of invention protection methods.

Figure II.29. Adoption and invention protection methods



Bubble size corresponds to innovation adoption
Countries with macro data have a clearer color
Countries in italics : the sum of contributions is less than 50% on the two axis

Figure II.30. Box plot: Main statistics for adoption rate according to protection methods



Statistics represented in this graph are:
- *the minimum (lower line out of the box)*
- *the first quartile (lower line of each box)*
- *the median (line inside each box)*
- *the third quartile (upper line of each box)*
- *the maximum or far value (upper line out of the box*

MAIN INSIGHT: Different countries profiles can be distinguished in terms of the use of invention protection methods (Figure II.29, see appendix II.6 for more detail on the PCA):

- The first (Finland and Austria) and second (France and Sweden) groups are characterized by an important use of all methods. For the first group, the percentage of firms having recoursed to strategic methods is particularly high, whereas for the second, it is the use of formal methods of protection.
- On the opposite, in the third and fourth groups (that bring together a lot of Eastern countries) the use of protection methods is not very important. For the fourth group, the recourse to strategic methods is particularly low.
- Finally, there is an intermediary group (Norway, Belgium, Latvia, Netherlands, Germany, Italy and Stonia) for which the use of methods is at a medium level or above the average notably for strategic methods of protection.

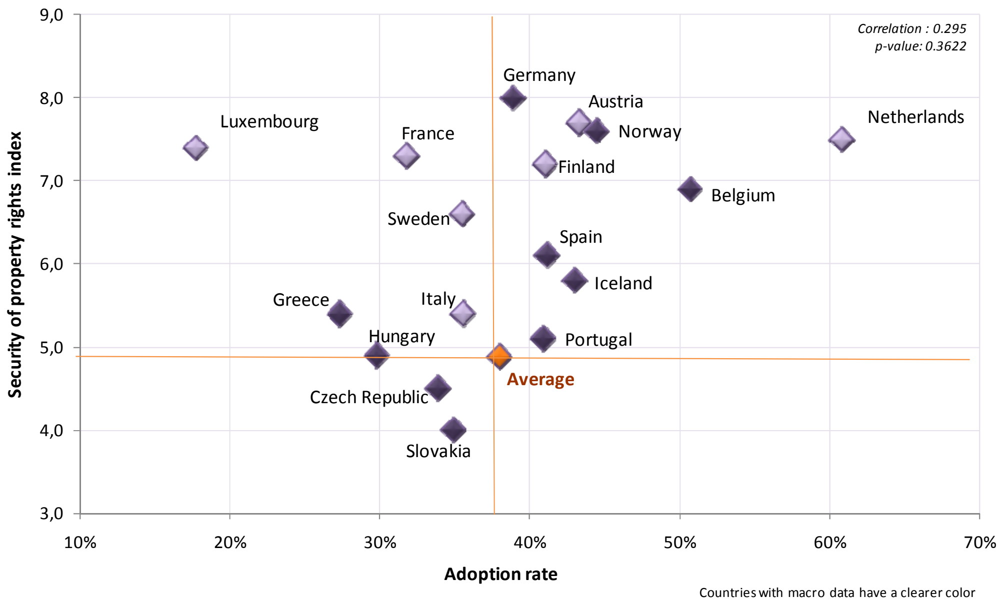
If we cross these different groups with the adoption rate (bubble size), we can observe that countries with **highest adoption rates are either** in the first group or in the fifth group, that is to say, **for countries in which the recourse to protection of invention and more specifically strategic methods is frequent.**

The box plot (Figure II.30) confirms that countries in the first and in the fifth group show higher innovation adoption rates, but also that for the third group, the average of adoption rate is high whereas the use of protection methods is not very important. The second and fourth groups gather mainly countries with low adoption rates but very different pattern of use of protection methods. Nevertheless, a one-way analysis variance shows that **average adoption rates are not significantly different according to the groups identified according to the different patterns in the use of invention protection methods** (F-statistic being equal to 1,764 and the significance value of the F-test being to 0,183).

C. Security of property rights. In order to examine more deeply the relationship between adoption rates and invention protection methods, we use now an indicator provided by the Economic Freedom of the World concerning the security of property rights.[38] This index is computed from the Global Competitiveness Report's question: "Property rights, including over financial assets are poorly defined and not protected by law (= 1) or are clearly defined and well protected by law (= 7)." This way, high values of the index indicate high protection levels.

Figure II.31 shows that **in most countries where the security of property rights is high, the adoption rate is also high**. Luxembourg appears with a specific profile, since the security is very high but the adoption rate is the smallest in the sample. The Pearson correlation is not significant with all countries (coefficient=0,295, p-value=0,250) but it becomes significant at a 5% level if we drop Luxembourg out (coefficient=0,513 ; p-value = 0,042).

Figure II.31. Adoption rate and security of property rights according to country



NB : Lithuania, Romania, Latvia, Estonia and Bulgaria are not represented because of missing data.

[38] The Economic Freedom Network considers security of property rights, protected by the rule of law, as essential to economic freedom: "*Freedom to exchange, for example, is meaningless if individuals do not have secure rights to property, including the fruits of their labor. Failure of a country's legal system to provide for the security of property rights, enforcement of contracts, and the fair and peaceful settlement of disputes will undermine the operation of a market-exchange system. If individuals and businesses lack confidence that contracts will be enforced and the fruits of their productive efforts protected, their incentive to engage in productive activity will be eroded*" (page 11 of the 2007 Annual Report of Economic Freedom of the World).

II.4.3.2. Internal Market and adoption rate

As detailed afterwards in Part III, it is not easy to account for the impact of IM on innovation adoption. Only indirect indicators can be used. A first set of indicators refer to **the Transposition Deficit Index,** which measure the percentage of Internal Market directives communicated as having been transposed (A). A second set of indicators can be extracted from the **Economic Freedom of the World** report and refer **to Product Market Regulations** (B). Finally, we will consider the indicator of **Product Market Regulation of OECD** (C). These indicators are presented below as well as their correlation with innovation adoption.

A. Transposition Deficit Indices (TDI). Two indicators of TDI are used in what follows: the global one that covers the 12 areas of EU directives (agriculture, environment, enterprise, innovation, competition, internal market, justice, energy, employment, taxes, education and health) and the specific low-level indicator that accounts for internal market directives in particular. This way, the first one is a more general one that, among other 11 subindicators, considers our second indicator. The higher the value of these indicators, the higher the transposition of EU directives.[39]

Is the adoption of EU regulations and directives clearly associated to higher rates of Innovation Adoption across countries?

Yes, in those countries where more EU regulations and directives are enforced we observe also higher rates of Innovation Adoption. The conclusion is even stronger when analysing the specific relationship with Internal Market directives. Therefore, the transposition of EU directives seems to favour Innovation Adoption.

[39] Correlations between innovation adoption with other specific areas of the TDI likely to interfere with innovation adoption, such as directives regarding enterprise, competition, education, employment, have also been studied. They are not reported here since no significant correlation appears with adoption.

Figure II.32. Adoption rate and global transposition deficit indicator

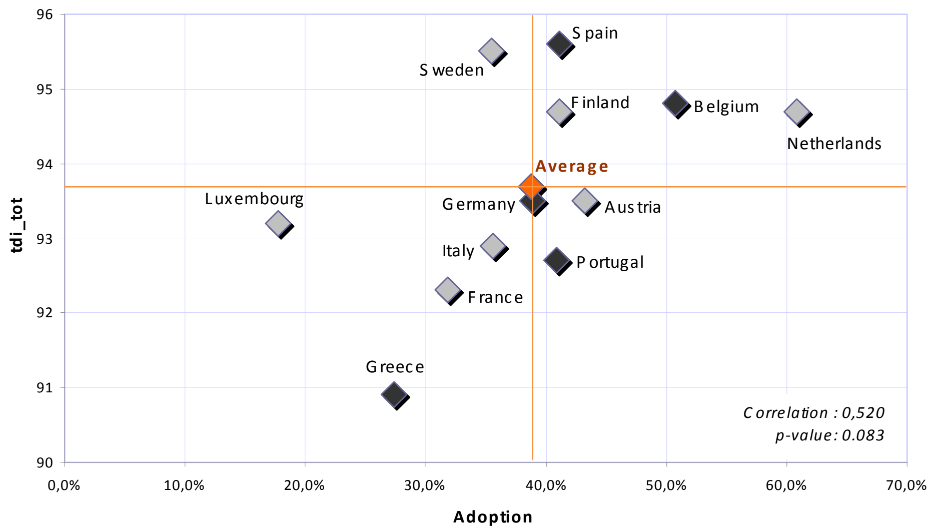
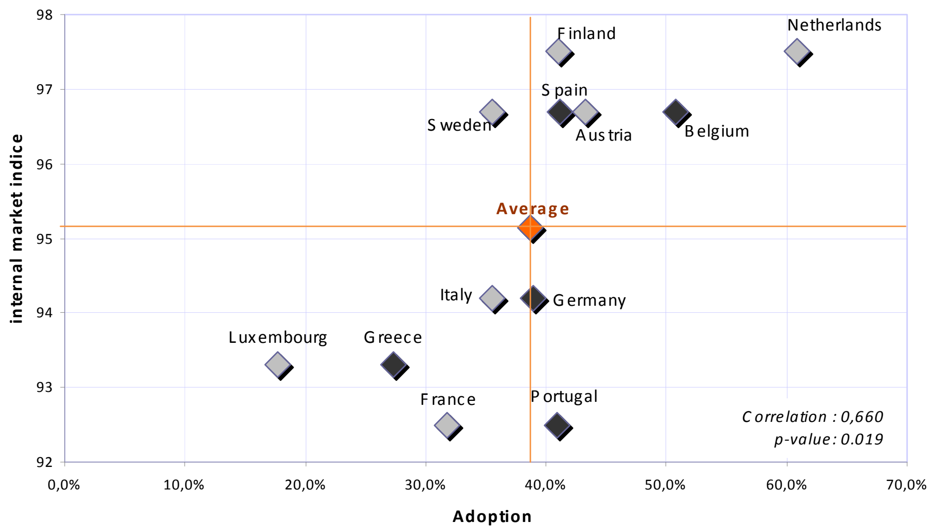


Figure II.33. Adoption rate and internal market transposition deficit indicator



MAIN INSIGHT: If we first consider the global TDI (Fig.II.33), a positive and significant correlation is observed**. The lower the level of transposition of Community law, the lower the level of adoption of innovation and the other way around.** Additionally, the correlation would even increase if Netherlands and Luxembourg were dropped.

The internal market TDI gives us a more accurate view of the correlation between Internal Market and innovation adoption activities. Except Sweden and Portugal, **the countries that have transposed most of the EU internal market directives are those that generate the highest adoption rates** (Netherlands, Finland, Spain, Austria and Belgium). Conversely, countries with the highest deficit of transposition (France, Luxembourg, Greece and Italy) are characterized by the lowest rates of adoption. The correlation coefficient is therefore positive and significant at a 5% threshold level.

Also, when we focus on product and process innovation adoption separately (and on the different areas for which the TDI's are proposed) we can observe how few of the Transposition Deficit Indicators (where higher values correspond to higher transposition rates of EU regulations in each analyzed area) are found to be statistically correlated to Innovation Adoption (product and processes)[40]. In particular, the strongest result is shown for TDI Internal Market (also for product and process innovation along with total innovation adoption). Regulations in the areas of Health seem instead associated to process innovation adoption while, on the contrary, the transposition of regulations on Employment matters seems to be positively correlated to product innovation adoption.

B. Product Market Regulation indicators by the EFW. In addition to the above measures of the IM, we can use another kind of proxy, accounting for product market regulations. A first set of variables come from the Economic Freedom of the World report, covering 5 areas:

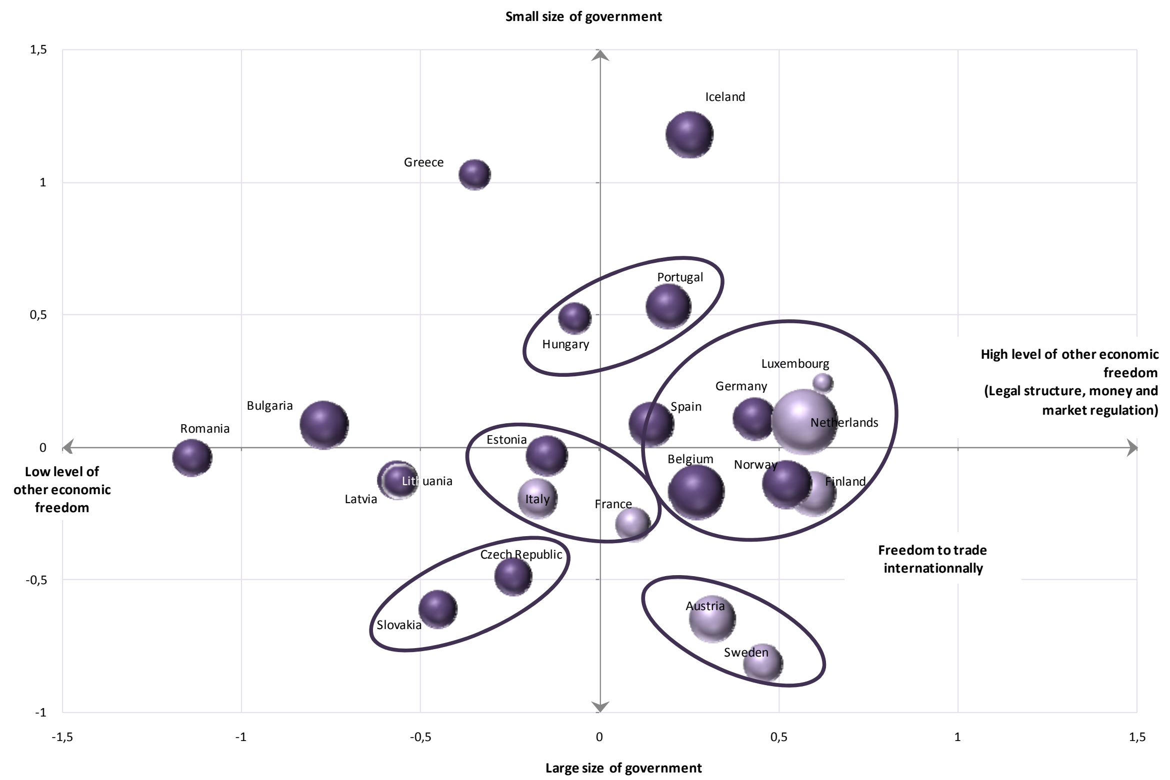
- Size of government: Countries with low levels of government spending as a share of total, a smaller government enterprise sector and lower marginal tax have the highest rates.
- Legal structure and security of property rights: The higher is the protection of property in the country, the higher the index rate.
- Access to sound money: The index shows high rates for countries that follow policies and adopt institutions that lead to low and stable rates of inflation and avoid regulations that limit the use of alternative currencies.
- Freedom to trade internationally: High rates of the index for countries that have low tariffs, a trade sector larger than expected, easy clearance and efficiency of administrations customs, a freely convertible currency and few controls on the movement of capital.
- Regulation of credit, labor and business: The index displays high rates for countries allowing markets to determine prices and refrain from regulatory activities that retard entry into business and increase the cost of producing products.

Therefore, all the indices have the same interpretation: high values correspond to better performance of the regulations and therefore of the system. Correlations among these five

[40] Results are detailed in Appendix II.10 for both product and process innovation adoption separately.

areas show that three of them are highly correlated one another[41] : Legal structure and security of property rights, Access to sound money and Regulation of credit, labour and business. In the ACP below (Figure II.34) they are represented on the same axis, labelled Other Economic Freedom. Freedom to trade is also correlated to it but to a lesser extent. The second axis represents the size of the government. This ACP allows us to cross the information about economic freedom with the adoption rates (represented by the bubble size). **The largest bubbles, which are associated to higher innovation adoption rates, can be observed for countries that exhibit also a high level of economic freedom.**

Figure II.34. Economic freedom and adoption rate



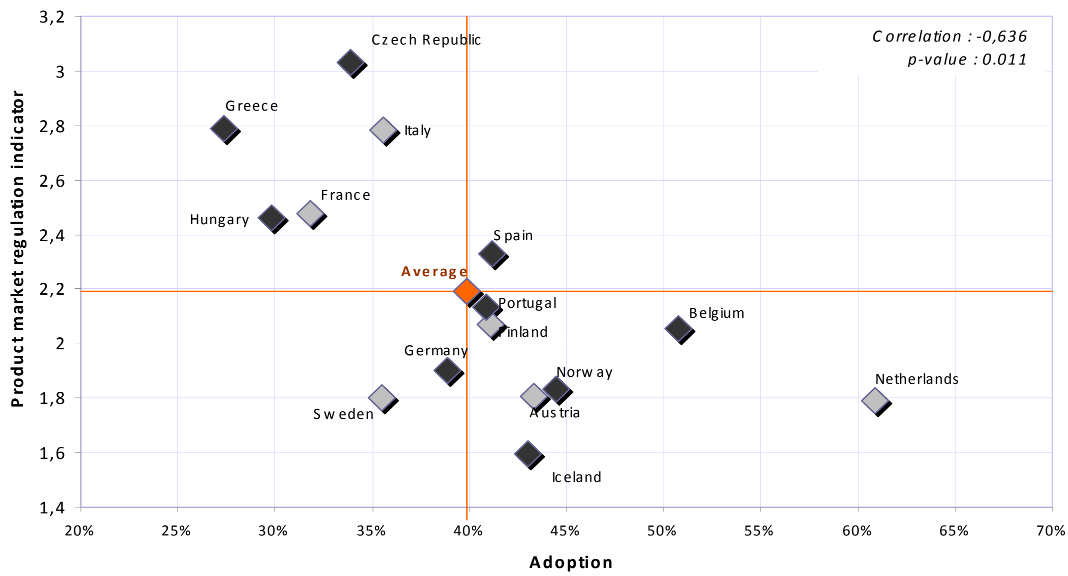
C. Product Market Regulation indicators by the OECD. Finally, we can use the Product Market Regulation indicator built by OECD, for which higher values imply tighter and burdensome regulation. In other words, the lower the value of the indicator, the better it is for the system since it implies that there is less burdensome product market regulation.

41 Correlation between "Access to sound money and Regulation of credit" and "Legal structure and security of property rights" is 0.801 (p-value = 0.000). Correlation between "Access to sound money and Regulation of credit" and "Labor and business" is 0.731 (p-vamue = 0.000). And finally, correlation between "Legal structure and security of property rights" and " Labor and business" is 0.879 (p-value = 0.000).

Does burdensome Product Market Regulation have a relationship with Innovation Adoption?

Yes, lower product market regulation seems to be associated to higher rates of Innovation Adoption on a EU cross country basis.

Figure II.35. Adoption and product market regulation



MAIN INSIGHT: Countries with high levels of regulation are characterized by low levels of adoption. This result confirms the hypothesis of a positive effect of the IM objective of reducing barriers in the product market on the adoption of innovation. The only clear exception would be Sweden, where low levels of product market regulation coexist with low levels of innovation adoption. It seems therefore that this country relies more on other ways of introducing innovation but not that of adopting it from either others or in cooperation with others.

The strong negative correlation between total innovation adoption rates and Product Market Regulation, PMR (where higher values of the PMR index indicate burdensome and oppressive regulations) is also robust in the case of product and process innovation adoption[42]. Results show negative and statistically significant coefficients of the correlation matrixes indicating a negative relationship between adoption of innovation and oppressive market regulations at the country level.

[42] Results are detailed in Appendix II.10 for both product and process innovation adoption separately.

All in all, it seems that **whatever the indicator used to proxy for the functioning of the IM,** the correlation it maintains with the adoption of innovation is clearly significant. **Reducing the intrusiveness of the government and favoring free circulation of goods, people and fostering competition at all levels seems to be associated to higher rates of innovation adoption.** However, we must keep in mind that our IM proxies may be strongly correlated to other determinants of adoption. The clear impact/effect of IM must be addressed through econometric tools only, in order to control for the effect due to other variables. This is done in Part III of this project.

Another way to assess the role played by IM on adoption is to study the evolution of adoption rates over time. Indeed, IM is being reinforced and some other countries are new entrants in the EU. If a significant increase of adoption rates arise over time, this may at least partly reflect the positive effect of IM. This issue is addressed in the next section.

In Table II.6 we offer a summary of the determinants of innovation adoption for which we have analysed their correlation with adoption rates. The result of such relationship obtained through the descriptive analysis is specified.

Table II.6. Potential determinants of innovation adoption analysed in the descriptive

DETERMINANTS	CORRELATION OBTAINED WITH INNOVATION ADOPTION RATES
A. Innovation inputs	
▪ Sources of information for innovation	Non-significant
▪ Innovation expenditure	Positive although not always significant
▪ Human capital resources	Non-significant
▪ Organisational changes	Positive and significant in some cases
▪ Cooperation in joint R&D	Non-significant
B. Market features	
▪ Competition	Non-significant
▪ Barriers to competition	Non-significant
▪ Trade	Non-significant
▪ Barriers to trade	Negative and significant
C. Regulatory environment	
➢ **Protection methods for inventions**	
▪ Patenting	Positive and significant (without France and Sweden)
▪ Other legal and informal protection methods	Non-significant
▪ Security of property rights	Positive and significant (without Luxembourg)
➢ **Internal Market regulations**	
▪ Transposition Deficit (high value: high transposition of EU directives)	Positive and significant
▪ Product Market Regulations by EFW (high value: better performance of regulations)	Positive and significant
▪ Product Market Regulations by OECD (high value: tighter and burdensome regulation)	Negative and significant

II.5. Time profile of innovation adoption in EU countries

The aim of this section is to shed some light on the time evolution of adoption in EU countries. This can be achieved by comparing the adoption rates recorded in the CIS3 over the period 1998-2000 and the adoption rates recorded in the CIS4 over the period 2002-2004. We do not have access to previous surveys (CIS2 in particular) that could have given us wider time coverage. The two available periods are not very distant but they may help us to observe some changes over time. In addition to a global evolution of adoption, these two waves of survey may provide some information about potential changes in the way adoption occurs, by confronting the evolution of cooperation-based adoption to the one of other organization-based adoption.

From a methological point of view, it is important to notice that we cannot provide a single indicator of adoption. Indeed, this has been possible using CIS3 thanks to the rescaling procedure we built to correct the double counting bias that arises on macro data. Regarding CIS4, all the data come from Eurostat website. Therefore, it is not possible to have an idea of the extent of the bias. For this reason, this part gives separated indicators of adoption for product and process innovation. Moreover, some missing observations prevent us to cover all the countries. Greece, Latvia and Iceland are therefore not covered.

II.5.1. Towards a more process oriented adoption

The two figures below show that **the average adoption rate increases between the two periods. This is mainly due to process adoption** that increases by 4.2 points of %. On the opposite, the product adoption remains stable (decrease of 0.1 point of %).

When crossing this information with the growth of innovation rates, it appears that **the increase in adoption is not necessarily associated with a global increase in innovation**. Product adoption growth does go together with an increase in process innovation (+6.3 points of %) whereas process adoption may be associated with a decrease in product innovation (-2.3 points of %).

Figure II.36. Growth of product adoption and innovation rates by country (in percentage points)

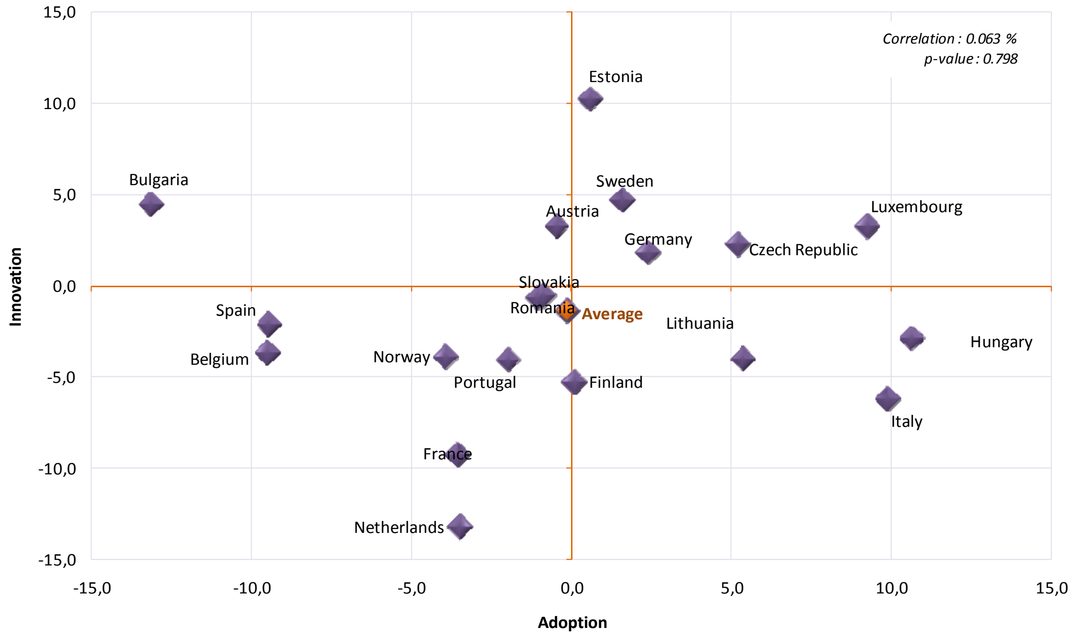
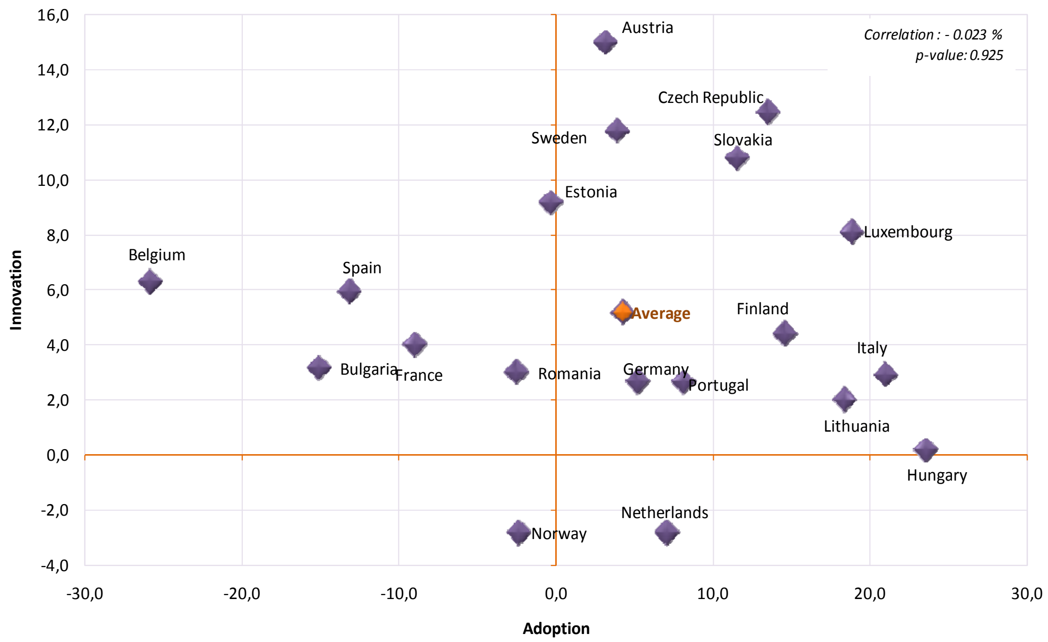


Figure II.37. Growth of process adoption and innovation rates by country (in percentage points)



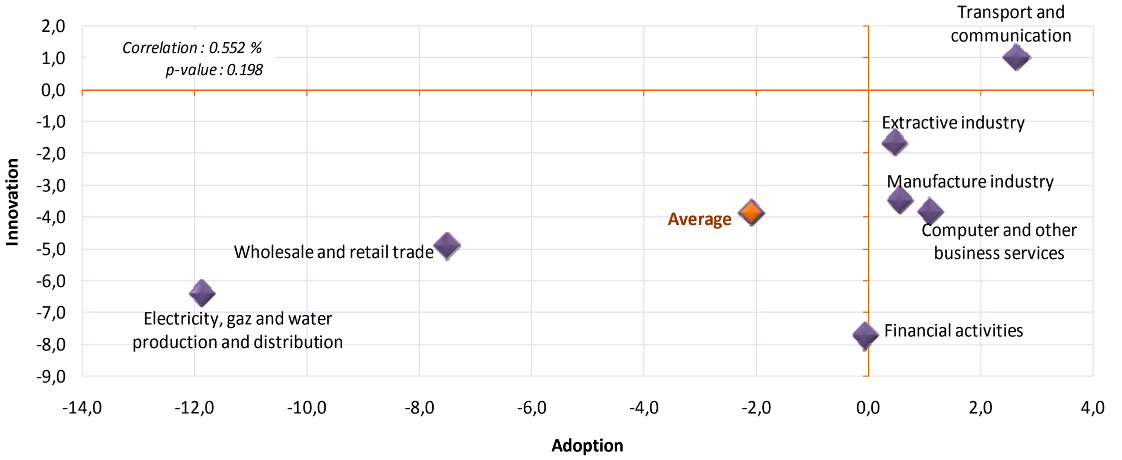
In the case of product innovations, this global trend is not shared by all countries. From the first graph above, we can distinguish four groups of countries, corresponding to each quadrant of the figure. In the bottom right quadrant, only three countries (Lithuania, Hungary and Italy) record an increase of the adoption rate but a decrease of innovation. In the bottom left quadrant, we can observe countries facing a reduction in both their product innovation and product adoption capability. This is particularly the case for Spain, Belgium, France, Netherlands, Portugal and Norway. On the opposite, the top right quadrant brings together five countries that improve both their product innovation and product adoption capability (Estonia, Sweden, Germany, Czech Republic and Luxembourg). Finally, Bulgaria exhibits a specific profile since its innovation rate increases while its adoption rate decreases.

The picture is slightly different **for process innovation. Most countries face a positive trend for innovation and adoption,** with several exceptions: Belgium is characterized by a high innovation growth and a strong adoption fall. In lower proportion, it is also the case for Bulgaria, Spain and France. Norway and Netherlands have a specific profile as they record a decrease of innovation rates.

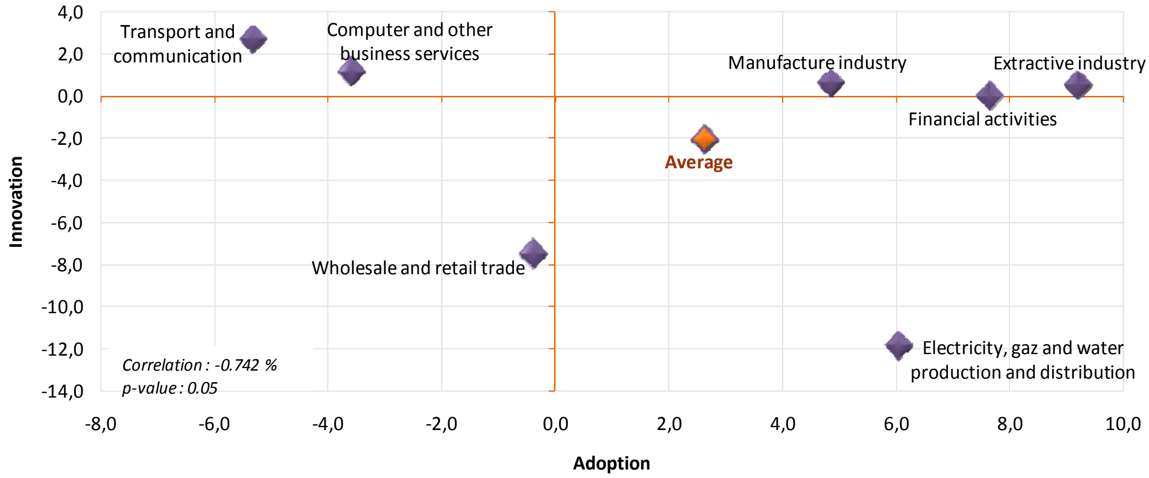
The analysis by sector confirms that we move towards a more process oriented innovation adoption (Fig II.38 and II.39). Regarding product innovation, two sectors face decreases in their adoption rates: Wholesales trade and energy supply. This evolution goes together with a decrease in their innovation rate. On the opposite, Transport and Communication is characterized by an increase in both its innovation and its adoption rate. In the other sectors, the magnitude of adoption clearly increases since their adoption rates rise while innovation rates fall.

The picture for process innovation is very different. Adoption increases for four sectors: manufacture industry, financial activities, extractive industry and energy supply. This last sector is nevertheless different from the three first because the innovation rate decreases by 12% whereas it remains stable for the others. Two sectors face a clearly decrease in their adoption rate: Transport/communication and Computer/other business services. This is not associated here with a decrease in their innovation capacity. The evolution for wholesale and retail trade is close to 0.

Figure II.38: Growth of product adoption and innovation rates by sector (in percentage points)



FigureII.39: Growth of process adoption and innovation rates by sector (in percentage points)



II.5.2. Divergence in the evolution of the nature of adoption for product and process innovation

Some changes in the way adoption occurred can also be observed. Here again, we can only observe product and process adoption separately. **Concerning product adoption** (figure II.40), in average, **firms tend to rely more on cooperation in their innovation adoption activities**. The percentage of cooperation based adoption increases by 1.5 percentage points between CIS3 and CIS4 while the percentage of other organization-based adoption decreases by 1.7 percentage points. For the majority of countries, the cooperation based adoption raises while the other organisation based adoption decreases. For only four countries, we can observe an increase of this last type of adoption. By sector (figure II.42), the fact is similar: except for wholesale and retail trade, the cooperation increases for all sectors. On the opposite, the other organisation-based adoption decreases for all sectors except for transport and communication.

Process adoption is characterized by a different evolution. **Because process adoption faces an important increase, we observe an increase in both cooperation-based adoption and other organization-based adoption, the latter being higher**. This fact is observed for 10 countries among the 22 studied countries (fig II.41). Therefore, product and process innovations face opposite evolutions in the way adoption is conducted. By sector (Fig II.43), the trend is little different. The increase in both cooperation and other organisation based adoption is noticed for manufacture and extractive industries. For the other sectors, the cooperation tends to decrease while the other organisation-based adoption increases.

Figure II.40. Growth of product cooperation-based adoption and other organisation-based adoption by country (in percentage points)

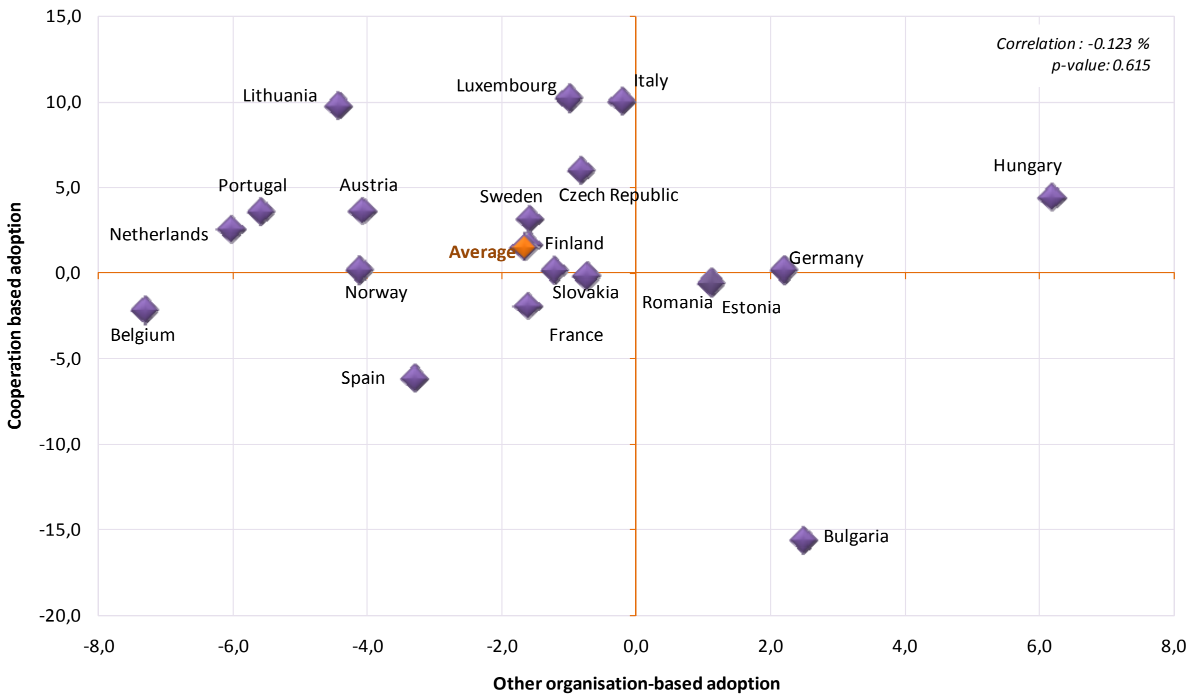


Figure II.41. Growth of process cooperation-based adoption and other organisation-based adoption by country (in percentage points)

Figure II.42. Growth of product cooperation-based adoption and other organisation-based adoption by sector (in percentage points)

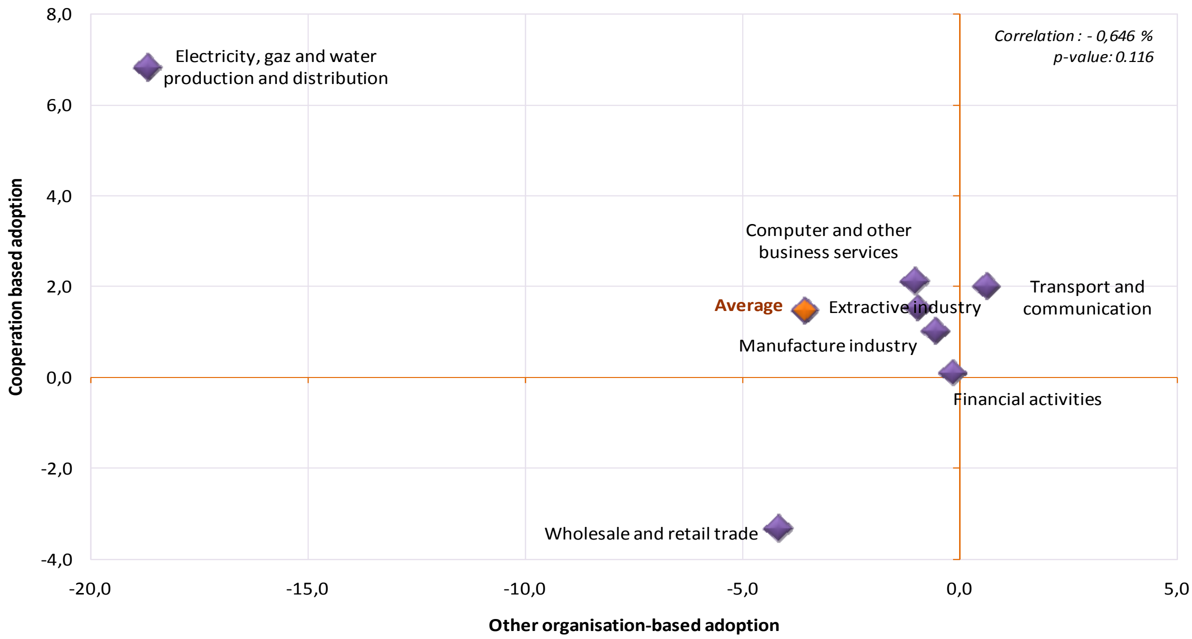
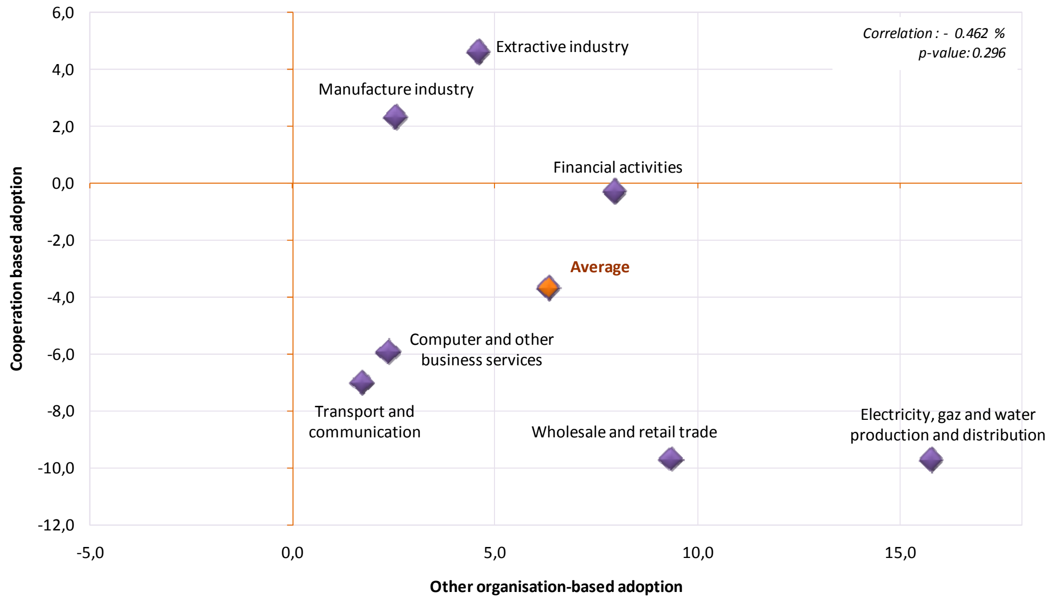


Figure II.43. Growth of process cooperation-based adoption and other organisation-based adoption by sector (in percentage points)



To conclude, **the comparison between CIS3 and CIS4 highlight an increase in innovation adoption, as well as a change in the nature of this process**. This can be observed in most countries and several sectors. Several factors are likely to explain this evolution. Among them, **one can think that the development of the Internal Market may at least partly have an influence**. Econometric investigations are made in Part III of this report to estimate the role played by the different determinants, and the specific role of IM.

II.6. Conclusion: Typology of countries according to their innovation adoption patterns

As a conclusion, this section summarizes the main points examined in Part II. Indeed, based on the level of adoption, but also in light of innovative activities (input and output), some country specificities can be identified.

To be slightly more precise, a typology has been elaborated from the following five variables:

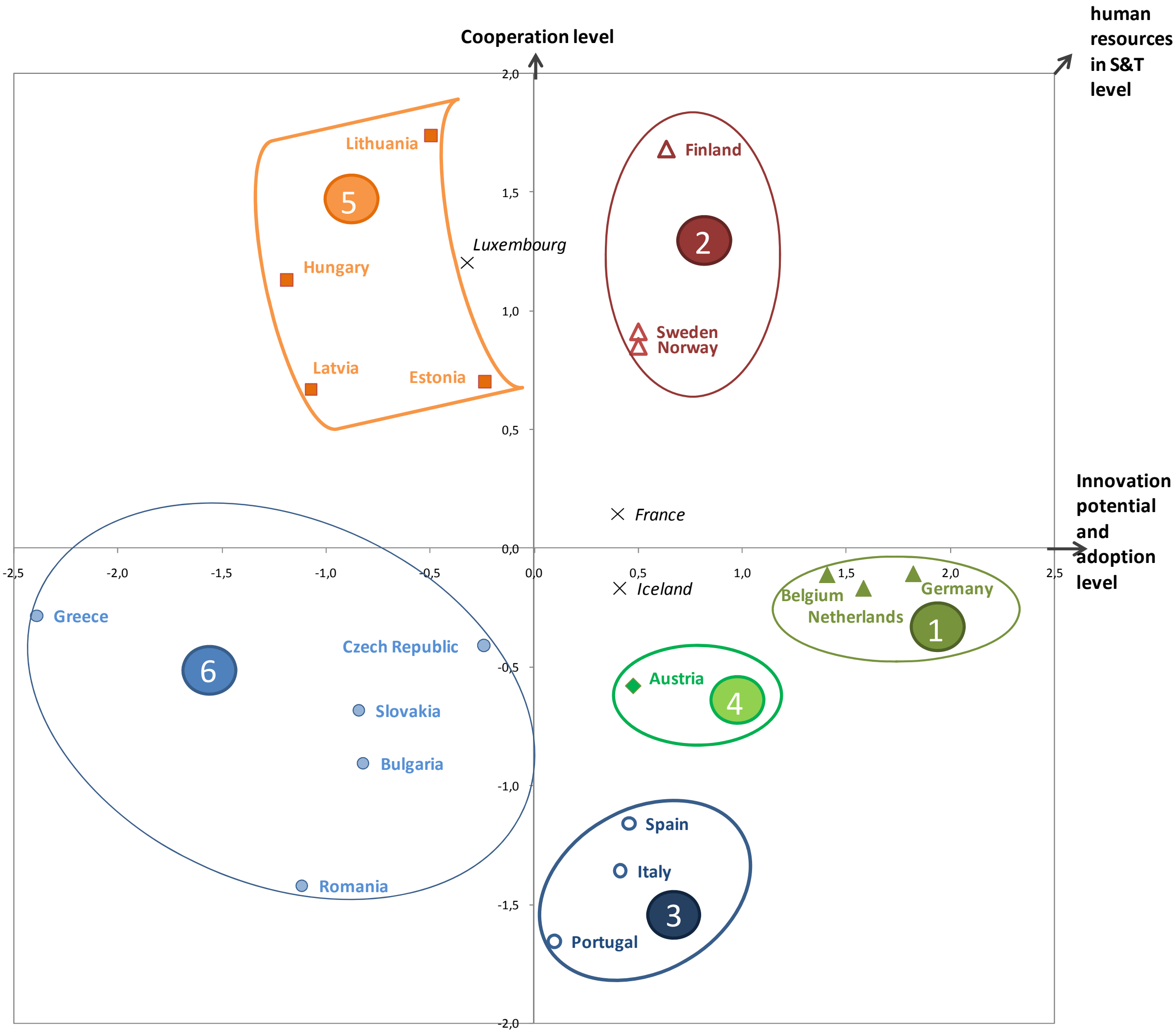
- The adoption rate
- The innovation rate
- The total innovative expenditure (in logs)
- Human resources in S&T (in the labour force)

- The cooperation rate.

The factorial map obtained with a PCA (principal component analysis)[43] is given below. It clearly shows a strong heterogeneity in terms of country profiles since we can distinguish 6 different groups and 3 specific countries.

This mapping allows us to identify the main feature of each group of countries, regarding the five variables used to build the map. By crossing this information with other determinants such as trade, market features and regulatory environment, it also provides us with additional insight about the specificities of country profiles.

Figure II.44 : Typology of countries according to their adoption, innovation and cooperation level



Countries in italics are not well represented on the two axes in terms of relative contributions.

[43] The two first axes account for 72% of the variance. See Appendix II.8 for more detailed results.

Group 1: High innovation performance countries with high levels of human resources in S&T: Belgium, Germany, Netherlands

This first group brings together countries with high rates of adoption and, specially, high rates of innovation, but also with high scores for R&D and human resources. It concerns 3 countries in the core of Europe: Belgium, Netherlands, and Germany, although Germany is less adoption-oriented than the two other countries.

If we cross this information with other potential drivers of adoption, we can observe that the firms belonging to this group of countries use intensively patents and more generally all invention protection methods (fig. II. 27 and II. 29). They are also characterized by a high competition index (see fig. II.22). In spite of different levels of exports, these three countries share a low level of barriers to trade (fig. II.26) as well as a low level of product market regulation (fig. II.35).

Group 2: High innovation performance countries with high levels of human resources in S&T and high rates of cooperation: Finland, Sweden and Norway

The second group contains only Scandinavian countries: Finland, Sweden, and Norway. It records relatively high level of innovation (less in the case of Norway) and adoption rates (Sweden register however a weaker rate of adoption than Finland and Norway). The human resources in S&T are also very important, and the non-tariff trade barriers index is also very high. Compared to the first group, these countries are characterized by a very high level of cooperation.

Crossing this information with other factors, three main common features arise for the three countries: As for group 1, all invention protection methods are used intensively (fig. II. 27 and II. 29), barriers to trade are weak (fig. II.26) as well as product market regulation (fig. II.35).

Group 3: Average innovation performance countries with weak cooperation activities: Spain, Italy and Portugal.

The third group (Spain, Italy and Portugal) registers relatively good level of innovation and adoption rates but the cooperation level is extremely low (Fig. II.19). Average number of employees with high educational innovative firms (Fig. II.16) and Human resources in S&T are also lower than the EU average (fig. II.17).

Crossing with other factors, this group is also characterized by a relatively low level of trade, in terms of export as well as in terms of innovative firms with international market (fig. II.24).

Group 4: A specific country between group 1 and 3: Austria

Between the first and the third group, we can find Austria which records innovation and adoption performances close to the first group but its R&D expenditures, cooperation and human resources in S&T are lower.

Group 5: Weak innovation performance countries with strong cooperation activities: Lithuania, Latvia, Estonia, and Hungary.

The fifth group gathers countries with important cooperation activities but the innovation and adoption are relatively low. It concerns Baltic countries (Lithuania, Latvia and Estonia) and Hungary. Estonia exhibits however higher innovation and adoption rates than the other countries of this group, as well as better trade performances (fig. II.24). Another common feature of these countries is their low level of economic freedom (fig. 34).

Group 6: Weak innovation performance countries with low levels of cooperation: Greece, Czech Republic, Slovakia, Bulgaria and Romania

For the sixth group (Greece, Czech Republic, Slovakia, Bulgaria and Romania), all indicators are generally low. Most of the characteristics of this group are opposed to the one of group 1 and 2. Adoption and innovation are weak (except adoption in Bulgaria), and in all cases, R&D, human capital and cooperation scores are low.

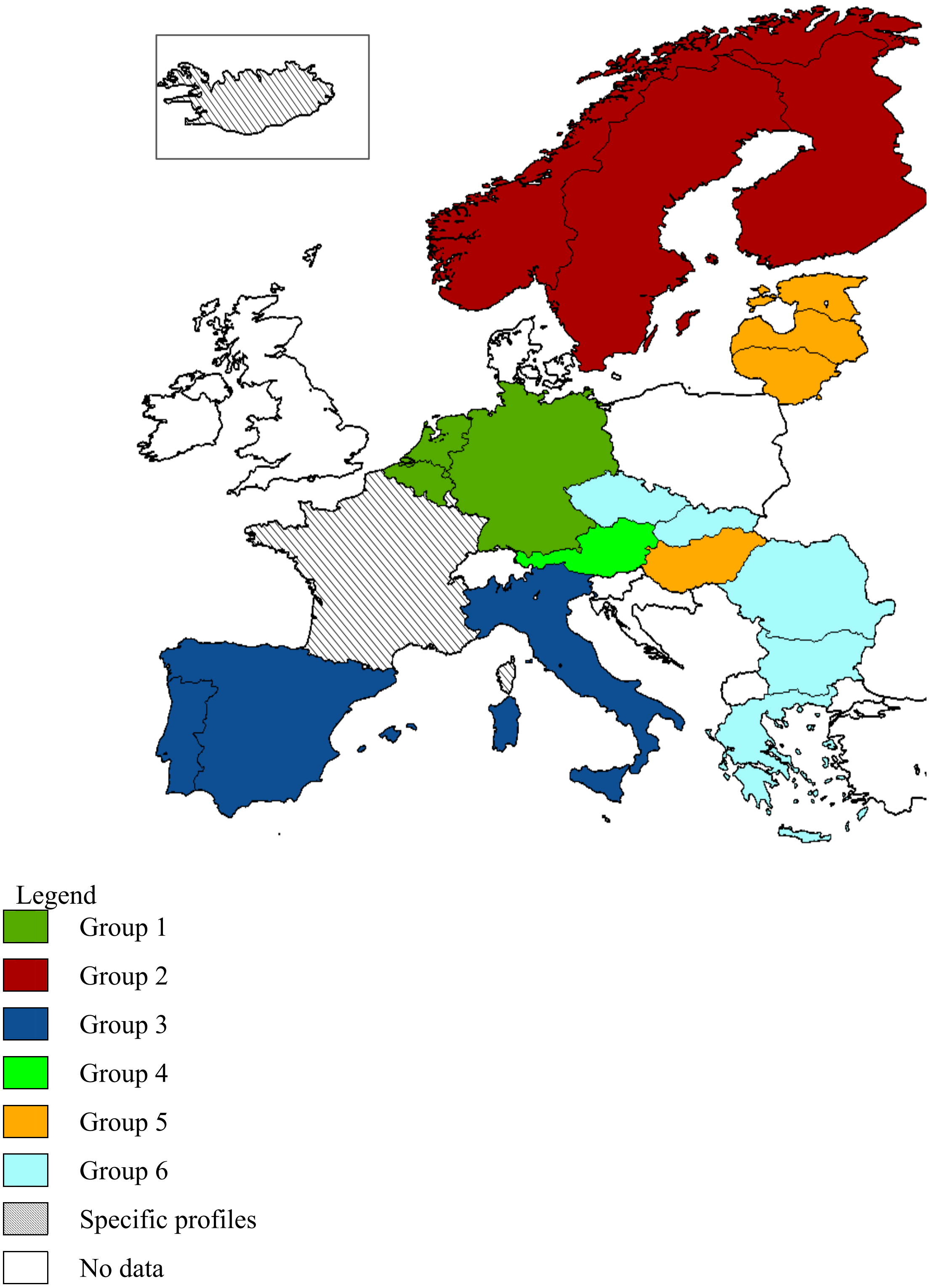
Crossing with other factors, we can observe that protection methods of innovation are also not very used (see fig. II. 27 and II.29). Moreover, as observed for Group 5, the level of economic freedom is lower than the EU average one (fig. II.34)

Finally, from the graph II.44, we can see three countries not well represented due to their specific profiles:

- Luxembourg: the profile is close to group 5 except that the innovation rate is very high.
- France: adoption is very low, but the innovation rate is close to the average. Also, the Product Market regulations index and R&D expenditures are noticeably high
- Iceland: adoption and innovation rates are high but competition and R&D expenditures recorded in the CIS are extremely low and the other indicators are close to the average.

This typology highlights a specific geographical pattern of the EU countries regarding adoption, innovation and cooperation performances. Plotting the six group of countries (see fig. II.45 below) shows that countries belonging to each group are geographically concentrated.

Figure II.45 : Geographical pattern of countries according to their adoption, innovation and cooperation levels



All in all, the typology given above shows that there is no strict correlation between the profile of the country and its ability to adopt. With different features, Group 1 and 2 face high adoption rates while on the opposite, group 5 and 6 that differ in their innovative and general economic features register low adoption rates. This typology shows also that beyond the different determinants examined here, some other structural determinants may impact on adoption. Country specialisation may partly explain these specificities. Due to the low number of sectors for which we have been able to have homogeneous information, it is difficult to enter into more detail for sectors. However, the strong differences observed across sectors need to be accounted for in the remainder of the study as well, and in particular in the econometric estimations made in the following Part. For these reasons, it will be important in the remainder of this study to control for these potential effects through a regression analysis. Indeed, the descriptive analysis provides only simple correlations. The econometric part will give a more comprehensive analysis of the role played by the different determinants. By controlling for all the potential drivers of adoption, the econometric analysis allows to consider the specific effect of each of them.

PART III

Econometric Analysis of the Impact of Internal Market on Innovation Adoption across EU countries

III.1. Introduction

The so called Internal Market directives is a set of rules of the game which has to be put in place for the EU citizens and firms in order to be able to freely move, locate, compete and exploit market potential wherever within the European boundaries. In other words, “the idea of the IM is therefore that of bringing forward proposals for legislation aiming to remove barriers, thus simplifying life for consumers and for businesses, stimulating competition, reducing prices and widening choice. This involves not only making it easier for goods and services to circulate, but also making it easier for EU citizens to work and to live in other EU countries” (Internal Market DG).

In Part II we have analysed the main relationship among innovation adoption and their potential determinants, just based on descriptive (bivariant) analysis. This is not enough because this relationship is affected by other control variables (indirect effects, spurious effects) that affects the real relationship among them. Therefore, it is necessary to do an econometric analysis in order to obtain the specific relationship among innovation adoption and their IM determinants.

The objective of the present part III is therefore that of proposing the main empirical results of the econometric analysis of the impact of IM regulations on Innovation Adoption. As we have already argued in previous Parts of this work, the impact that IM regulations may have on the adoption of innovation is likely to be channelled through the direct impact that the Internal Market (IM) regulations have on some macroeconomic dimensions. It is important to notice, as it was pointed out before, that usually the IM regulations are aimed at achieving specific goals which usually abstract from the direct objective of fostering innovation adoption or creation.

Hence, for example, the IM EU regulations are aimed at fostering the free movement of goods and people, at increasing competition and cooperation across member states. These dimensions, which we will call **“transmission channels”** are those which are **directly affected by the IM regulations**. This said, however, the transmission channels are going to have an impact on the diffusion and adoption of innovation.

More cooperation or trade, for example, are expected to positively impact the possibility that blueprints or innovation spill over from firms to firms as well as from country to country. At the same time, recent empirical and theoretical literature argues how more competition and neck-and-neck markets may incentivize innovation and therefore affect also positively the possibility of diffusion of new innovations and technology across countries.

Hence, in order to capture the effect of the IM regulation on the adoption of innovation at the EU level we have to carefully analyze the two-stages by which these regulations firstly affect the transmission channels and, secondly, how these channels affect directly innovation adoption rates.

The data we are going to use come from a selection of relevant variables of different international databases. The dependent variable (and some of the control variables) we will be using in the regression come from the Community Innovation Survey, CIS3 (already fully analyzed in part II of this report). As proxies for the impact of IM regulations, instead, we will be making use of the OECD data on Product Market Regulation (and its disaggregation) as well as the data of the Economic Freedom of the World index (both of them also already analyzed in part II of this report and to which we send the interested reader for their descriptive statistics).

In what will follow, then, we will explore different specifications trying to take advantage of the variety of data on IM which we have available. The rationale for the use of an indicator rather than another will be always that of its statistical significance. The idea is therefore to try to achieve the best econometric fit for all the regressions by also combining this with the economic intuition in the decision of the variables which will be eventually used in the regression.

From an econometric point of view a two-stages estimation (which makes use of Instrumental Variables techniques estimations) seems to be the best option to be pursued. In what follows, therefore we are going to estimate a set of first stage regressions which put in relation various IM regulation proxies with the detected transmission channels. Then, once we find a correct specification in the first stage we will use the fitted values of the channels (which will not be endogenous to the error process in the second stage) in order to estimate the indirect impact of the IM regulation on the share of innovation adoption across countries in the second stage estimation. This second stage is estimated at the global level using 2SLS (section III.4). However, in order to perform some robustness checks on the results obtained on aggregated data, additional estimations are made using micro data (section III.5).

III.2. First Stage analysis: the impact of IM regulations on the transmission channels of Innovation Adoption

III.2.1. Introduction to the first stage

Although several channels have been identified linking IM and innovation adoption, in our empirical analysis we focus on three major channels which are usually stressed in the literature as conductive to innovation and adoption. These are (i) trade, (ii) cooperation and (iii) competition.

(1.1) $Trade_{c,i} = \alpha_0 + IM_C \alpha_1 + ZTrade_c \alpha_2 + DUM_i \beta_3 + v_{c,i}$

(1.2) $Coop_{c,i} = \beta_0 + IM_C \beta_1 + ZCoop_c \beta_2 + DUM_i \beta_3 + \varepsilon_{c,i}$

(1.3) $Comp_{c,i} = \gamma_0 + IM_C \lambda_1 + ZComp_c \gamma_2 + DUM_i \beta_3 + \xi_{c,i}$

where *IM* are the Internal Market proxies; *Z_* are the control variables necessary to explain each dependent variable and *DUM* are the dummy sectoral variables.

As we already pointed out before, the impact of IM regulations on the adoption of innovation is going to be mediated by the particular impact that these regulations will have on the transmission channels which will eventually impact the overall level of innovation adoption on each country[44] and sector. Hence, our analysis will first have to focus on the impact of IM on the three channels and then, secondly, on the impact that these channels have on the overall adoption of innovation.

[44] Due to data availability issue, the regression we will propose in this sections (up to section III.4) will be mainly based on the following sample of EU core countries: Austria, Belgium, Czech Republic, Germany, Spain, Finland, France, Hungary, Italy, Netherlands, Norway, Portugal and Sweden. However, the actual number of countries in each regression will also depend on the particular data availability of the explanatory variables taken into considerations. So, some countries may be missing in specific cross-country tables.

III.2.2. Trade channel

The first channel we are going to focus on is that of trade. We express the dependent variable (LNTRADE) as the log of turnover that is exported in industry i and country c. This measure of exports is explained by the matrix of IM variables as well as by a set of control variables (when available) denoted ZTrade[45] and a matrix of dummies for each industry in order to pick up specific effects that the IM regulations may have at the sectoral level.

Table III.1 shows our preferred specification, that is, the one that will be used in the second stage of the estimation in order to check the impact of this channel on innovation adoption[46]. Our proxy of trade is accurately explained by 3 main explanatory variables as well as by the sectoral controls. The R2 is particularly high (0.83) pointing to the very good fit of the overall regressions presented in the Appendix III.1, which as the minimum takes a value of 0.76.

First, we introduce, as an explanatory variable, the turnover (as a proxy of the size of the different countries and sectors). This is because, in order to correctly disentangle the effects of IM regulation we firstly need to control for the heterogeneity of exports which could be accounted for by the size of the sectors and of the countries[47]. As one would expect, the higher the value of the total turnover, the higher will be the turnover exported. The coefficient for Log Turnover is in fact positive and statistically significant at 1% significance levels.

Other unobserved effects are then controlled for by the sectoral dummies we inserted in the regression so that we may be confident that the remaining variability in the data could be well ascribed to the IM explanatory variables.

[45] Another possibility for the endogenous variable is considering just the trade that each country makes with other EU countries. However, this data seems not to perform well in an econometric context so we decided to discard them for the present analysis. However, most trade in the EU countries is intra European. Therefore, not much difference should be encountered.

[46] For more details about this specification and some other alternatives, see Appendix III.1.

[47] LNTURNOVER is not directly an IM explanatory variable but a necessary control variable used in order to account for the differences in the size of sectors and countries within our sample.

Table III.1. Trade equation

Dependent Variable	Ln TRADE
Log Turnover	1.143
	(7.62)***
Involvement in Business Operation	-0.823
	(3.34)***
Freedom to Trade	1.335
	(3.09)***
DUMMY	Yes
Constant	-14.117
	(4.28)**
Observations	80
R-squared	0.83

t statistics in parentheses
***, ** and * significant at 1, 5 and 10 %

Table III.2. Cooperation equation

Dependent Variable: Cooperation	
Most People Can Be Trusted % (TRUST)	0.276
	(4.22)***
Regulatory and Administrative Opacity	-0.036
	(-2.86)***
Science and Technology Graduates	0.008
	(3.31)***
Log GVA sector	-0.044
	(-5.30)***
DUMMY	Yes
Constant	0.507
	(5.55)***
Observations	69
R-squared	0.51

t statistics in parentheses
***, ** and * significant at 1, 5 and 10 %

Table III.3. Competition equation

Dependent Variable: Mark up	
TDI Competition	-0.007
	(-6.32)***
State Control	0.016
	(1.52)
Sectoral and ad hoc State Aid as a % of GDP	0.077
	(3.29)***
Transfers and Subsidies from National govts. as % of GDP	-0.039
	(7.46)***
Log of number of firms in each sector	-0.007
	(-1.23)
Working days spent to deal with Bureaucracy	0.000
	(1.89)*
Number of bodies to be contacted in order to open a Business	0.005
	(2.85)***
DUMMY	Yes
Constant	0.855
	(6.94)***
Observations	76
R-squared	0.70

t statistics in parentheses
***, ** and * significant at 1, 5 and 10 %

Hence, we switch to the analysis of the impact of IM regulations which may affect the amount of turnover exported. Our preferred specification makes use of two main IM proxies. First, **“involvement in business operation”** is shown to be statistically significant and with the expected negative coefficient. This variable is the weighted average of two regulation indicators coming from the OECD Product Market Regulation database (see Conway, Janod and Nicoletti, 2005). In particular (and as detailed Conway, Janod and Nicoletti, 2005) the proxy for the Involvement of government in business operation is the weighted average of respectively Price Controls (with a weight of 0.45) and Use of command and Control regulation (with a weight of 0.55)[48] Price Controls get a higher value if the perceived regulation is strengthened. The “Use of command and Control regulation” variable are measuring the intensity by which central governments are impeding or distorting the free movement of goods across countries or, as in the case of price controls they are actually providing retail prices guidelines which may discourage traders to enter specific country-markets. Hence, for example, if the “government provide (strong) price guidelines to road freight companies” (item 4 of the price control proxy) this may discourage road freight companies to operate in that particular country and therefore impact negatively the trade channel. The same happens when we look at, for instance, the role played by air travel or railways regulation policies across countries in the sub-index “use of command and control regulation”. The tighter these regulations, for example, in terms of requirements imposed to domestic carriers or companies operating in providing railway infrastructures (items 10 and 11 of the “use of command” sub-index), the more difficult will become trading across countries with the regulatory burden imposing an implicit barrier to the amount of turnover exported.

An increase in the perceived control of prices and on the use of other control regulation will lead therefore to an increase in the value of the Involvement in Business and subsequently to a decrease in trade flows across countries. Less burdensome regulations in these two fields are

[48] In the table we do not present the results which make use of the more disaggregated sub-indices which compose “involvement in business operation”. The same strategy will apply also for other PMR indices which will be analyzed below in other tables. We do so because some of the most disaggregated components of the indices we analyze are sometimes highly correlated one another and the regression which take them altogether is somehow meaningless due to multicollinearity problems. This said, however, we propose in the text the description of the main sub-indices (components) of the variables which are actually analyzed in the regression (as it is the case here for “involvement in business operation”) with the corresponding weight which are used to compute the final variable used in the regression. This way we are able to analyze the deep determinants of each PMR proxy and infer something on their impacts on the dependent variable even if we do not directly put them in the regression. For more details about these variables see Appendix III.4.

therefore expected to reduce implicit trade barriers and to increase trade flows in the examined countries. All these reasoning seem to be strongly confirmed by our empirical analysis which argues for **less burdensome and more uniform set of price and control regulations as an important driver for freerer circulation of goods and increased trade across member states.**

The second IM regulation proxy that shows to be extremely significant in explaining the amount of turnover exported (Table III.1) comes from the Economic Freedom of the World Index (www.freetheworld.org) and it is called "**Freedom to trade Internationally**". Due to the way the overall index is built (higher values to countries where trade is made easier by regulations) this variable is statistically significant and with the expected positive coefficient meaning **that regulations which improve the easiness of trade are actually impacting positively the volume of turnover exported** in our sample. More in detail, also the index of "freedom to trade internationally" is the average of other sub-indices.[49]

Even if in Table III.1 we propose the best specification in terms of overall fit of the regression, other specifications have been tried in order to check the robustness of the result and to propose alternative (maybe less important) explanatory variables for the trade channel (see Appendix III.1). We have checked whether having an international market as main market destination is correlated to the amount of exported turnover. Empirical evidence seems to point into this direction. Also, we have tried different IM regulations such as using the overall Product Market Regulation OECD proxy. This variable shows the correct negative sign but it fails to be statistically significant pointing to the fact that only some of the features which attain the PMR index (in our case for example the involvement in business operation) are actually explaining the flow of exported turnover but no others such as administrative burdens on start-up or communication and simplification rules (which instead will be important for other channels such as that of cooperation). Also, we have proposed a robustness check of the result on the "involvement in business operation" variable by putting it into the same regression with the percentage of firms declaring to have as main market the

[49] These are: taxes on international trade (representing the revenues and mean tariff rates applied in each country as well as the standard deviation of these tariffs), regulatory barriers (as the average of hidden import barriers and cost of importing), actual size of trade sector compared to its expected size (derived from gravity analysis), differences between official exchange rates and black-market rate and finally international capital market controls (as the average of an index controlling for the access of citizens to foreign capital markets and *viceversa* and the restrictions on the freedom of citizens to engage in capital market exchange with foreigners). All these sub-proxies together give the index for the easiness by which trade transaction may take place across countries.

"international" one. The result shows how it is the IM business regulation to be the important determinant of trade flows.

III.2.3. Cooperation transmission channel

The second channel we are going to focus on is that of cooperation. This comes from the use of the CIS3 data. The dependent variable (COOP) is expressed as the percentage of firms which have cooperated (within the EU territory) in any kind of activity related to innovation. To be more specific we are going to propose as a baseline indicator of cooperation the total number of firms in each sector and country which participated in innovative cooperation activities divided by the total number of innovative firms. Cooperation activities, however, can be carried out both across countries (with firms which do not belong to the country of the interviewed firm) and at the national level (with firms of the same country only). The CIS3 data allows us to define two separate indicators for these channels of cooperation.

Due to the general scope of our research (the effect of the EU internal market on innovation adoption) we believe of particular interest the study of the "across-country" cooperation as a channel of innovation adoption. This is why we report, as our baseline specification, the results by using this specific cooperation channel. However, of interest is also the analysis of the impact of IM regulation on the level of cooperation within the same country (and then of this on overall innovation adoption). We propose the econometric results for this secondary specification in the appendix III.2.

Hence, going back to the interpretation of the transmission channel, the more the cooperation in innovation matters (for example fostered by the EU framework programmes, see Varga et al. 2008), the more we expect innovation to diffuse across borders, industries and firms. The analysis of the determinants of cooperation (that is of those policy regulations which help cooperation innovation) is therefore intrinsically important in our study. Table III.2 offers the best results for the first stage regression of cooperation, that is the one which is going to be used in the second step of the estimation in order to check the impact of this particular channel on innovation adoption[50].

[50] For a more details about this specification and some other alternatives, see Appendix III.2.

Cooperation (COOP) is explained, again, by 2 control variables and by a set of IM regulations. The first control variable is a proxy of the independent level of social capital (TRUST) in each country. It is well known that social and cultural features are at the basis of the different level of trust experienced across European countries (see Vadi, 2004). So, before testing for the impact of specific regulations on cooperation we argue it is important to expunge the likely heterogeneity of social capital and trust by controlling for differences across countries. The variable we use is a proxy of the degree of trust ("**most people can be trusted**") in each country coming from the World Social Survey. This variable shows up to be statistically significant and positive as one would expect. **The degree of cooperation across firms and countries is therefore explained in part by the degree of trust**.

Along with the overall trust experienced in each country, another aspect is particularly important when accounting for the degree of cooperation: the **average size of the sector** (log of GVA (Gross Value Added) of each sector in each country). We take into account the average dimension of the sector in our sample so as not to incorrectly attribute this size effect to other variables in the regression. In particular the intuition is that firms operating in smaller sectors will be those which more than others rely on cooperation while, in those sectors which reached a critical mass, firms have reached the sufficient size so as not to need to rely to cooperation as smaller firms may need to. In smaller sectors, then, part of the fixed costs of innovation can be therefore better internalized if the innovation is made in cooperation with other firms (which cooperate in the same project) rather than individual firms alone. Our empirical results confirm this intuition. **The average size of the sector is negatively and significantly related to the degree of cooperation.** This is to say that small firms are more likely, on average, to cooperate in innovative projects with other firms, whereas big firms in developed sectors would develop their innovations by themselves in a more competitive environment.

Also, at a side of this, another explanatory variable results to be very important in shaping the extent of cooperation across countries and firms. Human capital (our proxy is the **Science and technology graduates** by EUROSTAT) is found to be statistically significant and positive. The intuition behind this result is that better trained workforce is usually more prone to cooperation and that especially those graduated in scientific areas are going then to participate in bigger cooperative projects. In fact, those projects which usually need cooperation across firms (or countries) are those which more than other require high skill levels. It is not surprising, therefore, to find **a significant correlation between human capital levels and the degree of EU cooperation.**

Also, however, one would expect to be able to detect the impact of particular regulations and policies which may foster cooperation. The IM variable we propose in our preferred specification proxies for "**regulatory and administrative opacity**" and comes from the OECD PMR database. Due to the way this variable has been built, it **shows a negative and highly statistically significant coefficient pointing that regulations leading to easier communication are going to boost cooperation across firms and countries, as expected**.

The regulatory index is a composed measure of different sub-indicators. Hence, our econometric result is particularly interesting when looking more deeply at the issues that are considered in the construction of this OECD proxy (see Appendix III.4).

Within the regulatory and administrative opacity indicator we find the items of the indicator "communication and simplification procedure" which measures the extent by which national governments reduce information and cooperation costs. Hence, for instance, the third item "There are inquiry points where affected or interested foreign parties can get information on the operation and enforcement of regulations" is actually providing a measure of the extent by which national government foster and ease cooperation across national firms/individuals and other firms/individuals in other countries. Another example is the 8th item of the indicator which measures the presence of "a program to review and reduce the number of licenses and permits required by the national government". The presence of such type of programs is undoubtedly helpful in fostering cooperation making the start-up of business relations much easier not only at the national level but especially for foreigners who do not have to face too many "unknown" procedures in order to undergo their businesses abroad.

The empirical evidence that Table III.2 shows on these regards strongly supports all the reasoning above arguing for reducing communication burdens in order to achieve higher levels of cooperation across firms and therefore across industries and countries.

As done for the other channels, we also provide some additional robustness checks for cooperation by using alternative specifications (see Appendix III.2).[51] We propose the robustness check by using different variables both on (i) Cooperation across EU countries and, on the second definition, (ii) Cooperation within the same country.

In fact, in the last column of table A.III.2 in Appendix III.2 we re-run the baseline specification but using as a dependent variable the degree of **cooperation within the same country**. Results are basically the same. We argue, therefore, that the same IM policies affecting the cooperation across EU countries are likely to affect also the degree of cooperation within the same country as one would expect.

III.2.4. Competition channel

The last channel we believe may affect the diffusion and adoption of innovation is that of competition. The economic literature (both theoretical and empirical) has already studied the effect that the market structure and the degree of competition may exert on innovative output. In particular, recent theoretical models (see Aghion and Howitt 1996) argue that in a situation where firms which compete in innovation are leveled (as it is somehow the case for the EU firms) the competition neck-and-neck is going to increase the incentives to produce and exploit innovation. At the same time, **innovation adoption will be affected by competition in the way that more innovations will be available and, on average, therefore more adoption/diffusion possibilities will be there for firms to be taken** (see Part I for a detailed review on the impact of competition on innovation diffusion/adoption). Hence, the study of the determinants of competition at the EU levels (and in particular of the regulations which may foster competition itself) is of crucial importance to our ultimate target, the study of the determinants of innovation adoption.

[51] We tried to insert the Transposition Deficit Indicator for the regulations concerning education (**TDI EDUC**) and other measures of human capital. Apparently the reception of EU regulations in this field does not show to be statistically significant and does not explain the degree of cooperation across countries and firms. Also, other proxies of human capital fail to be more significant than the one used in the baseline specification. When we also account for the total turnover produced (as an alternative measure of the size of the firm) we find this to be significant (as expected) but the overall R2 of the regression is lower. If we also insert some other CIS-based controls such as belonging to a group (**GP**, whose sign on cooperation is expected to be negative) and having introduced recently some organizational changes (**Organizational Changes**), these control variables are not significant. But even when they are accounted for, the main result of the baseline equation stands.

The proxy that we use for measuring competition at the EU level is a measure of the markup in the fashion of that proposed by Griffith and Harrison (2004)[52]. **The higher the markup (above the value of 1), the less the competition achieved in the market under analysis** since more rents can be extracted by the distortion/absence of competition. On the opposite, perfect competition would imply a markup with a value equal to the unity.

Our preferred econometric specification is shown in Table III.3. The logarithm of markup is regressed again on some control variables as well as on IM regulation proxies. As before for the case of cooperation here we control for the average size of the firms. The intuition is that in markets where the average size of the firms is high (and therefore fewer firms are active) the competition will be lower since the market structure will be similar to an oligopoly and further away from high competition. We do not find direct evidence of such an assumption since the coefficient for the firm size control variable is not statistically different from zero. In our opinion, this may suggest that the sectoral dummies are already capturing much of the observed variability in the markup, since the size of the average firm is highly related to the kind of industry, leaving little significance to the other control variables. The R2 of the regression if quite high (0.70) pointing to a good fit of the specification proposed.

When we analyze the IM regulations which may affect the degree of competition, five main variables show up to be jointly significant in column (i). First of all the Transposition Deficit Indicator for Competition regulations (**TDI COMPETITION**). The TDI indicators, as already pointed out before, measure the percentage of EU norms and regulations which have been correctly applied in each member state in a particular field of interest. In the case of the TDI COMP these regulations are those planned to impact and boost competition at the EU level. The coefficient is highly statistically significant and negative as expected, **the more the regulations correctly applied, the lower the markup in each economy under consideration, and therefore more competition in the market.**

The second explanatory variable is the OECD PMR proxy named "**state contro**l". This indicator is the weighted average of two items, namely of "involvement in business operation" (with a weight of 0.44) and of "public ownership" (with a weight of 0.56). The first low-level indicator has already been examined in the text in the analysis for the trade

[52] The proxy is calculated as the ratio Value Added/(Labor costs+ Capital costs)

channel. The second, instead, is itself a weighted average of three other items, namely "scope of public enterprise sector", "size of public enterprise sector" and "direct control over business enterprises"[53]. Due to the way the "state control" index has been built this implies that higher values of the index imply tighter and burdensome regulation such that this will actually impede competition. The expected sign on markup is therefore positive[54].

It is important to notice how the "general constraints" category (one of the items included in the "Direct Control over Business"), that is the presence of constitutional constraints to the sale of government stakes or direct control over the decisions in publicly owned firms, is theoretically linked to a reduction in the competition level. The same happens when national governments can use special voting rights (as the golden share) in cases such as mergers and acquisitions of national firms by, for instance, foreign firms of private ones. Hence, an increase in the sub-index is theoretically (and we see in the table, empirically) related to a potential increase in markup values.

Our empirical evidence strongly support this reasoning with the estimated coefficient for the overall "State control" index being weakly statistically significant and positive meaning that **tighter control by the national government is actually reducing competition levels and leading to higher markups and rent acquisitions.**

Similarly to what happens for the "state control" proxy, the estimated markup level is also showed to be empirically explained (in Table III.3) by the value of the "**sectoral and ad hoc State aid as a percentage of GDP**"[55]. Intuitively, **the more the state aid, the less it will be the actual competition among firms** since some of them will be actually subsidized while others will not. This, inevitably, creates strong market distortions and therefore leads to higher rent extractions and less competition. Again, empirical evidence strongly supports this reasoning with the coefficient for the measure of the public aid being positive and highly statistically significant.

Finally, in our preferred specification we also control for the **transfers and subsidies from national governments as a percentage of GDP**. This proxy comes from the EFW index and

[53] The first two sub-items have a weight of 0.30 while the last one of 0.40.
[54] See Appendix III.4 for more details about this variable.
[55] This variable comes from the Internal Market scoreboard, Eurostat.

scores higher values for little subsidies granted to the national firms by their national governments. Obviously, **the less the subsidies, as we were pointing before, the more competition will be faced by firms in any given market**. Again, empirical evidence strongly supports this reasoning with high statistical significance.

Also, other proxies of the quality of bureaucracy in each country are shown to be statistically significant. In particular, the **Number of bodies to be contacted in order to open a Business** and the **Number of days spent by managers dealing with bureaucracy** are positively correlated to the level of markup (and therefore negatively correlated to the degree of competition as one would expect).

Similarly to what we did for the other channels, in Appendix III.3 we propose some alternative specifications through the use of some different explanatory variables. Along with "state control" also a proxy for "**regulatory barriers**" and "**barriers to entrepreneurship**" seem to explain the competition level across countries. The overall significance of the specification in column (ii) is lower than our preferred one. In column (iii) these same variables are accompanied also to the "**outward oriented policy**" item of the OECD PMR indicators. Again, the signs of the coefficients are those expected so that tighter regulations and direct control by the national government on the private business reduce the competition level (increases the value of the indicator). Other combinations of the same regulatory proxies have been tried in column (iv) and (v) such as "**Government enterprises and investment as a percentage of total investment"** (EFW) and they all show qualitatively the same result.
The next figure shows the main IM variables affecting the different channels.

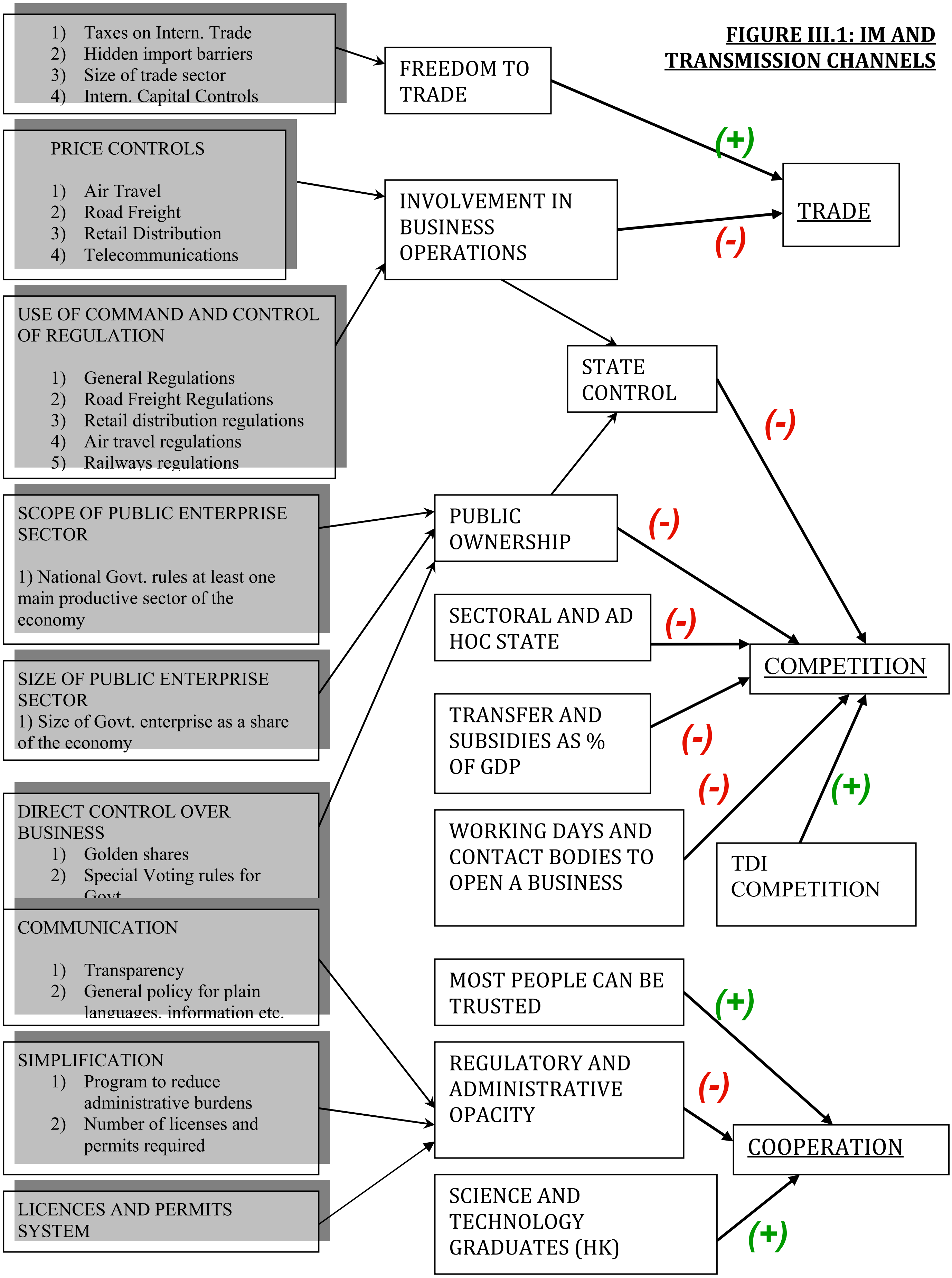


FIGURE III.1: IM AND TRANSMISSION CHANNELS
1) Taxes on Intern. Trade
2) Hidden import barriers
3) Size of trade sector
4) Intern. Capital Controls
PRICE CONTROLS
1) Air Travel
2) Road Freight
3) Retail Distribution
4) Telecommunications
USE OF COMMAND AND CONTROL OF REGULATION
1) General Regulations
2) Road Freight Regulations
3) Retail distribution regulations
4) Air travel regulations
5) Railways regulations
SCOPE OF PUBLIC ENTERPRISE SECTOR
1) National Govt. rules at least one main productive sector of the economy
SIZE OF PUBLIC ENTERPRISE SECTOR
1) Size of Govt. enterprise as a share of the economy
DIRECT CONTROL OVER BUSINESS
1) Golden shares
2) Special Voting rules for Govt
COMMUNICATION
1) Transparency
2) General policy for plain languages, information etc.
SIMPLIFICATION
1) Program to reduce administrative burdens
2) Number of licenses and permits required
LICENCES AND PERMITS SYSTEM
FREEDOM TO TRADE
INVOLVEMENT IN BUSINESS OPERATIONS
STATE CONTROL
PUBLIC OWNERSHIP
SECTORAL AND AD HOC STATE
TRANSFER AND SUBSIDIES AS % OF GDP
WORKING DAYS AND CONTACT BODIES TO OPEN A BUSINESS
TDI COMPETITION
MOST PEOPLE CAN BE TRUSTED
REGULATORY AND ADMINISTRATIVE OPACITY
SCIENCE AND TECHNOLOGY GRADUATES (HK)
TRADE
COMPETITION
COOPERATION
(+)
(-)
(-)
(-)
(-)
(-)
(-)
(+)
(+)
(-)
(+)

III.3. Second stage estimates: the impact of the Transmission Channels of Innovation Adoption

The impact of IM regulations on innovation adoption goes through the transmission channels. In what follows, therefore, we are going to show the main results of this second stage estimation where the fitted values of the chosen first stage regressions of the previous sections are going to be used as explanatory variables along with other specific variables which could be directly affecting innovation adoption (i.e. R&D expenditures and IPRs controls).

Hence, we are going to estimate the following specification:

$$InnoAdopt_{c,i} = \lambda_0 + \lambda_1 Coop_{c,i} + \lambda_2 Trade_{c,i} + \lambda_3 Comp_{c,i} + ZID_{c,i}\lambda_4 + DUM_i\lambda_5 + DUM_C\lambda_6 + \xi_{c,i}$$

where *InnoAdopt* is the innovation adoption rate, *Coop* is the fitted value of the cooperation variable obtained from the first stage, *Trade* refers to the fitted value of trade obtained from the first stage, *Comp* is the fitted value of competition obtained from the first stage; *ZID* are the different control variables of innovation adoption and *DUM* refer to either sectoral and country dummies.

Innovation adoption is computed as the share of innovative firms which have introduced an innovation in product or process either in cooperation or in isolation (hereinafter also referred to as "other organizations-based innovation adoption"). This variable, therefore, is aimed at measuring the degree of innovation adoption at the country and sectoral level. It is, however, a general definition since it does not distinguish between the innovation adoption which is done mainly through cooperation ("made in cooperation") among firms from that which is mainly direct adoption of blueprints or innovation developed elsewhere ("made in isolation"). Also, it does not distinguish between product and process innovation. These two types of innovation (product and process) may require different channels to be adopted or transmitted. Also, therefore, the same IM regulation may impact a specific type of innovation adoption (i.e. product made in cooperation) in a different way that it impacts another type of innovation adoption (i.e. process made in isolation).

Due to the very much disaggregated nature of the CIS database that we use for the analysis we are able to disaggregate the innovation adoption item into sub-categories and check whether the diffusion channels impact these sub-categories differently.

The categorizations of innovation adoption that we propose for estimation are therefore the following:

1) Total innovation adoption
2) Product innovation adoption
3) Process innovation adoption
4) Product innovation adoption made in cooperation
5) Product innovation adoption made in isolation
6) Process innovation adoption made in cooperation
7) Process innovation adoption made in isolation

Each one of these dependent variables will be regressed on the (fitted) transmission channels and on specific explanatory variables as well as on sectoral and country controls dummies to pick up any unobserved heterogeneity across the sample[56].

III.3.1. Total Innovation Adoption results[57]

In this section we are going to present the results of our main econometric specification for total innovation adoption. The idea is to check whether (and how much) the transmission channels (proxied by their fitted values coming from the first stage regressions) are impacting the overall index of innovation adoption. Along with the impact that the channels may have we will control for specific regulations (enforcement of IPRs for instance) which the economic literature argues may be affecting (boosting or slowing down) the diffusion and adoption of innovation and technology across countries, sectors and firms.

[56] We tried also to control for firm size but the result was not significant when we already took into account sectoral and country dummies.

[57] A complementary analysis using micro data only has been done in Appendix III.5. Anyway, we should take into account that the countries considered are not the same. Also, it is necessary to take into account the merge done in micro data in order to include it in the macro database (see appendix II.1)

In column (i) of Table III.4 we offer the best specification where we explain total innovation adoption with the transmission channels and country and sectoral dummies. The overall fit of the regression is quite good (R2 is 0.79).

Table III.4. Determinants of Innovation Adoption

Dependent Variable	Total Innovation Adoption (i)	Product Innovation Adoption (ii)	Process Innovation Adoption (iii)	Product Innov Adopt made in Coop (iv)	Product Innov Adopt made in Isolation (v)	Process Innov Adopt made in Coop (vi)	Process Innov Adopt made in Isolation (vii)
Cooperation	4.22	4.15	5.53	3.17	2.22	4.58	4.41
	(2.26)**	(1.86)*	(2.14)**	(1.36)	(0.93)	(2.00)*	(2.05)*
Markup	-7.83	-8.22	-6.28	-2.85	-9.76	-7.69	-3.00
	(-1.30)	(-1.58)	(1.04)	(-0.56)	(-1.82)*	(-1.48)	(-0.63)
Trade	-0.04	0.01	0.002	0.04	-0.06	0.048	-0.023
	(-1.50)	(0.27)	(0.05)	(1.31)	(-1.84)*	(-1.41)	(-0.70)
Legal Structure and Property Rights Protection	-0.51 (-1.77)*	-0.53 (-2.13)**	-0.46 (-1.60)	-0.281 (-1.18)	-0.459 (-1.80)*	-0.439 (-1.78)*	-0.284 (-1.29)
Other controls	yes	no	no	no	yes	yes	no
COUNTRY DUMMIES	Yes	Yes	Yes	Yes	Yes	Yes	Yes
SECTOR DUMMIES	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Constant	6.45	5.41	4.48	1.59	6.95	5.91	2.67
	(1.73)*	(1.61)	(1.15)	(0.49)	(2.04)**	(1.80)*	(0.94)
Observations	50	52	52	48	48	48	48
R-squared	0.79	0.64	0.55	0.47	0.48	0.72	0.35

t statistics in parentheses
***, ** and * significant at 1, 5 and 10 %

Other control variables inserted in the regression but not reported are: (a.) the firm belongs to a group, (b.) the firm has undertaken organizational changes, (c.) R&D expenditures total, (d.) the firm has been publicly financed.

One transmission channel is statistically significant and shows the expected sign. This is **cooperation which seems to impact positively the degree of total innovation adoption.** The coefficient for the (fitted) cooperation proxy is statistically significant at 5% confidence levels arguing that **more cooperation across firms and countries is going to be beneficial to the process of innovation adoption**. Behind this result, however, lies a more interesting consideration to be done on the impact of IM regulations on the total innovation adoption share. In fact, what we are measuring here is the indirect impact that IM regulations (those which foster and boost cooperation) are exerting on the level of total innovation adoption through the cooperation channel. An increase, for example, in the level of the "communication and simplification procedures", as detailed in the first stage regression for the cooperation channel through its impact on the index of "regulatory and administrative opacity", is going to impact positively the fitted value of "cooperation" which is used in the second stage regression. Indirectly, therefore, due to the positive and statistically significant coefficient of the "fitted cooperation" variable we can infer, for example, that the IM "regulatory and administrative opacity" and its subcomponents which foster cooperation (as well as the general level of trust and the stock of human capital) will positively affect the level of innovation adoption from a cross section point of view.

The coefficient for our fitted markup value (proxying for the channel of **competition**) is negative but not statistically significant at conventional significance levels.

Also the **trade channel does not show up to be statistically significant** in the regression proposed in column (i). We do not find a clear explanation for this result. It may be the case that trade acts differently depending on the specific kind of innovation and that, therefore, we may be averaging out its effect in the regression so that its coefficient is not significantly different from zero.

In column (i) of table III.4 we also insert a control for the **legal structure and property rights protection** of each country[58]. Among the dimensions considered in this variable, that we consider may have a closer impact on the adoption of innovation, we find the quality and strength by which IPRs are enforced in each country. Empirical and theoretical literature points to the enforcement of IPRs (and the overall legal structure) as a determinant of innovation and technology adoption. If IPRs foster innovation creation, they can be considered as a barrier to the free adoption (or appropriation) of innovation. Hence, the expected sign, once we control for the other diffusing channels, is negative in the sense that **the tighter the protection, the more difficult it will be for firms to exploit innovation discovered elsewhere**. It is important to notice that this result does not imply immediately

[58] This variable comes from the EFW index and is based on the Political Risk Component I (Law and Order) from the International Country Risk Guide. Source: PRS Group (various issues), International Country Risk Guide.

that, as a policy making decision, IPRs should be relaxed so as to achieve higher innovation adoption rates. In fact, what is important to bear in mind is the balance between innovation production (boosted by IPRs enforcement) and innovation adoption (slowed down by IPRs enforcement). The two effects are therefore difficult to be disentangled even if, in the case of EU countries, we may suspect that **the first effect (that of innovation creation) may be stronger than the second (innovation adoption) due to the high-tech nature of innovative European firms if compared to other regions in the world where countries rely on innovation adoption more than in innovation creation**.

So, the interpretation of the negative coefficient for legal structure simply goes in the direction of saying that, on average, **innovation adoption slows down when IPRs (among other factors) are strongly enforced**. This is a partial effect which abstracts from the overall (ambiguous) effect that IPRs may play on the creation of innovation which cannot be observed in the results we are presenting here

Additional control variables have been also inserted in column (i). We inserted respectively the R&D expenditures (in order to capture country and sectoral differences in the innovative effort) and other controls such as “belonging to a group”, “receiving public funds” or “having made any organizational change lately”. Even if none of these controls shows up to be statistically significant, our main results on the impact of the transmission channels are maintained and with a strong statistical significance.

III.3.2. Product Innovation Adoption

As we argued before, the way the transmission channels (or other regulatory proxies) impact innovation adoption may depend on the particular kind of innovation adoption we are looking at. So for example one channel may be important for product innovation adoption but less or irrelevant for process adoption. Next, we try to disentangle this partial effect by using as a dependent variable the different categories of innovation adoption starting from the adoption of product innovation (Table III.4).

In column (ii) we propose the best specification which makes use of the three fitted transmission channels and the control variable for the Legal Structure and Property Rights

Protection as well as country and sectoral dummy controls. As we were suspecting the picture here changes with respect to the results we obtained for the overall innovation adoption dependent variable even if the change is only marginal.

The cooperation channel is again the statistically significant in explaining the amount of product innovation adoption across EU member states. It seems that **creating a network of innovative firms (and therefore promoting and facilitating cooperation) act as a strong driver of product innovation adoption**. In this line of reasoning, therefore, **it should be seen as very important the effort made by the EU in order to promote cooperation across EU member states and in particular the cooperation among the old member states and the new entrants which, more than others, may have benefitted from innovation adoption channeled through cooperation in research projects**.

On the other hand, **competition, even if with correct sign, does not show up as a statistically significant channel of adoption** when it comes to the analysis of product innovation. Instead, the **trade channel is still not significant at the conventional confidence levels but the change in the sign of the coefficient** (from negative to positive) **points to a potential role played by trade in the adoption of product innovation.**

The intuition behind this result may be that, **when it comes to adopting a new "product" (which is a physical item) the more this item is traded, the more the possibility for this product to be known in new markets and therefore eventually adopted by other firms**. This said, the coefficient is not statistically different from zero so we cannot infer any causal relationship from the estimates but only guess on the economic intuition.

Again, also, the Legal structure proxy shows to be a statistically significant explanatory variable for the adoption of innovation (and in this case of product innovation). It seems the protection of property rights is particularly important for product (the coefficient is slightly more significant w.r.t. the case of overall adoption) and especially when this is compared to the non significant impact that protection of property rights and legal structure has on process innovation adoption as we will show in the next section.

III.3.3. Process Innovation Adoption

The results on the impact of the transmission channels on process innovation adoption confirm those already obtained for the overall innovation adoption and for that of product innovation only (Table III.4).

The cooperation channel shows a positive and statistically significant coefficient being the only transmission channel impacting positively and significantly the adoption of process innovation.

As in previous result the coefficient for **trade is not significant** pointing to the fact that process innovation adoption may not be affected by the trade channel. The **competition channel** also, **does not show to be statistically significant** in the overall regressions for process innovation adoption.

Also, this time, the proxy for the Legal Structure of each country is not found to be statistically significant even if, however, this shows the expected negative sign.

The non-significant result is unfortunately robust to the insertion of various control variables as we did for the total innovation adoption. We controlled for organizational changes, belonging or not to a group as well as total R&D expenditures and public funding. None of these control variables have shown statistically significant.

Due to the peculiarity of the CIS databases we are able to check whether the results which we have obtained in the baseline regressions are also robust to additional disaggregation of the innovation adoption proxy. **The channels may be actually working in different ways when the process (or product) innovation adoption comes as a result of a cooperative activity or whether it comes from the introduction of a process developed mainly by other firms** (namely "made in isolation). In order to control for these differences in the next section we disaggregate the innovation adoption even more into the categories of Product innovation adoption made in cooperation, Product innovation adoption made in isolation, Process innovation adoption made in cooperation and Process innovation adoption made in isolation.

III.4. Additional disaggregation of Innovation Adoption

In the next paragraphs we are going to check whether the results we obtained on the impact of the transmission channels (and ultimately of the IM which lie behind them) are the same when innovation adoption is disaggregated into its main sub-components.

As we already pointed out, innovation diffusion may be in principle the result of cooperation activities among firms (which then develop a product or a process together) or simply the acquisition of a product (usually a developed blueprint) or of a process by one firm which simply buys it from another one. Hence, the impact that some specific transmission channel may have on these different adoption mechanisms may be ambiguous and it deserves, therefore, some additional analysis.

III.4.1. Product Innovation Adoption made in Cooperation

We start the analysis by looking at the case of product innovation adoption made in Cooperation. Table III.4 (column iv) depicts the main econometric results.

None of the channels enter the regression with statistical significance even if all the coefficients show the expected signs. This unsatisfactory result is robust to the insertion of the legal structure proxy which, differently from the baseline regression is not here statistically significant. As pointed out in the descriptive part, however, product innovation adoption is relatively less important with respect to the adoption of process innovation overall.

III.4.2. Product Innovation Adoption made in Isolation

The Product Innovation Adoption made in cooperation with others is the result of the acquisition by a firm of a product which was mainly developed outside the firm itself. For this reason we would expect the cooperation channel to loose significance somehow (since all the IM regulations which are at the basis of our "fitted cooperation proxy" should not be directly relevant in the case of acquisition of innovation as a result of non-cooperative activities). In fact our econometric results in Table III.4 (column v) show how **cooperation is not statistically significant and showing a strong decrease in its statistical significance w.r.t. the case of product innovation adoption made in cooperation**.

Instead, **competition (which enters with a statistically significant coefficient) seems to explain much more strongly the diffusion and adoption of product innovation as a result of the direct acquisition from other firms when any cooperation activity took place**. This is an interesting result if we recall that the IM regulation which we used to proxy for competition were referring to the degree by which the state or the national governments enter or are involved in business operations. **A decrease in such government involvement is here proven to raise the "direct" acquisition of product innovation by firms**. This seems to point to the fact that **a more developed competition would allow firms to merge (and therefore acquire products) or to simply buy and exchange products in a much easier way**. **This directly affects the amount of product innovations which are actually diffused/adopted.** To be slightly more specific, all the IM regulations which we used to proxy the competition channel imply that **as soon as the involvement of the national government decrease competition will rise**. **This may happen when the national governments reduce their control over firms in different sectors.** See, for instance, the item **"national, state or provincial government control on at least one firm in one sector"** which we used to proxy for markup levels across countries which is likely to reduce the possibility for foreign investors to acquire market shares or compete in the same sector with the national governments. Also, the use (or non-use) of the **golden share option** by the national government is likely to reduce the possibility of mergers (and therefore reduce the chance of direct product acquisition by foreign firms for instance). All these aspects are then likely to affect the amount of product innovation adoption through direct acquisition of the innovation from other firms.

To the best of our knowledge, however, no much evidence has been proposed in the economic literature about the role played by competition on the adoption of innovation. We may assume that the more the effort in innovation, the more the production of new blueprints (innovation output). In this situation, theoretical models such as those by Barro and Sala-i-Martin (1997), Helpman (1993) or Aghion and Howitt (1992) implicitly assume that also the diffusion/adoption of technology will be faster. Therefore, the negative sign of the fitted markup is pointing exactly towards this direction arguing **for the positive effect that**

competition (and the IM regulations that we analyzed before which boost competition) will have on the adoption of innovation in EU member states.

Surprisingly, instead, trade seems to be statistically significant but with the negative coefficient. However, the result may depend on the fact that trade is mainly affecting innovation creation (rather than its adoption) and due to the way we built the adoption indicator (as a share on the total innovative firms) then trade may show up with a negative coefficient overall. This result, however, deserves to be better analyzed in future research probably (when it will be fully available) with the use of the CIS4 data and more observations for the regression.

The result is robust to the insertion of the legal structure variable (which is again proxying for the easiness by which imitation leading to adoption may take place in each country). Again, a **sound legal structure reduces ceteris paribus the amount of products which are adopted (and this is especially true when no cooperation has been carried out between innovative firms buying and selling).**

III.4.3. Process Innovation Adoption made in Cooperation

As pointed out before, the way the IM regulations, along with the transmission channels, impact innovation adoption is likely to be different when we analyze whether process adoption is the result of cooperation or not. We start showing in Table III.4 (column vi), the results for process innovation adoption made in cooperation.

In column (vi) the best specification shows how, as expected, **the cooperation channel is significant and with a positive coefficient pointing again that all the IM regulations facilitating cooperation are main drivers of process innovation adoption.**

The other two transmission channels (trade and competition) do not show to be significant. In fact, this is somehow an <u>expected</u> result.

If we take the case of **competition**, for example, there is no reason to believe that this channel should directly foster the production and adoption of process innovation. **Process innovation**

is, in fact, a rather intangible innovation (more related to organizational processes). Empirical and theoretical literature, instead, **has been looking at the role played by competition on the production of patents and tangible products rather than on the production or development of "processes**".

Instead, if we take the case of **trade,** as we already pointed out**, this channel works as a vehicle of transmission for products which are brought and sold into new markets.** Once, products reach new markets these are likely to be adopted. However, the reasoning is different when it comes to process innovation. **Processes are not directly tradable and the way they enter new markets is usually by spilling over through direct knowledge (tacit or not) and therefore, through direct cooperation across firms and individuals** which get to know how these new processes actually work and are implemented. It is not a surprise, therefore, that the cooperation channels achieves the highest significance exactly in the regression for process innovation adoption made in cooperation.

As before, only **legal structure shows up to be statistically significant and with the expected negative sign** while other controls do not seem to qualitatively change the baseline results.

III.4.4. Process Innovation Adoption made in Isolation

Finally, we look at the impact of IM regulations and transmission channels on the process innovation diffusion made in isolation, that is, of those processes which have not been developed in cooperation across firms but that are simply bought or directly acquired by one firm from another.

The best specification is included in column (vii) of Table III.4. Again, only cooperation shows to be a statistically significant driver of innovation adoption showing how the robustness of this explanatory variable as a driver of adoption of innovation across firms and countries.

III.5. Additional estimations on the second stage equation: Innovation Adoption equation using micro data[59]

In order to check the robustness of our results, additional estimations are made on individual firm data. It avoids the aggregation bias that arises when we use sector-country aggregated data. And it also allows us to use a homogenous database, since all the data come from CIS. The drawback however is that no variable can proxy for competition. Therefore this section focuses on two channels only: Trade and Cooperation. Also, not all the countries in the macro analysis are now considered, but only those available in the micro database of the CIS.

The dependent variable measures the fact that the firm has adopted an innovation (product or process) or not. More precisely, the decision to adopt an innovation is estimated by means of a binary choice model. The profit associated with adoption is considered to be the latent variable. Since a measure of this profit is not available, we use a probit model where the dependent variable takes value 1 if firm *i* adopted a product or a process innovation (developed by others or in collaboration with others) and 0 otherwise. Adoption is assumed to occur if the associated payoffs are positive.

In this section, we are just going to present the main results obtained. In that sense, our conclusions are basically drawn from table III.5. For more details about this micro-analysis, and the extensive explanation of the results obtained, see appendix III.5. In column i we explain the total innovation equation; in column iv, the adoption equation; in columns v and vii, we explain the product innovation and product adoption, respectively; in columns viii and x, the process innovation and the process adoption; and, finally, in column xii, the choice between cooperation-based adoption and other organisation-based adoption is explained.[60]

[59] The results obtained in the regression analysis at the micro level are not directly comparable with the ones at the macro level, given that the countries considered in both cases are different. The variable accounting for cooperation is also a little different. As explained in the descriptive part II, the micro database contains missing values for some countries (in particular Belgium, Spain and Greece) regarding the detailled information about location of partners. In the macro regressions, this problem has been overcome using the macro data available on Eurostat website. For micro regressions, we cannot fill in the missing observation. Therefore, in order to avoid to loose all the firms that belong to these three countries, we chose to work with overall cooperation instead of splitting in into European cooperation and National cooperation. As shown in the descriptive part II, the correlation between these three variable is however very strong.

[60] The number of columns are the same ones as in appendix III.5

Table III.5. Determinants of Innovation and Innovation Adoption

Variables	Total Innovation Selection eq.(i)	Total Adoption eq. (iv)	Product Innovation Selection eq. (v)	Product adoption eq. (vii)	Process Innovation Selection eq. (viii)	Process Adoption eq. (x)	Adoption made in isolation[61] eq.(xii)
Intercept	-1.535*** (0.063)	-0.627* (0.257)	-0.977*** (0.048)	-0.884*** (0.119)	-1.226*** (0.048)	-1.561*** (0.144)	-0.600 (0.412)
LNRTOT	Nc	0.0002 (0.003)	Nc	-0.020*** (0.003)	Nc	0.007 (0.004)	-0.005 (0.005)
LNTURN	Nc	0.044*** (0.009)	Nc	-0.0007 (0.009)	Nc	0.064*** (0.009)	Nc
LNEMPHI	0.200*** (0.006)	-0.075** (0.023)	0.188*** (0.006)	-0.040** (0.014)	0.209*** (0.006)	-0.032** (0.012)	-0.066*** (0.015)
PATENT	Nc	-0.178*** (0.024)	Nc	-0.124*** (0.032)	Nc	-0.210*** (0.029)	-0.370*** (0.063)
GP	0.190*** (0.019)	-0.250*** (0.031)	0.185*** (0.018)	-0.139*** (0.036)	0.159*** (0.019)	-0.254*** (0.032)	-0.201** (0.069)
ORGA	Nc	0.061* (0.029)	Nc	0.053 (0.038)	Nc	0.002 (0.033)	-0.091 (0.049)
PUBLIC	Nc	0.110*** (0.027)	Nc	0.011 (0.038)	Nc	0.119*** (0.032)	-0.031 (0.053)
LNEXP	Nc	-0.008** (0.003)	Nc	-0.004 (0.003)	Nc	-0.003 (0.002)	-0.008** (0.003)
COOP	Nc	0.487*** (0.026)	Nc	0.504*** (0.034)	Nc	0.336*** (0.031)	-0.086 (0.133)
TURNINC	0.109*** (0.028)	Nc	0.089*** (0.028)	Nc	0.117*** (0.028)	Nc	Nc
TURNDEC	-0.105** (0.034)	Nc	-0.086** (0.034)	Nc	-0.060 (0.034)	Nc	Nc
LNWTURN	0.057*** (0.005)	Nc	0.004 (0.004)	Nc	0.023*** (0.004)	Nc	Nc
LNEXP*INTMAR	0.021*** (0.001)	Nc	0.021*** (0.001)	Nc	0.022*** (0.001)	Nc	Nc
LNEXP*NATMAR	0.029*** (0.002)	Nc	0.029*** (0.001)	Nc	0.031*** (0.002)	Nc	Nc
LNEXP*LOCMAR	0.014*** (0.002)	Nc	0.016*** (0.002)	Nc	0.017*** (0.002)	Nc	Nc
EST	-0.232*** (0.036)	Nc	-0.248*** (0.034)	Nc	-0.378*** (0.034)	Nc	Nc
Sectoral Dummies (7)	No	Yes	No	Yes	No	Yes	Yes
Country Dummies (14)	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Lambda	Nc	-0.210 (0.148)	Nc	-0.001 (0.022)	Nc	0.001 (0.019)	0.817* (0.384)
Percent concordant	77.5	63.4	73.9	62.8	76.8	64.8	67.9
Likelihood	-23996.31	-9222.63	-22495.67	-4933.63	-22556.51	-6340.55	-3273.40
LR test (Beta=0)[62]	9848.80***	843.62***	6141.91***	721.30***	8342.67***	653.24***	513.47***
LR test (dummies=0)	2287.84***	152***	1402.67***	359.04***	2104.58***	257.7***	187***
Observations	46010	14445	46010	11658	46010	12530	5599

Note: **LNRTOT**: Total innovation expenditure of the firm, **LNTURN** : turnover of the firms, **LNEMPHI:** higher education-skilled workforce, **PATENT:** takes the value 1 if the firm uses patent protection and 0 otherwise, **GP**: dummy variable indicating whether the firm belongs to a group or not, **ORGA**: dummy variable for organizational innovation **PUBLIC**: public financial supports, **LNEXP**: exports, **COOP**: firms cooperate in innovation, **LNWTURN**: Firm turnover weighted by industry turnover, **INTMAR**: mainly international market, **NATMAR**: mainly national market, **LOCMAR**: mainly local market, **EST**: dummy for new established firm.
t-ratio are given in parenthesis level of significance: * 10%, **5%,***1%
(Columns i and iii: without correction of selection bias. Columns ii and iv: with correction of selection bias)

[61] The associated selection equation is the same as the equation (i). Moreover, results for total adoption made in cooperation are not reported since they are exactly opposite to the one obtained for total adoption made in isolation (the dependent variable being dichotomous)
[62] The LR statistics is compared to a Chi2 with the number of constraints as degree of freedom.

Following this table III.5, we can summarize the effects of the different variables over Innovation and Innovation adoption, as follows:

Table III.6. Determinants of Innovation and Innovation Adoption

Variables	Total Innovation		Product Innovation		Process Innovation		Total Adoption		Product Adoption.		Process Adoption		Total Adoption made in isolation		Total Adoption made in cooperation	
	+	-	+	-	+	-	+	-	+	-	+	-	+	-	+	-
R&D expenditure										yes						
Size of the firm	yes		yes		yes		yes				yes					
Higher education –skilled workforce	yes		yes		yes			yes		yes		yes		yes	yes	
Legal protection (patents)								yes		yes		yes		yes	yes	
Firms belong to a group	yes		yes		yes			yes		yes		yes		yes	yes	
Organizational innovation ?							yes							yes	yes	
Public funding of innovation							yes				yes			yes	yes	
Exports	yes		yes		yes			yes						yes	yes	
Cooperation							yes		yes		yes					
Foreign exposure-competition	yes		yes		yes											
Closure of an enterprise part		yes		yes		yes										
New established enterprises		yes		yes		yes										

On the whole, concerning the estimated impact of the different determinants over the adoption of innovation, different conclusions arise:

- The size of the firm positively impacts on innovation adoption. But its effect is due to process innovation and does not occur for product innovation adoption.
- Firms benefiting from public funding have a higher propensity to adopt innovation, and more specifically process innovation.
- Organizational innovations are also positively associated with adoption, but weakly significant.
- Then several variables produce a negative impact on adoption. This is the case for membership of a group, absorptive capabilities (measured by innovation expenditure and highly educated workers) and exports. This runs counter traditional theoretical model as well as empirical studies. This is due to our specific sample that covers only innovative firms. The selection equation highlights that a positive impact occurs on innovation. Then, compared to innovations developed within firms, these variables exert a negative effect on innovation acquired externally. Therefore, these variables increase the global propensity to innovate. Among the different ways of innovation however they foster generation of innovation instead of adoption.
- Cooperation increases the ability to adopt both product and process innovation. The impact is however higher on product adoption than on process adoption.
- Concerning the choice between adopting in cooperation or in isolation, one can distinguish different groups of determinant :
    - Firstly several factors positively impact the amount of total adoption while being neutral on the way adoption is made. This is the case for the size of the firm and for cooperation. These variables would thus be important characteristics of adoption, whatever the way this adoption is made.
    - Secondly some other factors which foster innovation adoption have also a positive impact on the choice to innovate through cooperation. As public fundings are very oftenly used to support collaborative R&D projects, it is not surprising that public funding seems to act not only as an incentive to adopt new technologies but also to do this in cooperation. Furthermore, adopting in cooperation may require a higher organisational flexibility within firms

explaining why the capacity of firms to implement organisational changes has a positive impact of the choice to adopt in cooperation instead of in isolation.

- Finally, the last group of determinant gathers those which simultaneously have a negative impact on adoption and a positive impact on the choice to adopt in cooperation instead of in isolation. These are higher education, ownership by a group, legal protection (patents), and exports which negative impact on diffusion is due to their positive impact on innovation *per se*. Consequently these factors appear as the main drivers of innovation in cooperation within highly innovative firms.

III.6. Conclusions

The impact of IM regulations on innovation adoption is a complex issue to be studied. In the empirical analysis that we just proposed we focused on the impact that different IM regulations have on some major macroeconomic dimensions (which we called transmission channels) and therefore on the impact that these IM regulations have on the intensity of innovation adoption through these channels.

Two kinds of issues have been, therefore, tackled in our analysis.

The first relates to the role played by IM regulations on the macroeconomic dimensions: the **transmission channels**. EU Internal Market regulations are put in place in order to grant free movement of goods (**trade**), free movement of people (**cooperation**) and to remove barriers, thus simplifying life for consumers and for businesses (**competition**). In brackets we have put the three transmission channels on which we focus in our analysis. Crucially, therefore, the majority of the IM regulations and directives are aimed at boosting these three channels, trade, cooperation and competition.

Nonetheless, (and this is the second issue tackled in the present empirical part) these same IM regulations are likely to have an impact (this time an indirect one) on the adoption/diffusion of innovation across the EU member states. In fact, the IM's impact is likely to work through the transmission channels; in other words, although most IM measures are not devoted to impact innovation adoption, they may have an indirect impact on it through the influence IM exert on trade, cooperation and competition, and the ulterior effect of those on the adoption of innovation. Recent empirical and theoretical literature points, in fact, to the role of trade, cooperation and competition as drivers of innovation and innovation adoption.

In order to correctly disentangle the **direct** effect of the IM on the transmission channels and the **indirect** one on the degree of innovation adoption we made use of a two-stage estimation procedure by using Instrumental Variables estimators. In the first stage we define the impact of some major IM regulations on trade, cooperation and competition across EU countries.

Our main results show how the impact of the transmission channels on innovation adoption is especially important for Cooperation, leaving Competition and especially Trade as apparently a minor channel of overall innovation diffusion. In fact these two channels are not statistically significant at conventional levels in the baseline regression for overall innovation adoption.

This said, however, some *caveats* should be stressed. If Cooperation, and all the IM regulations which boost it and that are detailed in the first stage analysis[63], seems to be the main determinant of innovation adoption across firms and countries whichever the type of innovation diffusion taken into consideration, the effect of the other two channels (Trade and Competition) varies, instead, depending on the type of innovation diffusion (whether this is made in cooperation or in isolation strategy or whether product rather than process innovation adoption is analysed).

So, we find that competition[64] is especially important when looking at the innovation adoption made in isolation. Instead, Trade seems to be of minor importance, as we argued before, in igniting overall innovation adoption but shows up to be a statistically significant driver of Product Innovation adoption made in isolation.

[63] The IM regulations and other important factors affecting the Cooperation level across firms and countries are Trust, Communication and Simplification Procedures and Human capital.
[64] The IM regulation governing the first stage for competition are found to be: State control, Public Ownership, Sectoral and ad Hoc State Aid and other measures of Subsidies of the Govt. as well as the bureacratic quality of each member state.

Different specifications have also been tried where we inserted a considerable number of control variables. In particular, we find that legal structure and protection of property rights, once we account for the transmission channels, reduces the speed by which innovation spills over across firms and countries. However, this result should be considered within a broader context where the legal structure and the protection of property rights (especially of IPRs) will lead to an increase in the innovative activity leading, contextually, to a potential increase in adoption also not captured directly by the regression analysis.

The econometric results proposed in this section of the report for a variety of variables are sometimes not statistically significant at conventional significance levels but still marginally significant. Hence, extra care should be used in the interpretation of these results even if, in many cases the coefficients seems to show the correct sign. Further analysis is indeed needed in order to get more robust estimates. This issue could be tackled by using more recent and complete databases such as the CIS4.

The detailed policy implications derived from the results we have obtained in this regression analysis can be found in Part V of this report.

PART IV

Analysis of the effects of innovation diffusion/adoption on productivity growth

IV.1. Introduction

Technological progress is a priority for all those countries which aspire to support economic development since innovation is widely regarded as an essential force for starting and fuelling the engine of growth (Romer, 1986). Such force crucially depends on the process of creation, accumulation and diffusion/adoption of knowledge which is often strongly localized into clusters of innovative firms, sometimes in close cooperation with public institutions such as research centres and universities.

This implies that local growth depends on the amount of technological activity which is carried out locally and on the ability to exploit external technological achievements through the diffusion/adoption of such technologies (Martin and Ottaviano, 2001, Grossman and Helpman, 1991, Coe and Helpman, 1995).

The idea in this Part IV is therefore to **provide an empirical verification of the relationship between innovation adoption and productivity (section IV.2) and between innovation adoption and productivity growth (section IV.3)**. In particular, we are going to provide evidence of the above-mentioned relationships through means of descriptive statistics.

IV.2. Empirical verification of the relationship between innovation adoption and productivity

According to our theoretical model outlined in Part I, the productivity level of each economy in any point of time is a positive function of the extent by which this same economy is able to innovate through R&D and adopt innovations and transpose them into productive activities. The result of the adoption of those innovations into productive processes makes the output of each economy rise by leaving constant factor inputs[65]. **The more the number of innovations adopted/diffused into the economy, the higher will be the productivity level of this same economy.**

[65]This is to say that, if output rises while capital and labor remain constant, this will be the result of an increase in productivity levels.

We turn now to **provide evidence** of the relationship between innovation adoption and productivity through means of descriptive statistics. We start by providing some scatterplots plotting the average productivity level in the Y-axis versus different indicators of the adoption of innovation. At a first stage the plots are given at the average level whereas afterwards we will turn to a sectoral disaggregated analysis.

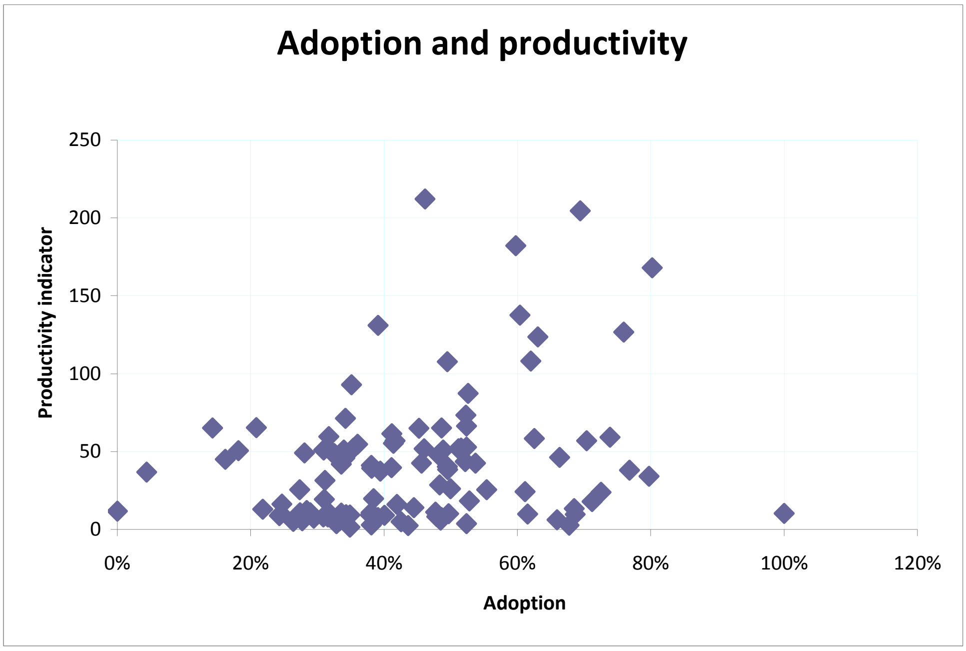
IV.2.1. Empirical verification of the relationship between innovation adoption and productivity at the global level

The productivity indicator we are going to use is labour productivity, that is, output divided by the number of employees obtained from EUROSTAT in year 2001.

In a first step, Figure IV.1 plots the average **productivity level** in the Y-axis versus the global indicator of the **adoption of innovation** with information at the more disaggregated level, that is, for all countries and sectors. The first conclusion that can be drawn is that the **coefficient of correlation is significantly positive**, as expected, although with a moderate value of 27.1%, confirming the theoretical assumptions.

Secondly, if looking at which sectors/countries the dots in the plot refer to, it can be observed how **this positive relationship is mostly due to the positive relationship among both variables under analysis for the countries with high productivity levels,** that seem to benefit more from the adoption of innovation. On the contrary we **do not observe such a clear relationship for the countries with low levels of productivity**, since there are very different patterns of some sectors with a very low rate of adoption of innovation (almost null) and some sectors with very high rate of adoption both having very low productivity levels. This is the case of the sector of Extractive industries in Slovakia or sector of Electricity, gaz and water production and distribution in Bulgaria with very low adoption rates and the sector of Extractives industries in Portugal with the highest adoption rate of all our observations.

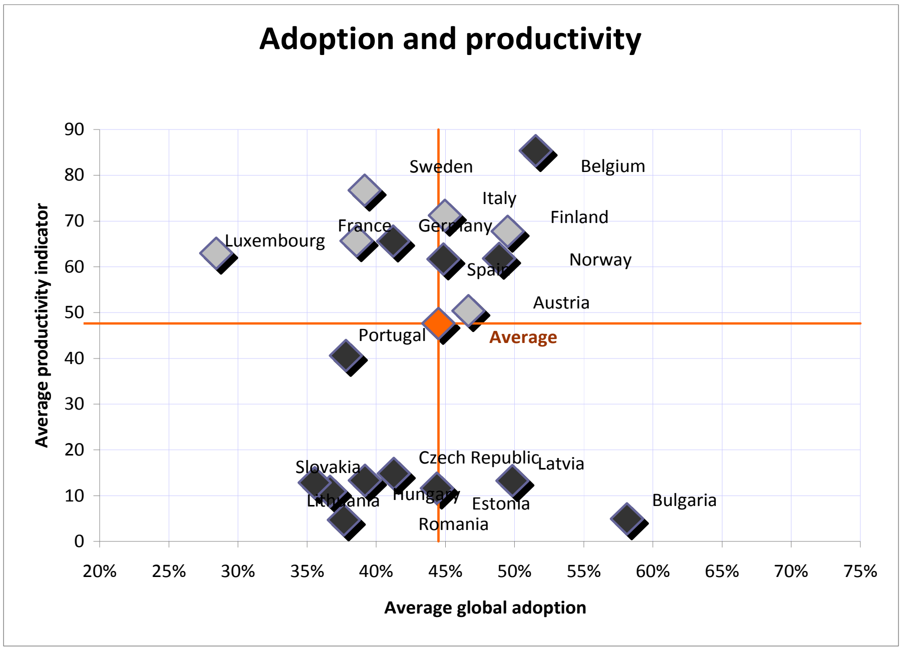
Figure IV.1. Scatterplot of Innovation Adoption and productivity with disaggregated information (country/sector level)



To make this point clearer, Figure IV.2 shows the same scatterplot but aggregated at the country level. It is clear that there **are two differentiated patterns of groups of countries** according to their productivity level.[66] **Those with productivities above the average** (Austria, Belgium, Finland, France, Germany, Italy, Luxembourg, Norway and Spain) **present a clear positive correlation with a significant value of 32.4% with the adoption of innovation**. On the opposite, those **countries with low levels of productivity** (Bulgaria, Czech Republic, Estonia, Latvia, Lithuania, Hungary, Portugal, Romania, Slovenia and Slovakia) **do not show a significant correlation** (value of 16.4%, not significant). It seems therefore that **the adoption of innovation affects productivity in those regions that experience high levels of productivity, probably due to the presence of other intangible assets such as human capital, social capital and entrepreneurship.**

[66] This seems to be consistent with the empirical evidence we showed in Part II in which we argued how countries with higher innovation adoption rates were also experiencing higher rates of innovative activities.

Figure IV.2. Scatterplot of Innovation Adoption and productivity at the country level



Note for this figure and followings in this section: Countries with macro data have a clearer color.

In the next figures we analyse the relationship between productivity and adoption rate in the case of product and process innovations separately. As depicted in Figure IV.3, we obtain again a **significantly positive relationship** at a 1% level, with a value of 31.3% **when considering product adoption, slightly higher than when analysed for the global rate of innovation adoption**. Again, we observe the pattern of sectors and countries with very different levels of adoption having very low values of productivity. However, there is a **clear positive relationship of some sectors/countries whose level of productivity seems to go parallel to their rate of adoption**. Such is the case of the sector of Electricity, gaz and water production and distribution in Sweden, Spain, the Netherlands, Italy, Denmark, Portugal and France (dots in with the highest level of both productivity and adoption in a clear diagonal).

The picture changes substantially when one studies **the relationship between productivity and adoption of process innovations,** which **is not significant** with a value of 12.1% (Figure IV.4). We observe again that the sectors and countries with low levels of productivity are associated with very different rates of adoption of process innovations.[67] This is something common with product innovation adoptions. The difference in the case of process innovations

[67] Recall, however, that our empirical evidence seems to show that much of the observed innovation adoption takes place in processes rather than products.

Figure IV.3. Scatterplot of product adoption and productivity with disaggregated information at the sectoral and country level

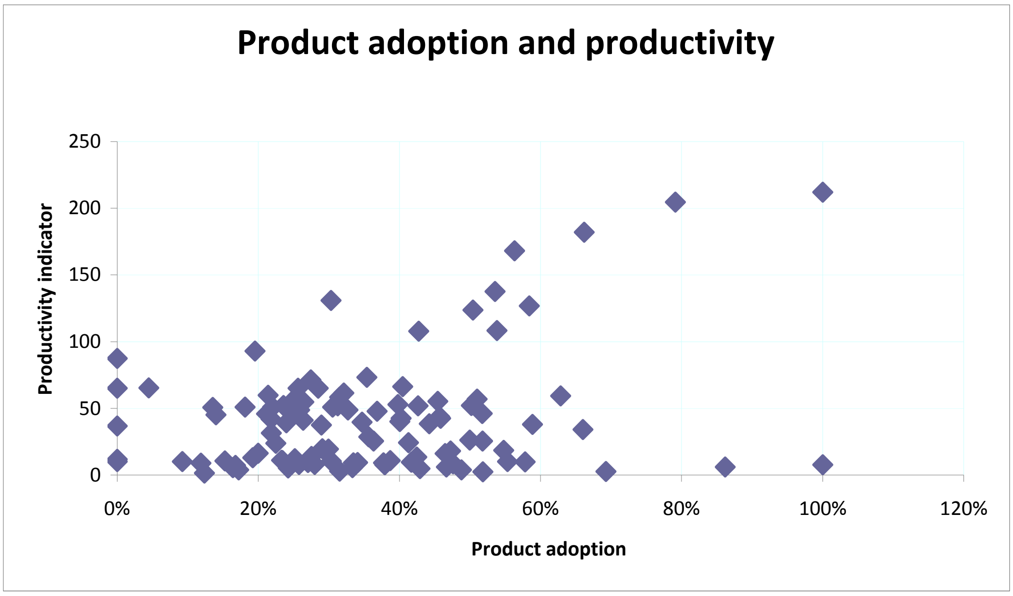
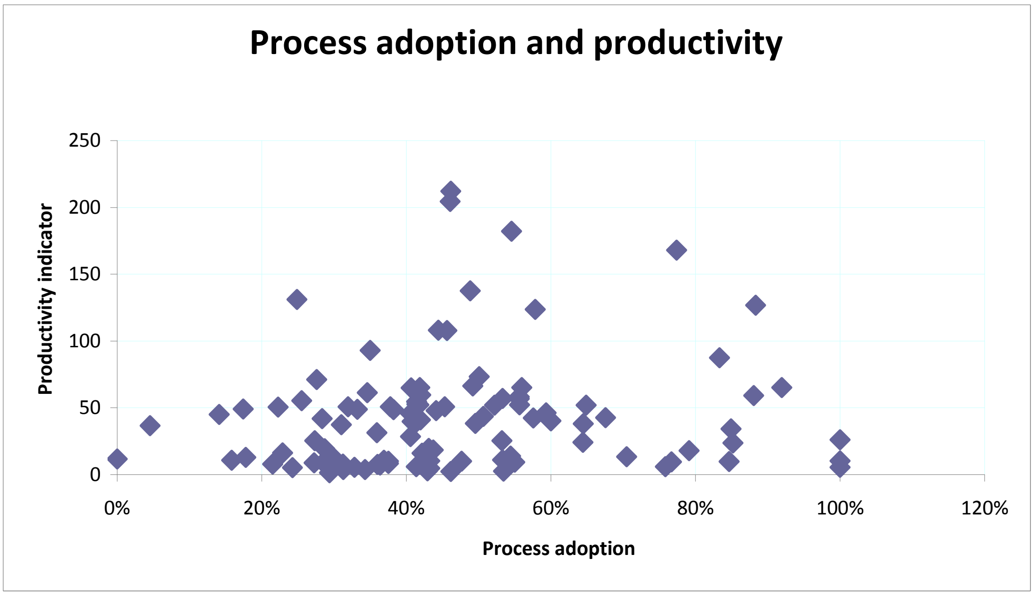


Figure IV.4. Scatterplot of process adoption and productivity with disaggregated information at the sectoral and country level



comes from the fact that some sectors in some countries adopt process innovations at an intermediate rate whereas they obtain the highest levels of productivity in Europe (sector of Electricity, gaz and water production and distribution in Belgium, Sweden, Spain, Italy, Denmark, Portugal and France) whereas this same sector in the Netherlands or in Finland adopt process innovations at a much higher rate. Therefore, no clear conclusion can be obtained. A possible explanation of the lesser impact of process innovation on productivity if compared with the impact of product innovation is that process inovation is more likely to result in price declines and not in changes in quantities of goods, which would imply lower productivity levels.

Similar conclusions are obtained when plotting the relationship between productivity and adoption of product/process innovations **in the case of cooperating** with other firms or institutions (Figures IV.5 and IV.6). Again **the relationship is significantly positive for product adoption, with a high value of correlation** (30.9%) similar to the global case, **whereas** it is not significant at a 5% level for **process adoption** (but would be at a 10%). However, in this second case, **the correlation value is of 17.8%, which is higher than in the global case of process adoption without specifying the cooperation link.** Again, one could argue that this lesser impact of process innovation on productivity if compared with the impact of product innovation is due to the effect these process innovations have in price declines and not in changes in quantities of goods. Using cooperation-based adoption however, tends to slightly improve the effect of process adoption on productivity.

Figure IV.5. Scatterplot of cooperation on product innovation and productivity with disaggregated information at the sectoral and country level

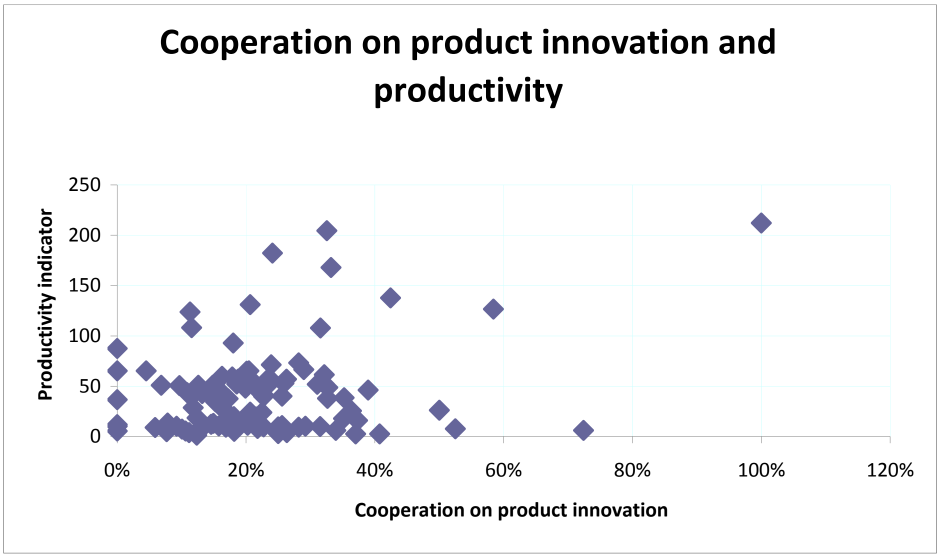
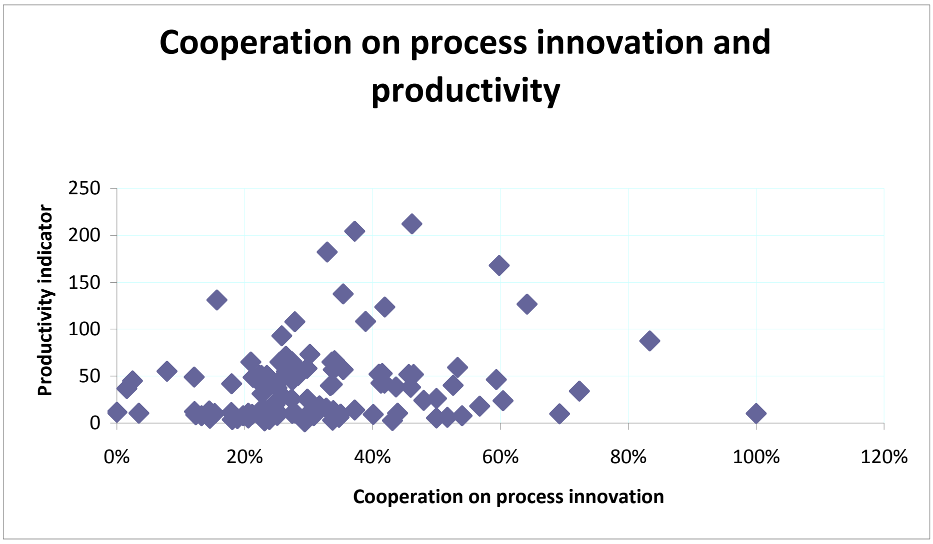


Figure IV.6. Scatterplot of cooperation on process innovation and productivity with disaggregated information at the sectoral and country level



IV.2.2. Empirical verification of the relationship between innovation adoption and productivity at the sectoral level

We turn now to investigate whether the positive relationship between innovation adoption and productivity that has been observed at the global level for all sectors and countries in the EU, is also obtained when analysing it for each sector under consideration. The scatterplots are shown in Figure IV.7. A summary of the correlations obtained for both variables in each sector is shown in Table IV.1.

A general conclusion for all sectors, **except for the case of Manufactures, is that the correlation between productivity and innovation adoption is not significant**. In all cases we observe that countries with similar low or similar high adoption rates of innovation lead to completely different magnitude of productivity. According to a broad theoretical and empirical literature, this will point to the fact that **productivity at the country level is specially related to the existence of physical capital and the endowments of a set of intangible assets (knowledge, human capital, social capital, entrepreneurship, among others), among which the adoption of innovation would be just a little part.** Additionally, if disentangling our sample of countries in the two well differentiated groups of productivity (EU-15 on the one hand, and the new member states on the other), we do not observe either any kind of separated behaviour. If we compare this conclusion with the one obtained when analysing all countries and sectors, we could think that **an important part of the correlation we obtained before is due to the existence of national correlations between productivity and innovation adoption**, which vanishes once we take into account different countries with different productivity levels and behaviours.

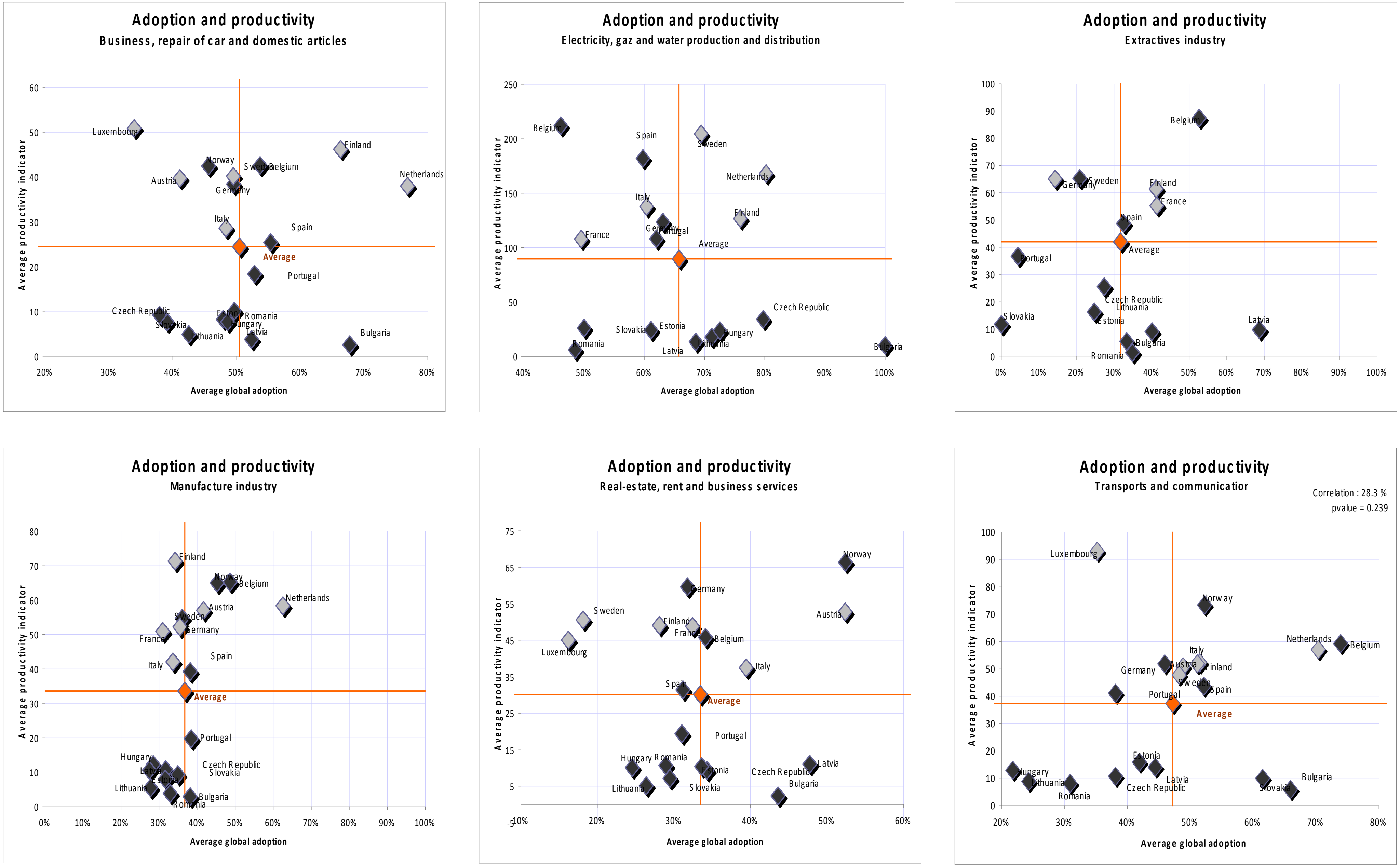
Table IV.1. Correlation rates between Productivity and Innovation Adoption Rates by sectors

Sector	Correlation
Business, repair of car and domestic articles	7.6% (0.75)
Electricity, gas and water production and distribution	-21.4% (0.40)
Extractives industry	3.9% (0.89)
Manufacture industry	56% (0.01)
Real estate, rent and business services	10.5% (0.66)
Transport and communication	28.3% (0.23)

P-values are given in parenthesis

The case **of Manufacturing industries** should be pinpointed apart since a **highly positive and significant correlation is found (56%).** This positive result is **forced by the fact that the countries with the lowest rates of innovation adoption are in the group of low productivity countries**, whereas the ones with highest adoption rates are in the group of high productivity. However, **among the group of countries with an intermediate level of innovation adoption rates**, we find both countries with productivities above the average such as Germany, Sweden, Finland and Spain, and with productivities below the average (Bulgaria, Romania, Portugal and Estonia). Additionally, it can be observed that in case the two groups of countries (low and high productivity) were considered separately, **such positive correlation would not be obtained.**

Figure IV.7. Scatterplots of Innovation Adoption and productivity in the different sectors under analysis

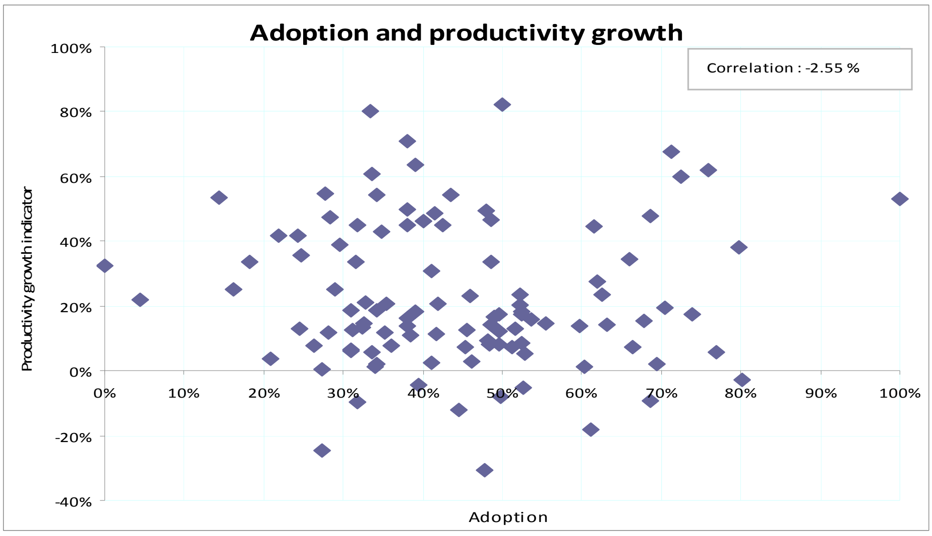


IV.3. Empirical verification of the relationship between innovation adoption and productivity growth

The expected relationship between innovation diffusion/adoption and productivity growth is positive as highlighted in previous empirical and theoretical literature. For instance, the Nelson-Phelps (1996) model of technology diffusion/adoption is based on the idea that changes in productivity and in total factor productivity depend, among other variables, on the rate of technology diffusion from the leader country to each of the countries under consideration. We follow the same idea, whereas instead of considering the diffusion from the leader country to the rest of countries we will consider a measure gathering the extent of the adoption of innovation in each country. In the next figures we will try to get evidence on this relationship in the case of the European countries using data for productivity growth in the period between 2001 and 2004 from EUROSTAT.

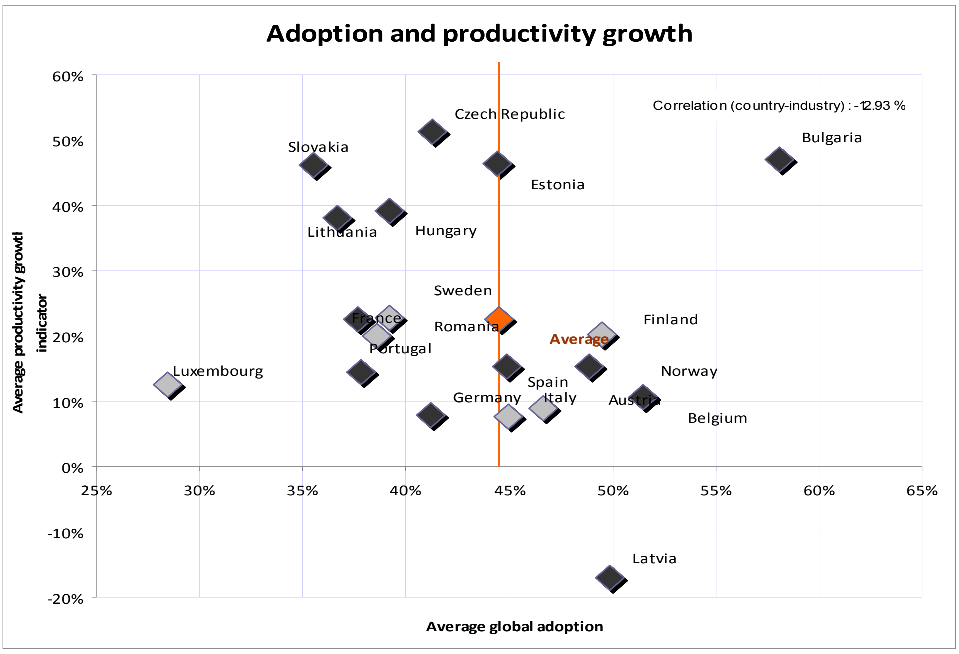
With the information for all countries and sectors, Figure IV.8 offers a non-significant coefficient of correlation with a negative value of -2.5%, in contrast with the theoretical assumptions and in contrast with the evidence obtained for the correlation between innovation adoption and productivity level (which was significantly positive, although with a moderate value).

Figure IV.8. Scatterplot of Innovation Adoption and productivity growth with disaggregated information (country/sector level)



When we plot the same figure but aggregated at the country level (Figure IV.9), the correlation is again negative with a low value of -12.9%. Two differentiated patterns seem to be observed according to the productivity growth rates of two different groups of countries. Those with growth rates above the average (Czech Republic, Slovakia, Estonia, Lithuania and Hungary) present a low adoption of innovation (the exemption is Bulgaria, with a high rate of productivity growth and high innovation adoption levels). On the other hand, the rest of countries display productivity growth rates below the average but without a clear correlation with the level of innovation adoption, since some of those countries present innovation adoptions above the average (Spain, Italy, Austria, Finland, Norway and Belgium) whereas others are below the average (Sweden, France, Portugal, Romainia, Germany and Luxembourg)[68]. Therefore, the global negative relationship is due to the existence of these two different patterns of productivity growth rates, whereas within each group such a negative relationship is not observed.

Figure IV.9. Scatterplot of Innovation Adoption and productivity growth at the country level

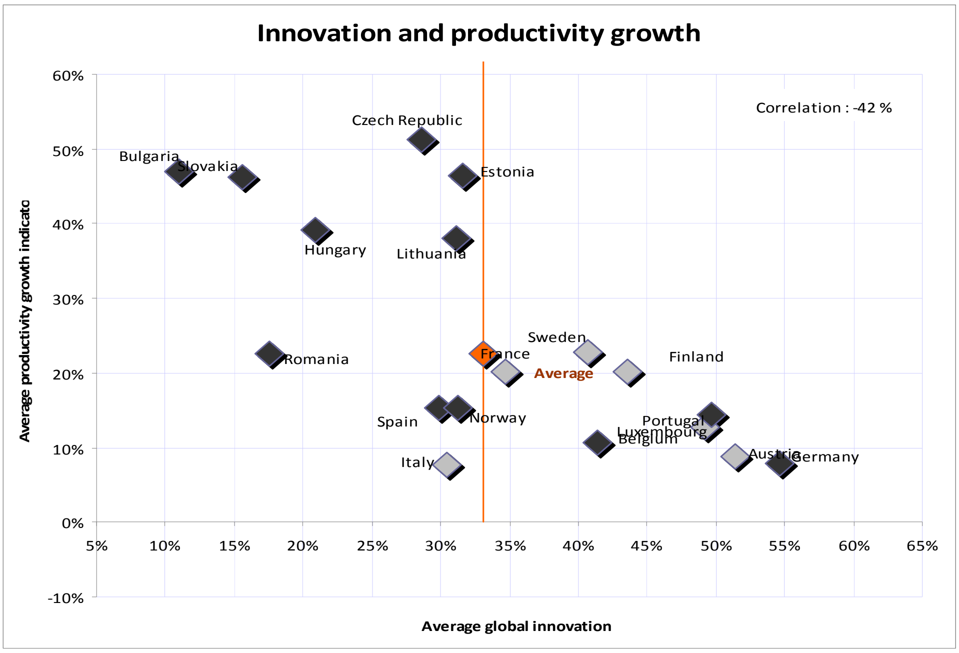


In conclusion, **we do not seem to obtain evidence in favour of the existence of a positive relationship between innovation adoption and productivity growth.** This is in contrast

[68] We know from existing literature that productivity growth is dependant of the initial level of productivity. The higher is the initial level of productivity, the lower is the possibility to continue growing. This could certainly explain why highly innovative countries are also countries where the productivity growth is the lowest and conversely.

with the negative correlation obtained between innovation and productivity growth (Figure IV.10), with a significant negative value of -42%. In the case of innovation, we observe how Eastern countries with high productivity growth rates clearly present low innovation rates whereas the more developed European countries with high innovation rates are at the same time those obtaining lower productivity growth rates.

Figure IV.10. Scatterplot of Innovation and productivity growth at the country level



Figures IV.11 and IV.12 analyse the relationship between productivity growth and the adoption rate in the case of product and process innovations respectively. Again, the correlation is not significant in any case, although the sign differs. Whereas we obtain a negative (almost null) correlation for product adoption, the relationship is positive and slightly higher (16.6%) for process adoption. These low values for the correlation are due to the fact that similar productivity growth rates can be obtained with very different adoption rates. The same pattern is displayed when considering cooperation with other firms or institutions on innovation adoption (Figures IV.13 and IV.14). Again, the relationship is negative but very low in the case of product innovation (-2.8%), whereas it is non-significant but positive for process innovations (10.4%). In this latter case, the correlation is, however, lower than in the global case of process adoption without specifying the cooperation link.

Figure IV.11. Scatterplot of Product Innovation Adoption and productivity growth with disaggregated information (country/sector level)

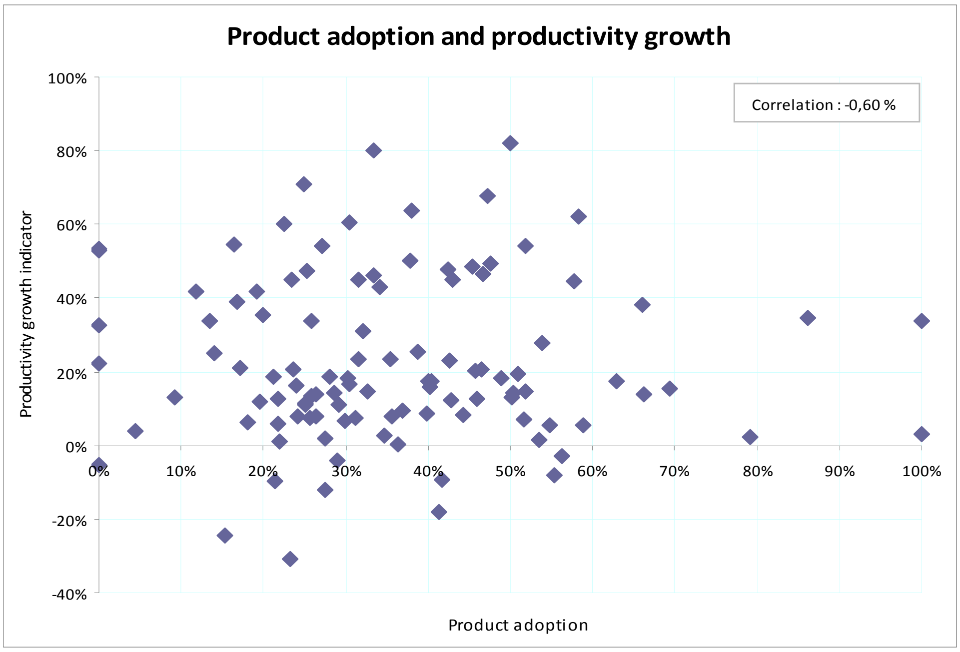


Figure IV.12. Scatterplot of Process Innovation Adoption and productivity growth with disaggregated information (country/sector level)

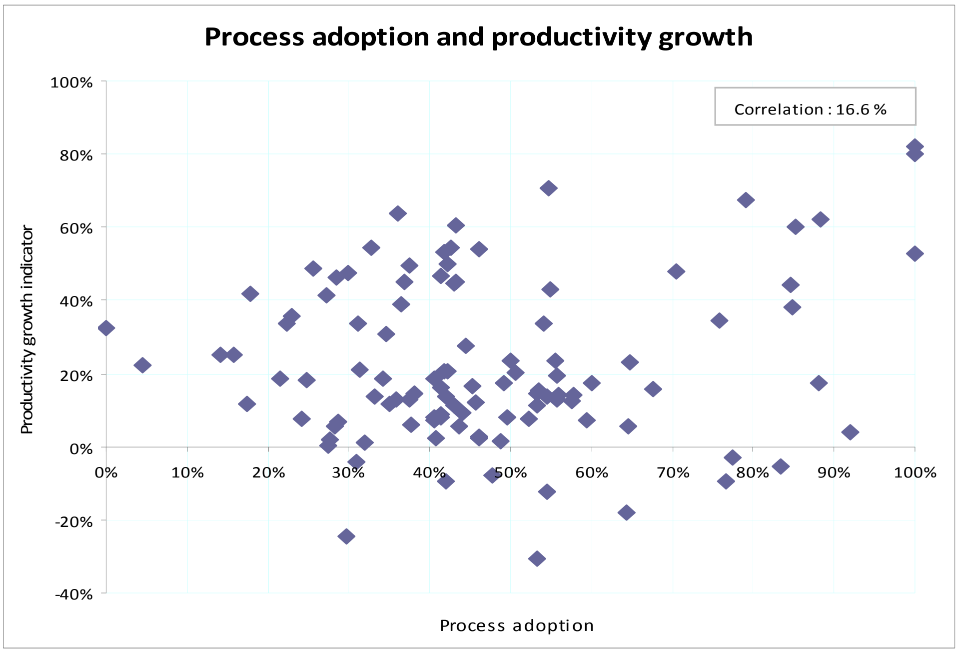


Figure IV.13. Scatterplot of Cooperation on Product Innovation Adoption and productivity growth with disaggregated information (country/sector level)

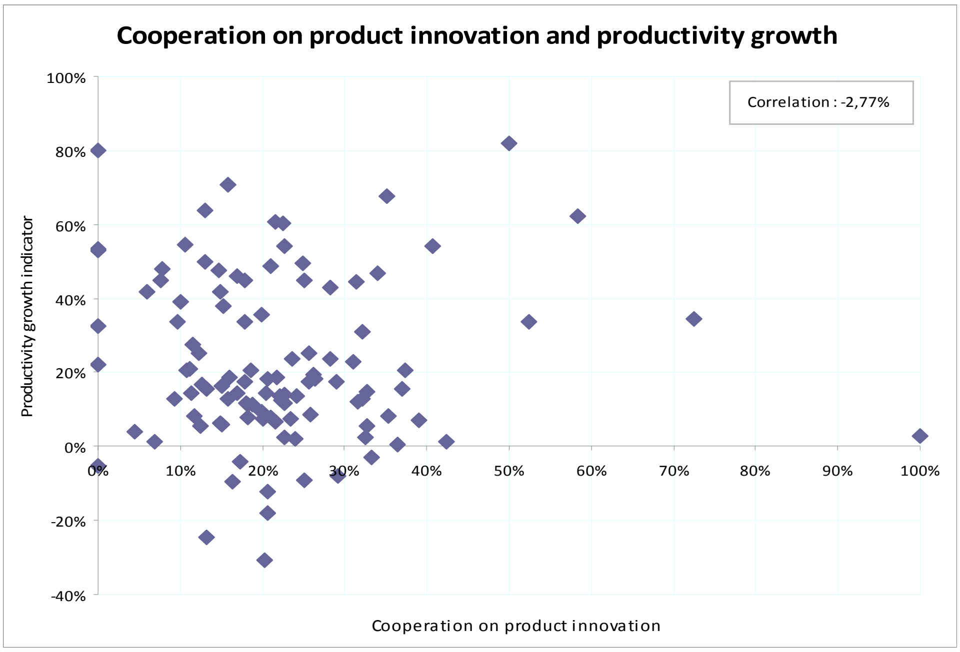
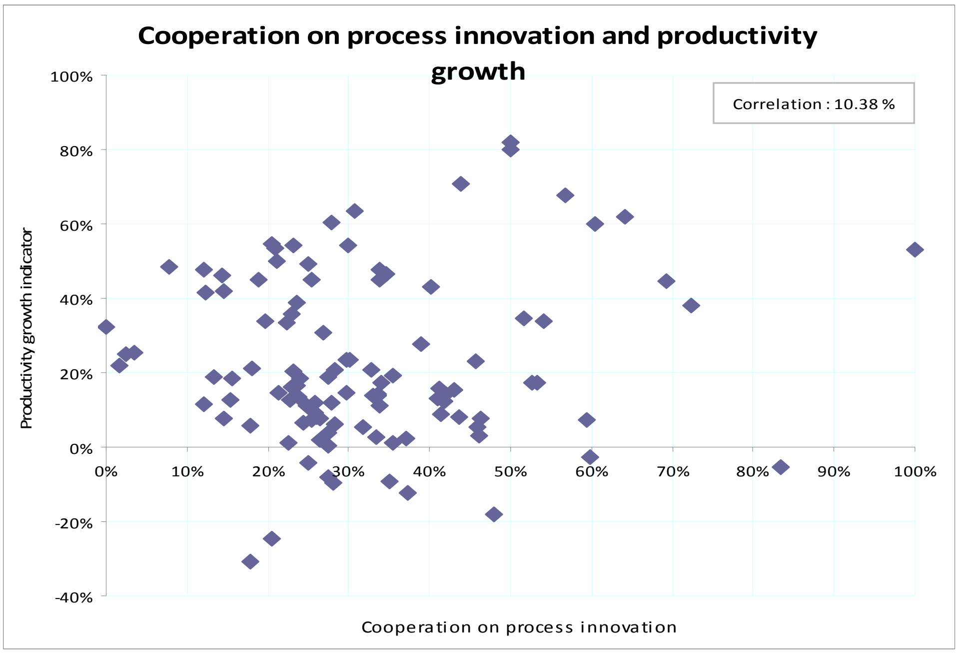


Figure IV.14. Scatterplot of Cooperation Process Innovation Adoption and productivity growth with disaggregated information (country/sector level)



We go next to analyse whether this lack of a clear relationship between innovation adoption and productivity growth is maintained for each sector under consideration. The scatterplots are shown in Figure IV.15 and Table IV.2 offers a summary of the correlations obtained between both variables in each sector.

Table IV.2. Correlation rates between Productivity Growth and Innovation Adoption Rates by sectors

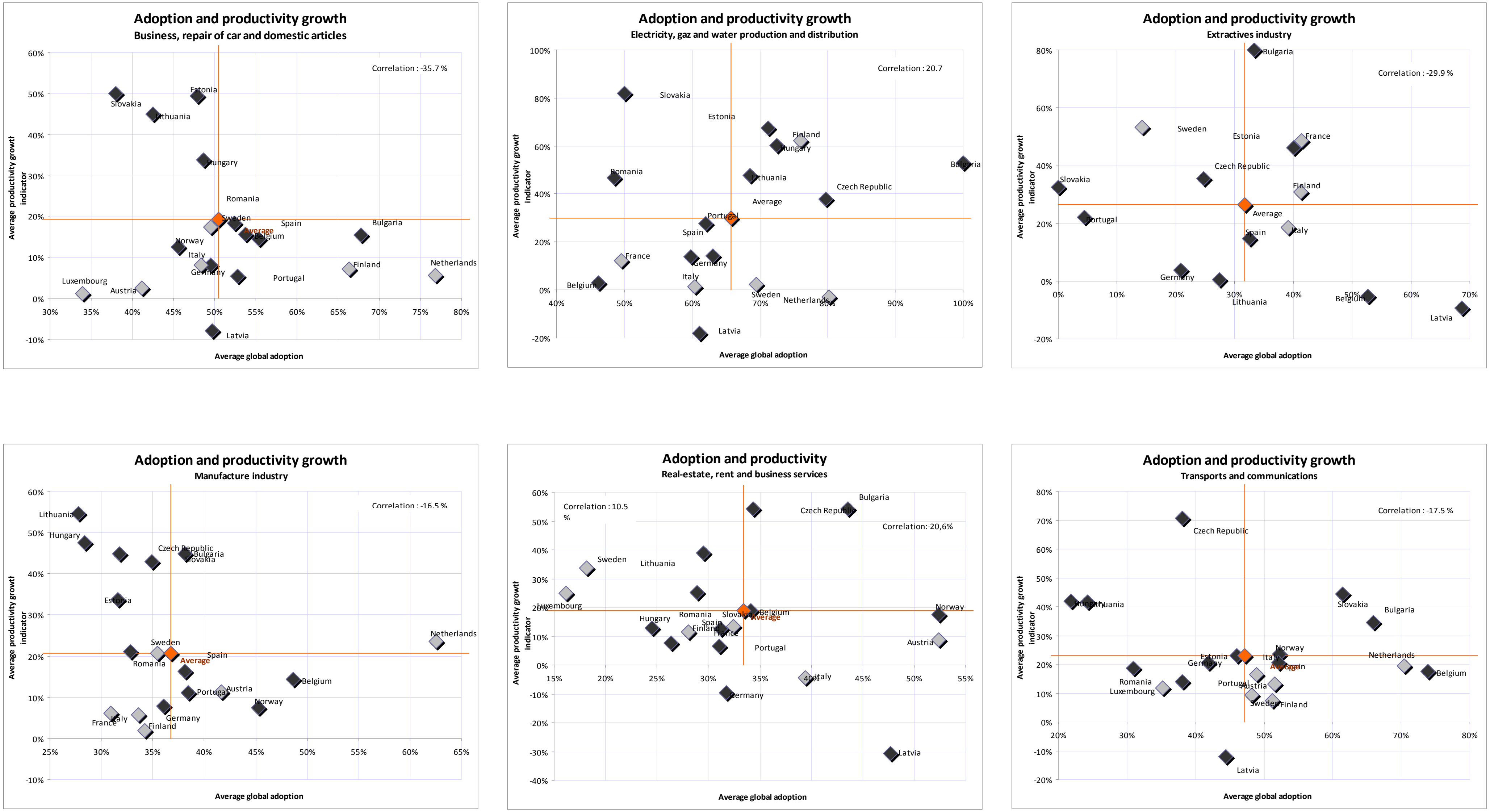
Sector	Correlation
Business, repair of car and domestic articles	-35.7%
Electricity, gas and water production and distribution	20.7%
Extractives industry	-29.9%
Manufacture industry	-16.5%
Real estate, rent and business services	-20.6%
Transport and communication	-17.5%

Similarly to what happened with the productivity levels, all the sectors except the one of Electricity, gas and water production and distribution share a general pattern: the correlation between productivity growth and innovation adoption is negative. The highest value is obtained for the sectors of Business, repair of car and domestic articles and Extractives industry. Again, this result seems to be due to the fact that two differentiated patterns of groups of countries are observed according to their productivity growth rates. Those with rates above the average (some of the Eastern countries) with low adoption rates of innovation and those with productivity growth rates below the average but without a clear correlation with the level of innovation adoption. Summing up, the global negative relationship observed for most sectors seems to be due to the existence of these two different patterns of productivity growth rates, whereas within each one the negative relationship is not so clear.

The case of the sector of Electricity, gas and water production and distribution is an exception to the pattern described above, since innovation adoption and productivity growth are positively related. Within this sector, a majority of countries obtaining productivity growth rates below the average present low innovation adoption rates (Belgium, France, Spain, Portugal, Spain, Germany and Italy), whereas some of the countries with high productivity growth rates in this sector offer at the same time high innovation adoption levels (Finland, Hungary, Lithuania, Czech Republic, Bulgaria and Estonia).

All in all, the general conclusion can be summarised as follows: **there is no clear relationship between innovation adoption and productivity growth. When such a relationship seems to be obtained, with a negative sign, it is more related to the existence of two groups of countries with different behaviours in the pattern of productivity growth: a majority of countries with high rates of productivity growth present low levels of innovation adoption (Eastern countries), whereas the countries with low productivity growth rates offer at the same time high and low innovation adoption rates.**

Figure IV.15. Scatterplots of Innovation Adoption and productivity growth in the different sectors under analysis



PART V

Policy recommendations

At this stage of the work we have been able to disentangle the effect of the Internal Market on innovation adoption across major EU countries. We analyzed how this impact actually works through three channels which are identified in trade, competition and cooperation.

We have been able to disentangle specific policies and regulations which may statistically affect each one of these channels. These results are of particular interest from a policy making point of view since they allow us to directly identify both channels of transmission of innovation adoption across EU firms and countries as well as the IM regulations which boost these channels and ultimately promote innovation adoption. It should be noted however that the results have been obtained thanks to a statistical analysis which includes some limitations. Firstly, our measure of diffusion focuses on adoption, and therefore does not allow us to cover the whole diffusion process. Secondly, the database used is of weak quality (due to double counting problems and missing observations). Therefore the policy recommendations drawn below should be taken when keeping this in mind. We first detail, here below, the main transmission channels of innovation adoption that we have been able to identify (Trade, Competition and Cooperation). Given our definition of innovation diffusion using CIS, we highlight how differently the determinants of diffusion can impact the different forms of adoption, being they cooperation-based adoption or adoption of technologies mainly developed by other enterprises. Indeed, this distinction may have policy implications. Then we present the IM policies which are found to statistically affect both the transmission channels and their indirect effect (being this positive or negative) on innovation adoption. We are also able to say something on the impact that some specific regulations may have on different kinds of innovation adoption. In particular, the distinction between product and process innovation adoption is worth noting and confirms somehow the necessity of considering them separately when defining public policies. Some useful elements concerning the relation between innovation adoption and productivity growth are also provided when relevant (as detailed in Part IV). Finally, beyond the global regularities identified above, we underline the potential impact of the diversity of the countries and sectoral contexts as revealed by the descriptive statistics of Part II. Indeed, results of global policies applied to highly diversified contexts are not always easy to anticipate.

V.1. Identifying the determinants of innovation adoption

We start by retracing the results of the macro-econometric analysis of the transmission channels (cooperation, competition and trade). Then, we present the main factors of the adoption choice as they emerge from the micro-economic analysis. Finally, using macro and micro analysis, the specific impact of the IPR environment on innovation adoption is underlined.

V.1.1. The transmission channels at the macro level

Using country and sectoral aggregated data, our econometric analysis of the role of Cooperation, Competition and Trade as channels for innovation adoption within the EU has gone deep into the determinants of innovation adoption not only by focusing on the total innovation adoption scores but also by disaggregating innovation adoption into different categories related to "product" and "process" and to additional sub-categories linked to the way the innovation has been adopted (mainly as a result of some kind of inter-firm cooperation or as a direct acquisition of the product or process developed externally from the acquiring firm). Summarizing the results we may highlight that:

i. **Cooperation** appears as the main factor likely to enhance the rate of innovation adoption.
   a. **Total innovation adoption** (product + process innovation adoption) **is strongly statistically correlated with cooperation activities** (being these carried out across countries or within the same country)
   b. **Cooperation is found to be especially important in the diffusion and adoption of new innovative processes**. **Product innovation adoption is also found to be statistically related to cooperation** (probably as the result of the work of different firms on the same R&D projects). However, it is process innovation adoption which is especially found to be highly correlated with the establishment of cooperative activities. This is to say that **making cooperation easier will incentivize process innovation adoption resulting from actual cooperation across firms**. Thereby this may contribute to an improvement of the efficiency of process adoption which generally necessitate direct

interactions in order to transmit tacit knowledge and know-how (Part IV has shown a higher impact of process adoption through cooperation on productivity).

Cooperation is a strong determinant of the innovation spillover observed across firms/countries and **should be strengthened** even more in order to achieve **higher levels of diffusion/adoption**. Facilitating cooperation could also lead to a better **efficiency especially in process innovation adoption** by giving incentives to firms to preferably choose the adoption through cooperation .

ii. **Competition** surprisingly does not show to be always a strong **determinant of total innovation adoption**. However, results are dependent of the nature of innovation adoption.

Particularly, when considering more precisely the nature of innovation adoption, our results show that **only product adoption acquired from outside the firm is positively and significantly impacted by the level of competition**. Such a result may be interpreted as follows. Competitive pressures often lead to innovation race which implies the shortening of the product life cycle and the strengthening of innovation protection, being they new products opening new market opportunities or new processes allowing a reduction of production costs. In such a context, appropriability matters are extremely sensitive implying that direct adoption is preferred to adoption through cooperation. Another interpretation is that in fact a more developed competition allows firms to merge (and therefore acquire products) or to simply buy and exchange products in a much easier way.

Competition foster innovation and it is also a **determinant of product innovation adoption**. Hence, as it eases the market for technology and at the same time contributes to the reinforcement of knowledge appropriability constraints within cooperation, **competition is a significant incentive only for direct acquisition of external new products innovation** and not for innovation made in cooperation.

iii. **The Trade channel** does not have a significant effect on the total adoption rate of **innovation.** More sophisticated channels than trade seem to be needed for total innovation adoption. It is possible that the Trade effect has not actually been picked up in our regressions due to the way we model the indicator of adoption (that is as a ratio of adoptive firms on total innovative ones). It is possible, therefore that the trade channel will work simultaneously on adoption and innovation creation such that its effect would pass unobserved in the econometric estimations.

From a more general perspective, we would like to stress that in various specification the estimated coefficients for the some transmission channels do not show the usual statistical significance, but are instead, only “marginally” significant. This leads to think that extra-care is needed when interpreting these coefficients. Also, we believe that further research may be needed (probably using more complete and recent databases such as the CIS4) in order to fully test the hypothesis of the current work on a larger number of observations which would allow a more robust empirical and statistical analysis.

V.1.2. Micro-economic determinants of innovation adoption

We have shown above to what extent adoption rates are dependent of the macro-economic conditions for cooperation, competition or trade. However, apart from these three channels, micro-economic analyses have pointed out other determinants of innovation adoption. Indeed, the global rate of adoption is also dependent of the innovative strategy of firms and especially, when they innovate, of their choice to innovate on their own or to acquire innovation made with or by other organisations. According to this micro-economic perspective, results are the following:

i. **The size of the firm positively impacts the choice to adopt external innovation (larger firms have a greater tendency to adopt external innovations)**. But its effect is seen for process innovation and does not occur for product innovation diffusion showing a higher importance of internal capacities of absorption for process adoption than for product.

ii. **On the contrary firms belonging to a group and being well endowed with skilled workers are more likely to choose to innovate by their own** than to adopt external innovation. For such firms, incentives to innovate may result in a reduction of the adoption rate.

iii. **The capabilities of firms to introduce organizational changes** show, instead, a mixed impact on innovation diffusion. They **are proven to be especially important (and statistically significant) for the diffusion of Cooperation-based** innovation as one would actually expect.

iv. **Public financial support acts as incentives to adopt**. Public funding of innovation appears efficient to foster adoption of innovation, more than generation of innovation in itself. This is certainly due to the use of numerous transfer-oriented policy instruments and this is especially true for process adoption.

v. **The role of Cooperation as a channel of innovation diffusion is confirmed at the micro-economic level**. The impact of cooperation is shown to be even stronger than in the macro-econometric analysis which is not surprising. Indeed, when controlling for other individual characteristics of firms, being a cooperative firm is important in the choice to adopt innovation from other organizations instead of generating proper innovation.

vi. **The channel of innovation diffusion that we named "Trade"** is in most cases showing a negative effect on the diffusion of innovation. This runs counter traditional theoretical model as well as empirical studies but it is probably due to our specific model which distinguishes effects on innovation from effects on the diffusion of innovation. As usually supposed **Trade has a positive and significant effect on innovation. However, among firms which have innovative activities trade has no significant or significantly negative effect on the choice to adopt instead of generate innovation**. As no variable accounting for competition has been integrated within the estimation, one can also assume that the Trade variable gathers international openness as well as competitive pressure effects on firms.

The size of firms is an important factor in the explanation of the adoption of innovation and so it highlights the role of absorptive capacities. Once taken into account the effect of such individual characteristics of firms as their size and their belonging to a group, **two factors seem to significantly contribute to the choice of adoption by firms: benefiting from public financial support and working in cooperation with other firms**. On the contrary, **certainly due to the competitive pressure which that supposes, being involved in international markets acts as an incentive to innovate internally instead of by adoption.**

V.1.3. Role of IPR

The impact of **Legal structure and protection of IPRs** on innovation diffusion has been lately debated in the empirical and theoretical literature. Our results show how:

i. The tighter the protection, the more difficult will be for firms to exploit innovations discovered elsewhere.

It is important to notice that this result does not imply immediately that, as a policy making decision, IPRs should be relaxed so as to achieve higher innovation diffusion. In fact, what it is important to bear in mind is the balance between innovation production (boosted by IPRs enforcement) and innovation adoption (slowed down by IPRs enforcement). The two effects are therefore difficult to be disentangled even if, in the case of EU countries, we may suspect that the first effect (that of innovation creation) may be stronger than the second (innovation adoption) due to the relatively high-tech nature of innovative European firms. **The same result seems to be found when we focus on micro data where the use of patents exerts a negative impact on innovation adoption.** Firms which base their innovation strategy on legal protection are primarily those who generate internal innovation instead of adopt them from other firms.

ii. The effect of Legal structure and Property rights Protection is observed for product adoption while it is not statistically significant for processes. This, would imply that it is the protection of product innovations (which are tradable) to be related to the speed and extent of adoption rather than to the adoption of processes which, instead, are somehow more difficult to be protected by patents or formal legal structures. As somehow expected, the legal structure and the protection of property rights seem to play a significant role only in the specific case of the **adoption of process innovations made in cooperation** by ensuring the firms which are cooperating on the same process innovation against possible free riding.

Independently of their incentive role on innovation, **the reinforcement of Legal structure and protection of IPRs reduces the proportion of adopted innovation compared to those internally generated. However as it has a clearly positive impact on innovation such reinforcement may enhance the absorptive capacities of firms and countries and so eventually participate to the growth of innovation diffusion.**

V.2. Identifying the IM regulations likely to boost the channels of innovation adoption

We turn, here below, to our analysis concerning the IM regulations affecting the transmission channels. Thus, we present the main conclusions related to the indirect impacts that the IM regulations may have on the adoption of innovation.

i. **Cooperation** (intended as the propensity of carrying out firm innovative activities together at the EU level) is shown to be positively correlated to the degree of **social trust** in each country. Policies aiming at ensuring a higher level of generalized trust may be helpful therefore in boosting cooperation.

    a. From a more IM regulation point of view, we have been able to detect a statistical significant correlation of cooperation activities with policies targeted at "**communication and simplification procedures**" (a sub-index of the "**regulatory and administrative opacity**" PMR index). In particular, the EU regulations should be addressed at **making regulations known and accessible** to affected parties or, among other things, **to reduce the number of permits and licences** required to start any business and cooperative activity as well as the **administrative burdens** imposed by governments on enterprises and/or citizens.

b. Also, strengthening **Human Capital** is shown to be statistically significant when explaining the degree of cooperation (especially in innovative projects). The use of framework programmes (such as the last EU 7FP) may therefore be seen as a way of efficiently exploiting the existing human capital and to foster additional cooperation at the EU level which, ultimately, will be conductive to innovation adoption and diffusion.

Therefore, policies contributing to reinforce social trust within countries especially through "**communication and simplification procedures**" are likely to develop cooperation among firms and consequently to achieve **higher levels of diffusion/adoption. Strengthening Human Capital also appears as an efficient way to enhance cooperation and consequently innovation adoption**.

Moreover, it should be noted that such an incentive to develop cooperation-based diffusion as well as the promotion of an increase in human capital levels will also have a positive impact on the **efficiency of process innovation adoption** and on the **global capacity of firms to innovate**.

ii. **Competition** has been one of the main priorities for the EU Commission and its various DGs. We have been able to detect how the work of the EU Commission started producing its results by increasing the competition level of the member states' economies. The level of competition is shown to be highly correlated with the adoption of the "competition regulations" proposed by the EU. In fact we are able to show how for those countries which are still lacking the full adoption of the EU regulations the markup levels are on average higher. **The Transposition of the EU-Competition regulations is shown to robustly provoke higher competition levels across the countries in our sample**.

a. From a more specific regulatory point of view, we detected how the **intrusiveness of national government** (when "national, state or provincial government controls at least one firm in one basic sector") is going to reduce competition so these kinds of behaviours should be strongly opposed.

b. At the same time we detected how the **size of the public enterprise sector should diminish** so as to foster more competition.
c. Finally, we find a **negative relation** between competition and the use by national governments of the **golden rule option**, or the presence of any **constitutional constraint to the sale of the stakes** held by national governments **in publicly controlled firms**.

Policies reducing rents, administrative burdens and national government controls should be therefore strongly implemented at the EU level in order **to achieve higher levels of competition and eventually higher shares of adoption of external product and productivity growth. On the other hand, augmenting competitive pressure is likely to discourage innovation made in cooperation. A sort of trade-off appears here. Indeed, augmenting the global level of competitive pressure within Europe could help firms developing market exchanges of technologies but, at the same time, it could impede cooperation between firms and thereby interactive activities favourable to innovation**

iii. **Trade** is positively affected by a reduction in the "**involvement in business operation**" by the national governments.

a. In particular our results show that regulations which imply heavy "**price controls**", especially those on air travel, road freight, retail distribution and telecommunications are going to decrease the amount of turnover exported. The intuition is that companies will trade more where they can freely decide prices or where the transportation sector (crucial for the export industry) is not heavily regulated by national governments.
b. Also, we provide evidence that at increasing "**use of command and regulation**" on domestic carriers or companies providing railway infrastructures, the volume of turnover exported significantly decreases.
c. **Trade** is also positively affected by **less restrictive trade barriers** and, in general, we showed how trade is positively associated with well known indexes of trade openness which suggest how, among other things, providing an **easier access of citizens to international capital markets** and *viceversa*

for **foreign investor the access to national capital markets** is going to foster international exchange also in tradable goods.

We therefore showed how **the indirect effect of policies reducing prices controls or the national government controls on the transportation sector are going to foster international trade and eventually affect the extent by which innovation can freely move within the EU borders and eventually been adopted**. We have not been able however to detect any statistically significant impact of trade on the adoption of innovation (and if any, we actually found that this channel is going to rise innovation creation rather than its diffusion). This result is puzzling and it seems to need further research.

All in all, we get the general picture that IM regulations undertaken by the European Commission are having their impact on the level of adoption of innovation in EU firms. It should be highlighted, however, that this influence goes through changes in a specific channel such as cooperation. which has been shown to have a real impact on the rate of innovation adoption. The importance of the other channels identified vary, instead, according to the type of innovation adoption we have considered. In particular, diffusion through cooperation will particularly be enhanced by policies aiming at facilitating cooperation whereas diffusion through direct purchases from other firms will be enhanced by policies aiming at augmenting competitive pressure and reinforcing IPR. Results obtained by the comparison between CIS3 and CIS4 certainly show that the development of the Internal Market may already have had an influence. **An increase in innovation adoption is generally observed which is higher for process innovation and innovation made in cooperation.** As countries have historically constructed themselves around specific mix of theses different features, we should bear in mind that the same global policy concerning IM regulation may have different implications depending of the context of their application. The descriptive statistics analysis we have done in Part II offers us tools to better apprehend this reality.

V.3. Dealing with the diversity of national profiles

The descriptive statistics given in part II lead on to the following results:

i. **Generally speaking, countries which display the highest level of innovation are also those which show the highest adoption rate** and conversely countries with weak capacity to innovate are also weak adopters. Thus, the complementary dynamics linking innovation and adoption seems to be at work in most of the European countries. However exceptions exist which are certainly not to neglect if we are to understand how countries can react to European incentives. **These exceptions are Luxemburg, France and Sweden which display low level of adoption compared to their innovative capacities, and Bulgaria which has a very high rate of adoption compared to its rate of innovation**. Specific characteristics of their system of innovation strongly oriented toward internal resources or sectoral specializations towards sectors of high intensity of internal innovation may explain the three former exceptions. Indeed, some sectors are essentially relying on adoption (Whole sale trade, Transport and communication, Electricity, gaz and water supply) while others are recording at the same time very high innovation rate and very low adoption rate (Manufacturing and Computer and other business services).

Generally speaking, the complementary dynamics linking innovation and adoption seems to be at work in most of the European countries. However exception exist which could be explained by cultural factors or by sectoral specialization. **Luxemburg, France and Sweden display low level of adoption compared to their innovative capacities, whereas Bulgaria has a very high rate of adoption compared to its rate of innovation**.

ii. **Globally also, and according to the first point, countries highly endowed with resources to innovate and using invention protect methods as incentive to innovate, display also high rates of adoption**. Exceptions are often the same than in the first point: France highly doted in R&D expenditures and human capital displays low adoption rate whereas Bulgaria is once more in the opposite place.

iii. **Concerning the organizational factors such as the capacity to introduce organizational change within the firm or the capacity to cooperate with other organizations, differences between countries do not recover exactly their differences in terms of innovative potential or adoption. Other cultural factors seem at work**. Thus, France and Bulgaria record very low level of organizational change whereas Romania, Germany and Austria have the highest rate of organizational change. Adoption in Scandinavian countries is largely cooperation oriented whereas in Hungary, Spain or Lithuania cooperation is less used in the adoption process.

iv. More generally, concerning the IM indicators, it seems that **two groups of countries correspond to the model described above either disposing of all the determinants of adoption and being well integrated in the UE with high adoption rate (group 1 and 2 of the typology proposed in part II: Belgium, Germany, Netherland, Finland and Norway and Sweden with some specificities) or, on the contrary, lacking of most of the determinants of adoption, being more weakly integrated with very low adoption rates (countries from the Eastern and Baltic countries, group 5 and 6 of the typology).**

In this last group of countries **(Easter and Baltic countries)**, **acting towards a better integration to the EU, using the policies presented above may permit to reinforce their capacity to adopt innovation. We should underline however that such a policy might have no effect if it is not accompanied by actions aiming at reinforcing the own innovative potential of these countries in order to boost their absorptive capacity.**

v. Another group of countries (Group 3 of the typology: Italy, Portugal and Spain) performs well in innovation performances and is relatively well integrated into the Internal Market (Barriers to trade and competition are low within these countries). However, **some weaknesses in their innovation potential and a low level of cooperation** prevent these countries to completely enter within the virtuous circle of innovation/adoption.

In such a context of low barriers to trade and competition, developing **IM regulations oriented towards the reinforcement of cooperation may particularly benefit to these three countries (Group 3) in order to reinforce at the same time their innovative potential and their capacity to absorb the innovation adopted.**

V.4 Suggestions for future implementation of CIS data and questionnaires

As a result of the experience working with the CIS dataset in order to study the innovation diffusion process in the EU countries, we can offer some suggestions for future implementation of CIS data and questionnaires:

- It is important for policy makers to dispose of precise information about the diffusion/adoption of innovation. In spite of the important limitations of the CIS data in measuring diffusion and adoption, these data are still probably the most relevant tool that is available at the moment, and the only one likely to provide a general overview of these processes at the EU level. Some improvements in the survey may allow coping with the main limitations highlighted in this study. In particular, **collecting more quantitative information** about the way innovation is produced would be of great help in econometric and economic analysis. For instance, the shares (or the intensity) of innovation made in isolation, in cooperation or developed by others should be registered directly for each case. Moreover, the usefulness of the CIS data comes from the possible crossing of several items. Most of these crossing cannot be implemented using aggregated data available on Eurostat website while micro data are needed. **Increasing the availability of data at the micro level** (which for now is restricted to only few EU member states) would thus provide more tractable information and richer analysis of the adoption process and its determinants.

- A second suggestion would be that of **trying to eliminate the subjectivity in some of the questions of the CIS** questionnaire in order to be able to better define categories and quantify the answers. Some of the present questions, for instance, ask to define whether an innovation has been developed “mainly” by other firms or in collaboration.

This subjectivity impedes to measure or consistently define the same processes across countries due to the possible biases related to the subjectivity of the answer. As suggested above, this subjectivity may be partly solved by asking the share of innovation that relies on each type of innovation and not as a result of the interpretation of the word “mainly”.

- **In the present CIS questionnaire, the items allowing to deal with innovation adoption question, do not provide separated information about diffusion occuring within the country and across countries.** A revision of this question may solve directly this problem.

- **EUROSTAT should provide a technical annex on how the macro data** provided in their web-site **have been treated starting from the micro data**. Aggregation issues and different methodologies may be in fact a problem for researchers which have to know, first, how the statistical office treated micro data in order to obtain macro ones.

- So far in CIS we know if a firm has made innovation or adoption but not **the intensity of such processes**. Therefore, a firm making some innovation but at a very small scale and a big firm making a lot of innovation are, at the moment, considered equally. Both of them would answer yes, and this is all the information given in CIS. We have information about the share of turnover due to innovation. But this is only available for product innovations. This can hardly be asked for process innovations or other types of innovation (organizational, marketing, etc). **However a question (even qualitative) about the importance of innovation in the firm activity could be added**. This question should be asked for each type of innovation (innovation made in isolation/ innovation made in collaboration / innovation made by others).

- Finally, in addition to these marginal changes, it may be useful to constitute a working group to suggest improvements of the CIS in order to better account for innovation diffusion. This working group might suggest for instance a set of items, in order to explicit and validate the different channels of transmission between IM and diffusion of innovation.

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Appendices of Part I

Appendix I.1. Deeper analysis of the authors with main contributions to the literature on innovation diffusion in the demand-side models

Griliches (1957) performed the first empirical study of the diffusion of technology, concretely, the hybrid corn seed in the Midwestern US in the period 1932-56. The study emphasized the role of economic factors such as expected profits and scale in determining the varying rates of diffusion across the Midwestern states. He found that the variation of initial start dates for the process depended on the spread with which the seed was customized for use in particular geographical areas. Thus, the diffusion process depends upon the capacity of technology suppliers to adapt it to local characteristics. This way, technological innovations could be analyzed from an economic perspective, objecting to existing economic theories that treated technological change as an exogenous factor unrelated to the larger economy. In addition, he devised a logistic growth curve to explain the economic factors underlying this spatial pattern, whilst his conclusion was that the behaviour of commercial seed producers was an important factor. Thus, these seed producers evaluated carefully the market potential in each state before introducing hybrid varieties (the hybrid seed did not spread at the same speed across states). Thus, states with larger farm, more accessible for seed suppliers, were covered the first.

Griliches' papers were soon considered as reflecting obvious aspects of the adoption of new technologies from the demand side, albeit some considerations of the potential profitability were taken into account, including the effects of incremental supply-side adoptions upon the diffusion process. In fact, his main hypothesis stated that the speed of diffusion would reflect the conditions having to do with the innovations profitability for a representative adopter.

Several years later within the epidemic models literature, Mansfield (1961), from the demand side, inquired into the diffusion of industrial innovations by applying the Griliches econometric approach. According to the author, information constrains hinder technology adoptions, but these constraints reduce their influence as soon as knowledge about the new innovation is being known. According to this author, the *word-of-mouth* diffusion mechanism influences more than other economic considerations. In his 1961 study of 12 major innovations in the coal, rail, iron and steel sectors, he found weak evidence that firms in competitive less concentrated industries adopted new technologies sooner. According to Karshenas and Stoneman (1995), it was this author who introduces one of the more successful extensions of the epidemic model: it is not so much knowledge on existence that is the problem, but rather uncertainty surrounding new technology as a result of poor information on the performance characteristics of such technologies. In such a setting, Mansfield constructed a model where this uncertainty is reduced over time as a result of learning from experience, obtaining a model where the speed of diffusion is a positive function of profitability and a negative function of the size of investment required.

Within the literature of the epidemic models from the demand-side, in 1969 **Bass** published the paper "A new product growth model for consumer durables", which has been widely used in market analysis and demand forecasting of new technologies. According to the author, consumers have the same tastes and the cost can be constant, but not all consumers are informed about the new technologies at the same time: thus, there exists an increasing rate of adoption. When, eventually, the market becomes saturated, the rate decreases again. Bass' original models were developed to predict the uptake of consumer products based on various advertising campaigns. The Bass Model quantifies the introduction of new technologies depending on the take up by innovators and imitators by estimating the introduction and acceptance rate variables. The basic model is fascinatingly simple, while at the same time it can capture a wide variety of diffusion patterns observed in practice. The model parameters can be interpreted in terms of internal effects (imitation), external effects (innovation), and saturation level (maturity).

These epidemic models, although being purely demand-based, have suffered some modifications especially with the idea of taking into account the supply-side. Glaister (1974) was one of the first who allowed the influence on diffusion of the cost of acquiring technology and advertising, although supply-side factors were included in an ad-hoc fashion. Gould (1970) and Tonks (1986) used these kinds of model considering certain supply-side issues, albeit it was Metcalfe (1981) who constructed a complete epidemic model including supply-side influences.

Appendix I.2. Deeper view of the forces that influence the diffusion of innovation according to the supply models

Improvements in inventions after their first introduction. According to Rosenberg (1972), most inventions are relatively crude and inefficient at the date when they are first recognized as constituting a new invention. The subsequent rate of improvement is an important determinant of adoption of the new technology. Indeed, it may be very true the case that such improvements will reduce total costs by an amount greater than the reduction in costs of the initial invention over the older techniques which it eventually replaced. Part of the economic literature points to the fact that the efficiency gain from a new technology is much larger during its enhancement stage than during the initial stage. Therefore, the rate of improvement of a technology subsequent to its early stage is of utmost importance for the adoption of the technology.

The development of technical skills among users. Another important factor affecting innovation diffusion from the supply side concerns the development of human skills upon which the use of the new technique depends in order to be effectively exploited. A learning period thus arises, the length of which will depend upon many factors, that is, the complexity of the new techniques, the extent to which they are novel or rely on skills already available or transferable from other industries, etc. Since it takes time to acquire certain skills, it will also take time to establish the superior efficiency of a new technique over existing ones. The development of a highly skilled labour force is crucial to the success of new technologies and the lack of such a labour force is one of the main impediments to its rapid diffusion. In fact, many of the new skills are acquired directly through the work participation, and if this new know-how is partly tacit, such skills are not transferable through formal education. So the movement of qualified personnel is highly required.

The development of skills in machine-making. This argument refers not to skills involved in using the new techniques, but in developing the skills and facilities in machine-making itself. Thus, successful diffusion of innovations requires a growth in the capacity to devise, adapt, and produce at low costs certain machinery to produce these new technologies. Historically speaking, lots of inventions have not arise to a marketable products due to the lack of the appropriate mechanical skills, facilities, and design and engineering capacity required to translate them into working reality. Thus, according to Rosenberg (1972), it is the state of development of the capital goods industries, more than any other single factor, which determines whether or to what extent an invention is ahead of its time.

Complementarities. A chiefly field affecting the path of diffusion lies in the complementarity in productive activity between different techniques. Thus, a given invention cannot fulfil anything unless other inventions are made, relaxing constraints which would otherwise hamper its diffusion through the existence of important bottlenecks. Needless to say, thus, that a single technological invention hardly ever constitutes a complete innovation.

Improvements in "old" technologies. According to Rosenberg (1972), there exist a close relationship between innovations and improvements in older technologies. That is, when a new innovation is a close substitute for an existing technology, then the innovation itself may induce providers of the old technology to make improvements with the aim of retaining their market position. What the author suggests is a possible lack of symmetry in the manner in which firms respond to alterations in their profit prospects, since the imminent threat to a firm's profit margins which are presented by the rise of a new competing technology seems often in history to have served as a more effective stimulus to own technological improvements. This will slow the diffusion of the new technology.

Diffusion and its institutional context. The productivity of any technology is never independent of its institutional context and therefore needs to be studied within that context, since institutional context can account for the very slow diffusion of a superior technology. Within the influence of institutional context on innovation diffusion, Hall and Khan (2003) consider the market structure and firm size as well as the government and regulation. According to Dorfman (1987) there are four arguments in favour of a positive impact of firm size and market share in determining the level of innovative activity and the level of use of new innovations:

- Large firms are more likely to undertake innovation from outside both because appropriability is higher for larger firms and because the availability of funds to these firms is greater. Firms with larger market share are more likely to adopt a new technology because they have a greater ability to appropriate the profits from the adoption.

- In the presence of imperfect capital markets, larger and more profitable firms are more likely to have the financial resources required for purchasing and installing a new technology.
- Firms with large market share are sometimes better able to spread the potential risks associated with new projects because they are able to be more diversified in their technology choice and are in a position to try out a new technology while keeping the old one operating.
- Many new technologies are scale-enhancing and therefore large firms adopt them sooner because of their economies of scale from production and can spread the other fixed costs associated with adoption across a larger number of units.

However, as stated by Henderson and Clark (1990), large size and market power may also slow down the rate of diffusion on a twofold base. Firstly, due to the higher levels of bureaucracy in larger firms which makes the decision-making process difficult. Secondly, because large firms may have many resources and human capital sunk in the old technology and its architecture, so that it can be relatively more expensive for them to adopt a new technology.

Appendix I.3. IPRs and the level of development of the economy and the endowment of other factors

One of the main issues when analyzing the impact of IPRs on technology diffusion (and the resulting economic growth from it) is to understand under which conditions the potential spillovers from the frontier are actually exploited by the technological followers, that is, under what conditions the absorption of technology fully works. The impact of tightening IPRs will depend on the level of development of the country (Acemoglu et al, 2006; Aghion et al, 2005) as well as on the endowment of other factors (Chen and Puttitanum, 2005).

IPRs and the level of development

A recent strand of literature argues how certain institutions which foster economic growth in developed countries may actually hinder the growth of least-developed ones. Acemoglu, Aghion and Zilibotti (2006), Aghion, Harris, Howitt and Vickers (2001), Aghion, Burgess, Redding and Zilibotti (2005) or Aghion and Howitt (2005) develop the idea of Gerschenkron (1962) that countries lagging behind the technological frontier, and that perform primarily technology imitation, may be better off by some non-competitive policies in the early stages of their development. This reasoning seems to generally apply to the case of IPRs.

As pointed out by Connolly and Valderrama (2005) a similar trade-off exists, on a cross-country basis, between developed countries (the innovators) and developing ones (the imitators). One of the arguments used by developed countries in favour of strong IPRs protection standards in developing countries is based on the fact that these are expected to promote own based research and innovation (discouraging imitation). On these regards, Grossman and Lai (2004) have recently analyzed a North-South environment where both regions own an innovative sector. Among other results they show how enforcing IPRs in the South may end up increasing the gains for the North at the expenses of the South which sees a reduction of its economic growth and welfare. Also, Lai (1998) links negatively the speed of imitation to the extent by which IPRs are enforced in the follower country.

IPRs and factor endowments

It is crucial, also, to notice how the specific impact of IPRs on an economy (especially on a developing one) will also depend on factor endowments of the economy under consideration and that the relation between tightening of IPRs and economic growth may not be a linear one. In a recent paper by Chen and Puttitanun (2005) it is shown the non linear effect of IPRs on economic growth and its peculiar impact in countries at different development stage and endowed with different economic fundamentals. In particular, Chen and Puttitanun (2005) build a theoretical model suggesting that domestic innovation is increasing in the enforcement of national IPRs but that the economic gains of enforcing IPRs diminish when a certain (middle income) development is reached. The empirical test of the model (done on a sample of 64 developing countries using panel data for the period 1970-2005) shows a U-shaped relationship between the tightening of the protection of intellectual property rights and economic growth. When they also include an interaction term between the development stage and the degree of enforcement of IPRs the empirical results seem to suggest that IPRs exert their growth enhancing effects on the countries with the highest level of development and which operate at the technological frontier. However, foreign entities generate more applications in those countries which reformed their IPR regimes. This suggests FDI as an alternative channel through which reforming countries could benefit from tighter IPR.

Schneider (2005) also analyzes the impact of IPRs on high-tech imports, FDI flows and economic growth by measuring innovation by U.S. patent applications made by residents of a given country. The results of the empirical research on a panel data of 47 countries over the period 1970-1990 show an uneven impact of IPRs across countries taken at different stages of their development. When the sample is split into developed and developing countries the effect of IPRs is positive in the formers while negative in the latter group.

Impact of IPRs on economic growth

As pointed out by Falvey and Foster (2006), there exists a small empirical literature which addresses directly the impact of IPRs **on economic growth**. The work of Gould and Gruben (1996), for example, employs a commonly used indicator of protection of property rights (the Rapp and Rozek (1990) index) to check whether there exists any discernable evidence of a positive impact of a strengthening of IPRs on economic growth on a wide sample of 95 countries over the period 1960-1988. The result is that, on average, IPRs exert a positive impact on economic growth and that their impact is stronger in countries which are more open to international markets.

A similar exercise has been undertaken in the work of Thompson and Rushing (1996) who, after having regressed the average growth rate of real GDP per capita for 112 countries on some control variables (such as education, population growth and investment rates) find a non significant effect of IPRs on growth. However, when the sample is splitted by using threshold regression techniques[69] the results change dramatically. For those countries below the threshold level the direct impact of IPRs on economic growth is found to be insignificant. This result is in line with the idea that these countries are found in the initial stages of development and that either their innovative and imitative capabilities are not sufficient to take advantage of the incentives given to innovation and technology diffusion coming from IPRs enforcement. For the other countries above the threshold, instead, the factor endowments (the presence of adequate human capital, institutions and a well functioning R&D sector) make the IPRs working as a growth enhancing mechanism. The sign of IPRs enforcement, when used as an explanatory variable for GDP per capita growth, is therefore found to be positive and statistically significant.

Later on, Thompson and Rushing (1999) expanded their previous analysis on the impact of IPRs **on total factor productivity** (in order to isolate the effect of IPRs on a somehow more "technologically oriented" measure of economic growth) reconfirming how the major (positive) impact of IPRs is experienced in already developed economies with functioning R&D sectors and innovative capabilities.

[69] The threshold regression method was developed by Hansen in his paper in 2000 to standard growh regressions. Hansen B. (2000) Sample splitting and threshold estimation, Econometrica, 68 (3), 575-604.

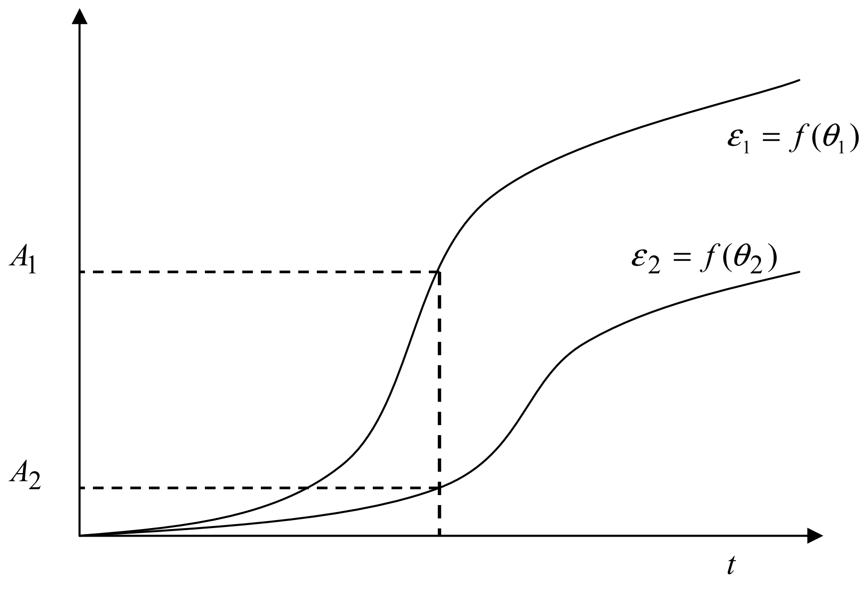
Appendix I.4. Different paths for the diffusion/adoption of innovation

As a result of assumptions in eq. (4) and (5) it is possible to define different paths for the diffusion of innovation and make some cross-country comparisons depending on the R&D effort of each economy and on the quality of the implementation of the Internal Market features. Here below we propose a simplified graphical representation where, for the sake of simplicity, the two countries under consideration only differ in the degree of implementation of the Internal Market, (θ), within their national boundaries.

Proposition 1: *An increase in the quality of the Internal Market implementation or in the quality of the overall absorptive capacity of the economy (an increase in* $\varepsilon(\theta)$*) will lead to a faster diffusion of innovation.*

The explanation of this proposition is quite straightforward. Country 1 achieves higher technological levels due to a higher speed (ability) of adopting innovation w.r.t. country 2. Slightly more formally it is possible to define that whenever $\theta_1 > \theta_2 > ...\theta_i$ then also $\varepsilon_1 > \varepsilon_2 > ...\varepsilon_i$ and $A_1 > A_2 > ...A_i$ in eq. (7).

Figure A.I.4.1. Paces of innovation diffusion for different IM levels

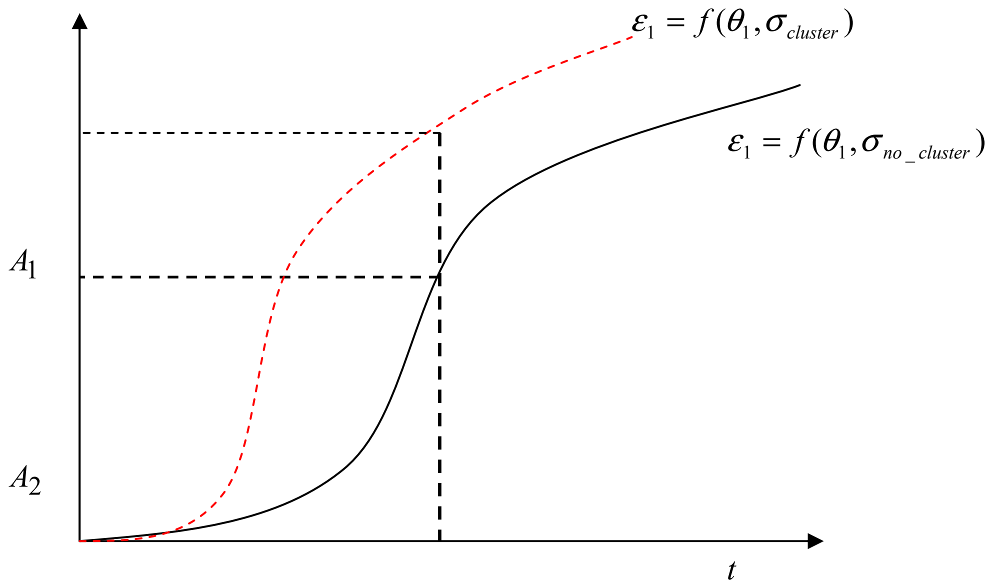


Proposition 2: *Those economies whose industrial composition heavily exploit "technological clusters" will experience a higher rate of technology diffusion.*

Regarding the spatial distribution of firms we can make two scenarios. In one case, country 1 owns a relatively high percentage of its firms (over the total) for which the $\sigma < 0 \Rightarrow \sigma_{cluster}$ (many firms form part of technological clusters). In the second case, instead, the same country (hence with the same degree of IM quality) does not rely on a large share of firms which form part of technological clusters (firms do not exploit spatially related technology spillovers). In that case we have: $\sigma > 0 \Rightarrow \sigma_{no\_cluster}$.

It is easy to show how the diffusion of innovation in this country will take place at higher paces in the case of presence of technological clusters ($\sigma_1 < 0$) rather than when firms are spatially isolated ($\sigma_2 > 0$).

Figure A.I.4.2. Paces of innovation diffusion for technological clusters



More on the effects of R&D on the Adoption of Innovation

The endogenous level of productivity for each country at time t is expressed as follows in the theoretical model:

$$(3) \qquad A(t) = \gamma A(t-n) - \left[\omega^{-1} + \left(1 - \frac{1}{1+\exp(\Delta^{-1} - \varepsilon)t} \right) \right] \qquad \gamma > 1$$

where with γ we denote the productivity augmentation term related to the adoption of the new technological paradigm. This is to say that $\gamma A(t-n)$ represents the maximum productivity level attainable with any given technological paradigm. The arrival of new technological paradigms over time continuously shifts this value upwards.

$A(t)$, therefore, represent the productivity level given by the difference between the maximum productivity level and the amount of new blueprints that have not yet been adopted in the productive process (the term in square brackets).

Let us now analyze the variables which define the amount of blueprints not already adopted in the square brackets. With ω we denote the effort exerted in the R&D sector by each economy whose result is a flow of blueprints[70]. Δ is the number of already adopted blueprints (innovations) for production in each economy over the total pool of blueprints available in each point in time. The parameter ε is the speed by which innovation diffuses within the economy. It is easy to notice how, increases in the value of all these three parameters (ω, Δ and ε) imply an increase in the number of already adopted blueprints in each point in time (i.e. a higher level of innovation diffusion), and therefore a lower value of the term in square brackets and a subsequent higher productivity.

The R&D effort (or blueprint flow, ω) and the number of already adopted blueprints for production (Δ) are obviously linked over time. As the R&D intensity increases, the relative number of already adopted blueprints in each point in time will decrease. The intuition behind this assumption is quite straightforward. The R&D sector continuously produces new blueprints which <u>may</u> be used into production. Some of them will be immediately adopted

[70] The arrival flow of blueprints may be formalized by using a Poisson arrival rate as in the model of Aghion and Howitt (1992).

while others will not. Hence, unless the rate of adoption is infinite (assumption which we rule out), any positive innovation shock (let us say an increase in ω) will imply that the number of **already** adopted blueprints over the total will relatively decrease due to the slowliness by which blueprints are being adopted.[71]

To put it another way, the R&D intensity determines (along with the Poisson arrival rate) the number of available blueprints that could be adopted. If adoption is slow and the creation of innovation is fast enough (situation that is experienced in the first part of the logistic curve) an increase in the rate of innovation will lead to a decrease in the "relative number of initially adopted blueprints" in each point in time.

This is to say that when a new innovation is discovered this will be adopted only with a lag in the next period. The time lag between the blueprint discovery and its adoption stands at the core of the negative relationship between the flow of new innovations and the number of already adopted blueprints.

[71] Notice that this condition holds for whichever positive rate of blueprints discovery.

Appendices of Part II

Appendix II.1. Problem of double counting from macro dataset and its implications

One of the priorities of this project has been that of having the widest database possible at the macro aggregated level so to be able to make comparisons with the major number of countries possible when analyzing the innovation adoption phenomena and their determinants.

In order to do so, in the analysis we used both the micro and macro databases provided by Eurostat. We aggregated the firm-level information available for 15 countries at a country level and then, merged this information with the web-site data whenever needed (that is when information for a country was not directly available in the micro-data).

This procedure has the advantage of providing us with a larger number of countries. However, due to the way the Eurostat web-site provides the data at a macro level, it is possible that a double counting problem arises. This is indeed the case here. Using the macro dataset, we face a double counting problem in our definition of innovation diffusion. Indeed, we can obtain the number of firms for which innovation has been developed "Mainly together with other enterprises or institutions" and "Mainly by other enterprises or institutions" in terms of product, on the one hand, and in terms of process, on the other hand. But, this information about product and process innovations cannot be crossed. So, firms for which both product AND process innovations have been developed in cooperation with others or mainly by others, are double counted. The problem here is, therefore, that for those countries for which we have data coming only from the web-site the rates of innovation adoption rates may be systematically higher than for the countries for which we only have data at the firm level. Nonetheless, in order to have the widest coverage as possible, we suggest using, for our adoption indicator, a procedure likely to correct the bias due to double counting. We first illustrate the potential importance of double counting. Then we detail the rescaling procedure we followed to compute a global rate of adoption.

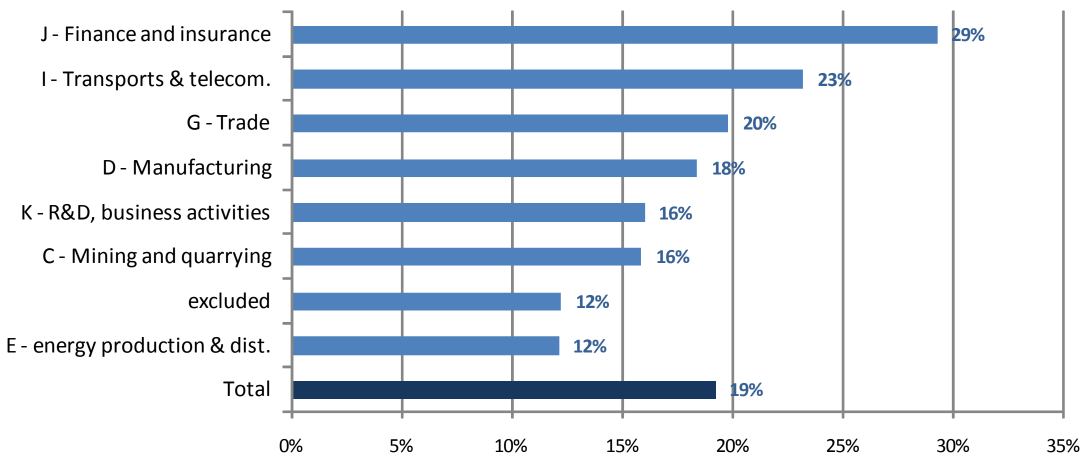
In addition to the double counting that arise when computing adoption rates, notice that this double counting prevent also to use some information contained in the CIS. On the one hand, we can not obtain the definition of adoption based on "the new to the firm" item in particular. But also we loss information regarding potential determinants of adoption; for instance it is impossible to know what are the sources of innovation used by adopting firms only.

A.II.1.1. Differences by industry and by country in terms of firm adoption practices

Due to the double counting of both product and process innovative firms, differences can emerge between the micro and macro datasets when measuring innovation adoption and moreover rates of adoption superior to 100% can be found in some industries .

To have a better knowledge of this bias, we have analyzed from micro data, sectors for which the share of both product and process adopting firms is the most important. Indeed, we can observe that for the Finance and insurance industry, the share of both product and process adopting firms (29%) is higher than for the other sectors (19% for total). Transport and telecommunications is at the second place (23%). So, for these two sectors, the double counting problem is more important. The consequence is that the adoption rate calculated from macro data is significantly higher than ratios calculated from micro data and can be even superior to 100%.

Figure A.II.1.1. Share of both product and process adopting firms over total adopting firms by sector

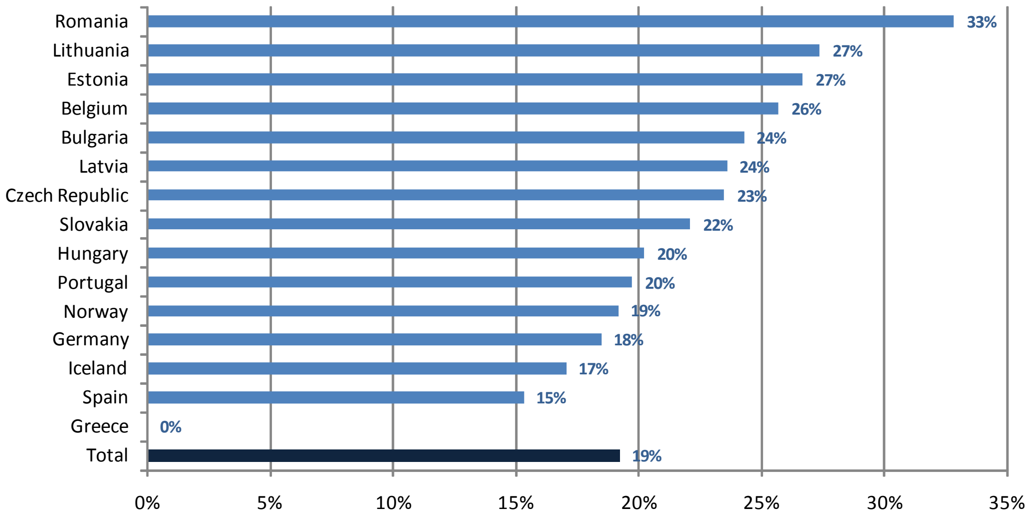


For total adoption rates computation, this results shows that:

- It is rather recommended to exclude the Finance and insurance sector because of the importance of both product and process adoption firms
- The interpretation of these rates for the other sectors must be done carefully even if double counting is less important.

Even by country, the difference between micro and macro rates of adoption can be important. The share of both product and process adopting firms is very important in Romania (33%) compared to other countries.

Figure A.II.1.2. Share of both product and process adopting firms over total adopting firms by country



A.II.1.2. The rescaling procedure:

To correct for these differences, macro data have been rescaled by using a common factor. This factor is the average of the ratios between the available observations common in macro and micro data. The common rescaling factor is equal to 1.05. All adoption rates calculated from macro data have been divided by 1.05.

A "caveat", when using this re-scaling procedure is that we will have to assume that the "re-scaling common factor" which we are able to compute for the countries for which we have data for both the micro and macro datasets will hold also for all the other countries. However, there is no obvious reason to believe that the "double counting problem" should affect the rest of the countries more than what it does for the countries we have data from micro and macro sources[72]. In fact, the double counting problem should apply the same way to all the other countries such that the use of the common factor is not a very restrictive assumption.

In order to check the robustness of this method, we compared results obtained from micro and macro datasets for informed countries (e.g. countries available in both micro and macro databases). The test is done from a panel composed of 44 crossed sector-country records. We can see that for 20% of records the gap is superior to 10%. A more precise analysis shows that this gap is above all due to the Finance and insurance sector. As underlined above, in this sector, the double counting problem is the most important because the share of both product and process adoption firms is the highest. So, for the total adoption rates calculation, we finally decided to drop this sector out.

Table A.II.1.1. Adoption rate gaps between micro and macro data

Gap	Number of crossed industry-country records	%
Between -5% et 0%	7	16%
Between 0% and 5%	12	27%
Between 5% and 10%	16	36%
Between 10% and 30%	9	20%
Total	**44**	100%

[72] We can think of the double counting as a random measurement error in the all sample.

Appendix II.2. Innovation Adoption by sectors

As noticed in sub-section II.1.5.2 of the report, the lack of information in the micro aggregated data base (some main European countries are missing) leads us to complete the information by using Eurostat website. This obliges us to restrict our analysis to six sectors. Indeed, the finest breakdown provided on the website distinguishes seven sectors only, and one of them, the finance sector, has been dropped out because of the double counting problem (see appendix II.1).

In order to provide a more accurate analysis of the adoption activities by sectors, this appendix focuses on the micro data set, for which a breakdown into twenty sectors is possible. The countries under consideration are Belgium, Bulgaria, Czech Republic, Germany, Estonia, Spain, Greece, Hungary, Iceland, Lithuania, Latvia, Norway, Portugal, Romania, and Slovakia.

Focusing on micro data also allows us to consider different definitions of adoption. Therefore several indicators of the magnitude of adoption can be computed as detailed in appendix II.3. The remainder of this appendix is organized as follows. Before analysing the magnitude of innovation adoption by sector and its nature, we present the main characteristics of the sample and the descriptive statistics about the level and the nature of innovation by sector.

A.II.2.1. Main characteristics of the micro data sample by sector

In the CIS survey, firms are classified according to the industry or service sector (NACE2) to which they belong. The sectoral breakdown is however not homogeneous between countries:

- some NACE2 sectors are merged in some countries
- there exist some inconsistent aggregations: for example, Iceland merges 2 very different industries: codes 14 and 15 which respectively concern “Other mining and quarrying” and “Manufacture of food products and beverages”.

Table A.II.2.1 shows how countries have aggregated the different NACE2 sectors. All groups which seem incoherent in terms of economic analysis appear in red in the table.

Table A.II.2.1. Number of firms by country and sector

		Countries															
	Nace2_N	BE	BG	CZ	DE	EE	ES	GR	HU	IS	LT	LV	NO	PT	RO	SK	*Total*
Mining and quarrying	10			11	41												*52*
	10_11										15				45	9	*69*
	10_11_12		21														*21*
	10_11_13						32						68				*100*
	10_11_14					34											*34*
	10_14	12										25					*37*
	11_12_14			40													*40*
	11_14							24									*24*
	12_13														15		*15*
	13_14		87											21		15	*123*
	14						142				11		39	21	51		*264*
	14_15									175							*175*
Manufacture of food products and tobacco	15	42	1354	120	145	172		213	70		188	114	133	93	868	38	*3550*
	15_15													57			*57*
	15_16	17					649	13	40		30	129	165			141	*1184*
	16		30	2	3										8		*43*
Manufacture of textiles, wearing apparel, tanning and dressing of leather	17	32	262	87	57	64	321	100	37		63	43	53	104	296	49	*1568*
	17_18									15							*15*
	18	11	1293	153	27	154	299	149	77		116	81		100	948	82	*3490*
	18_19												38				*38*
	19		186	28	16	30	228	45	33		20	17		52	340	47	*1042*
	19_20	16															*16*
Manufacture of wood, paper and publishing	20	6	280	88	29		282	14	20		102	220	139	65	351	58	*1654*
	20_21					234											*234*
	20_21_22									40							*40*
	21	16	117	28	47		181	28	10		13	22	50	48	62	19	*641*
	22			60	69	85	319	86	22		39	76	170	55	127		*1108*

	NACE2_N	BE	BG	CZ	DE	EE	ES	GR	HU	IS	LT	LV	NO	PT	RO	SK	*Total*
	22_23	40	244								27					43	*354*
Manufacture of coke, chemicals, plastic	23			5	17										11		*33*
	23_24					28	392	67				10					*497*
	24	99	180	48	107				25		29	17	71	57	135	32	*800*
	24_25									27							*27*
	25	53	243	101	150	53	244	69	33		43	28	64	59	141	52	*1333*
Manufacture of other non-metallic mineral products	26	36	263	108	88	61	416	92	21		63	38	74	83	211	60	*1614*
	26_27									25							*25*
Metallurgy	27	46	88	50	56		224	21	10				65	42	83	24	*709*
	27_28					141					56	84					*281*
	28	64	480	219	212		560	82	70	41			207	77	333	145	*2490*
Mechanics	29	108	489	136	253	57	368	69	67	16	41	49	176	57	275	141	*2302*
Electronics	30	6	15	15	13		37							3	9		*98*
	30_31					31		20	19			22	57			72	*221*
	31	37	166	88	106		196	9	16		16			47	93		*774*
	31_33									11							*11*
	32	14	59	42	37	19	144	4	18		12	8	44	25	30	18	*474*
	33	18	84	39	83		107	8	16			17	55	28	47	27	*529*
	33_34					25					32						*57*
Manufacture of motor vehicles, other transport eqpt	34	30	44	76	48		191	2	15				46	67	79		*598*
	34_35									17		32				36	*85*
	35	12	58	29	29	23	152	28	5		15		158	35	84		*628*
Manufacture of furniture	36	14		92	56	35	490		5		51	76	107	64	374		*1364*
	36_37		371			60			26	18						64	*539*
	36_40_41							91									*91*
Recycling	37	5		34	14		36				9	9	26	13	57		*203*
Electricity,	40		61	34	70	90	47		28	4	39			7	90		*470*

gas, steam and hot water supply ; Collection, purification and distribution of water	40_41	6										66	138			37	*247*
	41		58	38		25	74		24		28			12	118		*377*
Wholesale trade and commission trade	51	17 9	2297	761	270	392	526	105	95	116	338	340	237	160	946	279	*7041*
Transport	60		651	110	85	207	261		21		222	92	98	74	367		*2188*
	60_61											55					*55*
	60_61_62	79						22	33	25						70	*229*
	61				23		11					1	120		28		*183*
	61_62		25	5		13					10			13			*66*
	62				5		13						17		9		*44*
	62_63											132					*132*
	63	23	213	97	171	129	183	46	21	23	53		210	54	114	11	*1348*
	63_64															22	*22*
Postes et telecomm.	64	15	106	18	45	18	126	14	6		24	27	41	15	67		*522*
	64 65 66 67									49							*49*
Finance and insurance	65	41	65	65	97	15	69	8			12	32	105	52	47	17	*625*
	65_66_67								17								*17*
	66	3	27	37	43		90	12			21	15	38	24	32	15	*357*
	66_67					20											*20*
	67	24	53	53	43		44	34			13	8	42	23	13	4	*354*
Computer	72	72		133	105		266	38	14		29	32	21	20	250	35	*1015*
	72_73		160			45				47			234	17			*503*
R&D	73	8		25	64		89		16		14	23			187	26	*452*
Other business activities	74	89	149	225	182	124	215	30	21	31	69	53	242	60	138	46	*1674*
	Total	*12 73*	*10279*	*3300*	*2906*	*2384*	*8024*	*1543*	*951*	*680*	*1863*	*1993*	*3548*	*1804*	*7479*	*1734*	*49761*

For this reason, we have built a new classification in order to study if innovation adoption has some sector-specific features. This new classification is based on the following constraints:

- it relies on the aggregation made by countries
- it is consistent with traditional breakdown,
- it excludes inconsistent aggregations

This has lead to a new classification consisting of 20 sectors. They are detailed in table A.II.2.2 below. The most represented sectors (in terms of the number of firms recorded in the sample) are Wholesale trade, Manufacture of textiles, Manufacture of food products and tobacco, Manufacture of wood, paper and publishing, Metallurgy and Transport.

Table A.II.2.2. Distribution between sectors	**Weighted micro data**	**CIS3**

Sector	Nb of obs.	%
Computer	8472.4	2.7
Electricity. gas. steam and hot water supply ; Collection. purification and distribution of water	3605.6	1.1
Electronics	11811.0	3.7
Finance and insurance	7277.3	2.3
Manufacture of coke. chemicals. plastic	14657.1	4.6
Manufacture of food products and tobacco	24705.8	7.8
Manufacture of furniture	9221.4	2.9
Manufacture of motor vehicles. other transport eqpt	4611.5	1.5
Manufacture of other non-metallic mineral products	9385.1	3.0
Manufacture of textiles. wearing apparel. tanning and dressing of leather	25518.2	8.1
Manufacture of wood. paper and publishing	23066.1	7.3
Mechanics	15843.8	5.0
Metallurgy	26255.0	8.3
Mining and quarrying	2379.9	0.8
Other business activities	17119.2	5.4
Postes et telecomm	1994.0	0.6
R&D	1751.6	0.6
Recycling	1340.1	0.4
Transport	38480.8	12.2
Wholesale trade and commission trade	63837.4	20.2
Total	315381.3	100.0

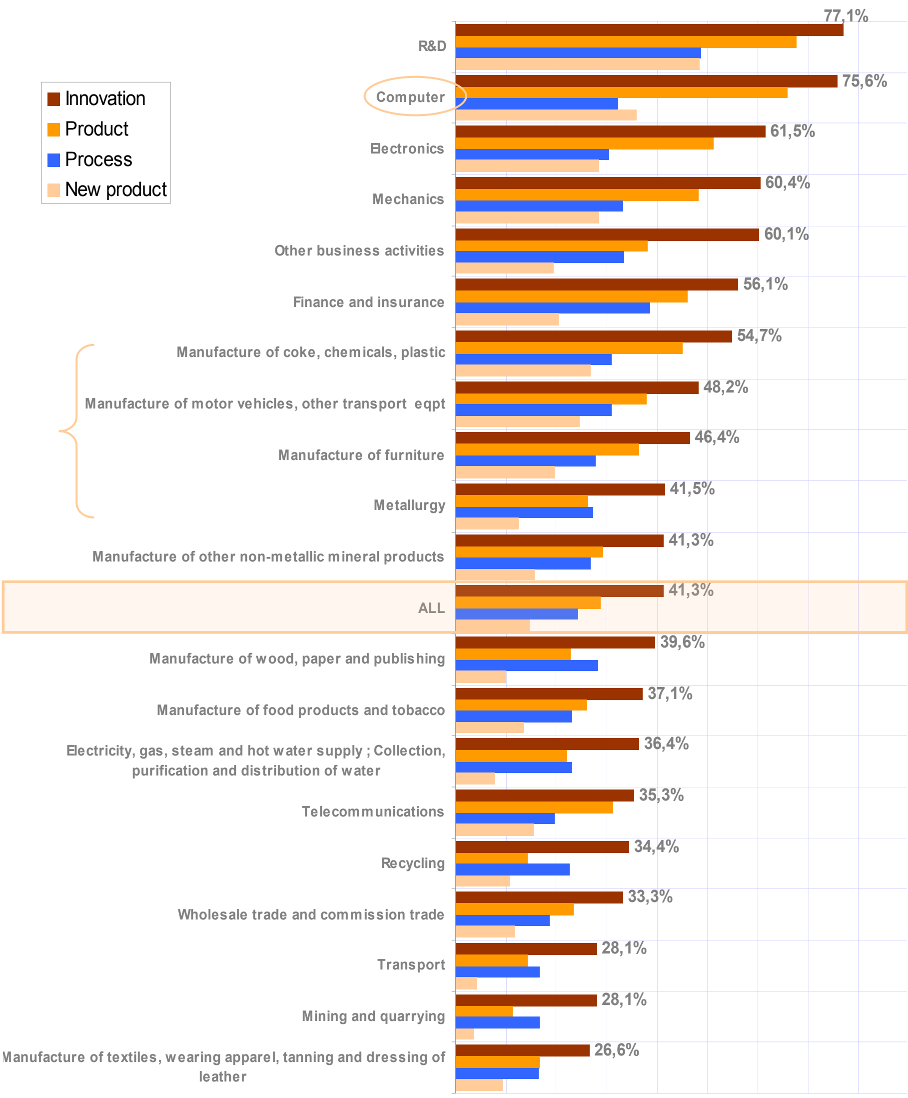
A.II.2.2. The role of Innovation at the sectoral level

Before going into the details of innovation adoption we turn to analyze the level and nature of innovation activity across sectors. Industries and service sectors show very different patterns in terms of level of innovation (see Figure A.II.2.1). The lowest rates of innovation are observed in Manufacture of textile, Transport and Mining. In these three sectors, less than one over three is engaged in innovative activities (in the sense of product, process, on going or abandoned innovations). Not surprisingly, the R&D sector is the more innovative one, for all types of innovations. Just behind R&D, computer sector faces very high rates as well.

More than three firms over four in these two sectors are engaged in innovative activities against 41.3% for all the sectors together. Electronics and mechanics follow, but with a much lower rates (less than two firms over three are innovative ones). In the service sectors, after R&D, Other business activities and Finance and Insurance are the most innovative ones.

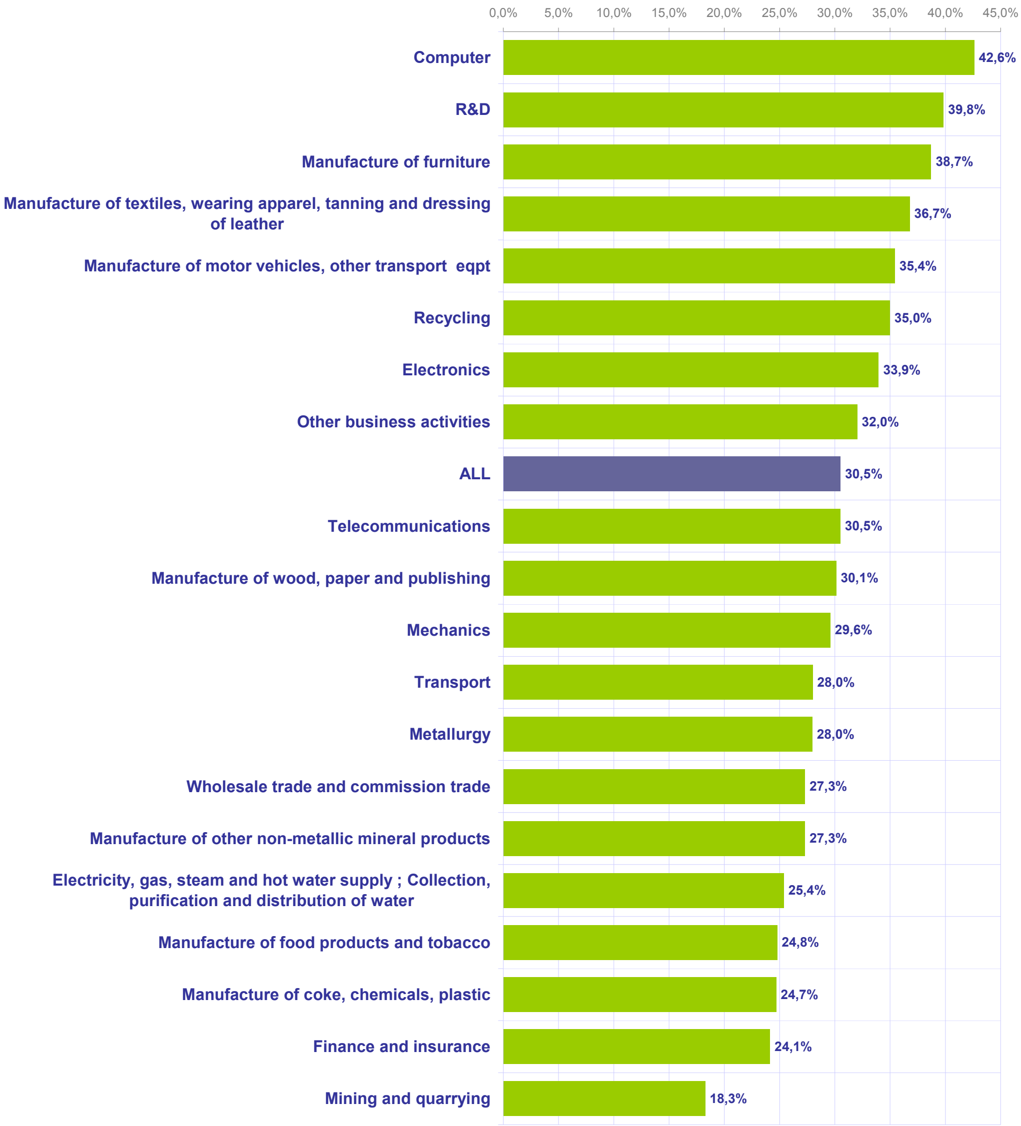
Product innovations are predominant in most sectors. Process innovations are predominant for only 6 sectors: Metallurgy, Manufacture of wood, Energy supply, Recycling, Transport and Mining.

Figure A.II.2.1: Nature of innovation by sector



Heterogeneity between sectors also arises in the share of turnover due to innovation (see Figure A.II.2.2). On average, 30.5% of firm sales are due to innovation. But it raises 42.6% in computer sector, and on the opposite it represents only 18.3% in Mining and quarrying. Innovative sales appear to be particularly low in service sectors. Finance and insurance, identified as relatively strongly innovative is one of the sectors in which innovative sales are the lowest (less than 25% of turnover is due to innovation). Other important service sectors, Wholesales trade and Transport, face also a relatively low share of innovative sales.

Figure A.II.2.2: Share of sales due to innovation



A.II.2.3. Magnitude of Innovation Adoption

Several sector specific features may be highlighted when we look at innovation adoption and not just general innovation. We first focus on the share of adopting firms and then we consider the share of sales due to innovation within adopting firms.

Share of adopting firms

Two main sectors can be identified as important actors of adoption (see Table A.II.2.3): Electricity and Finance and Insurance. These two sectors have the highest rates of adoption, whatever the definition. According to the broad definition of adoption, more than one innovative firm over two in these sectors is engaged in innovation adoption. On the opposite, some sectors do not rely strongly on innovation adoption. This is the case for two different kinds of sectors. The first set of sectors concerns high innovative ones: Computer, R&D, Mechanics, and to a lesser extent, Electronics. In these highly innovative sectors, innovation is mainly based on product and process innovations developed mainly within the firm. Therefore their high rates of innovation do not lead to high rates of adoption. The second set of sectors concerns conversely industries with few innovation activities: Mining and Manufacture of textile. In this case, the low level of innovation is general. It concerns at the same time the innovation developed within the firms and the innovation adopted from others or in collaboration with others, leading to low adoption rates.

The rates of adoption vary slightly according to the definition. This is the case in particular for Manufacture of wood and Recycling. Their adoption rate according to the restrictive definition of adoption (based on the item “New to the firm only”) is low, whereas their adoption rates based on the broad definition is relatively high.

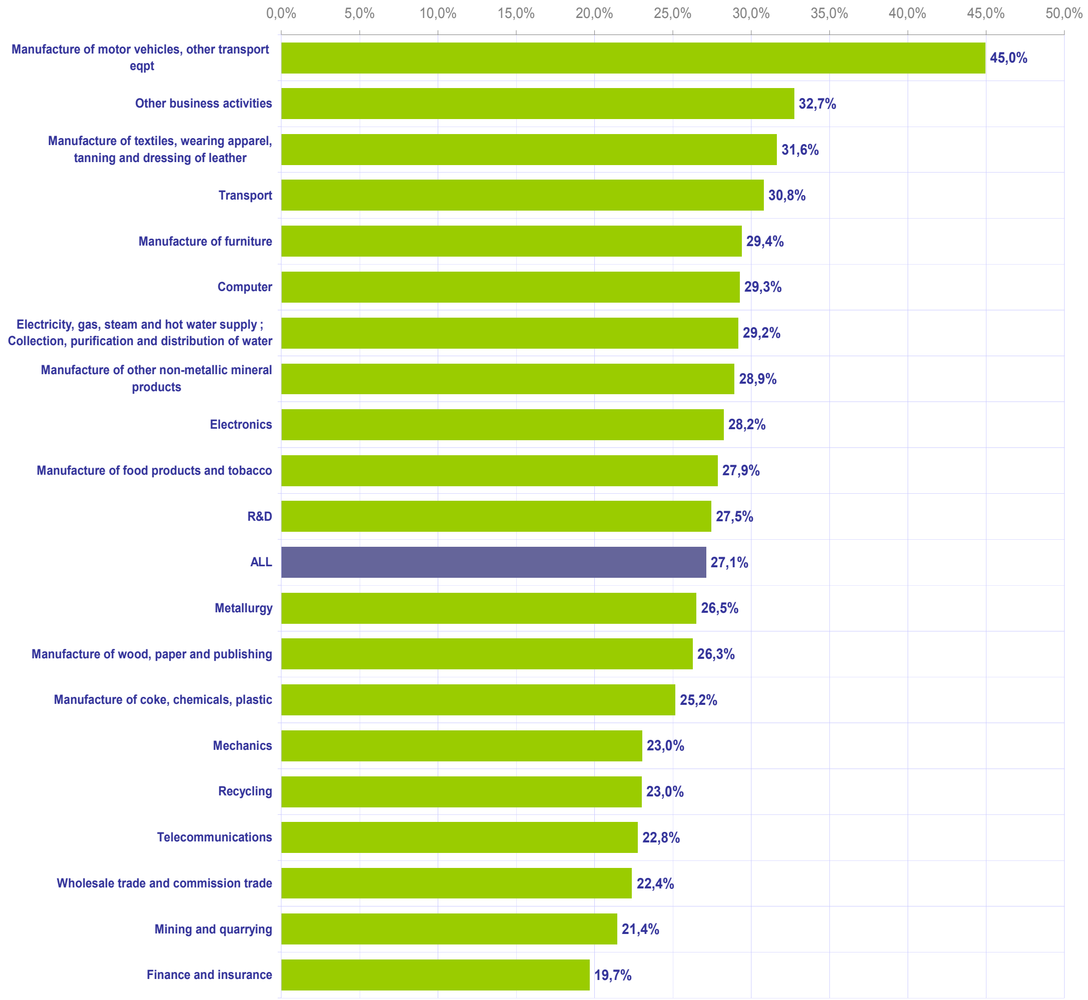
Table A.II.2.3. Innovation Adoption

Sector	"New to the firm" adoption		Broad definition of adoption	
	Nb of obs.	Adoption rate	Nb of obs.	Adoption rate
Computer	344.7	5.4%	1859.0	29.0%
Electricity. gas. steam and hot water supply	338.0	25.7%	833.4	63.4%
Electronics	605.0	8.3%	2149.3	29.6%
Finance and insurance	903.8	22.2%	2160.1	52.9%
Manufacture of coke. chemicals. plastic	893.7	11.1%	2598.8	32.4%
Manufacture of food products and tobacco	698.5	7.6%	2996.7	32.7%
Manufacture of furniture	267.0	6.2%	1266.9	29.6%
Manufacture of motor vehicles. other transport eqpt	145.8	6.6%	827.2	37.2%
Manufacture of other non-metallic mineral products	632.5	16.3%	1724.5	44.4%
Manufacture of textiles	348.8	5.1%	2405.5	35.5%
Manufacture of wood. paper and publishing	1285.6	14.1%	4688.2	51.3%
Mechanics	844.0	8.8%	2985.7	31.2%
Metallurgy	1135.8	10.4%	4293.3	39.4%
Mining and quarrying	31.1	4.6%	183.1	27.4%
Other business activities	1393.1	13.5%	3447.4	33.5%
Postes et telecomm	74.7	10.6%	234.5	33.3%
R&D	85.6	6.3%	464.3	34.4%
Recycling	31.8	6.9%	253.0	54.9%
Transport	1950.8	18.0%	5155.9	47.6%
Wholesale trade and commission trade	3374.7	15.9%	10710.6	50.4%
ALL	**15518.9**	**11.9**	**51862.1**	**39.9**

Share of sales due to adoption of innovation

Once again, the picture is very different once adoption is accounted for by the share of sales (see Figure A.II.2.3). Clearly, the adoption of innovation produces a positive impact on the turnover of firms belonging to the industry of transport (Manufacture of motor vehicles and other transport equipment). In this industry, firms engaged in innovation adoption declare that 45% of their sales are due to innovation. If we compare with Figure A.II.2.2, this is larger than the share of sales due to innovation in this whole sector (35.4%). This means that the impact of innovation on turnover is particularly high when innovation is based on adoption.

Figure A.II.2.3. Share of sales due to adoption ("New to the firm" adoption definition)



On the contrary, most sectors have lower share of sales due to innovation when we focus on adopting firms. This means that the impact of innovation on turnover is higher when innovation does not rely on adoption. This is the case for the whole sample (for which the share of sales fall from 30.5% to 27.1% when only adopting firms are considered) and especially for Computer, R&D, Manufacture of furniture, Recycling.

Service sectors are here clearly characterized by a low impact of innovation for firms that rely on adoption. Less than 20% of sales are due to innovation in adopting firms of Finance and insurance industry. Wholesales trade, as well as telecommunications, are also far below the average share of sales, with respectively 22.4% and 22.8%.

A.II.2.4. Nature of Innovation Adoption

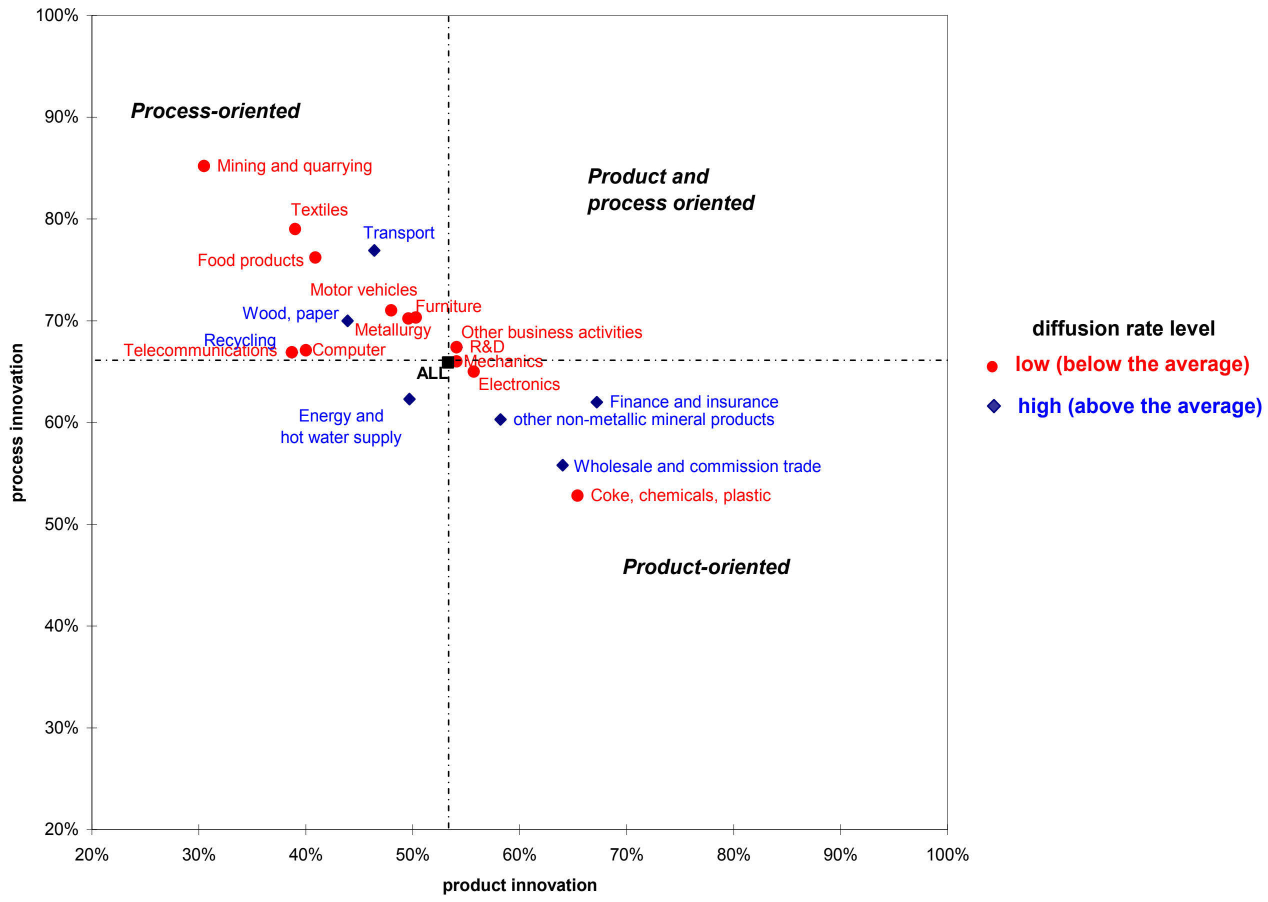
We can characterize sectors according to the nature of adoption that prevails within each of them. This is achieved first by considering product vs process innovation adoption. Then, we observe the differences between sectors regarding their level of cooperation. Notice however that the rates given bellow cannot be directly compared to those presented elsewhere in the report. Indeed they rely on ratios in which the denominator is the number of adopting firms, whereas the remainder of the report use the number of innovative firms as denominator.

Adoption of product innovation vs. adoption of process innovation

The Figure A.II.2.4 clearly shows sectors which are rather process-oriented in terms of innovation adoption[73]. Not surprisingly, they concern essentially industrial sectors like Mining, Textiles, Food products, Motor vehicles, wood, metallurgy and furniture. Only one service sector is represented here: Transport. The other service sectors are either product-oriented (Wholesale and commission trade, Finance and Insurance) or close to the overall situation (Other business activities, R&D). Manufacture of coke, chemicals and plastics has a specific profile compared to other industrial sectors since it is product-oriented.

[73] Notice that the rates recorded in this graph cannot be directly compared with the product and process adoption rates presented in Part II of the report. They are computed here as a ratio of the number of diffusing firms, whereas they are computed as a ratio of the number of respectively product and process innovative firms in the remainder of the report.

Figure A.II.2.4. Nature of innovation adoption by sector[74] – Product vs Process



Cooperation-based adoption vs. other organizations-based adoption

Sectors can also be compared by looking at how firms diffuse innovation. As previously mentioned, adoption may rely on adoption of product or process mainly developed by other firms or institutions, or on joint development of product or process based on cooperation with other firms or organizations.

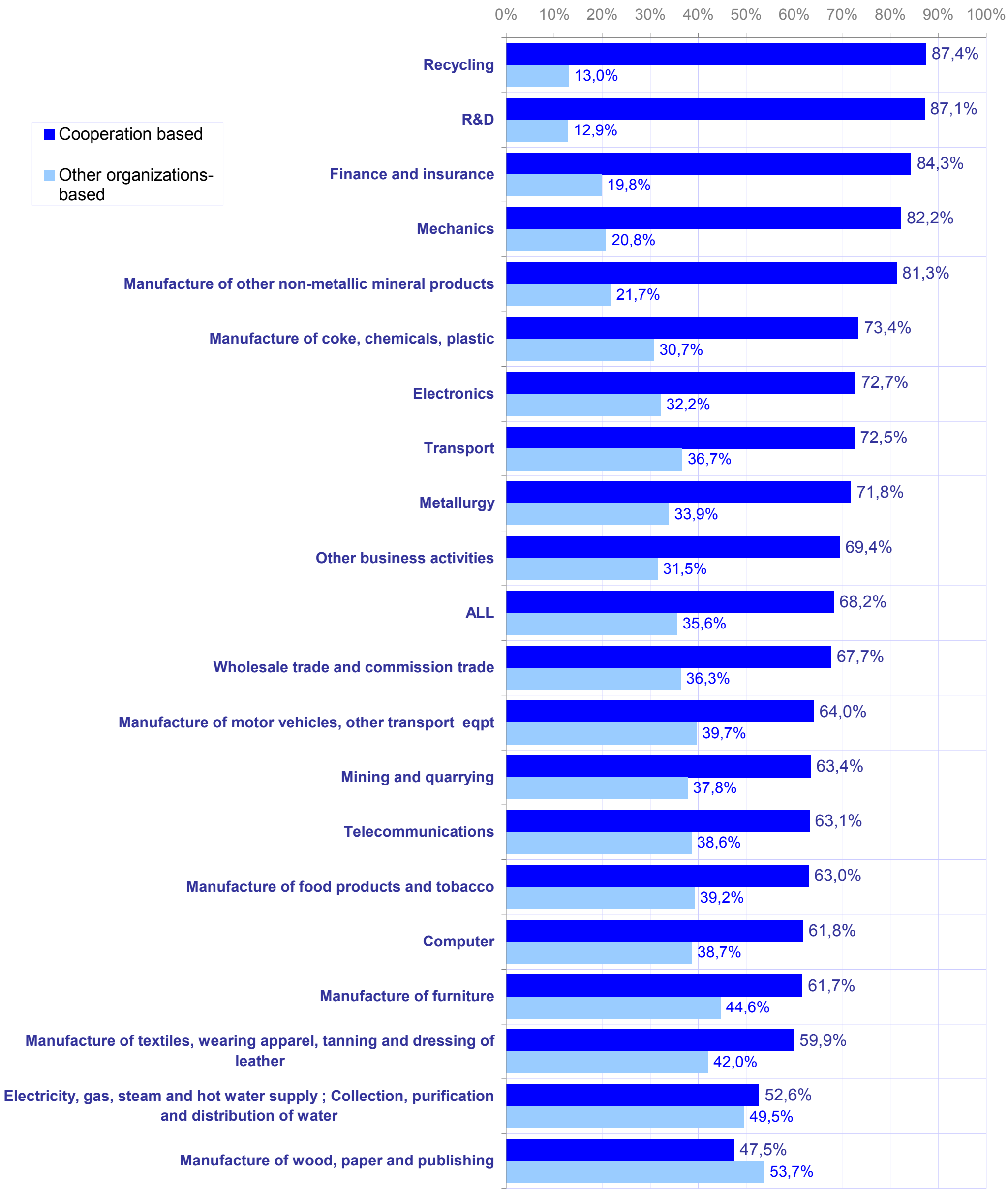
Although cooperation is the main vector of adoption in each sector, important disparities between sectors arise[75]. Cooperation-based adoption concerns 47% of adopting firm in Manufacture of wood, paper and publishing (this industry is the only exception for which

[74] X and Y axis correspond to respectively indicators 4 and 5 presented in the part II.2.3. The adoption rate corresponds to definition 2.

[6] Notice that the rates recorded in this graph cannot be directly compared with the cooperation-based and other organizations-based adoption rates presented in Part II of the report. They are computed here as a ratio of the number of diffusing firms, whereas they are computed as a ratio of the number of innovative firms in the remainder of the report.

cooperation-based adoption is lower than innovation developed mainly by others), whereas it exceeds 87% in R&D and Recycling.

Figure A.II.2.5. Cooperation based and other organisations-based adoption by sector



A.II.2.4. Conclusion on the analysis by sector

The Table A.II.2.4 gives a sectoral typology according to the product or process nature of innovation adoption and the level of cooperation.

Table A.II.2.4. Classification of sectors considering their rates of adoption in comparison with the total

		High level of cooperation	Low level of cooperation
Nature of adoption	Mainly process adoption	Transport Metallurgy	Wood, paper, publishing Computer Food products and tobacco Furniture, Motor vehicles, other transp eqpt Textiles Mining and quarrying Telecommunications
	Mainly product adoption	Finance and insurance Other non-metallic mineral products Coke, chemicals, plastics Electronics	Wholesale trade and commission trade
	Process and product adoption	Other Business activities	
	No specific profile	Recycling R&D Mechanics	Energy and water supply

NB: Countries have been classified thanks to a conformity test.

Two main groups of sectors appear:

- **Process-oriented sectors with a low level of cooperation**. This group concerns essentially industries: Wood/paper, Computer, Food products, Furniture, Motor vehicles, Textiles, Mining. Telecommunications is the only service sector in this group.
- **Product-oriented sectors with a high level of cooperation.** This group concerns 3 industries: Other non-metallic mineral products, Coke/chemicals/plastics and Electronics, and one service sector: Finance and insurance.

Finally, we can highlight from the Table A.II.2.4 a strong heterogeneity of profiles for service sectors.

Appendix II.3. Robustness check of our indicator of Innovation Adoption and discussion of alternative indicators

This appendix provides a review of the indicators that could be used to measure innovation adoption. They are presented in the first point, with some illustrations of the usefulness of these indicators and a discussion of some of their limitations.

Specially due to the impossibility to cross several items on Eurostat website, we choose to focus on a single definition of adoption, for which the double counting problem is less important. This said, we believe to be interesting to make some comparisons on different measures of innovation adoption that can be derived from alternative definitions of adoption.

Comparing the statistical results obtained by country provides us with some interesting information on the extent of adoption. These comparisons are presented in point 2 of this appendix. Notice however that these comparisons can be made only on the basis of the micro database, for which double counting problem does not occur. The number of countries is thus reduced to 14.

A.II.3.1. Alternative definition of adoption and related indicators of adoption magnitude

In the CIS, firms have to indicate whether their product innovations are new for the market or only new for the firm. Focusing on product that are new to the firm only will be more efficient to account for "pure" innovation adoption, since it considers only firms that adopt existing technologies, developed outside the firm. In other words, adding the "new for the firm only" item would ensure that the innovation already existed.

Although it obliges us to focus on product innovation only, this definition provides us with additional information, namely the turnover associated to innovation. Indeed, firms have to indicate the distribution of their turnover due to "new to the market" and to "new to the firm" innovations. This distribution gives interesting information. It allows us not only to identify innovation adoption but also to quantify innovation adoption. This leads to the following alternative indicators of the magnitude of adoption.

A.II.3.1.1. Share of sales

Following Mairesse and Mohnen (2002), the extent of innovation adoption can be measured by the share of sales due to innovation in adopting firms.

Indicator A.1: Turnover * share of sales due to innovation in adopting firms

This provides us with a measure of the magnitude of innovation adoption that can be observed at both firm and sectoral level.

A.II.3.1.2 Share of adoptive firms

An alternative method can rely on the share of adoptive firms. Two different ratios could be considered:

Indicator A.2a: Adopting enterprises / total number of enterprises

Problems of interpretation will arise with this indicator when comparing countries and sectors. Indeed, the differences between countries or NACE sectors could be due to the underlying differences in the magnitude of adoption but also from differences in the intensity of innovation (activities or countries with higher level of innovation will exhibit higher ratio). So, we suggest using a ratio based on innovative enterprises only.

Indicator A.2b: Adopting enterprises / number of innovative enterprises

This will ensure that cross country or cross sector differences in adoption magnitude are not due to differences in innovation intensity. It also provides us with more tractable data. Indeed, the percentages are higher than with indicator A.2a and its variance is higher as well. Therefore, the inference made on this basis will be more efficient.

This latter indicator is similar to the one used in the report which considers as innovative firms those engaged in product and/or process innovation activities, but also with "ongoing or abandoned innovation activities"). Compared to the share of turnover (Indicator A.1), these second kind of indicators are available at sector or country level only. This means that we cannot build an indicator of adoption intensity at the firm level. In this case, measuring magnitude of innovation adoption requires aggregated data.

A.II.3.2. Some comparisons of the different adoption indicators

A.II.3.2.1. Overall comparison

Table A.II.3.1 gives the main statistics obtained with the different indicators of magnitude. Sales are expressed as a percentage of turnover (this information being available only for firms that introduce product innovation). Compared to the share of sales due to innovative activities in the whole sample, the share of sales due to innovation in adopting firms is lower. For the whole sample, the average share of turnover due to innovation is 30.5% while it is 27.1% here. This means that the importance of innovation (in term of sales) is lower for adopting firms than for firms that innovate mainly by themselves.

Table A.II.3.1. Magnitude of Innovation Adoption

	Indicator A.1: Share of Sales	Indicator A.2a: % of firms	Indicator A.2b: % of innovative firms
"New to the firm" adoption definition	27.1	4.9	11.9
Broad adoption definition	-	16.4	39.9

Indicators A.2a and A.2b highlight that the definition based on " new to the firm" adoption only provides us with very low rates of innovation adoption. 4.9% of the firms participate to innovation adoption according to this definition, meaning that their product innovations, new to the firm only, were developed in cooperation with other enterprises or institutions or developed mainly by other enterprises or institutions. This rate is higher considering the broad definition of adoption. Indeed, for 16.4% of firms, product or process innovations have been developed "in co-operation with other enterprises or institutions" or "mainly by other enterprises or institutions".

These low rates of adoption will be more sensitive at the country level for the less innovative countries. This is especially the case of indicator A.2a, computed as the ratio between the number of "adopting firms" and the total number of enterprises. Once divided by the number of innovative firms only, the rates are higher for both definitions (respectively 11.9% and 39.9%), suggesting that this third indicator will be more tractable for econometric purpose.

These considerations lead us to favour in the report the broad definition of adoption and indicator A.2a of magnitude.

A.II.3.2.2. Comparison by country

Whatever the definition of innovation adoption used, Belgium, Norway and Bulgaria appear as highly adopting countries (see Table A.II.3.2). For the other countries their differences of ranking according to the definition used is higher. For example, firms from Iceland do not do much innovation adoption according to the restrictive definition of adoption ("New to the firm" adoption definition) whereas the magnitude of innovation adoption according to the broad definition of adoption for this country is among the highest.

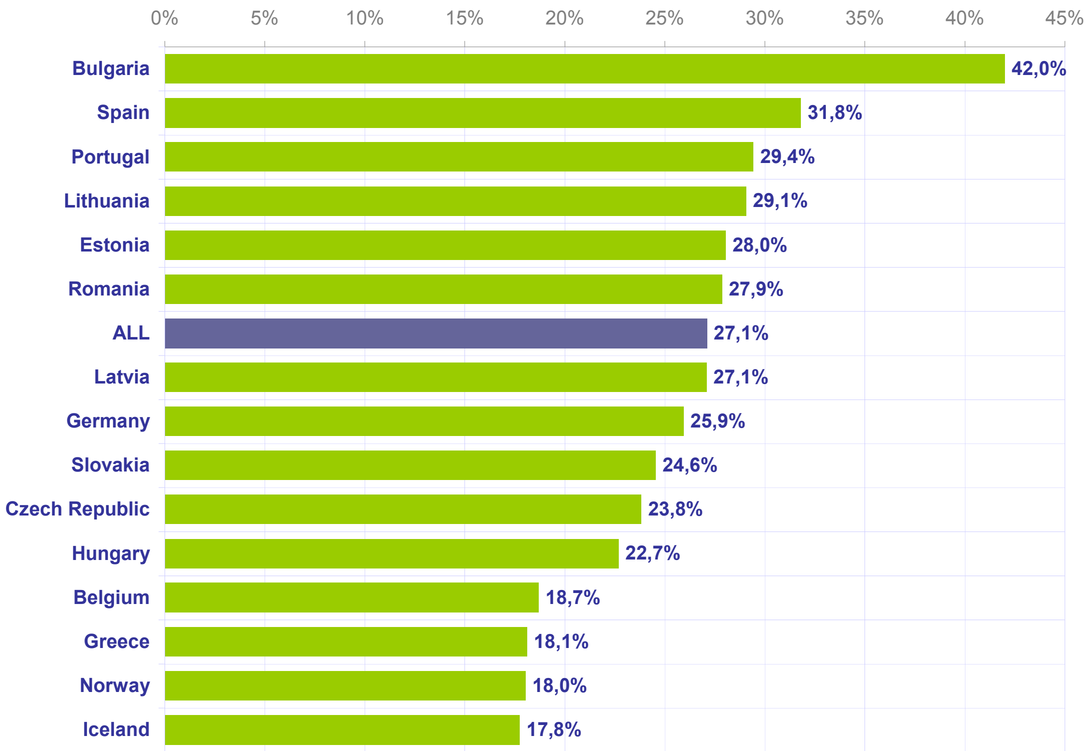
Innovation adoption can also be accounted for the share of sales due to innovation adoption (see Figure A.II.3.1 below). This gives a very different picture. Except Bulgaria that remains among the most adopting countries, the ranking of countries is drastically changed. In particular, Belgium, Iceland and Norway experience very low rates of sales due to innovation adoption. This means that even if the share of adopting firms is relatively high in these countries, the impact of this adoption in terms of sales is rather limited.

Table A.II.3.2. Magnitude of Innovation Adoption by country

Innovation adoption	"New to the firm" adoption definition		Broad adoption definition	
Country	**Nb of obs.**	**Adoption rate**	**Nb of obs.**	**Adoption rate**
Belgium (BE)	977	15,4	3170	50,1
Bulgaria (BG)	151	12,6	535	44,8
Czech Republic (CZ)	529	9,2	1937	33,8
Germany (DE)	9901	14,4	27248	39,6
Estonia (EE)	146	12,4	442	37,7
Spain (ES)	1897	8,7	9062	41,5
Greece (GR)	113	10,9	293	28,4
Hungary (HU)	396	13,2	899	30,1
Iceland (IS)	21	5,6	164	43,5
Lithuania (LT)	87	7,6	376	33,0
Latvia (LV)	38	5,1	271	36,2
Norway (NO)	429	13,4	1454	45,4
Portugal (PT)	639	6,1	4291	40,9
Romania (RO)	82	2,2	1321	34,8
Slovakia (SK)	113	9,8	398	34,3
Total	15519	11,9	51862	39,9

According to this indicator, we can notice the relative weak weight of the most developed countries. Belgium, Germany and Norway are representative in this sense with a high percentage of firms practising innovation adoption and a low share of sales due to this activity over the total of their turnover (see Figure A.II.3.1). **This would reflect the positioning of countries on the innovation life cycle. While developed countries would base most of their activities on the development of new products, less developed European countries would benefit from the adoption of existing technologies.**

Figure A.II.3.1. Share of sales due to adoption (based on "New to the firm" definition of adoption)



Appendix II.4. Principal Component Analysis (PCA) concerning sources of information for innovation

A.II.4.1. Objectives

The objectives of this PCA are to analyze correlations between various variables regarding the sources of information for innovation, on the one hand, and to describe European countries according to the importance of these different sources, on the other hand.

A.II.4.2. Database

At the beginning, the database contains the 22 studied countries (see Figure II.11) and 9 variables:

- SENT_HIGH : percentage of innovative firms highly using internal sources within the enterprise
- SGRP_HIGH : percentage of innovative firms highly using internal sources from other enterprises within the enterprise group
- SSUP_HIGH : percentage of innovative firms highly using market sources from suppliers of equipment, materials, components or software
- SCLI_HIGH : percentage of innovative firms highly using market sources from clients or customers
- SCOM_HIGH : percentage of innovative firms highly using market sources from competitors and other enterprises from the same industry
- SUNI_HIGH : percentage of innovative firms highly using institutional sources from universities or other higher education institutes
- SGMT_HIGH : percentage of innovative firms highly using institutional sources from government or private non-profit research institutes
- SPRO_HIGH : percentage of innovative firms highly using sources from professional conferences, meetings, journals
- SEXB_HIGH : percentage of innovative firms highly using sources from fairs and exhibitions

After a first analysis, we have finally dropped the Iceland and the variable SGRP due to numerous missing observations, which may have biased the results.

A.II.4.3. Results

We can observe that the two first axes account for 83,88% of the variance, which can be considered as a good result for a PCA (see Table A.II.4.1).

The correlation circle (Figure A.II.4.1**)** and Pearson correlation matrix (Table A.II.4.2) show:

- A strong and positive correlation between the two institutional sources on the axis 1 (SUNI_HIGH and SGMT_HIGH). Countries that are at the left of the graph (see Fig. II.11) record a high level of use of these two kind of sources.

Table A.II.4.1. Eigen values for each components

Axis	Eigen value	% explained	% acumulated
1	4,736743	59,21%	59,21%
2	1,973917	24,67%	83,88%
3	0,69401	8,68%	92,56%
4	0,300543	3,76%	96,32%
5	0,168939	2,11%	98,43%
6	0,063328	0,79%	99,22%
7	0,051378	0,64%	99,86%
8	0,011142	0,14%	100,00%
Tot.	8	-	-

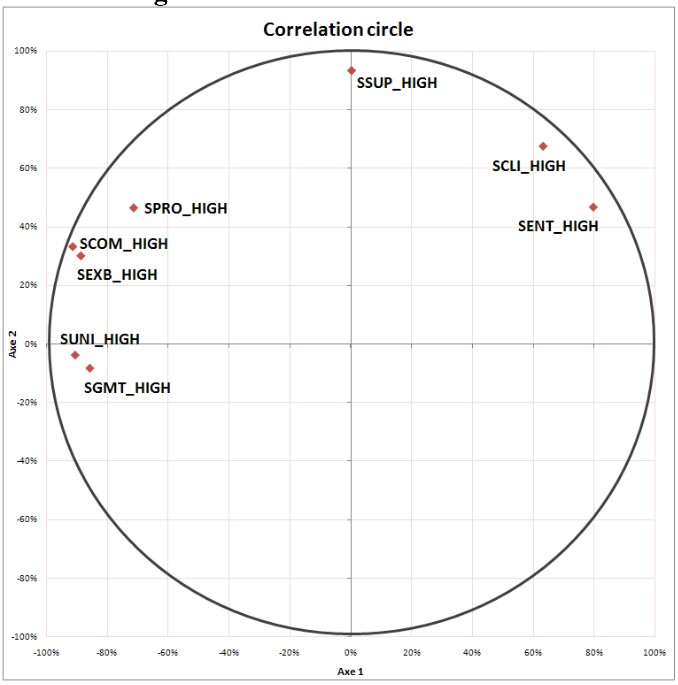
- A strong and positive correlation between the other external sources and information from competitors. These variables (SPRO_HIGH, SCOM_HIGH and SEXB_HIGH) are mainly present on the axis 1 and a somehow less on the axis 2. These 3 variables are generally well correlated with the institutional sources.
- A strong and positive correlation between internal and clients sources. Countries which are on the right of the axis 1 have a high level of internal source. If countries are also on the bottom, they record an important use of information from clients.
- The use of supplier sources is at the top of the graph. So, countries at the top of the graph exhibit a high level of use of this kind of information contrary countries at the bottom. This variable is only significantly correlated with client sources.

Table A.II.4.2. Pearson correlation matrix and level of significance (in italics)

	SENT_ HIGH	SCLI_ HIGH	SSUP_ HIGH	SPRO_ HIGH	SCOM_ HIGH	SEXB_ HIGH	SGMT_ HIGH	SUNI_ HIGH
SENT_HIGH	1	**0,814****	0,433	**-0,539***	**-0,461***	**-0,591****	**-0,600****	**-0,655****
		0,000	*0,050*	***0,012***	***0,035***	***0,005***	***0,004***	***0,001***
SCLI_HIGH		1	**0,561****	-0,415	-0,122	-0,381	-0,511	**-0,515***
			0,008	*0,062*	*0,599*	*0,089*	*0,018*	***0,017***
SSUP_HIGH			1	0,258	0,311	0,304	-0,045	-0,006
				0,258	*0,170*	*0,181*	*0,845*	*0,978*
SPRO_HIGH				1	**0,777****	**0,916****	**0,663****	**0,733****
					0,000	***0,000***	***0,001***	***0,000***
SCOM_HIGH					1	**0,825***	0,405	**0,487***
						0,000	*0,069*	***0,025***
SEXB_HIGH						1	**0,707****	**0,769****
							0,000	***0,000***
SGMT_HIGH							1	**0,979****
								0,000
SUNI_HIGH								1

** The correlation is significant at 1% level.
 * The correlation is significant at 5% level.

Figure A.II.4.1. Correlation circle



Appendix II.5. Factorial Correspondence Analysis (FCA) and additional descriptive statistics concerning innovative expenditure

A.II.5.1. Objectives

The objectives of this FCA are to analyze the correlations between various variables regarding the different modalities of R&D expenditures, on the one hand, and to identify European countries profiles according to the R&D expenditure nature, on the other hand.

A.II.5.2. Database

The database contains the 19 countries (Austria, Luxembourg and Sweden are not included because of missing values, see Figure II.14) and 4 variables:

- RRDINX : amount of innovative expenditure engaged in intramural R&D
- RRDEXX : amount of innovative expenditure engaged in extramural R&D
- RMACX : amount of innovative expenditure engaged in the acquisition of machinery and equipment
- ROEKX : amount of innovative expenditure engaged in the acquisition of other external knowledge

ROTHX (amount of expenditures engaged in training, market introduction of innovations and design) is not included in this analysis because this variable contains various types of expenditures.

A.II.5.3. Results of the FCA

Firstly, we can observe that the two first axes account for 95,86% of the variance, which can be considered as a very good result for a FCA[76].

Table A.II.5.1. Eigen values for each components			
Axis	**Eigen value**	**% explained**	**% acumulated**
1	0,1189	72,08%	72,08%
2	0,0392	23,78%	95,86%
3	0,0068	4,14%	100%

Khi² test shows that the dependence between rows and columns is very significant (the observed value of Khi² is equal to 5,12E+10 and the p-value to 0,00).

[76] The authors may provide more detailed information on the outputs of the PCA to the interested readers.

Table A.II.5.2. Additional descriptive statistics on innovation expenditure

Country	INNOVATION	Intramural research & experimental development	Acquisition of R&D (extramural R&D)	Acquisition of machinery & equipment	Acquisition of other external knowledge	Training	Market introduction of innovations	Design, other preparations for production/deliveries
Belgium	19,3%	42,1%	12,0%	61,2%	28,0%	38,3%	32,2%	17,6%
Bulgaria	17,4%	34,9%	6,6%	70,1%	18,2%	35,4%	30,3%	19,4%
Czech Republic	45,5%	36,3%	25,2%	74,4%	24,8%	35,7%	19,1%	11,9%
Germany	35,7%	56,2%	30,7%	36,8%	20,0%	39,9%	27,5%	22,4%
Estonia	45,2%	54,4%	25,0%	44,3%	14,9%	36,8%	35,6%	34,1%
Spain	18,7%	36,1%	15,5%	71,8%	23,8%	33,7%	31,5%	56,6%
Finland	28,0%	47,0%	13,2%	76,5%	32,3%	38,6%	40,7%	23,2%
France	36,2%	35,7%	11,6%	66,3%	16,9%	30,0%	16,5%	17,6%
Greece	52,9%	27,3%	16,4%	15,5%	6,7%	22,0%	22,2%	12,5%
Hungary	23,8%	47,7%	22,4%	39,6%	26,1%	12,4%	25,2%	6,3%
Iceland	14,3%	58,8%	15,7%	68,6%	11,7%	48,2%	46,9%	41,5%
Italy	40,1%	58,3%	20,6%	38,1%	13,4%	39,9%	30,5%	25,8%
Lithuania	44,9%	70,7%	37,8%	53,8%	25,3%	36,5%	31,0%	21,4%
Latvia	31,8%	34,0%	14,2%	59,1%	19,6%	29,9%	24,8%	18,1%
Netherlands	36,4%	40,7%	19,1%	56,5%	23,6%	37,8%	25,8%	23,4%
Norway	59,8%	50,4%	21,1%	73,1%	23,2%	57,2%	51,4%	57,3%
Portugal	31,7%	42,1%	15,8%	42,3%	17,0%	32,6%	37,5%	21,0%
Romania	11,5%	8,4%	13,1%	34,5%	13,5%	18,1%	21,2%	24,3%
Slovakia	49,1%	58,4%	25,5%	59,6%	18,4%	49,7%	37,0%	27,0%

Appendix II.6. Principal Component Analysis (PCA) concerning invention protection methods

A.II.6.1. Objectives

The objectives of this PCA are on the one hand, to analyze correlations between various variables regarding invention protection methods and, on the one hand, to describe European countries according to the importance of these different methods (see section II.4.3.1), on the other hand.

A.II.6.2. Database

The database contains the 22 studied countries (see Figure II.27) and 8 variables:

- PAAP : percentage of innovative firms having apply for at least one patent (between 1998 and 2000)
- IN_PAVAL : percentage of innovative firms being valid patent owner
- PROREG : percentage of innovative firms using registration of design patterns
- PROTM : percentage of innovative firms using highly trademarks
- PROCP : percentage of innovative firms using copyright
- PROSEC : percentage of innovative firms using secrecy
- PRODES : percentage of innovative firms using complexity of design
- PROTIM : percentage of innovative firms using lead-time advantage on competitors.

A.II.6.3. Results

As a first result, we can observe that the two first axes account for 81,56% of the variance. This can be considered a good result in a PCA context.

Table A.II.6.1. Eigen values for each components			
Axis	**Eigen value**	**% explained**	**% cumulated**
1	5,427731	67,85%	67,85%
2	1,097113	13,71%	81,56%
3	0,726168	9,08%	90,64%
4	0,372155	4,65%	95,29%
5	0,202075	2,53%	97,82%
6	0,10377	1,30%	99,11%
7	0,04535	0,57%	99,68%
8	0,025638	0,32%	100,00%
Tot.	8	-	-

The correlation circle (see Figure A.II.6.1) and Pearson correlation matrix (see Table A.II.6.2) show that almost all variables are positively and significatively correlated to each other.

The first axis of the factorial map will allow us to identify which are the countries which heavily rely on protection (both strategic and formal), as all variables are well represented on the right of the axis.

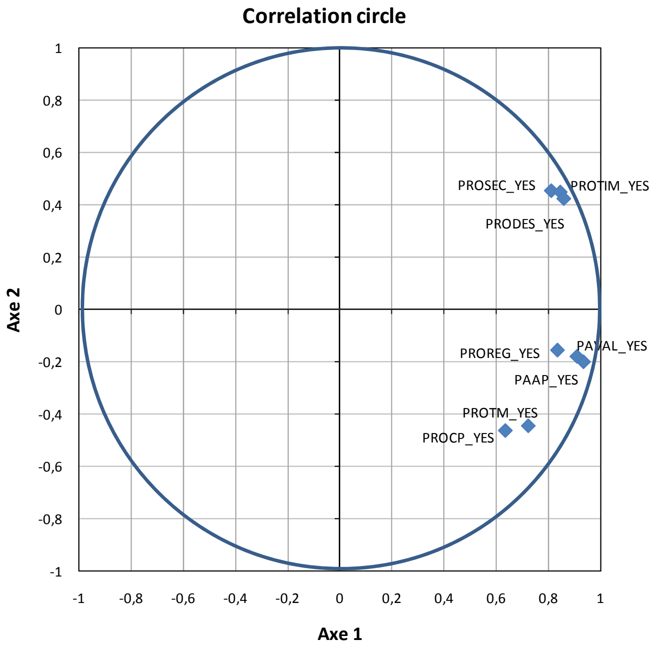
The second axis will allow us to distinguish countries relying mainly on strategic methods versus countries relying mainly on formal methods.

Table A.II.6.2. Pearson correlation matrix and level of significance (in italics)

	PAAP	IN_PAVAL	PROREG	PROTM	PROCP	PROSEC	PRODES	PROTIM
PAAP	1	**0,97***	**0,89***	**0,71***	**0,55***	**0,62***	**0,67***	**0,68***
		0	***0***	***0,000***	***0,007***	***0,002***	***0,001***	***0,000***
IN_PAVAL		1	**0,89***	**0,63***	**0,53***	**0,59***	**0,64***	**0,67***
			0	***0,0013***	***0,0091***	***0,0031***	***0,0009***	***0,0005***
PROREG			1	**0,53***	**0,45***	**0,58***	**0,56***	**0,55***
				0,0097	***0,0322***	***0,0041***	***0,0058***	***0,006***
PROTM				1	**0,63***	0,40*	**0,49***	**0,45***
					0,0012	*0,0575*	***0,0171***	***0,0297***
PROCP					1	0,39*	0,37*	**0,46***
						0,0648	*0,0868*	***0,0261***
PROSEC						1	**0,82***	**0,86***
							0	***0***
PRODES							1	**0,93***
								0
PROTIM								1

*** The correlation is significant at 0.01 level.
** The correlation is significant at 0.05 level.
* The correlation is significant at 0.10 level.

Figure A.II.6.1. Correlation circle



Appendix II.7. Descriptive statistics by country and sector

The distribution of firms among sectors in each country may, at least partly, explain the innovation and adoption performances of countries. In order to explore this issue, the three tables below record for each country respectively the distribution of firms among sectors, the innovation rates and adoption rates.

On the first table (Table A.II.7.1), numbers are written in bold character when there is a specialisation of the country in the sector (compared to the all EU distribution of firms). In order to see to what extent these specialisations may impact on the innovation and adoption rates, two criteria have been applied: the country/sector percentage must exceed the EU one by 20%, and it must also exceed 15% of firms of the country. This second criteria insures that the specialisation could impact on the country's overall innovation or adoption rate. Indeed, the strong specialisation of Norway in extractive insdustries cannot impact significantly on innovation performances. Even if innovation performances in this sector are low, less than 2% of Norvegian firms belong to this sector. This is therefore unlikely to impact on the averall Norvegian innovation and adoption rates

Table A.II.7.1. Distribution of firms by country and sector

	Extractives industry	Manufacture industry	Electricity, gaz and water	Wholesales and retail trade	Transports and communications	Financial activities	Computer and other business services	Total
Austria	0,80%	48,96%	1,08%	21,96%	14,25%	5,76%	7,20%	100,00%
Belgium	0,46%	45,96%	0,15%	**27,85%**	**16,25%**	3,07%	6,27%	100,00%
Bulgaria	1,07%	62,32%	1,18%	22,70%	9,83%	1,43%	1,47%	100,00%
Czech Republic	0,67%	61,62%	1,51%	17,58%	9,00%	1,35%	8,27%	100,00%
Germany	0,43%	42,57%	1,41%	18,83%	**17,72%**	3,10%	**15,95%**	100,00%
Estonia	1,14%	53,07%	4,30%	20,09%	**15,33%**	1,56%	4,52%	100,00%
Spain	1,09%	60,93%	0,58%	21,69%	10,36%	1,55%	3,79%	100,00%
Finland	0,46%	53,60%	2,92%	16,86%	**15,62%**	0,00%	10,53%	100,00%
France	0,84%	58,27%	0,47%	**24,58%**	0,48%	3,65%	11,70%	100,00%
Greece	0,81%	**81,63%**	0,03%	6,11%	4,16%	4,17%	3,09%	100,00%
Hungary	0,00%	62,54%	1,26%	19,43%	8,91%	2,07%	5,79%	100,00%
Iceland	0,82%	45,39%	0,92%	**25,52%**	10,31%	10,42%	6,62%	100,00%
Italy	0,75%	**73,54%**	0,39%	11,17%	8,11%	1,72%	4,33%	100,00%
Lithuania	0,98%	40,81%	2,78%	**25,02%**	**22,22%**	1,54%	6,65%	100,00%
Luxembourg	0,00%	24,10%	0,94%	19,26%	**21,28%**	**21,79%**	12,63%	100,00%
Latvia	0,85%	48,37%	2,91%	**24,42%**	**15,68%**	2,22%	5,55%	100,00%
Netherlands	0,36%	42,21%	0,33%	**27,83%**	**15,92%**	4,39%	8,96%	100,00%
Norway	1,81%	45,15%	2,73%	**23,94%**	**15,58%**	3,76%	7,03%	100,00%
Portugal	1,40%	68,72%	0,24%	20,25%	5,69%	1,85%	1,84%	100,00%
Romania	0,75%	62,16%	1,37%	20,97%	8,96%	1,30%	4,48%	100,00%
Sweden	0,36%	46,65%	1,51%	21,82%	14,19%	2,65%	12,82%	100,00%
Slovakia	0,87%	54,92%	1,31%	**26,59%**	6,92%	1,68%	7,71%	100,00%
ALL	0,73%	57,76%	0,92%	18,93%	11,11%	2,51%	8,05%	100,00%

Table A.II.7.2 Innovation rates by country and sector

Country	Extractives industry	Manufacture industry	Electricity, gaz and water production and distribution	Wholesale and retail trade	Transports and communications	Financial activities	Computer and other business services	Innovation total	Innovation total whithout Financial sector
Germany	44,6%	66,1%	49,5%	51,8%	39,2%	74,2%	76,7%	60,3%	59,8%
Iceland	100 %	48,5%	66,7%	35,5%	44,1%	68,6%	43,2%	54,0%	52,9%
Austria	32,8%	53,3%	37,8%	35,2%	22,9%	74,5%	94,1%	48,8%	47,2%
Belgium		57,3%	34,2%	46,1%	24,0%	36,3%	70,5%	48,8%	49,1%
Luxembourg	NC	49,7%		42,7%	35,9%	52,3%	69,1%	48,3%	47,1%
Sweden	24,6%	47,7%	100%	53,8%	22,6%	48,6%	59,9%	46,8%	46,7%
Portugal	29,5%	44,9%	67,3%	46,0%	41,0%	71,4%	69,3%	45,9%	45,5%
Netherlands	41,8%	54,6%	63,1%	39,9%	22,4%		57,2%	45,3%	45,2%
Finland	55,9%	49,5%	31,9%	43,1%	26,1%	NC	55,1%	44,9%	44,9%
France	20,4%	46,0%	23,7%	22,9%	41,3%	58,7%	48,8%	40,8%	40,1%
Estonia	28,0%	39,9%	26,3%	36,3%	24,1%	47,8%	35,2%	36,6%	36,4%
Italy	35,7%	40,2%	21,2%	20,3%	16,0%	41,5%	49,4%	36,3%	36,2%
Norway	38,8%	38,9%	40,8%	35,6%	13,9%	42,9%	36,8%	36,0%	35,7%
Spain	24,9%	37,1%	30,5%	20,4%	18,9%	48,5%	47,7%	32,0%	31,8%
Czech Republic	29,6%		21,7%	24,8%	21,8%	42,3%	39,3%	31,9%	31,7%
Lithuania	31,7%	35,3%	38,7%	25,1%	11,2%	44,2%	44,5%	28,2%	28,0%
Hungary	NC	29,1%	18,6%	9,3%	9,5%	13,5%	38,0%	23,5%	23,8%
Slovakia	14,1%	22,7%	8,0%	13,4%	3,6%	36,3%	31,8%	19,6%	19,3%
Latvia	29,0%	23,2%	17,2%	13,6%	10,0%	44,3%	24,8%	19,3%	18,7%
Romania	12,3%	19,7%	17,2%	10,1%			37,0%	17,2%	17,4%
Greece	NC	13,6%	NC	14,9%	9,6%	12,6%	42,6%	14,2%	14,3%
Bulgaria	5,6%	13,6%	9,2%	6,6%	4,7%	22,1%	26,2%	11,6%	11,5%
ALL	29,9%	43,1%	34,7%	31,8%	25,6%	54,3%	61,8%	40,7%	40,4%

Table A.II.7.3 Adoption rates by country and sector

Country	Extractives industry	Manufacture industry	Electricity, gaz and water production and distribution	Wholesale and retail trade	Transports and communications	Financial activities	Computer and other business services	Adoption total	Adoption total whithout Financial sector
Netherlands	62,4%	59,3%	76,1%	72,9%	66,8%	57,0%	37,1%	60,7%	60,9%
Iceland	NC	47,1%	50,0%	58,7%	37,9%	78,9%	38,7%	52,0%	43,0%
Belgium	52,6%	48,7%	46,2%	53,7%	73,9%	23,9%	34,1%	50,1%	50,7%
Norway	61,4%	45,2%	60,2%	45,6%	52,3%	67,7%	52,4%	48,2%	44,4%
Austria	NC	41,6%	NC	41,1%	51,6%	65,2%	52,4%	45,2%	43,3%
Bulgaria	33,3%	38,1%	100%	67,8%	66,0%	56,3%	43,6%	44,5%	44,5%
Spain	32,5%	38,2%	59,8%	55,4%	52,2%	55,9%	31,2%	41,5%	41,1%
Finland	41,2%	34,2%	76,0%	66,3%	51,2%	NC	28,1%	41,1%	41,1%
Portugal	4,4%	38,4%	62,0%	52,8%	38,1%	40,6%	31,0%	41,0%	40,9%
Germany	20,8%	36,0%	63,1%	49,6%	46,0%	56,5%	31,7%	39,6%	38,9%
Estonia	40,1%	31,6%	71,2%	47,9%	41,9%	57,1%	33,6%	37,9%	37,3%
Italy	39,1%	33,6%	60,4%	48,4%	48,9%	74,8%	39,4%	36,3%	35,5%
Latvia	68,7%	27,4%	61,1%	49,7%	44,5%	40,0%	47,7%	36,2%	35,9%
Sweden	13,6%	33,6%	65,9%	47,0%	45,7%	58,2%	17,2%	36,1%	35,5%
Romania	34,9%	32,9%	48,5%	52,4%	30,9%	31,0%	26,4%	34,8%	34,8%
Slovakia	NC	34,9%	50,0%	38,0%	61,5%	16,6%	28,9%	34,3%	34,9%
Czech Republic	24,7%	31,7%	79,7%	39,1%	38,0%	27,3%	34,3%	33,8%	33,9%
Lithuania	27,4%	27,8%	68,6%	42,5%	24,3%	47,3%	29,5%	33,0%	32,6%
France	41,4%	30,9%	49,5%	35,8%	NC	NC	32,4%	30,1%	31,8%
Hungary	NC	28,4%	72,6%	48,6%	21,8%	50,2%	24,5%	30,1%	29,8%
Greece	NC	25,7%	NC	32,4%	26,7%	55,6%	38,3%	28,4%	27,3%
Luxembourg	NC	NC	NC	32,2%	33,3%	32,3%	15,3%	21,2%	17,7%
ALL	31,7%	36,3%	61,6%	50,8%	48,0%	50,3%	32,9%	39,5%	39,1%

Appendix II.8: Typology of EU countries

In order to build a typology of the EU countries, a Principal Component Analysis has been made, based on the following variables:

- The adoption rate
- The innovation rate
- The total innovative expenditure (in logs)
- Human resources in S&T (in the labour force)
- The cooperation rate.

The two first axes account for 72% of the variance, which can be considered as a relative good result for a PCA.

Table A.II.8.1. Eigen values for each components

Axis	Eigen value	% explained	% cumulated
1	2,183	43,656 %	43,656 %
2	1,422	28,441 %	72,097 %
3	,764	15,283 %	87,380 %
4	,385	7,694 %	95,074 %
5	,246	4,926 %	100%

From correlation matrix and correlation circle, we can see that:

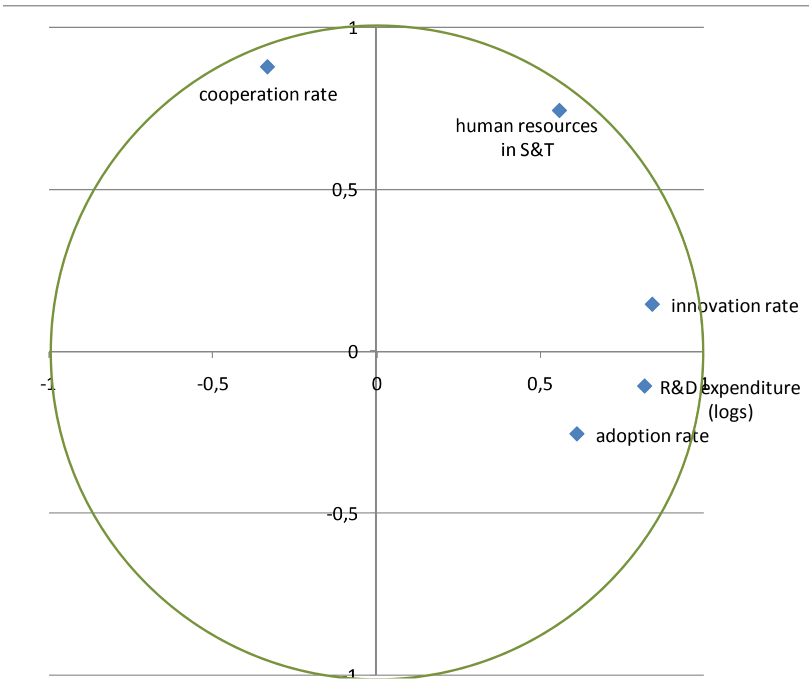
- Innovation rate is positively and significant correlated with R&D expenditures and human resources in S&T. These variables are well represented on the first axis. The adoption rate is also well represented on the first axis.
- The cooperation rate is well represented on axis 2.
- The human resources in S&T are well represented on the two axes.

Table A.II.8.2. Pearson correlation matrix and level of significance (in italics)

	innovation rate	adoption rate	R&D expenditures	human resources in S&T	cooperation rate
innovation rate	1	0,277	**0,604****	**0,484***	-0,185
		0,212	***0,003***	***0,023***	*0,409*
adoption rate		1	0,314	0,226	-0,322
			0,155	*0,311*	*0,144*
R&D expenditures			1	0,294	-0,309
				0,184	*0,161*
human resources in S&T				1	0,379
					0,082
cooperation rate					1

** The correlation is significant at 1% level.
* The correlation is significant at 5% level.

Fig A.II.8.1: Correlation circle



Appendix II.9. Summary of the variables used in part II

Table A.II.9.1. Summary of the variables used in part II					
Category	**Variables**	**Description**	**Type**	**Year**	**Source**
Innovation and adoption	Innovation rate	Share of innovative firms (in percentage of the total number of firms)	Quantitative	2000	CIS3
Innovation and adoption	Innovation adoption rate	Share of adopting firms (in percentage of total number of innovatives firms)	Quantitative	2000	CIS3
Innovation and adoption	Cooperation-based adoption	Share of innovatives firms which mainly cooperate for developing innovation	Quantitative	2000	CIS3
Innovation and adoption	Other organisation-based adoption	Share of innovatives firms which rely on innovation developed mainly by others	Quantitative	2000	CIS3
Innovation and adoption	No adoption	Share of innovatives firms which develop innovation by themselves	Quantitative	2000	CIS3
Innovation and adoption	Product innovation	Share of product innovative firms (in percentage of the total number of firms)	Quantitative	2000	CIS3
Innovation and adoption	Product adoption	Share of product adopting firms (in percentage of product innovative firms)	Quantitative	2000	CIS3
Innovation and adoption	Process innovation	Share of process innovative firms (in percentage of the total number of firms)	Quantitative	2000	CIS3
Innovation and adoption	Process adoption	Share of process adopting firms (in percentage of process innovative firms)	Quantitative	2000	CIS3
Sources of information	Internal sources	Share of innovative firms which use information from internal sources at high level	Quantitative	2000	CIS3
Sources of information	Market sources	Share of innovative firms which use informations from market sources at high level	Quantitative	2000	CIS3
Sources of information	Institutional sources	Share of innovative firms which use information from institutional sources at high/medium/low level or not	Quantitative	2000	CIS3
Sources of information	Others sources	Share of innovative firms which use information from internal sources at high level	Quantitative	2000	CIS3
Innovation expenditure	Intramural R&D	Share of expenditure for intramural R&D (in percentage of total innovation expenditure)	Quantitative	2000	CIS3
Innovation expenditure	Acquisiton of machinery and equipment	Share of expenditure for acquisiton of machinery and equipment (in percentage of total innovation expenditure)	Quantitative	2000	CIS3
Innovation expenditure	Extramural R&D	Share of expenditure for extramural R&D (in percentage of total innovation expenditure)	Quantitative	2000	CIS3
Innovation expenditure	Training, market introduction of innovations and design	Share of expenditure for training, market introduction of innovations and design (in percentage of total innovation expenditure)	Quantitative	2000	CIS3

Innovation expenditure	Acquisition of other external knowledge	Share of expenditure for acquisition of other external knowledge (in percentage of total innovation expenditure)	Quantitative	2000	CIS3
Innovation expenditure	Total innovative expenditure	Expenditure for innovation (only for innovatives firms and transformed with neperian logarithm)	Quantitative	2000	CIS3
Human capital ressources	Education level	Average number of employees with high education in innovative firms	Quantitative	2000	CIS3
Human capital ressources	Human ressources in Science and technology	Share of labor force in science and technology domain	Quantitative	2000	CIS3
Human capital ressources	Organizational changes	% of innovative firms having implemented new or significantly changed organisational structures	Quantitative	2000	CIS3
Cooperation	Cooperation	Share of innovative firms engaged in R&D cooperation	Quantitative	2000	CIS3
Market features	Competition	Value-added as a share of labour and capital costs	Quantitative	1998	Griffith et al. (2006), OECD Stan Database
Market features	Barriers to competition	Index (from 1 to 10) of the importance of barriers to competition	Qualitative	1998	OECD PMR indicators
Market features	International market	Share of innovative firms with international market as the most significant one	Quantitative	2000	CIS3
Market features	Exports	Share of export sales (in percentage of the turn over)	Quantitative	2000	CIS3
Market features	Non-tariff trade barriers	Index (from 1 to 10) of the importance of non-tariff barriers to trade	Qualitative	1995	Economic Freedom of the World report
Market features	Barriers to trade and investment	Index containing information about ownership barriers, discriminatory procedures, regulatory barriers and tariffs	Qualitative	1998	OECD PMR indicators
Protection methods	Patents application to protect innovation	Share of innovative firms which have applied for at least on patent to protect inventions	Quantitative	2000	CIS3
Protection methods	Intellectual protection methods	Share of innovative firms using intellectual protection methods (formal or strategic)	Quantitative	2000	CIS3
Protection methods	Security of property rights	Index (from 1 to 10) of the importance of security of property rights	Qualitative	1995	Economic Freedom of the World report
Internal Market	Global transposition deficit indicator	Share of EU directives communicated as having been transposed	Qualitative	1999	Eurostat
Internal Market	Internal market transposition definit indicator	Share of internal market directives communicated as having been transposed	Qualitative	1999	Eurostat
Internal Market	Product market regulation	The indicators are constructed from the perspective of regulations that have the potential to reduce the intensity of competition in areas of the product	Qualitative	1998	OECD PMR indicators

		market where technology and market conditions make competition viable. They summarize a large set of formal rules and regulations that have a bearing on competition in OECD countries			
Innovation and adoption growth	Innovation growth	Increase/decrease of innovation rate between CIS3 and CIS4	Quantitative	2000 / 2004	CIS3 / CIS4
Innovation and adoption growth	Adoption growth	Increase/decrease of adoption rate between CIS3 and CIS4	Quantitative	2000 / 2004	CIS3 / CIS4
Innovation and adoption growth	Cooperation-based adoption growth	Increase/decrease of cooperation-based adoption rate between CIS3 and CIS4	Quantitative	2000 / 2004	CIS3 / CIS4
Innovation and adoption growth	Other organisation-based adoption growth	Increase/decrease of other organisations-based adoption rate between CIS3 and CIS4	Quantitative	2000 / 2004	CIS3 / CIS4

Appendix II.10. Product and Process Innovation Adoption correlation matrices

Barriers to trade	Adoption	Process adoption	Product adoption
Barrier to trade	**-0,547****	-0,375	**-0,523****
	0,043	*0,186*	***0,055***

Competition	Adoption	Process adoption	Product adoption
Barriers to competition	0,015	0,1691	-0,1769
	0,638	*0,546*	*0,528*
Markup	-0,13	-0,2584	-0,0835
	0,687	*0,4173*	*0,796*

Human resources	Adoption	Process adoption	Product adoption
Human resources in S&T	0,226	0,302	0,033
	0,3108	*0,170*	*0,881*
Average number of employees with high education in innovatives firms	0,0493	0,125	0,144
	0,827	*0,588*	*0,532*

Organisational changes	Adoption	Process adoption	Product adoption
Firms with new or significantly improved changed organisation structures	0,027	-0,040	-0,078
	0,904	*0,861*	*0,737*

PMR	Adoption	Process adoption	Product adoption
Product Market Regulation (OECD)	**-0,636****	**-0,615****	**-0,570****
	0,011	***0,011***	***0,021***

Innovation expenditure	Adoption	Process adoption	Product adoption
Intramural R&D	0,354	0,367	0,037
	0,137	*0,123*	*0,882*
Extramural R&D	0,112	0,159	-0,085
	0,647	*0,517*	*0,730*
Acquisition of machniery and equipment	0,015	0,292	0,160
	0,951	*0,226*	*0,513*
Acquisition of other external knowledge	-0,006	-0,020	-0,111
	0,982	*0,935*	*0,652*
Training, market introduction of innovations and Design	-0,175	-0,129	-0,346
	0,473	*0,598*	*0,147*
Total innovation expenditure	0,299	**0,504****	-0,063
	0,214	***0,028***	*0,798*

Sources of information	Adoption	Process adoption	Product adoption
Clients or customers	-0,218	-0,056	-0,347
	0,318	*0,801*	*0,105*
Competitors	0,072	0,103	0,081
	0,744	*0,639*	*0,712*
Within the enterprise	-0,095	-0,044	-0,284
	0,666	*0,841*	*0,189*
Fairs, exhibitions	-0,002	0,161	0,053
	0,992	*0,462*	*0,810*
Government or private non-profit research institutes	-0,165	0,009	**-0,406***
	0,452	*0,967*	***0,055***
Professional conferences, meetings	-0,048	0,054	0,060
	0,829	*0,807*	*0,786*
Suppliers	-0,334	-0,116	**-0,407***
	0,119	*0,598*	***0,054***
Universities or other higher education institutes	0,083	0,199	0,137
	0,707	*0,364*	*0,534*

Transposition Deficit Index	Adoption	Process adoption	Product adoption
tdi_agr	-0,236	-0,438	-0,154
	0,461	*0,154*	*0,634*
tdi_comp	0,228	0,529	-0,134
	0,477	*0,077*	*0,679*
tdi_educ	0,062	0,116	0,243
	0,849	*0,720*	*0,446*
tdi_empl	0,455	0,347	**0,619****
	0,137	*0,269*	***0,032***
tdi_ener	0,084	0,355	-0,047
	0,795	*0,258*	*0,884*
tdi_entr	0,205	0,284	0,114
	0,522	*0,371*	*0,724*
tdi_env	0,317	0,327	0,128
	0,315	*0,299*	*0,693*
tdi_health	**0,561***	**0,779*****	0,261
	0,058	***0,003***	*0,413*
tdi_intmk	**0,660**	**0,553**	**0,526**
	0,019**	***0,062****	***0,079****
tdi_rd	0,223	0,116	0,482
	0,486	*0,720*	*0,113*
tdi_tax	-0,095	-0,171	-0,282
	0,770	*0,595*	*0,375*
tdi_tot	**0,520***	**0,681****	0,309
	0,083	***0,015***	*0,328*

Invention protection	Adoption	Process adoption	Product adoption
Apply to at least one patent to protect inventions	0,1937 *0,3878*	0,2739 *0,2173*	-0,008 *0,9718*
Registration of design patterns	0,1402 *0,5338*	0,3093 *0,1613*	-0,065 *0,7739*
Trademarks	-0,0577 *0,7987*	0,0016 *0,9945*	-0,0436 *0,8471*
Copyright	-0,0673 *0,7661*	0,1348 *0,5499*	-0,1348 *0,5499*
Secrecy	0,3059 *0,1662*	0,2951 *0,1824*	0,1664 *0,4592*
Complexity of design	**0,363*** ***0,0969***	0,2825 *0,2027*	0,1447 *0,5206*
Lead-time advantage on competitors	0,3884 *0,0741*	0,391 *0,0719*	0,1151 *0,6099*
Valid patent owner	0,0577 *0,7986*	0,0869 *0,7005*	-0,1779 *0,4284*
Valid patent owner for innovatives firms only	0,2271 *0,3095*	0,2744 *0,2165*	-0,0152 *0,9464*
Security of property rights index	0,295 *0,2504*	0,2457 *0,3418*	-0,0711 *0,7861*

Number in italics are p-values.
* Significant to the level of 10%
** Significant to the level of 5%
*** Significant to the level of 1%

Appendices of Part III

Appendix III.1. Determinants of trade

Table A.III.1. Determinants of trade

Dependent Variable: ln TRADE	(i)	(ii)	(iii)	(iv)	(v)	(vi)
Log Turnover	1.143	0.883	1.078	1.108	1.157	1.404
	(7.62)***	(9.86)***	(6.62)***	(6.61)***	(7.60)***	(7.39)***
Involvement in Business Operation	-0.823				-0.828	-0.179
	(3.34)***				(3.34)***	-0.52
Freedom to Trade	1.335	1.247	1.732	1.554	1.249	2.624
	(3.09)***	(5.03)***	(3.63)***	(2.94)***	(2.76)***	(3.94)***
Mainly international Market (% of innov. firms)		4.224		1.79	1.273	
		(3.15)***		-0.8	-0.65	
Product Market Regulation			-0.35	-0.513		
			(-0.65)	(-0.88)		
TDI Int. Market						-0.068
						-0.4
DUMMY	yes	yes	yes	yes	yes	yes
Constant	-14.117	-10.471	-17.427	-16.621	-13.935	-26.133
	(4.28)**	(4.53)***	(4.63)***	(4.26)***	(4.20)***	(-1.6)
Observations	80	125	80	80	80	58
R-squared	0.83	0.76	0.8	0.8	0.83	0.84

t statistics in parentheses
***, ** and * significant at 1, 5 and 10 %
Sectoral Dummies are inserted in all regressions

Appendix III.2. Determinants of Cooperation

Table A.III.2. Determinants of Cooperation

Dependent variable: Cooperation Across EU firms	(i)	(ii)	(iii)	(iv)	(v)	Cooperation within firms of the same country (vi)
Most People Can Be Trusted % (TRUST)	0.276	0.243	0.123	0.281	0.281	0.391
	(4.22)***	(3.34)***	(1.46)	(3.34)***	(4.22)***	(3.35)***
Regulatory and Administrative Opacitity	-0.036	-0.011	0.005	-0.023	-0.039	-0.051
	(-2.86)***	(-0.458)	(0.42)	(-1.63)	(-2.96)**	(-2.26)**
Science and technology graduates	0.008	0.006		0.005	0.008	0.016
	(3.31)***	(2.50)**		(1.86)*	(3.19)***	(3.64***
Log GVA sector	-0.044	-0.007	-0.038		-0.048	-0.064
	(-5.30)***	(-3.20)***	(-3.67)***		(-4.66)***	(-4.33)***
TDI Education		-0.001				
		(-1.14)				
EMPHI share						
Youth Education Attainment Level Total			0.001			
			(1.41)			
Log Turnover				-0.023		
				(-2.83)**		
Organizational Changes					-0.000	
					(-0.57)	
Group					0.000	
					(1.00)	
DUMMY	yes	yes	yes	yes	yes	yes
Constant	0.50	0.071	0.058	0.085	0.550	-0.81
	(5.50)***	(-0.9)	(-1.1)	(-1.13)	(5.10)***	(5.01)***
Observations	69	56	76	73	69	69
R-squared	0.51	0.58	0.38	0.34	0.52	0.43

t statistics in parentheses
***, ** and * significant at 1, 5 and 10 %
Sectoral Dummies are inserted in all regressions

Appendix III.3. Determinants of Competition

Table A.III.3. Determinants of Competition

Dependent variable: Mark up	(i)	(ii)	(iii)	(iv)	(v)
TDI Competition	-0.007	-0.003	-0.003	-0.006	-0.006
	(-6.32)***	(-3.12)***	(-3.15)***	(-6.06)***	(-3.68)***
State Control	0.016	0.031	0.022	0.028	0.043
	(1.52)	(2.40)**	-1.54	(2.67)***	(4.46)***
Sectoral and ad hoc State Aid as a % of GDP	0.077				0.023
	(3.29)***				-1.09
Transfers and Subsidies from National govts. as % of GDP	-0.039			-0.022	-0.035
	(7.46)***			(-6.09)***	(-6.96)***
Log of number of firms in each sector	-0.007				
	(-1.23)				
Working days spent to deal with Bureaucracy	0.000				0.000
	(1.89)*				(-0.03)
Number of bodies to be contacted in order to open a Business	0.005				
	(2.85)***				
Regulatory And Administrative Opacity		0.011	0.013	0.009	
		(-1.66)	(1.94)*	(-1.57)	
Barriers To Competition		0.026	0.022		
		(1.43)	(1.23)		
Outward Oriented Policies			0.037		
			(-1.5)		
Govt. enterprises and investment as a %of total investment					0.003
					(-1.12)
Log Firm Size					-0.007
					(-0.85)
Log GVA sector					-0.015
					(-1.4)
DUMMY	yes	yes	yes	yes	yes
Constant	0.855	0.338	0.313	0.692	0.973
	(6.94)***	(2.37)**	(2.21)**	(5.64)***	(7.60)***
Observations	76	77	77	77	61
R-squared	0.7	0.44	0.46	0.63	0.82

t statistics in parentheses
***, ** and * significant at 1, 5 and 10 %
Sectoral Dummies are inserted in all regressions

Appendix III.4. Some explanations about variables used in Part III and their definitions

A. Involvement in business operation

"Involvement in business operation" is the weighted average of two regulation indicators coming from the OECD Product Market Regulation database (see Conway, Janod and Nicoletti, 2005). In particular (and as detailed in Conway, Janod and Nicoletti, 2005) the proxy for the Involvement of government in business operation is the weighted average of respectively Price Controls (with a weight of 0.45) and Use of command and Control regulation (with a weight of 0.55). To be more specific on these issues, as pointed out by Conway, Janod and Nicoletti (2005), the low level indicator for "price controls" can be disaggregated into 4 sub-indices: air travel, road freight, retail distribution and telecommunication. All of these sub-indices get a higher value as the perceived regulation is strengthened. Here below we give the detail description of how the indicator for price controls is computed by the OECD:

Price Controls Indicator

1. Air travel

1.1 Prices of domestic air fares are regulated

1.2 Number of 5 or 4 busiest international routes subject to price regulation (n)

2. Road freight

2.1 Retail prices of road freight services are regulated in any way by the government

2.2 Government provides pricing guidelines to road freight companies

2.3 Professional bodies or representatives of trade and commercial interests are involved in specifying or enforcing pricing guidelines or regulations

3. Retail distribution

3.1 Retail prices of the following products are subject to prices controls:

- Retail prices of certain staples (e.g. milk and bread)
- Retail prices of gasoline
- Retail prices of tobacco
- Retail prices of alcohol
- Retail prices of pharmaceuticals
- Retail prices of the other product

4. Telecommunication

4.1 Retail prices of digital mobile service in telecommunications are regulated

Along with price controls sub-index, also the specific regulations attaining the "use of command and control regulation" seem to negatively affect the turnover exported. Here below we give a brief description of the specific feature composing the use of command and control regulation sub-index:

Use of command and Regulation

1. General information

1.1 Regulators are required to assess alternative policy instruments (regulatory and non-regulatory) before adopting new regulation

1.2 Guidance has been issued on using alternatives to traditional regulation

2. Sector-specific information

2.1 Road freight

2.1.1 Regulations prevent or constrain backhauling (picking up freight on the return leg)

2.1.2 Regulations prevent or constrain private carriage (transport only for own account)

2.1.3 Regulations prevent or constrain contract carriage (contractual relation between an otherwise independent hauler and one shipper)

2.1.4 Regulations prevent or constrain intermodal operations (operating or ownership links between firms in different transportation sectors)

2.2 Retail distribution

2.2.1 Shop opening hours are regulated

2.2.2 Government regulations on shop opening hours apply at national level

2.2.3 The regulation of opening hours became more flexible in the last 5 years

2.3 Air travel

2.3.1 Carriers operating on domestic routes are subject to universal service requirements (e.g. obligation to serve specified customers or areas)

2.4 Railways

2.4.1 Companies operating the infrastructure or providing railway services are subject to universal service requirements (e.g. obligation to serve specified customers or areas)

Again the sub-index of use of command and control regulation can be decomposed into 2 main sub-areas: general information, and sector specific information.

B. Regulatory and administrative opacity.

The two sub-indexes that are considered in the construction of this OECD proxy are:

Communication and Simplification
1. Communication
1.1 There are systematic procedures for making regulations known and accessible to affected parties
1.2 There is a general policy requiring "plain language" drafting of regulation
1.3 There are inquiry points where affected or interested foreign parties can get information on the operation and enforcement of regulations
1.4 Affected parties have the right to appeal against adverse enforcement decisions in individual cases
1.5 Government policy imposes specific requirements in relation to transparency/freedom of information government wide
2. Simplification
2.1 National government (all ministries and agencies) keeps a complete count of the number of permits and licenses required
2.2 There is an explicit program to reduce the administrative burdens imposed by government on enterprises and/or citizens
2.3 There is a program underway to review and reduce the number of licenses and permits required by the national government

And

Licenses and permits system	**Question Weights (c_k)**	**Coding of answers**	
		Yes	**No**
The 'silence is consent' rule (i.e. that licenses are issued automatically if the competent licensing office has not acted by the end of the statutory response period) is used at all.	1/3	0	6
There are single contact points ("one-stop shops") for getting information on notifications and licenses.	1/3	0	6
There are single contact points ("one-stop shops") for issuing or accepting on notifications and licenses.	1/3	0	6
Country scores (0-6)	$\sum_k c_k$ answer$_{jk}$		
Note: Missing data points: if at least two of the three data points are available, the indicator is calculated as a simple average of the available data points.			

C. The public ownership proxy

The The public ownership proxy can be approximated by the followings sub-indexes:

The "**scope of public sector"** low-level indicator refers to the control exerted by the state on an array of industries. The more the industries directly controlled by the national government, the less the competition level (conversely the higher the estimated markup index).

Scope of Public Sector		
	National, state or provincial government controls at least one firm in:	
ISIC (Rev. 3.1) code	**Sector**	**Weight (a_I)**
16	Manufacture of tobacco products	1
232	Manufacture of refined petroleum products	1
27	Manufacture of basic metals	1
28, 29	Manufacture of fabricated metal products, machinery and equipment	1
4010	Electricity: electricity generation/import or electricity transmission or electricity distribution or electricity supply	1
4020	Gas: gas production/import or gas transmission or gas distribution or gas supply	1
4100	Collection, purification and distribution of water	1
50, 51	Wholesale trade, incl. motor vehicles	1
55	Restaurant and hotels	1
601, 6303	Railways: Passenger transport via railways, Freight transport via railways, Operation of railroad infrastructure	1
6021	Other urban, suburban and interurban passenger transport	1
6021	Other scheduled passenger land transport	1
6023	Freight transport by road	1
6303	Operation of road infrastructure	1
61	Water transport	1
6303	Operation of water transport infrastructure	1
62	Air transport	1
6303	Operation of air transport infrastructure	1
642	Telecommunication: fixed line services, mobile services, internet services	1
6519, 659, 671	Financial institutions	1
66, 672	Insurance	1
74	Other business activity	1
851	Human health activities	1
9211, 9212	Motion picture distribution and projection	1

The item referring to the "**size of public enterprise sector**" is instead given by the following classification and data sources:

Size of public enterprise sector			
	A	B	C
Source	CEEP (1997)	Gwartney and Lawson (1997)	OECD estimate based on A and B
Definition of indicator	State ownership in the non-agricultural business sector (overall and by sector)	Size of government enterprises as a share of economy	Size of public enterprises sector
Units	% of 1995 non-agricultural business GDP	Index: scale 0-10 from largest to smallest size	Index: scale 0-10 from largest to smallest size
Coverage	15 European countries	115 OECD and non-OECD countries	29 OECD countries
Criterion for scale		10 = less than 1% 8 = only natural monopolies 6 = less than 10% 4 = more than 10% less than 20% 2 = more than 20% less than 30% 0 = more than 30%	Gwartney and Lawson index revised and updated with CEEP data

Finally, the item referring to the "**direct control over business enterprises**" can be summarized by the following:

Direct control over business enterprises

1. General constraints

There are any legal constitutional constraints to the sale of the stakes held by government in these firms

Strategic choices of any publicity-controlled firms have to be reviewed and/or cleared in advance by national, state, or provincial legislatures

2. Golden shares

National, state or provincial governments have special voting rights (e.g. golden shares) in any firms within the business sector

3. Extent of the special voting rights

These special rights can be exercised in:

- merger with or acquisition by another company
- change in controlling coalition
- choice of management
- strategic management decisions

Appendix III.5. Determinants of Innovation and Innovation Adoption at micro level

As we have explained in section III.5, we present here the detailed results related with the determinants of innovation adoption at micro level. The dependent variable measures the fact that the firm has adopted an innovation (product or process) or not. More precisely, the decision to adopt an innovation is estimated by means of a binary choice model. The profit associated with adoption is considered to be the latent variable. Since a measure of this profit is not available, we use a probit model where the dependent variable takes value 1 if firm *i* adopted a product or a process innovation (developed by others or in collaboration with others) and 0 otherwise. Adoption is assumed to occur if the associated payoffs are positive.

For each firms, adoption is assumed to occur if and only if the expected profit, noted Π_i is positive. So, the probability that adoption occur in firm *i* is $P_i = P(\Pi_i > 0)$. For each firm, the profit associated with adoption is given by:

$$\text{(A.1)} \qquad \Pi_i = V_i + \xi_i$$

where V_i is a function of all the characteristics of firm *i* likely to impact on the decision to diffuse. ξ_i is a random perturbation. We choose a linear expression for V_i :

$$\text{(A.2)} \qquad V_i = \beta X_i$$

where X_i is the vector of the observable characteristics of firm i and β is the vector of the parameters to be estimated. These characteristics may be associated with the firms themselves (ZID_i) but also with their position in the market (Trade) and their propensity to collaborate (Coop), as well as with their country and sector specific features, hence leading to the following latent model:

$$\text{(A.3)} \; \Pi_i = \lambda_0 + \lambda_1 Coop_i + \lambda_2 Trade_i + ZID_i \lambda_3 + DUM_i \lambda_4 + DUM_C \lambda_5 + \xi_i$$

The hypothesis of an impact of IM will be tested indirectly by looking at the sign and significance of the coefficients associated respectively with TRADE (*Trade*) and COOPERATION (*Coop*).

Only innovative firms (in terms of product or process) are included in the sample, so that the absence of adoption cannot be explained by the absence of innovation. Therefore, the analysis focuses on the reasons that lead to adopt an existing technology or a process, instead of developing it within the firm.

As for the explanatory variables, two sets of variables are considered. On the one hand, the channels (Trade and Cooperation) through which IM is likely to impact innovation adoption. Trade is measured by the level of exports of the firm (LNEXP), while cooperation is accounted for by a dummy variable (COOP) that takes value 1 if the firm has been involved in cooperation activities for its innovation. On the other hand, a set of control variables (ZID) is used. These latter are drawn from the theoretical studies detailed in Part I of this report. Six variables are introduced:

- First of all, the equation of innovation adoption includes the turnover of the firms, (**LNTURN**) in order to measure the firm size effect. As mentioned in Part I, we can expect a positive effect of this variable on the propensity to adopt a technology, via the absorptive capacity of the firms. However, a large size may also reduce this propensity due to a lack of flexibility.
- The absorptive capacity of firms does not only rely on a size effect. It is usually associated with the level of skill within the firm or with the Research and Development investment made by the firm. For this reason, we include in the equation the number of workers with higher education (**LNEMPHI**). We include the total innovative expenditure as well (**LNRTOT**). A positive sign is expected for these two variables.
- As detailed in Part I of this report, IPR may also play a crucial part in the way innovation is likely to diffuse across firms. The variable **PATENT** takes the value 1 if the firm uses patent protection and 0 otherwise. Note however that this variable is observed at the firm level. Therefore it cannot account for the impact of the IPR intensity that prevails in the sector. This variable measure to what extent firms with patenting policies are more likely to adopt innovation than firms with no patent policy. We can expect a positive sign of the associated parameter. Since adoption may lead to new innovation, patenting firms

may have more incentives to adopt. On the opposite, a negative sign may occur if there exists a trade off between own firm innovations and adoption. In this case, patenting activities may characterize firms that mainly innovate by themselves, whereas mainly adoptive firms would have a low propensity to patent.

- Adoption of innovation is also closely linked in the literature to the ability of firms to adapt their organizational structures. The dummy variable **ORGA** is introduced to account for this potential effect. A positive sign of the associate coefficient is expected. Firms that introduce organizational innovation would be more likely to adopt new technologies.
- The public financial supports have also been highlighted as a positive factor for innovation adoption. A dummy variable, labelled **PUBLIC**, accounts for this potential effect. A positive coefficient is expected.
- In addition to these variables, we also include in the estimation a dummy variable indicating whether the firm belongs to a group or not **(GP)**[77]. Although the literature does not stress this point, it appears that this can affect the ability to adopt an innovation. On the one hand, one can consider that belonging to a group increases the opportunities to adopt technologies. On the other hand, due to the way our dependent variable is built, a negative sign may be expected. Indeed, innovations adopted from the remainder of the group are excluded of our definition of adoption. Therefore, if firms that belong to a group rely on innovation developed by the remainder of the group, this will reduce their share of adoption based on external innovation only (which is our definition of adoption). More practically, it is also important to control for this characteristic because some firm may have answered certain items refering to the whole group instead of the firm only.
- Finally, the set of control variables includes both industry and country dummies. These variables measure the net effect of all the industry and country specific features (Competition, IPR, geographical distribution, etc) that impact on the innovation process.

From a methodological point of view, adoption choice is only observed by the enterprises which have decided to innovate. Therefore, our estimation is exposed to the well-know "selection bias" (Heckman, 1979). Consequently, we choose to estimate the probabilities to

[77] This is an item from CIS. A firm belongs to a group when more than 10% of its capital is owned by another firm.

adopt new technologies following the method of Van de Ven and Van Praag (1981). This approach[78] applies the Heckman's method in a context of binary endogenous variable.

For this reason, we estimate three main equations. Equations (i) explains the innovation decision meanwhile Equations (iii) and (iv) explain the innovation adoption decision. Equation (i) can be referred as the selection equation. This model (i) allows for the calculation of the Inverse Ratio of Mills (IRM) for the computation of the model (iv). Equation (iv) in Table A.III.4 is our main equation of interest. Equation (iii) is the model of adoption estimated by a standard probit method, without selection bias correction, in order to allow the comparison with equation (iv) including IRM. Equation (ii) is an alternative selection equation that was estimated to check the robustness of equation (i). It is estimated to distinguish the effects of exports (LNEXP) from the crossing variables of the model (i).

In order to respect identification condition, equations (i) and (ii) (related to innovation) include variables that are different from the one included in the adoption equations (iii and iv). Concerning identification condition, at least one variable of the model (i-ii) must be excluded from model (iii-iv). The variable EST is considered sufficiently correlated with the innovation decision but not correlated with the adoption decision. **EST** is a dummy variable indicating that the firm was newly established during the period 1998-2000. This variable is likely to impact negatively the decision to innovate. This is due to the definition of innovation retained in the CIS. It is clearly mentioned in the CIS user guide for the respondent that, in all cases, the innovation or improvement must be considered in reference to the enterprise. They may not necessarily be innovations or improvements for the market or relatively to the enterprises of your sector (or of any other firm). An additional item is devoted to product innovations that are new to the market as well. Therefore, even if some new firms are set up because they provide new product or process compare to other firms, these innovations are not new in reference to the firm previous activity. As a consequence, new established firms are unlikely to be registered as innovating in the CIS. A firm with only one or two years of life is indeed less likely to change its product or process than older firms.

Other structural changes faced by the firm during the period 1998-2000 are also included. The variable **TURNINC** is a dummy variable that takes value 1 if the firm increased its turnover

[78] This method (also used by Sollogoub and Ulrich, 1999) include a heteroscedastic correction for robust standard error.

by 10% or more, due to merger with another enterprise or part of it. Similarly, the variable **TURNDEC** takes value 1 for firms that experienced a decrease in their turnover of 10% or more due to sale or closure of part of the enterprise. A positive impact of TURNINC is expected. The merger with another enterprise often goes together with a reorganization of the production process and/or with a redefinition of the firm product range. Conversely, the sale or closure of part of the firm is usually associated with a reduction phase of the firm activity, rarely associated with a dynamism in terms of innovation.

Following Mairesse and Mohnen (2002), a size variable (**LNWTURN**) is also added in the model (i-ii). This variable captures the firm turnover. In order to make the specification of our innovation equation different from our adoption equation however, this variable is crossed with the industry specific effects. LNWTURN is thus the enterprise sales weighted by the share of sales generated by the industry to which the enterprise belongs. This measure of size reflects access to finance, scale economies, and differences in the organization of work. Therefore, a positive sign of the coefficient associated with this variable is expected. The group membership variable (GP) is included as well. Firms that are members of a group are expected to benefit, for instance, from intra-group knowledge spillovers and internal access to finance.

This first stage includes also the variable LNEXP. The rate of export is known as a factor that stimulates competition pressure. Therefore a positive impact on innovation is expected. The other explanatory variables that are included in our adoption equation (COOP, PUBLIC, ORGA) cannot appear into this first stage. These variables are observed for innovative firms only. Similarly, the industry dummies are not introduced in these first stage equations. The correlation with LNWTURN is such that multicolinearity would arise in a specification including industry dummies.

Estimations are first run on the whole sample. The aim is to study the determinants of the adoption of an innovation, this latter being product or process innovation. One can think however that the underlying mechanisms are different according to the nature of innovation. The IM may impact differently on product innovation adoption and process innovation adoption. In order to assess the very existence of such differences, estimations are then run separately for product innovation and process innovation.

A.III.5.1. Innovation Adoption in both product and process

The preliminary results are reported in table A.III.4 Innovation equation results are reported in columns (i) and (ii), while columns (iii) and (iv) report the adoption equation results, respectively without and with the selection bias correction. We firstly briefly comment on the innovation equation results. After that we focus on adoption equations, our main equations of interest.

Model (i) and (ii) reveal that **the firm size**, measured by the firm turnover, weighted by the industry turnover (LNWTURN) as well as GP (i.e. membership of a group) **exert a positive impact on the firm propensity to innovate**. These results are consistent with those obtained in previous studies (Mairesse and Mohnen, 2002). In the same way, **the number of workers of higher education level** (i.e. LNEMPHI) **influences positively and significantly the probability to innovate.** A **positive effect** is found for the **firm exportations** (LNEXP). The crossing variables of LNEXP with the type of market – local (i.e. LOCMAR), national (i.e. NATMAR) and international (i.e. INTMAR) – suggest a **greater benefice of exportation with a higher competition** (i.e. NATMAR and INTMAR). This positive role of foreign exposure is consistent with the results obtained by Mairesse and Mohnen (2005). Using a dummy variable indicating whether or not the international market is the main market or not, they observe a positive and significant impact on innovation. Lastly, **new established enterprises** (EST) **have smaller probabilities to innovate**. The variables TURNINC[79] (i.e. an increase of turnover of 10% due to merger with other enterprise) and TURNEC (i.e. a decrease of 10% of turnover due to closure of a enterprise part) have remarkable symmetric effect, respectively positive and negative.

From the model (iv), IRM is not significant. This correction captures some negative trends of intercept and the correction on the other variables is weak. Despite these results, we choose to comment our results from (iv), since this model include a weak correction of selection bias.

[79] This variable also reflects a structure change and probably a need of new technology.

Table A.III.4. Total Innovation Adoption				
Variables	**Innovation Selection eq. (i)**	**Innovation Selection eq. (ii)**	**Adoption eq. without correction (iii)**	**Adoption eq. with correction (iv)**
Intercept	-1.535*** (0.063)	-1.076*** (0.046)	-1.109*** (0.141)	-0.627* (0.257)
LNRTOT	nc	nc	0.015* (0.007)	0.0002 (0.003)
LNTURN	nc	nc	0.047*** (0.010)	0.044*** (0.009)
LNEMPHI	0.200*** (0.006)	0.232*** (0.005)	-0.058*** (0.012)	-0.075** (0.023)
PATENT	nc	nc	-0.176*** (0.025)	-0.178*** (0.024)
GP	0.190*** (0.019)	0.184*** (0.018)	-0.229*** (0.028)	-0.250*** (0.031)
ORGA	nc	nc	0.076* (0.031)	0.061* (0.029)
PUBLIC	nc	nc	0.096*** (0.028)	0.110*** (0.027)
LNEXP	nc	0.024*** (0.001)	-0.006** (0.002)	-0.008** (0.003)
COOP	nc	nc	0.496*** (0.027)	0.487*** (0.026)
TURNINC	0.109*** (0.028)	0.105*** (0.027)	nc	nc
TURNDEC	-0.105** (0.034)	-0.105** (0.033)	nc	nc
LNWTURN	0.057*** (0.005)	0.023*** (0.003)	nc	nc
LNEXP*INTMAR	0.021*** (0.001)	nc	nc	nc
LNEXP*NATMAR	0.029*** (0.002)	nc	nc	nc
LNEXP*LOCMAR	0.014*** (0.002)	nc	nc	nc
EST	-0.232*** (0.036)	-0.361*** (0.033)	nc	nc
Sectoral Dummies (7)	no	no	yes	yes
Country Dummies (14)	yes	yes	yes	yes
Lambda	nc	nc	nc	-0.210 (0.148)
Percent concordant	77.5	76.9	63.8	63.4
Likelihood	-23996.31	-24027.49	-9223.66	-9222.63
LR test (Beta=0)[80]	9848.80***	9786.45***	841.55***	843.62***
LR test (dummies=0)	2287.84***	2323.87***	150.26***	152***
Observations	46010	46010	14445	14445

Note : **LNRTOT**: Total innovation expenditure of the firm, **LNTURN** : turnover of the firms, **LNEMPHI:** higher education-skilled workforce, **PATENT:** takes the value 1 if the firm uses patent protection and 0 otherwise, **GP**: dummy variable indicating whether the firm belongs to a group or not, **ORGA**: dummy variable for organizational structure **PUBLIC**: public financial supports, **LNEXP**: exports as in CIS, **COOP**: firms cooperate in innovation, **LNWTURN**: Firm turnover weighted by industry turnover, **INTMAR**: mainly international market, **NATMAR**: mainly national market, **LOCMAR**: mainly local market, **EST**: dummy for new established firm.
t-ratio are given in parenthesis level of significance: * 10%, **5%,***1%
(Columns i and iii: without correction of selection bias. Columns ii and iv: with correction of selection bias)

[80] The LR statistics is compared to a Chi2 with the number of constraints as degree of freedom.

Our results suggest that **the variables influencing positively the probability to innovate influence negatively the probability to adopt a new technology.**[81]

The global quality of the model is not very high. We succeed in predicting innovation adoption behaviour for 63% of the sample only. This statistic refers to traditional indicators based on Probit estimation. We consider the predicted value of the latent variable. If it exceeds 0.5, we consider that the predicted dichotomous variable is 1, and conversely, if the propensity remains below 0.5, we consider that the predicted dichotomous variable equal 0. We then compare it with the observed sample and compute the proportion of correct predictions. **The introduction of the channels (Trade and Cooperation) improves substantially the model.** Several other specifications have been tested but none of them increases the explanatory power.

The firm turnover (expressed in logarithm, LNTURN) exerts a positive and significant impact, supporting the idea of a **positive size effect on innovation adoption**. The coefficient associated with research expenditure (LNRTOT) has the expected sign. Hovewer, the significance disappears once the selection bias is accounted for. **The amount of R&D does not appear as a specific feature of adopting firms, compare to firms that generate innovation**.

On the opposite, **the number of workers with a higher education (LNEMPHI) has a significant and negative coefficient**. This is consistent with the fact that only innovative firms are considered in our sample. Firms that do not adopt innovation are firms that innovate by themselves. Therefore, they hire a larger number of high skilled workers. **Among innovative firms, those with the lowest number of high skilled workers are more likely to build their innovative strategies on external knowledge, and thus to adopt innovation developed by other firms.**

The variable PATENT exerts a negative impact as well. **Firms that base their innovation strategy on legal protection are primarily those who generate internal innovation**.

The coefficient associated with the dummy variable GP has a negative sign, which was the expected sign. **Firms that belong to a group have lower rates of adoption**. This is due to

[81] This result is also confirmed by the sign of estimated coefficient of IRM.

our definition of adoption. Within group adoption is recorded as generation of innovation, and not as adoption.

The idea of organizational innovation as a pre-requisite to adopt technology developed outside is only partly confirmed. The coefficient of the corresponding variable (ORGA) is significant at a 10% threshold only. This does not mean organizational innovations are not necessary, but they do not play a very specific role on adoption compared to "internal" innovation.

According to the positive coefficient associated with the variable PUBLIC, public financial support would provide incentives to adopt. **Public funding of innovation would be efficient to foster adoption of innovation, more than generation of innovation**. This could result from the type of instruments used by policy makers, but it can also result from a different level of incentives associate to generation and adoption of innovation. One may hypotheses that incentives to generate innovation (due to temporal monopoly power) are high enough to lead firms to produce innovation. Incentives associated with innovation adoption would conversely be more reduced, and public policies would have a more critical impact on firm choices.

Regarding the channels through which IM may impact on innovation adoption, two sources are studied. The first one, LNEXP gives the amount of exported sales (expressed in logarithm). The negative effect of LNEXP is unexpected. Theoretical model as well as empirical studies have shown the positive impact of trade on innovation adoption. However, once again, we must be careful in interpreting this coefficient. **Compared to innovations developed within firms, exports exert a negative effect on innovation adoption**[82]. However, the global impact on innovation remains positive. This interpretation is clearly confirmed by our first stage estimation. In the innovation equation, LNEXP has a positive and significant coefficient. Therefore, it appears that **exports impact positively on both generation and adoption of innovation, compared to the non innovative choice. However, in the choice between adoption and generation of innovation, the level of export favours generation**.

[82] However, one should take this result with caution. The use of the micro database restricts the analysis to a subset of countries which, as we pointed out in part II, are not the EU-core countries.

The effect of cooperation on adoption is conversely positive. Among innovative firms with cooperation activities are more likely to adopt innovation, while non cooperative firms are more likely to generate innovation. This result corroborates the theoretical hypothesis. **Cooperation is a powerful driver of innovation adoption**. Note however that the potential impact of cooperation on the propensity to innovate cannot be addressed here, since the cooperation variable is observed for innovative firms only.

A.III.5.2. Innovation Adoption according to the nature of innovation

Innovation adoption may be driven by different factors according to the nature of innovation. In order to evaluate these potential differentiated effects, this second part explores separately firms that introduce product innovations and those that introduce process innovations.

A.III.5.2.1. Product Innovation Adoption

We consider here a sub-sample of firms, those that innovate in product (and possibly in process as well). This way, we are going to analyse the impact of our explanatory variables on the decision to adopt a product innovation or to develop it within the firm. Table A.III.5 gives the results obtained for the same specifications as in Table A.III.4. A selection bias arises once again in this estimation. Information regarding product adoption is available for product innovative firms only. Therefore, in a first stage, we should estimate the propensity to innovate in product.

The equation selection (v) is estimated using all the observations in the sample. It differs from selection (i) since the dependent variable takes value 1 if the firm has introduced product innovation during the period 1998-2000 and 0 otherwise (e.g. if firm has not introduced innovation at all, or if it has introduced process innovation only). The lambda parameter accounting for the selection bias is not significant and the results obtained for equation (vi) and (vii) are very similar.

Table A.III.5. Product Innovation Adoption

Variables	Product Innovation Selection eq. (v)	Product adoption eq. without correction (vi)	Product adoption eq. with correction (vii)
Intercept	-0.977*** (0.048)	-0.961*** (0.166)	-0.884*** (0.119)
LNRTOT	Nc	-0.024*** (0.004)	-0.020*** (0.003)
LNTURN	Nc	0.008 (0.011)	-0.0007 (0.009)
LNEMPHI	0.188*** (0.006)	-0.043** (0.015)	-0.040** (0.014)
PATENT	Nc	-0.137*** (0.034)	-0.124*** (0.032)
GP	0.185*** (0.018)	-0.147*** (0.038)	-0.139*** (0.036)
ORGA	Nc	0.060 (0.040)	0.053 (0.038)
PUBLIC	Nc	0.028 (0.040)	0.011 (0.038)
LNEXP	Nc	-0.004 (0.003)	-0.004 (0.003)
COOP	Nc	0.504*** (0.036)	0.504*** (0.034)
TURNINC	0.089*** (0.028)	Nc	Nc
TUNRDEC	-0.086** (0.034)	Nc	Nc
LNWTURN	0.004 (0.004)	Nc	Nc
LNEXP*INTMAR	0.021*** (0.001)	Nc	Nc
LNEXP*NATMAR	0.029*** (0.001)	Nc	Nc
LNEXP*LOCMAR	0.016*** (0.002)	Nc	Nc
EST	-0.248*** (0.034)	Nc	Nc
Sectoral Dummies	No	Yes	Yes
Country Dummies	Yes	Yes	Yes
Lambda	Nc	Nc	-0.001 (0.022)
Percent concordant	73.9	68.1	62.8
Likelihood	-22495.67	-4476.78	-4933.63
LR test (Beta=0)	6141.91***	695.72***	721.30***
LR test (dummies=0)	1402.67***	323.52***	359.04***
Observations	46010	11658	11658

Note: **LNRTOT**: Total innovation expenditure of the firm, **LNTURN** : turnover of the firms, **LNEMPHI:** higher education-skilled workforce, **PATENT:** takes the value 1 if the firm uses patent protection and 0 otherwise, **GP**: dummy variable indicating whether the firm belongs to a group or not, **ORGA**: dummy variable for organizational structure **PUBLIC**: public financial supports, **LNEXP**: exports as in CIS, **COOP**: firms cooperate in innovation, **LNWTURN**: Firm turnover weighted by industry turnover, **INTMAR**: mainly international market, **NATMAR**: mainly national market, **LOCMAR**: mainly local market, **EST**: dummy for new established firm. t-ratio are given in parenthesis level of significance: * 10%, **5%,***1%
(Columns v and vii: without correction of selection bias. Column vi: with correction of selection bias)

They show that the prediction power of the model is higher than on the whole sample. Regarding the control variable, **the effect of LNEMPHI, PATENT and GP are unchanged with a negative sign. LNRTOT becomes significant and negative whereas LNTURN, PUBLIC and ORGA becomes non significant**. As for the channels of IM impact, the results are partly different to those obtained on the whole sample. The influence of export becomes non significant. **Cooperation is confirmed as a key driver for product innovation adoption.**

A.III.5.2.2. Process Innovation Adoption

This subsection assesses the impact of our explanatory variables on the decision to adopt a process innovation (see Table A.III.6). We consider here a sub-sample of firms that innovate in process. The selection bias we have to deal with here is due to the propensity to innovate in process.

The selection equation (viii) does not differ from the one of product innovation. **The determinants of product innovation are almost similar to those of process innovation,** except LNWTURN that exerts a positive impact on process innovation, as it was already observed for total innovation.

As already observed for the product innovation sub-sample, the explanatory power is slightly higher than with the whole sample. This improvement is however lower here than for product innovation if we consider the equation corrected for the selection bias (x).

Several differences appear compared to product innovation. First of all, the size effect captured by the variable LNTURN is significant. **Larger firms are more likely to adopt process innovation than developing them by themselves**.

Public funding is also significant. **Public financial support would foster process adoption more than product adoption.**

Similarly to product adoption, the coefficient associated with the introduction of **organizational innovation is again non significant.**

Table A.III.6. Process Innovation Adoption

Variables	Process Innovation Selection eq. (viii)	Process Adoption eq. without correction (ix)	Process Adoption eq. with correction (x)
Intercept	-1.226*** (0.048)	-1.615*** (0.162)	-1.561*** (0.144)
LNRTOT	Nc	0.012** (0.004)	0.007 (0.004)
LNTURN	Nc	0.067*** (0.011)	0.064*** (0.009)
LNEMPHI	0.209*** (0.006)	-0.039** (0.013)	-0.032** (0.012)
PATENT	Nc	-0.199*** (0.030)	-0.210*** (0.029)
GP	0.159*** (0.019)	-0.269*** (0.034)	-0.254*** (0.032)
ORGA	Nc	-0.016 (0.036)	0.002 (0.033)
PUBLIC	Nc	0.128*** (0.033)	0.119*** (0.032)
LNEXP	Nc	-0.004* (0.002)	-0.003 (0.002)
COOP	Nc	0.323*** (0.033)	0.336*** (0.031)
TURNINC	0.117*** (0.028)	Nc	Nc
TUNRDEC	-0.060 (0.034)	Nc	Nc
LNWTURN	0.023*** (0.004)	Nc	Nc
LNEXP*INTMAR	0.022*** (0.001)	Nc	Nc
LNEXP*NATMAR	0.031*** (0.002)	Nc	Nc
LNEXP*LOCMAR	0.017*** (0.002)	Nc	Nc
EST	-0.378*** (0.034)	Nc	Nc
Sectoral Dummies	No	Yes	Yes
Country Dummies	Yes	Yes	Yes
Lambda	Nc	Nc	0.001 (0.019)
Percent concordant	76.8	65.1	64.8
Likelihood	-22556.51	-5734.57	-6340.55
LR test (Beta=0)	8342.67***	614.80***	653.24***
LR test (dummies=0)	2104.58***	246.98***	257.7***
Observations	46010	12530	12530

Note : **LNRTOT**: Total innovation expenditure of the firm, **LNTURN** : turnover of the firms, **LNEMPHI:** higher education-skilled workforce, **PATENT:** takes the value 1 if the firm uses patent protection and 0 otherwise, **GP**: dummy variable indicating whether the firm belongs to a group or not, **ORGA**: dummy variable for organizational structure **PUBLIC**: public financial supports, **LNEXP**: exports as in CIS, **COOP**: firms cooperate in innovation, **LNWTURN**: Firm turnover weighted by industry turnover, **INTMAR**: mainly international market, **NATMAR**: mainly national market, **LOCMAR**: mainly local market, **EST**: dummy for new established firm.

t-ratio are given in parenthesis level of significance: * 10%, **5%,***1%

(Columns viii and ix: without correction of selection bias. Column x: with correction of selection bias)

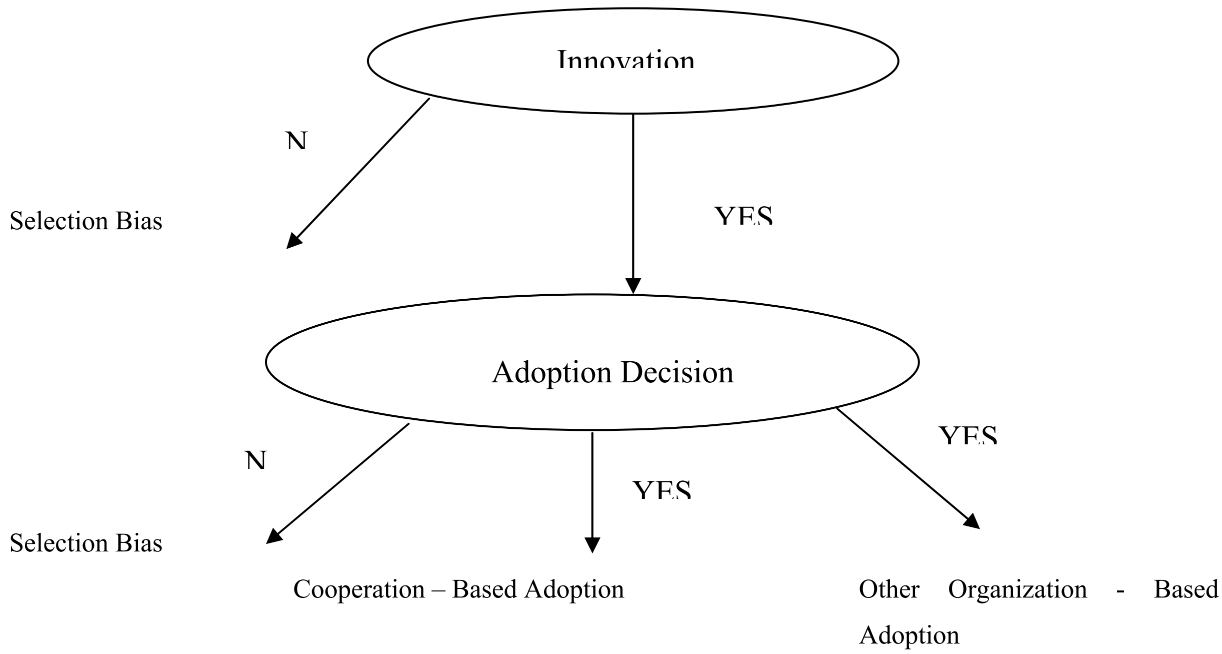
Regarding the channel of IM**, export is non significant whereas cooperation remains positive** and significant. However the coefficient is slightly smaller than the one observed on product adoption (the marginal effects that allow to compare the value of the coefficients are respectively 0.119 for product and 0.097 for process, and the difference is statistically significant). **Cooperation would favour product innovation more than process innovation.**

A.III.5.2.3. Cooperation-based adoption vs other organization-based adoption

Our definition of innovation adoption relies on two different items regarding the way product and process innovations occurred. The first one refers to "innovation developed mainly in collaboration with other firms or institutions", while the second one deals with "innovation developed mainly by other firms or institutions". These two items pointed two different ways of adopting innovation. Their determinants, including IM channels, may differ.

In order to examine this issue, estimations are made considering as dependent variable the choice made by firms between the adoption developed mainly in collaboration and the adoption developed mainly by other firms or institutions.

Therefore, two selection biases are faced. The first one, as in previous estimations is due to the rejection of non innovative firms. The selection equation is the same as the equation (i) reported in Table A.III.4. In addition to that, a second selection bias can appear as our estimation is conditional to the adoption of a new technology. Indeed, in order to analyse the way adoption occurs, we reject from the sample of innovative firms, those firms that mainly develop their innovations by themselves. To say it differently, only adoptive firms are observed in our final equation. Therefore, two selection equations are needed to account for the two restrictions imposed: only innovative firms, and among them, only adoptive ones. The following diagram summarizes the potential biases:



The second selection bias is corrected using estimation (iv). Consequently, model (xii) estimates the probabilities to adopt a technology developed by other organizations or institutions (model xi is estimated without bias selection to allow comparison).[83] In order to respect the identification condition, LNTURN is assumed to influence the choice to adopt or not only, and not the choice between made in cooperation and in isolation.

The estimations are reported in Table A.III.7 below. Concerning the selection equations, LAMBDA is significant. The IRM captures unobservable effects included in the intercept suggesting that correction is needed. The selection bias is positive, which means that the unobserved characteristics affecting positively the probability to adopt influence positively the probability to adopt product or process developed by others. Conversely, they affect negatively the probability to adopt by cooperation.

Equation (xii) shows that **several significant differences appear between adoption made in cooperation and in isolation**. Four explanatory variables influence significantly the way adoption is made. **The higher the level of highly educated workers and export, the lower the propensity to adopt innovations developed by others** (and hence, the higher the propensity to adopt innovations by cooperation). Similarly, **belonging to a group and using**

[83] See Guironnet (2006) and Giret and Hatot (2001).

patent protection reduce the probability of adoption made in isolation (and hence, increase the probability of adoption made by cooperation).

Table A.III.7. Cooperation-based adoption vs other organization-based adoption[84]

Variables	Total Adoption made in isolation without correction (xi)	Total Adoption made in isolation with correction (xii)
Intercept	0.266***	-0.600
	(0.070)	(0.412)
LNRTOT	-0.007	-0.005
	(0.005)	(0.005)
LNEMPHI	-0.058***	-0.066***
	(0.015)	(0.015)
PATENT	-0.278***	-0.370***
	(0.040)	(0.063)
GP	-0.094*	-0.201**
	(0.044)	(0.069)
ORGA	-0.129**	-0.091
	(0.047)	(0.049)
PUBLIC	-0.096*	-0.031
	(0.045)	(0.053)
LNEXP	-0.007*	-0.008**
	(0.003)	(0.003)
COOP	-0.352***	-0.086
	(0.044)	(0.133)
Sectoral Dummies	Yes	Yes
Country Dummies	Yes	Yes
Lambda	Nc	0.817*
		(0.384)
Percent concordant	67.8	67.9
Likelihood	-3275.12	-3273.40
LR test (Beta=0)	7062.26***	513.47***
LR test (dummies=0)	182.56***	187***
Observations	5599	5599

Note: **LNRTOT**: Total innovation expenditure of the firm, **LNTURN** : turnover of the firms, **LNEMPHI:** higher education-skilled workforce, **PATENT:** takes the value 1 if the firm uses patent protection and 0 otherwise, **GP**: dummy variable indicating whether the firm belongs to a group or not, **ORGA**: dummy variable for organizational structure **PUBLIC**: public financial supports, **LNEXP**: exports as in CIS, **COOP**: firms cooperate in innovation
t-ratio are given in parenthesis level of significance: * 10%, **5%,***1%

The correction of the second selection bias modifies substantially the level of significance of the variables that account for organizational innovation **(ORGA)** and cooperation activities (**COOP).** This means that, once the selection bias is accounted for **there is no significant impact of these two variables on the choice between adopting innovation in collaboration or adopting innovation developed by others.**

[84] The selection equation is not reported here because it it the same as equation as the equation (i) reported in Table A.III.4. Moreover, results for total adoption made in cooperation are not reported since they are exactly opposite to the one obtained for total adoption made in isolation (the dependent variable being dichotomous)

On the whole, concerning the estimated impact of the different determinants over the adoption of innovation, different conclusions arise[85]:

- The size of the firm positively impacts on innovation adoption. But its effect is due to process innovation and does not occur for product innovation adoption.
- Firms benefiting from public funding have a higher propensity to adopt innovation, and more specifically process innovation.
- Organizational innovations are also positively associated to adoption, but weakly significant.
- Then several variables produce a negative impact on adoption. This is the case for membership of a group, absorptive capabilities (measured by innovation expenditure and highly educated workers) and exports. This runs counter traditional theoretical model as well as empirical studies. This is due to our specific sample that covers only innovative firms. The selection equation highlights that a positive impact occurs on innovation. Then, compared to innovations developed within firms, these variables exert a negative effect on innovation acquired externally. Therefore, these variables increase the global propensity to innovate. Among the different ways of innovation however they foster generation of innovation instead of adoption.
- Cooperation increases the ability to adopt both product and process innovation. The impact is however higher on product adoption than on process adoption. However, this variable does not impact differently the choice between other adoption made in cooperation and adoption made in isolation. Cooperation would thus be an important characteristic of adoption, whatever the way this adoption is made.
- Several factors impact on the way adoption is made. Higher education, legal protection (patents), ownership by a group, organizational changes, public funding of innovation and exports are the main drivers of cooperation-based adoption. They conversely influence negatively adoption made in isolation.

A.III.5.2.4. Some ancillary statistics

Here below we provide some additional statistics on the main variables that have been used in the second stage regression at a micro level.

[85] Table A.III.8 sumaries some of the results presented in this micro analysis.

Table A.III.8. Descriptive statistics					
	Mean	**Std. Dev.**	**Min**	**Max**	**Num. Obs.**
LNRTOT	4.970	5.93	0	22.179	29010
LNTURN	14.275	2.213	0	24.532	47759
LNEMPHI	1.747	1.473	0	10.073	47045
PATENT	0.213	0.409	0	1	47759
GP	0.215	0.411	0	1	48790
ORGA	0.509	0.500	0	1	47759
PUBLIC	0.070	0.255	0	1	47759
LNEXP	6.500	6.723	0	23.981	45324
COOP	0.293	0.455	0	1	14217
TURNINC	0.110	0.313	0	1	49064
TUNRDEC	0.067	0.251	0	1	49061
LNWTURN	12.805	2.463	0	23.869	47712
LNEXP*INTMAR	3.206	6.005	0	23.981	45324
LNEXP*NATMAR	2.239	4.855	0	21.184	45324
LNEXP*LOCMAR	1.036	3.348	0	20.978	45324
EST	0.048	0.215	0	1	49139
Adoption	0.125	0.331	0	1	49139
Product adoption	0.041	0.199	0	1	47759
Process adoption	0.059	0.235	0	1	47759
Cooperation-based adoption	0.277	0.447	0	1	14145
Other organisations-based adoption	0.126	0.332	0	1	14145

Table A.III.9. Correlation matrix

	PDT	PROC	LNRTOT	lnturn	lnemphi	patent
PDT	1.00000	-0.05189	0.19041	0.07171	0.06929	0.11667
PROC	-0.05189	1.00000	0.33004	0.17034	0.12323	0.15420
LNRTOT	0.19041	0.33004	1.00000	0.37525	0.34184	0.48220
lnturn	0.07171	0.17034	0.37525	1.00000	0.53623	0.28196
lnemphi	0.06929	0.12323	0.34184	0.53623	1.00000	0,26935
patent	0.11667	0.15420	0.48220	0.28196	0.26935	1.00000
GP	0.06511	0.09907	0.26198	0.43628	0.34948	0.24335
orgalarg	0.09197	0.13301	0.20131	0.24156	0.26982	0.32270
public	0.11644	0.21220	0.43136	0.19365	0.18986	0.27651
lnexp	0.04567	0.10542	0.30857	0.38680	0.27701	0.26989
CO	0.07918	0.06568	0.20683	0.15857	0.24090	0.18471

	GP	orgalarg	public	lnexp	CO
PDT	0.06511	0.09197	0.11644	0.04567	0.07918
PROC	0.09907	0.13301	0.21220	0.10542	0.06568
LNRTOT	0.26198	0.20131	0.43136	0.30857	0.20683
lnturn	0.43628	0.24156	0.19365	0.38680	0.15857
lnemphi	0.34948	0.26982	0.18986	0.27701	0.24090
patent	0.24335	0.32270	0.27651	0.26989	0.18471
GP	1.00000	0.16033	0.12970	0.23587	0.21217
orgalarg	0.16033	1.00000	0.17534	0.10926	0.08850
public	0.12970	0.17534	1.00000	0.16930	0.20948
lnexp	0.23587	0.10926	0.16930	1.00000	0.16061
CO	0.21217	0.08850	0.20948	0.16061	1.00000

Appendix III.6. Summary of the variables used in part III

Table A.III.10: Summary of the variables used in part III					
Category	**Variables**	**Description**	**Type**	**Year**	**Source**
Innovation and adoption	Innovation rate	Share of innovative firms (in percentage of the total number of firms)	Quantitative	2000	CIS3
Innovation and adoption	Innovation adoption rate	Share of adopting firms (in percentage of total number of innovatives firms)	Quantitative	2000	CIS3
Innovation and adoption	Cooperation-based adoption	Share of innovatives firms which mainly cooperate for developing innovation	Quantitative	2000	CIS3
Innovation and adoption	Other organisation-based adoption	Share of innovatives firms which rely on innovation developed mainly by others	Quantitative	2000	CIS3
Innovation and adoption	No adoption	Share of innovatives firms which develop innovation by themselves	Quantitative	2000	CIS3
Innovation and adoption	Product innovation	Share of product innovative firms (in percentage of the total number of firms)	Quantitative	2000	CIS3
Innovation and adoption	Product adoption	Share of product adopting firms (in percentage of product innovative firms)	Quantitative	2000	CIS3
Innovation and adoption	Process innovation	Share of process innovative firms (in percentage of the total number of firms)	Quantitative	2000	CIS3
Innovation and adoption	Process adoption	Share of process adopting firms (in percentage of process innovative firms)	Quantitative	2000	CIS3
Internal Market Proxy	Involvement in Business Operations	Weighted average of two regulation indicators: Price Controls (with a weight of 0.45) and Use of command and Control regulation (with a weight of 0.55)	Quantitative	1998	PMR OECD
Internal Market Proxy	Price controls	4 sub-indices: air travel, road freight, retail distribution and telecommunication.	Quantitative	1998	PMR OECD
Internal Market Proxy	Use of command and Control regulation	Controls over Road freight, Retail distribution, Air travel and Railways			

Internal Market Proxy	Communication and simplification Procedures	Regulations aimed at increasing communication. See above in Appendix A.III.4. for more detail description	Quantitative	1998	PMR OECD
Internal Market Proxy	State Control	Overall index for Scope of public enterprise sector, Size of public enterprise sector, Direct control over business enterprise, Use of command & control regulation, Price controls (for detailed description of sub-indices see above in Appendix A.III.4)	Quantitative	1998	PMR OECD
Internal Market Proxy	Licenses and Permits system	Easiness to Obtain Licenses, see above in Appendix A.III.4	Quantitative	1998	PMR OECD
Internal Market Proxy	Regulatory and Administrative Opacity	Overall index for: (License and permits system, Communication and simplification of rules and procedures, Administrative burdens for corporation, Administrative burdens for sole proprietor firms, Sector-specific administrative burdens)	Quantitative	1998	PMR OECD
Internal Market Proxy	Barriers to Competition	Index (from 1 to 10) of the importance of barriers to competition	Quantitative	1998	PMR OECD
Internal Market Proxy	Product Market Regulation	Overall index of Product Market Regulation as in Conway, Janod and Nicoletti, (2005). The indicators are constructed from the perspective of regulations that have the potential to reduce the intensity of competition in areas of the product market where technology and market conditions make competition viable. They summarize a large set of formal rules and regulations that have a bearing on competition in OECD countries	Quantitative	1998	PMR OECD

Internal Market Proxy	Working days spent to deal with Bureacracy	Index of bureaucratic quality	Quantitative	1998	PMR OECD
Internal Market Proxy	Number of bodies to be contacted in order to run a business	Index of bureaucratic quality	Quantitative	1998	PMR OECD
Internal Market Proxy	Sectoral and ad Hoc State Aid	Proxy for fair competition	Quantitative	1999	Eurostat, Internal Market Scoreboard
Internal Market Proxy	TDI indexes	Number of EU regulations (according to areas) which have been transposed by each member state over the total	Quantitative	1999	Eurostat
Internal Market Proxy	Freedom to Trade	Overall index for: taxes on international trade (representing the revenues and mean tariff rates applied in each country as well as the standard deviation of these tariffs), regulatory barriers (as the average of hidden import barriers and cost of importing), actual size of trade sector compared to its expected size (derived from gravity analysis), differences between official exchange rates and black-market rate and finally international capital market controls			Economic Freedom of the World Index
Internal Market Proxy	Transfer and Subsidies as a % of GDP	Country's ratio of transfers and subsidies to GDP	Quantitative	1995	Economic Freedom of the World Index, International Monetary Fund, *Government Finance Statistics Yearbook* (various years)
Internal Market Proxy	Government enterprises and investment as a percentage of total investment	Data on the number, composition, and share of output supplied by State-Operated Enterprises (SOEs) and government investment as a share of total investment	Quantitative	1995	Economic Freedom of the World Index, International Monetary Fund, *Government Finance Statistics Yearbook* (various years)

Internal Market Proxy	Legal Structure and Security of Property Rights	Overall index for protection of property rights	Quantitative	1995	Economic Freedom of the World Index, Global Competitiveness Report.
Internal Market Proxy	Trust	"Most people can be trusted" index in each country	Quantitative	2000	World Social Survey
Innovation expenditure	Total innovative expenditure	Expenditure for innovation (only for innovatives firms and transformed with neperian logarithm)	Quantitative	2000	CIS3
Human capital ressources	Education level	Average number of employees with high education in innovative firms	Quantitative	2000	CIS3
Human capital ressources	Human ressources in Science and technology	Share of labor force in science and technology domain	Quantitative	2000	CIS3
Human capital ressources	Organizational changes	% of innovative firms having implemented new or significantly changed organisational structures	Quantitative	2000	CIS3
Transmission Channel	Cooperation	Share of innovative firms engaged in R&D cooperation	Quantitative	2000	CIS3
Transmission Channel	Markup	Value-added as a share of labour and capital costs	Quantitative	1998	Griffith et al. (2006), OECD Stan Database
Transmission Channel	Trade	Share of export sales (in percentage of the turn over)	Quantitative	2000	CIS3

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