Innovation and Employement in European Firms: Microeconometric Evidence

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PREFACE

Within the Fifth Framework Programme of the European Union for Research and Technological Development (1998-2002), the Key Action "Improving the socio-economic knowledge base" carried broad and ambitious objectives, namely: to improve our understanding of the structural changes taking place in European society, to identify ways of managing these changes and to promote the active involvement of European citizens in shaping their own futures. A further important aim was to mobilise the research communities in the social sciences and humanities at the European level and to provide scientific support to policies at various levels, with particular attention to EU policy fields.

The Key Action Call "Improving the socio-economic knowledge base" had a total budget of 155 Million of Euros and was implemented through the launch of three Calls for proposals. As a result, 185 selected projects for funding have started their research work respectively in 1999, 2001 and 2002, involving more than 1600 research teams from 38 countries.

At least half of these projects are now finalised and results are (being) systematically published in the form of a Final Report.

The Calls have addressed different but interrelated research themes which have contributed to the objectives outlined above. These themes can be regrouped under a certain number of areas of major policy relevance, each of which are addressed by a significant number of projects from a variety of perspectives.
These areas are the following:

- Societal trends and structural changes;
  16 projects, total investment of 14.6 Million Euro, 164 teams
- Quality of life of European Citizens,
  5 projects, total investment of 6.4 Million Euro; 36 teams
- European socio-economic models and challenges
  9 projects; total investment of 9.3 Million Euro; 91 teams.
- Social cohesion, migration and welfare
  30 projects, 28 Million Euro; 249 teams.
- Employment, and changes in work
  18 projects; total investment of 17.5 Million Euro; 149 teams
- Gender, participation and quality of life
  13 projects; total investment of 12.3 Million Euro; 97 teams
- Dynamics of knowledge, generation and use
  8 projects; total investment of 6.1Million Euro; 77 teams
- Education, training and new forms of learning
  14 projects; total investment of 12.9 Million Euro; 105 teams
- Economic development and dynamics
  22 projects; total investment of 15.3 Million Euro; 134 teams
- Governance, democracy and citizenship
  28 projects; total investment of 25.5 Million Euro; 233 teams
- Challenges from European enlargement
  16 project; total investment of 12.8 Million Euro; 116 teams
- Infrastructures to build the European Research Area
  9 projects; total investment of 15.4 Million Euro; 74 teams.

The work undertaken by the project "Innovation and Employement in European Firms: Microeconometric Evidence" has contributed primarily to the area "Economic development and dynamics".

The research was carried out by 4 teams over a period of 3 years (2001-2004). The report contains the main scientific findings of the project and their policy implications.

The project aimed at studying the effects of innovation on the performance and growth of firms, with a focus on the effects on employment. The research carried out can be grouped under four general subjects: European innovation data, competition and innovation, innovation and productivity, and innovation and employment.

As the results of the projects financed under the Key Action 'Improving the Socio-economic knowledge base' become available to the scientific and policy communities, Priority 7 "Citizens and Governance in a Knowledge Based Society" of the Sixth Framework Programme of the European Union for Research and Technological Development (RTD) is building on the progress already made and aims at making a further contribution to the development of a European Research Area in the social sciences and the humanities.

I hope that readers find the information in this publication both interesting and useful, as well as clear evidence of the importance of the European Union's fostering of research in the field of social sciences and the humanities.

T. Lennon
Director

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Abstract

The research project "Innovation and Employment in European Firms: Microeconometric Evidence," was aimed at studying the effects of innovation on the performance and growth of firms, with a focus on the effects on employment. In addition, the project set as an objective the coordinated work across countries using firm-level data, assessing the data available and trying to develop ways to use them for research at the European level. The research project also shared a methodological approach in the use of advanced econometric techniques. The research carried out can be grouped under four general subjects: European innovation data, Competition and innovation, Innovation and productivity, and Innovation and employment.

The research made use of the Third Community Innovation Surveys (CIS3), which is an EU-harmonised statistic, to assess the factors affecting innovation across countries. While this is a harmonised study, some important differences remain in the wording and different institutional framework for some questions and variation in statistical methods used. Taking this into account, the exploration of the remaining differences suggested at least three important forces: a trend towards incentive equalization derived from the EU; an increasing European-wide dimension of each market, which is likely to influence its inter-country structure; individual country and industry composition and evolution.

Our research on cooperation and innovation, confirms that firms' ability to take advantage of incoming spillovers, in the form of publicly available knowledge, and limit outgoing spillovers and appropriate the returns to their innovative efforts, has a positive effect on the likelihood of R&D agreements. Firms also appear less likely to engage in cooperation in industries with strong legal protection methods, and public support is positively related to the probability of undertaking cooperative agreements. Other findings on the relationship between competition and innovation stress the role of competitive pressure (entry, foreign advanced technological competition) in stimulating innovation.

Innovation and productivity outcomes confirm the usual results with respect to the traditional effects linking R&D, innovation and efficiency: size influences the propensity to perform R&D but not its intensity; R&D plays a role in explaining innovation together with size and the (corresponding) indicators of demand pull (in product innovation) and cost push (in process innovation); innovation outputs positively influence labour productivity. In the last stage of the project, effort has been made towards the coordinated estimation of a multi-equation version of the structural model linking these effects, using the CIS3 data. The econometric results show some interesting heterogeneity across the four countries.

Our research on Innovation and employment has empirically investigated the firm-level employment effects of innovation, making three main contributions: the use of a unique comparable firm-level data set across countries, the application of a simple model of innovation and employment that disentangles many of the effects at work and, finally, evidence for the service sector. The main results reveal that, in manufacturing, although process innovation tends to displace employment, compensation effects are prevalent, and product innovation is associated with employment growth. In the service sector, there is less evidence of displacement effects from process innovation, but growth in sales of new products also accounts for a non-negligible proportion of employment growth.

2. Executive summary.

The research project "Innovation and Employment in European Firms: Microeconometric Evidence," started with several lines of research (innovation and productivity; innovation and firms' demand and market shares; innovation, employment, wages and prices) and was aimed at studying the effects of innovation on the performance and growth of firms, particularly the effects on their employment. In addition, the project set as one of its objectives coordinated work on European data, assessing the data available and trying to develop ways to use them for research at the European level. The research project also shared a methodological approach in the use of advanced econometric techniques. An additional line of research was added to focus on the relationships between competition and innovation: product market competition and innovation.

In the second phase of the project lifetime, a number of common papers were planned, that involved collaborative work by the researchers of the four countries involved, following the lines of the research started with more country-oriented papers. Most of this work has been grounded in the access to the firm-level data generated by the harmonised survey CIS3 (Community Innovation Survey, third wave), facilitated by the statistical offices and corresponding institutions on a country basis. Other, more country-specific data bases have helped to complement these data.

The final result of the project is summarised in five main collaborative papers, which follow many other previous papers, and are accompanied by some complementary papers, which develop the approach and methodology with particular detail for some of the countries involved. These common papers have four subjects, closely related to the project's lines and work packages, that have organised the final steps of the research.

The first subject is the assessment of the comparability of European innovation data as well as the characterisation of the main traits of innovative activity in the four European countries. CIS3 data, generated according to the Oslo manual definitions, is the natural option for working at the European scale. But given the different wording of the questionnaires, the different institutional framework for some questions and even the different statistical practices, comparability across countries should be assessed, especially for a microeconometric exploitation of the data. In addition, description at the four countries' level was the first step needed to develop the rest of the work.

The other three subjects are: competition and innovation, innovation and productivity, and innovation and employment. We briefly describe in turn the setup and main results of the work under these headings.

Using European innovation data

The results of the CIS3 show significant differences among European countries in most innovation indicators at the aggregate level, with respect to firm participation in innovation, innovation efforts (expenditure for innovation over total turnover), and share of turnover associated to new products. This is true even when comparing the four large European countries, France, Germany, Spain and the United Kingdom (UK).

This pattern raises at least two important questions: firstly, whether the data are really comparable, i.e., whether the information is homogeneous enough and sufficiently precise to admit comparison-based inferences across countries; secondly, and more substantially, if it is the case that data are reasonably comparable, which effects mainly drive the aggregate differences. Differences may be related to the incentives for firms to innovate on a country level, i.e., country-specific features common to all industrial sectors (differences in the macroeconomic environment, degree of competition, structures of market factors, regulation, technology policy including the aspect of public support) But differences in innovation performance at the aggregate level can also be due to varying sector compositions of economic activity given sector-specific innovation behaviours.

Although CIS3 is an EU-harmonised statistic, some differences remain across countries, which imply that very specific comparisons must be made with care. In particular, statistical errors, the different wording and the different institutional framework for some questions and the various methods used for dealing with non-response can lead to statistical differences in the numbers. The data used must then be checked in these respects, both at the national and international levels, as we have done with our particular samples, ensuring that the employed indicators present a useful and reliable picture taken as a whole.

The exploration of the differences suggests there are at least three important forces at work: (i) a trend towards incentive equalization derived from the development of an integrated European market; (ii) the own increasing European-wide dimension of each specific market, which is likely to influence its inter-country structure (e.g., dominant acquired positions, possibly due to economies of scale, previous sunk investments, technological advantages and so on, may induce intra-market inequalities); (iii) each country industry composition and its evolution. Our exercises have, however, shown that the influence of the last factor is, in general, negligible.

As a summary of facts, we can say the shares of innovators do not seem to be strikingly different sector by sector, with the exception of Germany, where they are consistently higher across sectors. Specific high values are detected, however, for particular countries and sectors, which can be linked either to some European leadership of the firms in the sector (product innovation), or particular efforts to reduce costs and become more competitive (process innovation).

There is some additional heterogeneity, however, in innovation input measures. Germany often – but not always – shows the highest industry values while, at the other extreme, Spain consistently shows the lowest values (at the aggregate level, partly due to relative industry concentration in the low-technology sectors). Heterogeneity in input measures (e.g., firms' R&D intensity) across countries in the same industry can be considered to reflect relative European-wide market positions of the firms involved (and hence also sometimes the primary domestic-market -or export to third parties- orientation of some of them). More heterogeneity may be implied in behaviour, where cooperation shows, somewhat surprisingly, one the largest and most different variations. France and the UK, with proportions of firms which are close to each other, present the highest degrees of cooperation, while Germany is only intermediate and Spain the lowest one. Average proportions of financially supported firms tend to be similar with the exception of the UK (whose proportion of supported firms in high-technology sectors is, however, not so dissimilar). Nonetheless, proportions of supported firms may be hiding important differences in the amount of funds received by firms and the process by which these funds are assigned.

With reasonably comparable data and significant differences among the values of the innovation variables (e.g., intensity, inputs and outputs, behaviour and public support), as well as forces which can explain many dimensions of the differences (by industries intra-country, intra-industry in European global markets, across countries), the type of work represented by the lines of research in this project is possible and important. Cross-country comparable samples, consisting of observations of many firms from different industries (including manufacturing and services), treated with suitable microeconometric techniques, are the only way to generate reliable evidence in support of (empirically or theoretically) presumed regularities and to quantify them, to explore and understand the underlying behavioural mechanisms as well as to evaluate both the potential and results of economic policies. The assessments, quantifications, conclusions and questions which emerge in the rest of this summary are derived from this type of work.

Competition and innovation

The relationship between market competition and innovation has for a long time been a question of interest for economists and policymakers. Economic theory predicts several difficulties for the innovative activities to be carried out at an optimal level in a fully competitive environment. The character of the input “knowledge” (freely usable when displayed), the presence of important fixed -and often sunk- costs of innovative activity investments, and the uncertainty associated with the results, are likely to provide few incentives to firms to allocate enough resources to an activity that, on the other hand, shows important positive externalities towards other firms and consumers. But, at the same time, as many empirical works have shown, competitive pressure seems in many circumstances to strongly stimulate innovative activities and the introduction of innovations by firms, both in their processes and products.

With the ultimate interest of stimulating innovation, a lot of attention has been recently focused on the subject of cooperative R&D of firms, or agreements by which firms share the costs and returns of innovative projects, sometimes with other firms and sometimes with research institutions. These agreements, from the positive point of view, are likely to show mechanisms by which firms can profitably appropriate free flows of knowledge and protect them. Hence they are an interesting guide to normative regulation, which must try to consolidate mechanisms of incentives and at the same time avoid harming market competition.

The final stage of the research has involved extensive research focussed on cooperation. This has found that firms’ ability to take advantage of incoming spillovers, in the form of publicly available knowledge, and limit outgoing spillovers and appropriate the returns to their innovative efforts, both have a positive effect on the likelihood of firms undertaking cooperative R&D agreements. Moreover, incoming spillovers have been found to be a more important factor in determining collaborative agreements with research institutions, and appropriability a more important determinant of vertical cooperative agreements up and down the supply chain.

In our coordinated econometric exercise, carried out with samples of the four countries, the results support those findings in that we found a positive relationship between the likelihood of undertaking a cooperative agreement and both incoming knowledge spillovers and the extent to which firms find strategic methods important in appropriating the returns to innovative activity. However, it is also found that, on average, firms are less likely to engage in cooperative agreements in industries where legal protection methods such as patents are important for securing returns to R&D. At the same time, public support is positively related to the probability of undertaking cooperative agreements, particularly with regard to the likelihood of cooperation with the research base.

The project has also produced evidence on the following questions related to the dynamics of technology: the relationship between ownership and convergence of technology, the probability of introducing process innovations according to the age of the firm, the identification of spillovers and conscious sourcing strategies by firms, and the impact of foreign competition and entry.

Innovation and productivity

There are a considerable number of national firm-level studies analysing the relationship between innovation and productivity, but cross-country comparisons using micro data are still rare. Our work here contributes to the literature by investigating the innovation-productivity nexus at the firm-level for the four European countries using the CIS3 data. It applies a structural model that describes the link between R&D expenditure, innovation output and productivity (CDM model).

The first outcomes obtained (CIS2 data) confirmed the usual results with respect to the most traditional effects: size influences the propensity to perform R&D but not its intensity; R&D plays a role in explaining innovation together with size and the (corresponding) indicators of demand pull (in product innovation) and cost push (in process innovation); innovation outputs positively influence labour productivity.

In the last stage of the project, effort has been made towards the coordinated estimation of the structural model with the CIS3 data. The econometric results show some interesting heterogeneity across the four countries. Using different innovation output indicators, it is found that the innovation output is significantly determined by the innovation effort in three of the four countries (France, Germany, the UK); the results for Spain are less clear in this respect. In contrast to that, productivity effects of innovation showed up only for France, Spain and the UK, but not for Germany.

Another, different strand of research, done with panel data, has stressed the forms of the impact of innovation on productivity, relating them to the age of the firms. Firms demonstrate high TFP (total factor productivity) growth up to the eighth year in the market, and then growth converges to a common rate (different according to activities). The introduction of process innovations boosts productivity growth for more than one year, but the firm must continue introducing process innovations in order to keep the common pace of productivity growth.

Innovation and employment

The consequences of innovation for employment are of particular interest, but the relationship between innovation and employment is complex. On the one hand, the long-run macro-economic impact of innovation on employment is clearly not negative; many decades, and even centuries, of innovation in advanced economies have not been accompanied by ever-decreasing levels of employment. Yet, at the same time, the impact of innovation on employment at the firm level remains unclear. Individual innovations may destroy jobs, but innovation can also stimulate demand, and evidence suggests that, on average, innovative firms are more likely to survive and grow than firms that do not innovate.

The firm-level relationship between innovation and employment is an important topic of research for several reasons. For example, the effects of innovation on employment at the firm level are likely to influence the extent to which different agents within the firm resist or encourage innovation. In addition, the incentives of managers and workers will determine the types of innovations that are introduced and their subsequent effects on prices, output and employment. Understanding these incentives and welfare effects at the micro level is essential for the effective design of innovation policy, and for predicting how other interventions, such as labour market regulations, might affect the rate of innovation.

Our work here develops an empirical investigation of the firm-level employment effects of innovation, making three main contributions to the literature. First, it uses a unique comparable firm-level data set across four large European countries. Firms in these countries operate in different economic and institutional environments, and the results identify several common robust effects as well as interesting cross-country differences in the firm-level relationship between innovation and employment. Secondly, the structure of the data allows us to apply a simple model of innovation and employment that disentangles many of the different effects at work. In particular, the mix of each firm's output growth between existing and newly introduced products is observed, enabling us to quantify the employment effects of product innovation. Finally, evidence is presented from roughly 19,000 firms, more than 6,000 of which are in the service sector.

The main results reveal that, in manufacturing, although process innovation tends to displace employment, compensation effects are prevalent, and product innovation is associated with employment growth. The destruction of jobs through process innovation appears to be partly counteracted by compensation mechanisms that increase demand through lower prices. At the same time, no evidence of displacement effects associated with product innovation is found, and compensation effects resulting from the introduction of new products are significant even when the cannibalization of old products is taken into account. In the service sector, there is less evidence of displacement effects from process innovation, and though less important than in manufacturing, growth in sales of new products accounts for a non-negligible proportion of employment growth. Interestingly, our results match well with the scarce evidence available.

Overall, the results are similar across countries, although there emerge some interesting differences which might also merit further investigation. For example, no evidence for a net displacement effect of process innovation in Spanish manufacturing is found, possibly due to greater pass-through of productivity improvements in lower prices. Product innovation appears to play a larger role in employment growth in Germany than in the other countries, and possibly a smaller role in the UK, while higher levels of firm-level employment growth over this period in Spain are largely explained by faster growth in the output of existing products.

Additional research with Spanish panel data which allow for modelling agents' reactions shows that innovation displaces labour but also creates the firm-level conditions which compensate displacement. Process innovations reduce marginal costs and this reduction can be passed on to prices to expand demand with an employment effect that doubles the first effect. In addition, product innovations, which most of the innovative firms carry out at the same time as process innovations, double the expanding effect obtained by unity of innovative expenditure. Positive potential net effects of process innovation are estimated to be reduced in the long run, when competitors match the innovations, but positive potential net effects of product innovation of a significant magnitude tend to persist in the long run.

Results also show, however, that the working of the compensation mechanisms can be dampened by the behaviour of the firm agents. In any case, average global actual net employment effects of innovations are estimated to be positive, even in the long run. A caveat to take into account is that innovation is only one of the sources of firm-level productivity growth and that other sources (embodied technical change, learning, spillovers, "outsourcing" of firm activities) can have more negative net effects on employment.

Policy implications

Aggregate productivity indicators systematically detected a slower growth of the EU economy in the 90's when compared with the US. This, although particularly based on the behaviour of certain sectors and their presumably general role in the economy (ICT's, some services), has been the cause of greater concern and discussion on the ability of the European economy to develop, diffuse and apply the new technologies, transforming them into an engine of growth. The "Lisbon strategy," a policy response to this challenge, embodied a broad set of structural reform targets, with the global aim of making the European economy an advanced knowledge-based competitor by 2010. The development of these policies continues today, being a subject of primary attention. The results of this project, focussed on the description and understanding of several firms' innovative activities and decisions, have some general implications for these policies.

The premise is, as our results show, that innovative activity enhances productivity. This effect is quite robust to all markets, countries and ways of measurement, although its magnitude can differ broadly. The question is how to reinforce the best realisations of this fact.

First of all, as it has already been stressed, the European unified (manufacturing) markets which emerge from our characterisation are far from homogeneous, including –even for the same activity- different rates of participation in the innovative activities, different levels of resource commitment and different degrees of coordination of R&D activities. Sometimes the differences seem to be linked to the size of the firms, as a possible effect of the sunk costs associated with the innovative activities (too high for small competitors), but a less-than-perfect practical unification or globalisation of markets can probably explain many other situations. From this point of view, policies directed towards the reduction of inequalities in the intra-European dimension of the markets, by limiting segmentation and promoting the benefits of technological competition, seem to have an important margin for improving efficiency.

All our results show that the highly competitive situations tend to promote stronger rates of efficiency increase and a faster approximation to the technological frontier. Entering and young firms show faster productivity growth and create positive technological spillovers in their markets; proximity to foreign, technologically developed firms, either because of its penetration of domestic markets or the conscious sourcing pursued in foreign markets, stimulates technological development. This fact, combined with the intra-market inequalities which emerge from our previous description, points to a role for an active competition policy supporting entry, foreign investments, product development and the like.

Cooperation clearly emerges from our results as a way, still very unequally developed, to face the challenges of technological developments by enhancing profitable innovation. This is a timely subject. Both the OCDE and the European Union support the idea of developing stronger industry-science linkages. The British and German governments have defined precise policies to encourage collaborative activities. Other countries are considering doing the same. Our findings support the idea that both the presence of "incoming spillovers" and the ability to "appropriate" the returns from innovation stimulate cooperation, which means that the enlargement of collaborative practices can strengthen innovation and this can be policy-promoted. In fact, the results already show some positive association between cooperation and public support, which possibly stresses the presence of an already active supporting policy.

Finally, innovation emerges from our study as positively influencing the employment of established firms. However, a distinction must be made between: a) the acute process innovations made in isolation to rationalise costly processes, which will mainly and inevitably cut jobs; b) the process innovations associated with price reductions which tend to create their own compensation mechanisms; and c) the strong positive effects detected to stem from product innovation. Labour market policy should be directed towards making the processes of the first type as painless as possible, making this compatible with encouraging the high flexibility necessary to ensure all the advantages coming from product and other process innovations. The positive effects are likely to need, for example, a high turnover of skills and new training facilities. Our results also stress the damage that a high degree of appropriability of the innovation returns may inflict on the employment effects, when they come from wages or prices too high. The promotion of technological competition can again be an important tool here for ensuring the spreading of the benefits.

2. Background and objectives of the project.

The research project "Innovation and Employment in European Firms: Microeconometric Evidence," started with several lines of research (Innovation and productivity; Innovation and firms' demand and market shares; Innovation, employment, wages and prices) and was ultimately aimed at studying the effects of innovation on the performance and growth of firms, particularly the effects on their employment. In addition, the project set as one of its objectives the coordinated work on European data, assessing the data available and trying to develop ways to use them for research at the European level. The research project also shared a unifying methodological approach: the use of the advanced econometric techniques necessary to reach the analysis goals. At the very beginning, one line more of research was added to focus on the relationships between competition and innovation: Product market competition and innovation (see the Periodic progress report corresponding to the first 12 months).

In the second phase of the project lifetime, a series of common papers was planned, to be elaborated coordinately by researchers of the four countries involved, following the lines of the research started with more country-oriented papers (see the Periodic progress report corresponding to the second 12 months). Most of this work has been grounded in the access to the firm-level data generated by the harmonised survey CIS3 (Community Innovation Survey, third wave), facilitated by the statistical offices and corresponding institutions on a country basis. Other, more country-specific data bases have helped to complement these data.

The final result of the project is summarised in five main collaborative papers, which follow the many other previous papers, and are accompanied by some complementary papers, which develop the approach and methodology with particular detail for some of the countries involved. These common papers have four subjects, closely related to the definitional lines and work packages of the project (see Annex C for details), that have organised the final steps of the research.

The first subject is the assessment of the comparability of European innovation data as well as the characterisation of the main traits of innovative activity in the four European countries. CIS3 data, generated according to the Oslo manual definitions, is the natural option to work at European scale. But comparability across countries, given the different wording of the questionnaires, the different institutional framework for some questions and even the different statistical practices, should be assessed, especially for a microeconometric exploitation of the data. In addition, description at the four countries level was the first step needed to develop the rest of the work.

The other three subjects just imply a slight reordering of the previous lines under simpler headers, which puts together the topics relative to firms' demand and market share with competition: Competition and innovation, Innovation and productivity, Innovation and employment.

The first subject is the assessment of the comparability of European innovation data and their usefulness while testing European inferences on innovation, its sources and its effects, as well as the characterisation of the main traits of innovative activity in the four European scale countries. Research has been organised around two documents. The first is the document entitled "Basic CIS3 statistics on four European countries (France, Germany, Spain and United Kingdom)," which uses the raw data to form country comparisons of the main indicators disaggregated by industries at a level not exploited by Eurostat (this document is due mainly to the efforts of E.Kremp, A.Lopez, B.Peters and H. Simpson). The second is the paper "National differences in innovation behaviour: facts and explanations. Results using basic CIS3 statistics for France, Germany, Spain and United Kingdom," by L.Abramowsky, J.Jaumandreu, E.Kremp and B.Peters, which compares the indicators and explores facts and interpretations.

The second subject is the relationship between innovation and competition. The final stage of research has been focussed on the timely subject of the cooperation in R&D, and its relationship to the possibilities and difficulties of firms' "appropriability" of the return of their innovation efforts. The central paper is entitled "Understanding cooperative R&D activity: evidence from four European countries," by L.Abramowsky, E.Kremp, A.Lopez, T.Schmidt and H.Simpson, and develops the characterisation of the main traits of cooperation in the four countries, carrying out a detailed microeconometric analysis of their influences and determinants. Two specific papers develop complementary analysis for Germany and Spain, "Knowledge flows and R&D cooperation: firm-level evidence from Germany," by T.Schmidt, and "Determinants for R&D cooperation: evidence from Spanish manufacturing firms," by A.Lopez, respectively. Six more papers have contributed to this broad subject during the project, focussing respectively on the questions of firms' age, ownership, technological sourcing and entry and their impact on innovation performance.

The third subject is the effect of innovation on productivity. The final stage of research has been coordinated around a four-country common assessment of the relationships which go from R&D effort to the implementation of process and product innovations, and from innovations to firm-level productivity, using a detailed multi-equation model and microeconometric techniques to treat their interrelationships. The coordinated paper is entitled "Innovation and productivity across four European countries," by R.Griffith, E.Huergo, J.Mairesse and B. Peters. A related paper is "Research, Innovation and Productivity: A New Look," by E.Kremp, J.Mairesse and P.Mohnen. Eight other papers have contributed to this line of research.

The fourth subject is the impact of innovation on firm employment. The final efforts have been focussed in a coordinated paper which develops a microeconometric model to separate a few well-established employment effects of firms' process and product innovation and applies it to the data on the four countries. The paper is entitled "Does innovation stimulate employment? A firm-level analysis using comparable micro data from four European countries," by R.Harrison, J.Jaumandreu, J.Mairesse and B.Peters. A complementary paper is focussed on Germany, "Employment effects of different innovation activities: Microeconometric evidence," by B.Peters, as well as two previous papers that were focussed on Spain (one developing the model with more complete panel data).

3. Scientific description of the project results and methodology.

In what follows, we develop the scientific description of the project divided into these four subjects. In each one, emphasis is put on the coordinated research that has focussed the final stage of the project and the main corresponding paper. Some space is, however, dedicated to some of the complementary papers and previous contributions. Some earlier papers, with strong comparative analysis content, are reviewed in relation to the first subject[1].

3.1 Exploring the use of European innovation data.

The results of the CIS3 show significant differences among European countries in most innovation indicators at the aggregate level, both with respect to firm participation in innovation (share of innovators), to innovation efforts (expenditure for innovation over total turnover), and innovation success (share of turnover associated to new products) (see Eurostat (2004)). This is even true when comparing the four large European countries: France, Germany, Spain and the United Kingdom (UK).

This pattern raises at least two important questions: firstly, whether the data are really comparable, i.e., whether the information is homogeneous enough and sufficiently precise to admit comparison-based inferences across countries; secondly, and more substantially, if it is the case that data are reasonably comparable, which effects mainly drive the aggregate differences.

Differences may be related to the incentives for firms to innovate on a country level, i.e., country-specific features common to all industrial sectors (differences in the macroeconomic environment, degree of competition, structures of factor markets, regulation, technology policy including the aspect of public support…) But differences in innovation performance can also be due to varying sector compositions of economic activity given sector-specific innovation behaviours. This would be the type of differences suggested by the ongoing process of European economic integration and globalisation facilitated by the EU, which both increase active (through growing export orientation) and passive (through growing import competition) international competition of domestic firms. Increased international competition in principle means that market structures of national markets should become more homogenous, with better access by firms to foreign factor markets (which would lead to an assimilation of factor prices). As a result, innovation incentives for firms from different countries in the same product market would be aligned, which should harmonise innovation behaviour of firms across countries. In the extreme case, with strong industrial specialisation and strong harmonisation of institutions, we should observe similar values for innovation indicators across countries when comparing only one sector. Thus, national differences in innovation behaviour would primarily be due to varying sector structures across countries.

1 See the previous reports for more detail.

In 2001, CIS3 were conducted under the coordination of Eurostat in the (at that time) 15 European Union (EU) member states as well as Norway, collecting data on innovation activities in the enterprise sector in the reference period 1998 to 2000. So far, Eurostat has published only results on a highly aggregated sector level (manufacturing, wholesale trade, producer services) for each country (Eurostat, 2004). Eurostat's online data base, New Cronos, also provides data on that sector level only.

The purpose of this part of the work was to explore the comparability of the data available for the four countries involved and, once this comparability was assessed as reasonable, to describe the main facts related to innovation across countries and try to answer the question of whether country-specific differences or differences in the industrial composition of economic activity across countries are the driving forces for the observed innovation pattern. Of course, this part of the work also constitutes the ground for the rest of the exercises, based on the massive use of the micro data for each of the countries.

At some point in time, an important number of indicators were put together, systematically comparing definitions and computations for manufacturing, in the document "Basic CIS3 Statistics on Four European Countries (France, Germany, Spain and United Kingdom)" (this document is mainly due to the efforts of E.Kremp, A.Lopez, B.Peters and H. Simpson). The document reviews input and output indicators of innovation activities for eleven manufacturing sectors in the four countries, using the available firm-level data from CIS 3 (made available in each country to the research team by the corresponding statistical offices and/or institutions in charge). By applying weighting factors, these innovation indicators are representative of the total firm population in each sector and thus enable sector comparisons between countries.

Using this document as a base, a more complete comparison has been made with five selected innovation indicators (or indicator types) in the paper "National differences in innovation behaviour: facts and explanations. Results using basic statistics CIS3 for France, Germany, Spain and United Kingdom," by L.Abramowsky, J.Jaumandreu, E.Kremp and B.Peters. Firstly, the share of firms that have successfully introduced product and/or process innovations gives an indication of the spread of innovation activities and is strongly influenced by the behaviour of small and medium-sized enterprises (SMEs), as these importantly influence the total number of firms. Secondly, as developing innovations requires several inputs, it is convenient to have some input indicators. The ratio of innovation expenditure to total turnover, which is a measure for input efforts, is one of the indicators employed. The share of innovators that perform R&D, which gives a hint of the extent of new knowledge production in the course of innovation activities, is another. Thirdly, the share of sales associated to new products is used as a quantitative indicator for the success of product innovation activities. Fourthly, the share of innovative firms with cooperations in innovation projects is used as a measure of inter-firm knowledge spillovers. Finally, the share of innovative firms with public financial support is employed to explore the role and extent of innovation policy activities for innovation in firms.

In what follows, we first briefly comment on the data and its comparability. Then, we summarise the main facts shown by the comparison, and next we explain the methodology which has been applied to answer the question of the relative importance of country-specific differences as opposed to a structural explanation of the aggregated differences. Finally, we comment on the comparisons and innovation modelling contributions in the early stage of the project.

3.1.1 Data sets and comparability

The Community Innovation Surveys take place every 4 years in European countries to investigate firms' innovation activities. The third wave was conducted in 2001. The CIS3 follow the recommendations of the OSLO Manual on performing innovation surveys (see OECD and Eurostat, 1997). The surveys were carried out by national authorities[2] and were coordinated by Eurostat. The questionnaire (including definitions), which was sent by post to the firms, is harmonised across countries and includes some core as well as some optional questions. In what follows, we concentrate on questions common to all countries. Beyond the questionnaires, statistical survey methods as well as data mining and analytical methods are also coordinated by Eurostat. A table in the second of the papers mentioned includes a summary of the main features of the surveys in each of the four countries considered.

The CIS3 cover all enterprises with 10 or more employees. An enterprise is defined as the smallest combination of legal units that is an organizational unit producing goods or services. In France, however, the target population for CIS 3 covers firms with 20 or more employees, only. This fact impedes cross-country comparisons between Spain, the UK and Germany on the one hand and France on the other hand. In CIS 2, launched in 1997, the target population also was enterprises with at least 20 employees[3]. One aim pursued with the new CIS 3 was to better understand the innovative activities among small firms which are a main part of the economy. This implies that one must be careful in comparing indicators, looking for ways to minimise the effect of this difference in coverage (e.g., sticking to strictly comparable samples and weighted aggregates for firms with at least 20 employees in all countries when there are major differences).

CIS 3 is based on stratified samples of the total firm population in each country, typically applying disproportional drawing probabilities by size class and sector. While for most countries, carrying out the CIS3 participation in the survey is voluntary for firms (such as in Germany and the UK), some countries have set the CIS3 as compulsory (such as France and Spain).

Net sample sizes (i.e., the number of firms returning a completed questionnaire) vary considerably among the four countries. Although Germany has the largest total population of firms, the net sample size is the lowest. This is caused by a small sampling frame due to financing restrictions of the German CIS survey and a low response rate as a result of voluntary participation combined with a somewhat greater reluctance of German firms to participate in surveys. The largest net samples are available for France and Spain as a result of compulsory surveys. The sampling ratios range from 3.4 % (Germany), 7.9 % (UK) and 13.7 % (Spain) to 18.6 % (France). In order to control for a response bias in the net sample, non-response analyses (NRA) have been carried out in Germany. A stratified random sample of

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2 In Spain, the survey was carried out by the national statistical office (INE Instituto Nacional de Estadstica). The DTI (Department of Trade and Industry) and SESSI (Industrial Statistics Bureau of the Ministry of Industry) were responsible for it in the UK and France, respectively. In Germany, the ZEW (Centre for European Economic Research) conducted the survey on behalf of the Federal Ministry of Education and Research.

3 The different target population in CIS 2 and CIS 3 hinders direct comparisons between the two waves (without losing much information).

firms in the gross sample that did not respond to the questionnaire was asked a few questions relating to core innovative activities, using a computer-assisted telephone interview technique. The sample size of the NRA was about the same size as the net sample in order to compensate for the low sample ratio. According to Eurostat methodology, the results of the NRA were used to adjust weighting factors for each responding firm in order to represent differences in the response behaviour of innovating and non-innovating firms.

CIS 3 was launched in 2001 with reference year 2000; the total firm population thus refers to the year 2000. The size of the total firm population differs only slightly among the four countries. Germany shows the largest firm population in manufacturing (approximately 49,500 firms with 10 or more employees), followed by Spain (44,200) and the UK (39,400). France, for which the total population refers only to firms with 20 or more employees, shows a total population of 24,500. This is the smallest figure even when compared with the respective total populations of firms with 20 or more employees in the other three countries (Germany: 38,300, UK: 27,700, Spain: 25,500). The large number of firms in Spain is somewhat astonishing as the country size in terms of GDP is only about a third of that of Germany, and only half of that of France and the UK. This result stresses that firm density in Spanish manufacturing is high, and the average firm size is low, i.e., the share of small firms is much higher than in the other three countries. The average size of Spanish firms, measured by the number of workers, is only somewhat higher than 50% of the size of its European counterparts. In only a few isolated cases, size is more similar to the firms' sizes in other European countries (e.g., high technology firms in Spain and UK). Smaller size implies even a more pronounced difference in the relative structure when measured in workers or sales.

Not surprisingly, average firm size is higher in innovative firms in each country. This is in line with empirical findings showing that incentives to innovate increase with firm size. In Spain, the size difference is even somewhat more pronounced in the case of innovative firms, probably because innovative firms of small size are numerous. The average size of Spanish innovative firms is only close to the size of the British firms in some high-technology sectors (chemicals) and even greater in another (transport), but it is far from the sizes of the German and (not directly comparable) French firms in these sectors. These figures may also be related to the size of the domestic market (which in Spain is clearly smaller than in the rest of the countries). Size obviously can represent a problem for affording some fixed or sunk costs of research.[4]

Total population of firms by sector reveals the well-known differences in sector specialisation. Germany has a comparatively large share of firms in machinery, electrical engineering (including medical, precision and optical instruments), plastics and metals. Spain's firm population shows relatively high shares in food, textile, non-metals and NEC. The firm population in the UK is rather strongly represented in transport, chemicals, and wood/paper, while France shows comparatively high firm numbers in food, textile, and metals. In total, Germany has a larger weight of high technology sectors (32% of the total number of firms), followed by the UK and France (29 and 27%, respectively), while Spain has only one out of five firms in the high-technology sectors (19%). As market incentives to innovate, as well as technological opportunities for developing new products and processes,

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[4] But it would be interesting to explore how much of the small size of Spanish firms can just be attributed to the opposite, i.e., to a low growth just due to weak innovative activities.

are typically larger in high-technology sectors, one may expect a higher share of innovative firms in Germany and a lower one for Spain.

In general, the conclusion of the data exploration is that although CIS3 is an EU-harmonised statistic, some differences remain across countries, which implies that very specific comparisons must be made with care. In particular, statistical errors associated with each number can differ greatly, and the different wording and the different institutional framework for some questions may induce somewhat different responses. Importantly, the various methods used for dealing with the difficult problem of item-non-response can lead to further differences in the numbers, both across countries and potentially within the national statistics. Therefore, it is important to carefully check the numbers of the indicators involved in any particular comparison both at the national and international levels, to ensure that they present a useful and reliable picture taken as a whole.

3.1.2 Five innovation indicators.

In this section, we summarise the results of comparing the selected basic CIS3 statistics on innovative activities in manufacturing at an aggregate as well as sector level. The figures show significant differences among countries in most innovation indicators, both with respect to firm participation in innovation, to innovation efforts, and innovation success.

Spread of innovative activities

The share of firms that have successfully introduced new products and/or processes gives an indication of the spread of innovative activities. The share of innovators out of total population is highest in Germany for manufacturing as a total as well as in all the eleven industries considered. The differences in the spread of innovative activities across the countries are substantial. While Germany exhibits 60% of its firms to be innovative in manufacturing during the period 1998-2000, only about 34% of UK firms introduced innovations.[5] The divergences are smaller for the share of product innovators and the share of process innovators, respectively, but the shares are still substantially higher for Germany than for the rest of the countries.

The most innovative industries come from the high-technology sector and are chemicals for France (64%), Spain (53%) and the UK (50%) and machinery for Germany (74%). Among the low-technology sectors, rubber and plastic is the industry with the highest share of innovators in all four countries. This pattern, however, is mainly driven by the share of product innovators; a different picture emerges for process innovators. Industries that are

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[5] However, when calculating the share of firms with positive innovation expenditure in year 2000, a different picture emerges as about one half of the UK firms report that they have positive innovation expenditure. For the other three countries, the difference between both indicators is much smaller (F: 33%, GER: 64%, S: 32%). The large divergence between both indicators in the UK may be a real phenomenon and can be explained by a lag between an input into the innovation process and its output, i.e., an innovation. But as this phenomenon occurs not only in one specific industry (e.g., chemicals) but in all industries, another likely explanation is due to the fact that there is an important difference between the Eurostat and UK questionnaire because in the UK there is no filter, thus *all* firms answer the question on R&D and innovation expenditure. In France, on the other hand, innovation expenditure questions were not well answered.

under pressure to reduce costs usually tend to increase their efforts to generate process innovations. Low-technology sectors compete more with prices than with quality, which can explain why the difference between the low-tech and high-tech sectors in the share of process innovators is smaller than the share of product innovators. Country differences in the share of process innovators in certain industries might also be the result of the different pressure on firms to reduce costs or increase flexibility.

Spain shows a country-specific phenomenon in the relative importance of product and process innovations. It is the only one of the four countries where the share of process innovators is higher than the share of product innovators. This is mainly driven by the low-technology sector, where all but the rubber and plastics industry have a higher share of process innovators. In the other three countries, even for low-tech industries, the share of product innovators is larger.

A fairly large amount of firms in all countries introduced both types of innovation, which can be seen from the fact that the sum of the share of product and process innovators is higher than the overall share of innovators. This is not surprising, as different types of innovations tend to be developed together, e.g., the production of a new product often also requires an innovative production technology. Some specific high values of the share of product relative to that of process innovators in low-technology sectors point to the fact that these industries are trying to avoid price competition by producing high-quality products. One example is the textile and leather industry in Germany, which is well-known for its so- called "smart textiles," which are very innovative products.

Innovation inputs.

Developing innovations requires various inputs. R&D activities are a special part of innovative activities. They tend to be more institutionalised than innovation activities, and are usually regarded as the core of innovative activities. The share of manufacturing firms engaged in intramural R&D[6] shows a structure about the same as for the share of innovators: Germany is leading with 39%, followed by France (30%), the UK (22%) and Spain (14%). Calculating the share of R&D performers out of total innovators, however, the structure is changed. In France, about 75% of all innovators perform intramural R&D, in the UK this figure is 66% and in Germany it is 65%. Spain still remains at the end of the list with 40%. This suggests that for Spain, firms' innovation activities which do not reach the level of R&D are important. One reason for this may be the size structure of the Spanish industries with a substantially smaller average firm size. For some industries (chemicals and transport), it is close to the UK but still much smaller than in Germany and France. As larger firms are more likely to engage in R&D, this can explain some of the differences.

[6] To be more precise, it is the share of firms with positive intramural R&D expenditure in 2000. The figures must be interpreted with care, because more detailed investigations have shown that there is some underestimation of French innovation expenditure and there are some interpretation problems with R&D expenditure and R&D employment in the UK.

A common phenomenon in all countries is that high-technology industries have a higher share of firms engaged in intramural R&D than low-technology firms, which is not surprising. However, while nearly 60% and 50% of German and French high-tech firms perform intramural R&D, it is only about one third in Spain and the UK. The industry with the largest share in all countries is the chemical industry, which is known for its heavy reliance on basic research and institutionalised R&D efforts. Among the low-technology sector, the plastic/rubber industry is the one with the largest share of firms with intramural R&D in all countries but Germany. This industry is a major supplier for other industries (e.g., the automobile industry) which require an ongoing increasing performance and quality of plastic and rubber materials. In order to be able to develop these products, R&D is necessary. In Germany, the glass/ceramics as well as the textile/leather industries also demonstrate extraordinarily high shares of R&D firms. For the glass/ceramic industry, the explanation is similar to the rubber and plastics industry, as it is under immense pressure to satisfy user needs from the high-tech industries. And the German textile industry is trying to produce very high-quality textiles in order to weaken competition from low-cost countries, as mentioned before. To improve the quality of textiles and leather products, own R&D is obviously necessary.

The R&D intensity (ratio of intramural R&D expenditure over total turnover) is much more similar across Germany (2.6%), France (2.1%) and the UK (2.2%) than the share of R&D performers itself. However, the effort of Spanish firms performing R&D is just one third of the effort of its European counterparts and the difference is firmly rooted in the effort differences in the high-technology sectors[7]. The difference between high-tech and low-tech is substantial in all countries. In Spain, the R&D intensity in high-tech is about three times that of low-tech; in France, it is about five times higher; in Germany, eight times; and in the UK, 14 times. As far as industries are concerned, once again the country-specific set-up, strategy and environment of an industry play an important role. The UK chemical industry, for example, has an extremely high value for R&D intensity of 7.1% for all firms and 9% for innovators, respectively. A large proportion of UK R&D is concentrated in this sector.

Developing innovations requires various inputs like human resources, physical capital and know-how. The ratio of innovation expenditure to total turnover usually referred to as innovation intensity is an indicator for input efforts.[8] At the aggregate level, the indicator demonstrates differences similar to the R&D intensity: Germany has the highest innovation intensity with 5%, followed by France (3.9%) and the UK (3.5%).[9] The relative behaviour of Spanish firms slightly improves (1.9%), again pointing to the importance in Spanish firms of innovative activities which do not reach the category of R&D.

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7 Differences are not, however, so high in R&D employment, which suggests that some of the differences can be related to the cost of R&D personnel (by composition reasons or wage levels).

8 Innovation expenditure includes: R&D expenditure, expenditure for the acquisition of machinery and knowledge related to innovation and expenditure for training and marketing related to innovations.

9 Calculating the ratio of innovation expenditure over turnover of innovators instead of turnover of all firms leads to a slightly different structure. In this case, the UK is in second place, followed by France and Spain.

Again, we do observe major differences across countries if looking at a particular sector, e.g., the French electrical industry is the one with the highest innovation effort (11.7%). In Germany and Spain, this industry is the one with the largest intensity, too, but with much smaller values (9% and 6.5%, respectively). In the UK, however, the electrical industry is in second place behind the chemical industry (mainly explained by the concentration of R&D in the pharmaceutical sector in the UK).

The firms in the high-tech sector are not only more frequently spending some amount on innovative activities than low-tech firms but are also spending a larger proportion of their sales. This is the case in all countries and independent of whether we look at the innovation intensity for all firms or just for innovative firms, with the remarkable exception of Spain. Spanish innovators in the low-technology sector spend a larger share of their turnover on innovation activities than the high-tech sector. The wood and paper industry, despite its comparatively low share of innovators, now has the highest innovation intensity in Spain.

Innovation Output.

The share of sales with new or significantly improved products is used as a quantitative indicator for the success of product innovation activities. Since no harmonised output indicator for process innovations is available, we will focus only on product innovation success. The share is highest in Germany with 45%, followed by Spain (32%) and the UK (30%). The large share for the high-tech sector in all countries can be seen in part as a result of the high quality, and eventually the high prices, of the products these industries produce. In addition to that, the products of most of these industries have a shorter life cycle than the products of the low-tech industries (with the exception of Chemicals). On the other hand, some low-tech industries earn a substantial amount with product innovations, like the NEC and recycling industry in France, Spain, Germany and the UK. What is even more surprising is that, due to product innovations, the German wood and paper industry has a share of turnover of almost 50%. Here the shares in certain industries differ substantially among countries, pointing again to the fact that there are still national peculiarities at work.

Innovation cooperation.

The proportion of innovative firms with cooperations in innovation projects represents a measure of inter-firm knowledge spillovers. Cooperation is a major topic for policy makers nowadays as more and more public funding for R&D and innovation is directed at fostering cooperation among companies and among companies and public institutions like universities or research labs. The rational behind this policy is to generate or improve knowledge spillovers between public institutions and private firms or between private firms, as these spillovers are assumed to essentially lead to more growth and a better performance of the national system of innovation. We come back to this matter in the next section.

Interestingly enough, this is one of the innovation indicators with sharper variation across countries. Innovative manufacturing firms in France cooperate the most (35%), whereas the value for the UK is at 26%, followed by Germany (19%) and Spain (10%). This ranking of the countries is not only valid for manufacturing as a whole, but can also be found for most of the sectors within manufacturing, except for textile/leather, where the UK has a slightly higher rate than France, and machinery, where the UK is substantially ahead. For all countries and partners, the high-tech sectors exhibit a higher percentage of innovators involved in innovation cooperation than the low-tech sector. This is not surprising, as high-tech sectors in general have a greater need for outside knowledge and are involved in riskier and more costly projects. A noteworthy result is that the glass/ceramics industry has the highest cooperation intensity in Germany although it belongs to the low-tech sector and is the industry with one of the lowest rates of innovators. This industry also has an exceptionally high rate of cooperating firms in France. The high variance of this indicator in an industry across countries suggests that it is not only the sector composition of a country that leads to a high or low level of cooperation but also the specific conditions and setup of certain industries within a country.

The decomposition of cooperation figures by type of partner shows that cooperative agreements with competitors from a firm's own industry (*horizontal cooperations*) are relatively rare in general. The highest share of firms with cooperative agreements with competitors can be found for the German chemical industry (19%). This sector is for all countries one of the industries with the largest rate of cooperation. The tough competition in the industry, a long development time for products and intellectual property rights might play a role in the emergence of this structure. Sometimes firms have to cooperate in order to be able to use certain patented technologies or processes. The largest difference between countries can be found in the food industry. In France and the UK, this industry has one of the largest percentages of cooperation with competitors, but only a few enterprises in that industry cooperated with competitors in Germany and Spain.

Cooperative agreements with the research base (*scientific cooperations*) are especially common among the high-technology industries, especially in chemicals industries. This is not surprising, as the high-technology industries are often more important in the first stages of the innovation process and thus normally rely more on basic knowledge. Usually, it is research institutes and universities which produce this kind of knowledge. In Germany, it is again the glass/ceramics exhibiting the largest percentage of cooperating firms (31%). This share is also relatively high for France (23%). This is an indication that those innovators which cooperate in that industry are developing fairly sophisticated products and processes, even though they are considered to be low-technology firms. They probably profit significantly from research into new materials. The high importance of sophisticated textiles for the competitiveness of the European textile and leather industry is confirmed by the high percentage of innovators cooperating with the research base in three of the four countries.

Cooperation with suppliers or customers (*vertical cooperations*) are relatively rare in Spain compared to other countries. Only 5.3% of Spanish innovators cooperated with customers or suppliers. In other countries like France and the UK, the percentages are about four times higher. A comparison between the figures for cooperation with the research base and vertical cooperations points out that, for manufacturing in France and Germany, scientific institutes are more frequent cooperation partners, while for Spain and the UK, vertical cooperations are more important.

Increasing globalisation and competition in the home market have led to an increase in the importance of knowledge and partners from sources outside the home country. French innovative manufacturing firms have more cooperative agreements with foreigners than their European counterparts. Especially surprising is the low number of German firms which are involved in common innovation projects with foreigners. However, this small share is mainly driven by the low-technology sector. The global markets and relatively high number of multinational firms in the chemical industry is certainly one reason for the high percentages of foreign cooperations in all four European countries.

The analysis of cooperation data is continued in the part of this report dedicated to the analysis of the relationship between competition and innovation.

Public financial support for innovation.

Innovation is seen as one of the major drivers of growth, competitiveness and wealth of a nation. Due to problems of market failure (moral hazard, free riding, imperfect appropriability, spillovers etc.), R&D and innovation investment is supposed to lag behind optimal values. In order to correct this market failure, governments try to support the development of innovations in various ways. Measures adopted include intellectual property rights, tax credits for certain investments or direct public subsidies for R&D and innovative activities, and they vary substantially between the countries in detail.

One interesting indicator of the amount of market intervention is the share of innovators which received public financial support for innovation in the period 1998-2000. France, Spain and Germany show a very similar pattern; almost 30% of innovators received at least some amount of public financial support. However, this share amounts to only 20% in the UK. This difference may be one of the explanations for the fact that the UK in general is lagging behind France and Germany in the spread of innovative activities.

Splitting up manufacturing into low-tech and high-tech, one can see that there is only a small difference between the two groups in France and Spain and a larger difference for UK and Germany. That relatively fewer low-technology firms receive public funding is not surprising, as most countries try to support technologies that are complex and sophisticated or less standardised.

The structure of funding of certain industries differs a lot between the countries, e.g., in Germany, about 48% of all innovators in transport received public support; in France, the largest share can be found for the electrical industry (38%); in Spain, for food, tobacco and beverages (39%); and in the UK, for machinery (29%).

All the results have to be interpreted with care since they reflect the different public policies with regard to funding in general and funding of specific industries or technologies. Note that the indicator only reflects the share of innovators in an industry that have received public funding and not the amount of public money a certain industry received. Proportions of supported firms may be hiding important differences in the amount of funds received by firms and the process by which these funds are assigned.

3.1.3 A methodology for assessing the driving factors

To analyse which effects mainly drive differences across countries, a simple decomposition exercise can be performed. Our work has systematically applied this decomposition to the main innovation indicators[10]. To compare the difference in a particular innovation indicator at the aggregate level for two countries and decompose it into a "structure" as well as a "sectors" effect, let R and C be the aggregate values of an indicator for two countries (R for row and C for column country) and *i*=1,…. S is an index for the industry. The indicators can be written respectively as

$$R = \sum_{i=1}^{S} w_{R,i} I_{R,i} \quad and \quad C = \sum_{i=1}^{S} w_{C,i} I_{C,i}$$

which represent the weighted sums of the sector values of the country indicators with weights derived from the industry structure. Sector values may refer to any aggregation level and we use the split of manufacturing in eleven industries[11]. It easy to see that the difference between indicators can be written as[12]

$$R - C = \sum_{i=1}^{S} \left(w_{R,i} - w_{C,i} \right) I_{R,i} + \sum_{i=1}^{S} w_{C,i} \left(I_{R,i} - I_{C,i} \right)$$

which decomposes the difference in a "structure effect" and a "sectors effect." The structure effect is calculated as the difference between the row country minus a virtual row country with the industry structure of the column country, while the sector effect is the difference between a virtual country with indicator sector values of the row country and structure of the column country minus the column country. Thus, the first term gives the role of the industrial structure, the second the role of the differences which are encountered "sector by sector."

Suitable weights differ according to the indicator. For the shares of firms measured as a percentage of all firms (i.e., share of innovators), the weight of sector *i* in country *j=C,R* is simply based on the ratio of the number of firms in sector *i* to total population. In the case of indicators like the share of cooperation among innovating firms, the weight is given by the ratio of the number of firms in sector *i* to total population times the share of innovators in sector *i* and divided by the overall share of innovators. Concerning innovation intensity measured as innovation expenditure over total turnover, the correct weight to be applied would be the ratio of sales of sector *i* to total sales. However, as this information is not available for the countries, we approximate sales by employees (computed from the number of firms and average firm size). The divergence of the explained differences compared to the actual differences in the tables is due to the imperfection of the weights approximation.

[10] An extension to include the dimension size and to take a European average as the benchmark is planned for the forthcoming revision of the corresponding paper.

[11] The simple split in two sectors –high-technology sectors and low technology sectors–would also be possible.

[12] $R - C = \sum_{i=1}^{S} w_{R,i} \left(I_{R,i} - I_{C,i} \right) + \sum_{i=1}^{S} \left(w_{R,i} - w_{C,i} \right) I_{C,i}$ is an equivalent decomposition.

The decomposition for several innovation indicators is given in tables. For each couple of countries, the first entry is the difference between the indicators at the aggregate level while the second and third rows report the structure and sectors effect, respectively. Each couple of countries admits two similar comparisons, which usually give similar results.

The tables reveal that differences in the industrial composition between Germany and the other countries are responsible only to a minor extent. For example, only 1.5 out of 19 percentage points of difference in the proportion of innovative firms between Germany and France can be explained by the diverging industrial structure. Even when comparing with Spain, where the share of firms in high-technology sectors is substantially lower, the structure effect is only slightly more important. Industrial structures play a more important role in explaining national differences in innovation intensities[13] . However, sector effects still dominates the structure effects for each couple of countries.

The results clearly indicate that it is not mainly the countries' industrial composition of economic activity but rather that there are country-specific (common to all sectors in one country) as well as country-sector specific effects which drive the innovation differences across countries to a large extent.

3.1.4 Previous comparisons and modelling

CIS data includes the share of innovative sales, i.e. the share of sales due to new or improved products for the firm (alternatively, it can be defined more restrictively as new for the market) introduced in the last three years. This is an output indicator of innovation which can be seen as a sales-weighted measure of the number of innovations. It also indicates the degree of penetration which innovated products reach in the demand for the firm products. Part of the early project research was devoted to the modelling of this indicator and the comparison of its value across countries, using CIS data previous to CIS 3. Some of these exercises will be worthy of being repeated in the future with the new data and insights.

Several papers by J.Mairesse and P.Mohnen, "To be or not to be innovative: An exercise in measurement", "Accounting for innovation and measuring innovativeness: An illustrative framework and an application", "Innovativeness: A comparison across seven European countries," propose, develop and apply a conceptual framework for dealing with this indicator. The share of innovative sales is related to a series of explanatory variables, and they define the expected share of innovative sales as the percentage of sales predicted by these explanatory variables. A second indicator, innovativeness, is defined as the difference between the observed and the expected share of innovative sales. This decomposition may be seen as analogous to the decomposition performed in total multifactor productivity analysis. Innovativeness is (TFP are) the residual percentage (sales) left after subtracting a weighted sum of the innovation inputs (production factors). Measured innovativeness is then, like TFP, conditional on the model's relating the innovative sales to their explanation. In addition, it also assesses the impact of unmeasured factors of performance.

[13] Similar results have been found for the R&D intensity.

The exercises of measurement are performed using a selectivity model. Innovative sales are observed only for the innovating firms (as defined by the survey), and the model uses the propensity to innovate to obtain an unconditional estimate of the intensity of innovative sales. The explanatory variables include industry dummies, (log of) size and a dummy of group membership in the propensity equation, and an additional set of R&D and environmental variables in the intensity equation. The dependent variable of this equation is the logistic transformation of the share of innovative sales. The R&D variables include effort (R&D over sales), dummies for performing and continuously performing R&D, as well as a dummy for collaborative firms. Two dummy environmental variables measure the strength of competition as perceived by the firm and the proximity to basic research.

The main exercise is conducted with firm-level CIS data referring to the period 1990-1992, comparing the expected innovative sales (and their components) and innovativeness for seven European countries (Belgium, Denmark, France, Germany, the Netherlands, Norway and Italy). The model points to significant differences among the countries with respect to a hypothetical "average Europe" (and between the high-R&D and low-R&D sectors). The expected share varies more across countries in the high-R&D sectors, while innovativeness varies more across countries in the low-R&D sectors.

A paper by N.Janz and B.Peters, "Innovation and innovation success in the German manufacturing sector: econometric evidence at the firm level," takes some steps in the modelling of the relationship between innovation inputs and output, i.e., the innovation's production function. Data come from the Mannheim Innovation Panel (MIP) and refer to the period 1996-1998. The share of innovative sales is modelled as a function of innovation intensity (innovation expenditure over sales) and exogenous variables, while innovation intensity is taken as a contemporaneously endogenous variable (depending on the innovative sales and other variables). The framework is also the selectivity model. Both endogenous variables (share of innovative sales and innovation intensity) are assumed to be observable depending on the value of the index in a propensity-to-innovate equation.

The share of innovative sales is measured alternatively for the products new to the firm ("product innovations") and new to the market ("market novelties") and the whole exercise is performed for the two variables (defining innovative firms accordingly). Innovation intensity is measured including the expenditures of the following innovation activities: intramural and extramural R&D, acquisition of machinery and equipment, acquisition of other external knowledge, training, market introduction of innovations, design and other preparations for production/deliveries.

The propensity equation includes as explanatory variables industry dummies, size and a group membership dummy (plus other related dummies: multinational subsidiary, joint venture participant) and other controls, but also an inverse measure of product diversification (share in sales of the most important product), firm market share (measured at the three-digit NACE level), and worker skills. The intensity and share equations include industry dummies, size variables, different controls, the corresponding cross endogenous variable and a small number of additional determinants. Intensity is related to the degree of product diversification and public support of the innovation activities, and the share of innovative sales ("success") to worker skills.

Results give interesting insights. The probability of innovation is higher the greater internationalisation, product diversification and worker skills are. Size turns out to be important for product innovation but not for explaining the probability of introducing market novelties. Simultaneity of the intensity-share equations is confirmed (intensity shows feedback from innovative sales), determinants are significant with the expected sign, and size shows no effect on the share of market novelties.

3.2 Analysing the relationship between competition and innovation.

The relationship between market competition and innovation has for a long time been a question of interest for economists and policymakers. Economic theory predicts several difficulties for the innovative activities to be carried out at an optimal level in a fully competitive environment. The character of the input "knowledge" (freely usable when displayed), the presence of important fixed -and often sunk- costs of innovative activity investments, and the uncertainty associated with the results, are likely to provide few incentives to firms to allocate enough resources to an activity that, on the other hand, shows important positive externalities towards other firms and consumers. But, at the same time, as many empirical works have shown, competitive pressure seems in many circumstances to strongly stimulate innovative activities and the introduction of innovations by firms, both in their processes and products.

With the ultimate interest of stimulating innovation, a lot of attention has been recently focused on the subject of cooperative R&D of firms, or agreements by which firms share the costs and returns of innovative projects, sometimes with other firms and sometimes with research institutions. These agreements, from the positive point of view, are likely to show mechanisms by which firms can profitably appropriate free flows of knowledge and protect them. Hence, they are an interesting guide to normative regulation, which must try to consolidate mechanisms of incentives and at the same time avoid harming market competition.

As the final stage of the research has been extensively focussed on cooperation, which summarises many of the questions at stake (spillovers, "appropriability," relative roles of rivalry and cooperative outcomes, influence and role of public policy…), we first extensively review the work on cooperation. Then we move to the papers generated at earlier stages of the project, works which deal with market competition of the relationship between ownership and convergence of technology, the probability of introducing process innovations according to the age of the firm, the identification of spillovers and conscious sourcing strategies by firms and the impact of foreign competition and entry.

The paper "Understanding co-operative R&D activity: evidence from four European countries," by L.Abramowsky, E.Kremp, A.Lopez, T.Schmidt and H.Simpson, investigates the extent to which European firms engage in cooperative behaviour, and aims to shed light on the determinants of such activity. The papers "Knowledge flows and R&D c-operation: firm-level evidence from Germany," by T.Schmidt and "Determinants for R&D cooperation: evidence from Spanish manufacturing firms," by A.Lopez, develop complementary analysis (see also the more detailed description of cooperation in papers reviewed in the first subject). Cooperative innovative activity is a topical policy issue, in the context of technology transfer (most prominently from universities to business), and in its interactions with competition policy. Both the OECD and the European Union support the idea of strong industry-science linkages to maximise the returns from both private and public research investments, and recognise a role for policy.

In this context, it is important to understand which types of firms tend to engage in cooperative R&D, the motivations for such activity and whether public policy is effective in increasing collaborative research. The investigation uses the framework developed in Cassiman and Veugelers (2002) (henceforth CV) that looks at the effects of both incoming and outgoing knowledge spillovers on the likelihood of engaging in cooperative R&D, using data from the 1st Community Innovation Survey (CIS) for Belgian manufacturing firms. Here the information from the CIS 3 is used for the four countries and the analysis is extended to the service sector. Additionally, the effect of receiving public financial support on the likelihood of undertaking cooperative R&D is considered.

3.2.1 R&D cooperation among European firms.

Innovative firms are defined as those that introduced a product and/or a process innovation, or engaged in innovative activities during the period 1998-2000. A broad definition of cooperative activity includes cooperation with customers and suppliers (vertical cooperation), cooperation with competitors, and cooperation with universities or research laboratories (cooperation with the research base). At a first look, the proportion of *innovative* firms undertaking any of these three forms of cooperative innovative activity is highest in France and the U.K, followed by Germany and then Spain. Interestingly, in Germany, Spain and the U.K., there is little difference between the manufacturing and service sectors in the proportion of innovative firms engaging in cooperative activity, but in France, innovative firms in the manufacturing sector are more than twice as likely to cooperate as those in the service sector. Within the manufacturing sector in all four countries, on average, innovative firms in high-tech manufacturing sectors are more likely to engage in cooperative activity than those in low-tech manufacturing sectors.

It is interesting to look at whether cross-country differences in the extent of overall collaborative activity are driven by differences in specific types of cooperative agreements (the percentages of innovative firms undertaking different types of cooperative agreement in the four countries). In the U.K and France, the most common type of cooperative R&D activity is with suppliers or customers. In Spain, the most common form of cooperative activity is with universities or research laboratories. In Germany, cooperative activities with suppliers or customers and with universities or research laboratories are equally common. In all countries, agreements with competitors are the least frequent type of R&D agreement. Despite the recent policy concern in the U.K., the proportion of firms undertaking cooperative agreements with universities or research laboratories does not appear to be particularly low compared to the other countries. Across all four countries, cooperative agreements with the research base appear to be more prevalent in the manufacturing sector than in the service sector. However, when looking at business-to-business cooperation (both vertical and horizontal), in some countries these types of agreements are more widespread in the service sector.

Finally, it is interesting to explore whether cooperative firms perform differently from non-cooperative firms. First, looking at labour productivity, it is found that, across all four countries in the manufacturing sector, firms that engaged in cooperative R&D tended to have higher labour productivity than those that did not. Those that entered into cooperative agreements also reported that a higher proportion of their sales were due to innovative products introduced between 1998 and 2000. In the service sector, the picture was more mixed. For example, there was no clear correlation between labour productivity and cooperative activity.

The focus of this investigation is on the analysis of CIS3 firm-level data, pooling the manufacturing and service sector, using the framework of CV to investigate the firm characteristics that are associated with cooperative activity of innovative firms within each country, and how the degree to which firms benefit from information flows and can successfully appropriate the returns to their innovative activity affect the likelihood of undertaking cooperative R&D[14]. The importance of public support to undertaking different types of cooperative agreements is also investigated. The findings are then compared across the four countries in order to shed some light on the mechanisms affecting cooperative activity. The next section discusses reasons why firms might engage in collaborative activity, including the effects of both incoming and outgoing information flows. Then, in the following section, some characteristics associated with different types of cooperative activity in each country are described. In the section after that, more causal determinants of collaboration are explored.

3.2.2 Why do firms undertake collaborative R&D?

Firms may engage in collaborative R&D for a variety of reasons; for example, if it is seen that spreading the cost and risk associated with an R&D project leads to higher expected profits or lower cost for one firm than carrying out the project individually. CV chose to focus on the influence of two types of knowledge flows on the likelihood of cooperation: the extent of *incoming spillovers*, that is, beneficial knowledge flows; and *appropriability*, that is, the ability of firms to capture the returns to their innovative activity, the converse of which can be thought of as the extent of outgoing spillovers.

In general, we would expect the extent to which firms are able to appropriate the returns to innovative activity to have a positive effect on the extent to which they undertake R&D activity. But how might we expect it to influence their incentives to engage in collaborative R&D? On the one hand, in the face of appropriability problems, firms might try to internalise outgoing spillovers by forming explicit collaborative relationships, rather than conducting R&D on their own. On the other hand, an inability to appropriate the returns to one's own R&D efforts, even in a collaborative arrangement, might lead to free-riding either inside or outside collaborative agreements, and hence decrease the likelihood of such agreements occurring.

The extent to which an individual firm can capitalise on knowledge generated elsewhere is also likely to have a positive effect on the probability of being a successful innovator. We might also expect firms' ability to assimilate publicly available knowledge to be positively associated with the likelihood that they undertake formal collaborative research with other firms and institutions. For example, some firms may simply have superior R&D capabilities or absorptive capacity, which make them more likely to take advantage of flows and perhaps more attractive cooperation partners. Firms may also engage in cooperative R&D in order to benefit from knowledge spillovers generated by their partners, which may be complements or substitutes for other publicly available sources of information. While firms may undertake collaborative R&D to overcome financial constraints or to pool risks, they may nonetheless face other constraints to cooperative activity. For example, the presence of

[14] Here the denomination "appropriation" is used to refer the "outgoing spillovers" of CV.

market failures, such as coordination or information failures, may rationalize the existence of public support programmes to encourage cooperative R&D and technology transfer between universities and firms.

The discussion above highlights the fact that the extent to which firms benefit from incoming spillovers, the extent to which they can appropriate the returns to their innovative activity, and the extent to which they face constraints in their innovation activities may themselves be related to whether or not firms engage in cooperative R&D, in addition to other firm and industry-specific factors. The empirical framework used in CV aims to take account of this potential endogeneity. Before turning to the results, we first look in more detail at some characteristics of firms that undertake cooperative R&D.

3.2.3 Measuring and assessing characteristics of collaborative firms.

The characteristics focused on here are measures of incoming spillovers, appropriability, constraints on innovation (a combination of cost and risk factors that hamper innovation), firms' R&D intensity and whether or not firms received financial public support for innovative activities. Information from the CIS3 survey is used to construct firm-level and industry-level variables where possible in line with those used in CV (see the paper for detailed variable definitions).

The extent of *incoming spillovers* is measured as a continuous variable bounded between 0 and 1, where a higher value implies that firms placed more value on publicly available sources of information in carrying out their innovation activities. The measure is derived from a question that asks firms to rate the importance of different information sources for the firm's innovation process during the period 1998-2000. The information sources considered include professional conferences, meetings, journals or technical/trade press and fairs and exhibitions.

The measure of *appropriability* is based on information on the extent to which firms use strategic methods to protect their innovations. These are secrecy, complexity of design and lead-time advantage on competitors. This measure is again scaled between 0 and 1 and is increasing in the importance of these methods. We also construct an industry-level measure of the importance of *legal protection* methods such as patents and trademarks, again an index measure between 0 and 1.

A measure that combines the extent to which firms are hampered in their innovation activities by cost and risk factors is constructed. This variable is called *constraints* and includes the extent to which cost factors such as the availability and cost of finance and excessive perceived risks, impeded firms' ability to innovate. The index measure varies between 0 and 1 and is increasing in the extent to which these factors are declared to impose a constraint.

A measure of whether firms received public support for innovation activities is also constructed. This is an indicator variable that takes the value 1 if the firm has received any kind of public financial support for innovation activities from local or national sources and takes the value of 0 otherwise.

Measures of the firm's technological and absorptive capacities are also considered. A measure of *complementarities*, which aims to capture the extent of technological know-how within the firm, and a measure of firms' internal R&D capabilities, *R&D intensity*, are constructed. The former is an index between 0 and 1. The higher this index is, the less importance a firm places on a lack of technological information as an obstacle to innovation.

The latter is the ratio of intramural (or internal) R&D expenditure to turnover in the year 2000.

When the sample mean values are examined, for both firms that engage in cooperative activity and for those that do not, for each of the variables, some interesting facts emerge. *Within* countries, the mean values of most variables are significantly different across cooperative and non-cooperative firms, except in the case of the measure of complementarities. For the UK, there are no significant differences between the two groups in terms of the extent to which they perceive constraints (cost and risk factors) to be a barrier to innovative activity. However, in the other two countries, those firms that undertook cooperative R&D appeared to be more constrained by these factors in their R&D activities.

Across all countries, firms that are undertaking cooperative agreements typically place greater importance on incoming spillovers (*incoming spillovers*), place greater importance on the use of strategic methods for appropriating the returns to R&D (*appropriability*) and are typically in industries where a higher importance is placed on legal methods of protecting the returns to innovation. Firms that engaged in cooperative agreements also show higher R&D *intensity*, and were typically larger than those that did not take part in cooperative agreements. These findings are in line with those of CV.

It was also examined whether there were significant differences in the mean values of these variables *across* countries within the two categories of firms – e.g., comparing cooperative firms in France with those in Germany. It was found that in the vast majority of cases there are significant differences across countries. For example, firms in Germany that undertook cooperative agreements placed more importance on incoming spillovers than those in Spain, the U.K. and France, and firms engaged in cooperative agreements in the UK placed more importance on strategic methods of protection (appropriability) than those in Germany, France and Spain. Among cooperative innovative firms, R&D intensity was highest in Spain and lowest in the UK. The proportion of cooperative firms that received public support for innovation was highest in Germany and lowest in the UK.

The focus of the investigation is on the effects of incoming spillovers, appropriability and the use of financial public support on the probability of cooperation, taking into account other traditional factors which are thought to affect R&D cooperation, such as firm size, constraints (cost and risk sharing), and R&D intensity. As a first step, some simple probit models were estimated for each country. In these models, the dependent variable takes on a value of one if the firm is engaged in a cooperative agreement.

The results can be summarised as follows. In all three countries, firms that placed a higher importance on strategic protection methods (*appropriability*) were more likely to be engaged in cooperative R&D, which is in line with the findings in CV. In general, cooperating firms were less likely to be in industries where legal methods of protection are considered important, although this variable is only significant for Germany and the UK. Conditional on other factors, firms were more likely to be engaged in cooperative agreements the higher their R&D intensities, though again this is only significant for two countries, Spain and France. Also, in all countries, firms that were engaged in a cooperative agreement were more likely to have received financial public support than those that were not engaged in such activity. In the UK and France, we find that firms that were engaged in cooperative agreements place a higher importance on incoming knowledge spillovers. However, as mentioned above, there are reasons to believe this variable is endogenous. Turning to the measures of the extent to which constraints such as cost and risk factors are perceived as an obstacle to R&D activity, it is found in all countries apart from the UK that firms that are engaged in cooperative research were more likely to see these factors as obstacles (for the UK, the sign of the marginal effect is positive but not significant).

3.2.4 Looking at the determinants of cooperation.

The investigation replicates the CV approach for the four countries, also considering the potential endogeneity of the constraints variable. CV uses a two-step approach. First the potentially endogenous variables are regressed on a set of (assumed) exogenous variables. The predicted values of the potentially endogenous variables are obtained from the first-step regression and are used in place of the endogenous variables in the second-step regression. The same three variables are instrumented as in CV – *incoming spillovers, appropriability* and *R&D intensity*- and the *constraints* variable is also considered endogenous. The same set of assumed exogenous variables is employed as instruments plus a set of 2-digit industry dummies. Other details can be consulted in the paper.

The findings for the effects of incoming spillovers and appropriability show very few departures from the original findings in CV for Belgium. What is interesting, and different from the findings in CV, is that cooperation is less likely in industries where legal methods of protecting innovations are more effective. Taking this together with the findings on appropriability for France, Germany and Spain, it may be that cooperative activity is a method of internalising outgoing knowledge flows in industries where legal protection methods are weak, and for firms for whom more strategic methods of appropriating returns are more important.

The findings in CV also suggested that incoming spillovers were an important factor in determining cooperation with research institutions, but not vertical cooperation, and while appropriability was an important factor in determining vertical cooperation, it was not for cooperation with research institutes. The findings here are not entirely consistent. Turning to cooperative agreements with the research base, it is found that, as in CV, the extent to which firms value incoming spillovers has a positive effect on the probability of undertaking collaborative research with universities and that it is greater than the effect on the probability of cooperating with other type of partners. However, unlike the findings in CV, it is found that strategic protection has a positive influence, and that the importance of legal protection measures has a negative influence. In France, it is found that firms with lower intramural R&D intensity are more likely to engage in cooperative R&D with the research base. This same relationship was also marginally significant for Germany. It may be that intramural R&D intensity is not adequately capturing any absorptive capacity on behalf of the firm that is needed for this type of collaboration. Looking at cooperation with customers and suppliers and with competitors, contrary to the findings in CV, it is found that incoming spillovers have a positive and significant effect on the probability of cooperation, though, as might be expected, the marginal effects are smaller than for cooperation with the research base. It may be that the information flow variables considered here do not capture the strategic reasons for undertaking these types of collaborative projects.

Receipt of public support is positively correlated with the probability of cooperating with the three types of partners in Germany and Spain. In France, only a significant positive correlation with the probability of cooperating with the research base is found, and in the UK, no relationship with the probability of cooperating with competitors is found. In all countries, the marginal effects are highest with regard to cooperating with the research base. This finding is consistent with the aims of policy in this area in terms of encouraging cooperation between firms and universities.

3.2.5 The impact of ownership, age, sourcing and entry on innovation.

The paper “Foreign ownership and technological convergence at the micro level,” by R.Griffith, S.Redding and H.Simpson, looks at the convergence in Total Factor Productivity (TFP), at the establishment level, to the technological frontier. The technological frontier is defined by the productivity level reached by the establishment with the highest TFP in the relevant sector and point of time. The UK establishment ARD data set is used to compute productivity measures for thousands of establishments and to identify the technological frontier for over 200 four-digit production industries from 1980 to 1995.

The paper explores whether or not there is convergence in TFP and whether this convergence is influenced by the presence of foreign-owned establishments and the relative international technological position of UK industries. Underlying this exercise is the idea that foreign establishments may present technological advantages and that their proliferation in an open economy may induce productivity shifts, both stimulating technological transfers (spillovers) and the strength of competition.

The exercise is based on a model of TFP growth, by which the growth of productivity for any establishment is assumed to be the result of a direct effect, which comes from the growth of productivity at the frontier establishment, and an additional effect, which is proportional to the technological gap. The coefficient on the measured technological gap gives the importance of technological transfers.

Productivity is measured in the usual terms, using a translog technology assumption to smooth observed factor shares by using the coefficients from a regression on relative input use. The relative TFP levels are measured with respect to the suitable reference (the TFP of a sector and time-specific reference establishment computed using the geometric means of the relevant outputs, inputs and factor shares). The model of TFP growth is applied to the differences of TFP levels over time, relating the change for each establishment to the change for its relevant frontier and to the TFP gap that the frontier establishment presents with respect to its productivity.

The effects of foreign presence are measured by means of an extra term on a variable measuring foreign presence (proportion of employment in foreign-owned establishments in the previous period) and the same variable interacted with the gap. The disturbance term allows for establishment-fixed effects and common macroeconomic effects affecting all establishments captured by time dummies. Regressions are carried out with all the non-frontier domestic-owned establishments. IV estimation is used to deal with the potential correlation of the computed gap with the remaining equation error.

Results show that 24% of frontier establishments are foreign-owned establishments, 2/3 of them US-owned, the average TFP of non-frontier establishments is about 65% of the TFP of frontier establishments, and that establishments remain at the technological frontier for 4 years. Regressions obtain positive and significant effects both on the TFP growth of the frontier establishment and on the gap term. Consequently, establishments that are further behind the technological frontier experiment higher productivity growth, i.e., there is catch-up to the frontier. Regressions also obtain some evidence that catch-up is faster the larger the foreign presence within an industry.

The paper “How does probability of process innovation change with firm age?”, by E.Huergo and J.Jaumandreu, looks at the probability of introducing process innovations by manufacturing firms at the different stages of their lives, once controlled for differences attributable to the firms’ activity and size. The aim is to make a contribution to the knowledge of the dynamics of industries' process innovations. Small size is likely to hamper innovative activities, but newly-born firms are typically small and very innovative, and it is necessary to separate the effects of entry from the effects of size. Once differences related to activity and size are controlled for, probability of innovating is examined in its variations over entry, the post-entry ages, and the advanced ages of mature firms. The association between exit from the market and pre-exit innovation is also examined.

The exercise is based on the estimation by semiparametric methods of probability as an unknown function of age. It uses firm-level longitudinal data on process innovation counts from 1990 to 1998 and data on age and other firm characteristics. The data set is an unbalanced panel of more than 2,300 firms representative of manufacturing, and comes from the ESEE.

Results show that the probability of innovating diverges by activity, and that small size per se reduces the probability of innovation. But they also show that entrant firms tend to present the highest probability of innovation, while the oldest firms then show lower innovative probabilities. However, some sets of firms with intermediate ages also present a high probability of innovation, and exiting firms are instead clearly associated with lower levels of introducing innovations. This is consistent with an industry setting in which entrant and young firms make the most numerous process innovations, growing bigger, and at the same time, less active as they mature. Some entrant firms, however, have to exit as they are not able to innovate enough.

The paper "Technology sourcing by UK manufacturing firms: an empirical analysis using firm-level patent data," by R.Griffith, R.Harrison and J.Van Reenen (more recent versions have changed the title to "How special is the special relationship? Using the impact of US R&D spillovers on UK firms as a test of technology sourcing") addressed the question of the measurement of international knowledge spillovers associated with "technology sourcing." Several authors have recently suggested that gaining access to new technologies is an increasingly important reason for firms to locate R&D activities abroad, geographically close to leading technological activities, i.e., in order to show a "technology sourcing" behavior. The paper is aimed at testing for the presence of this effect, by exploring whether UK firms which locate their R&D activity in the USA benefit more than other UK firms that benefit from knowledge spillovers originating from US R&D. The paper uses firm-level panel data on a sample of UK firms matched to information on their patents, including information on the location of the inventor.

Research on spillovers at the firm-level has been based mostly on the regression-based estimation of the returns to a measure of "outside" R&D in a product (or cost) framework. A crucial aspect of this type of exercise is the specification of the "spillover pool" available to firms. A big problem with these specifications is the difficulty in distinguishing the effects that result from spillovers from the effects that simply reflect spatially-correlated technological opportunities. The paper introduces an original way to identify international spillovers based on the specification of their international geographical components.

The model is based on a (value added) production function with constant returns to scale with respect to the labor and capital inputs, augmented in the R&D variables. The other function arguments are the current stock of knowledge capital, cumulated through the own expenditure on R&D, and the R&D stocks available at the firms' two-digit industry both in the UK and the USA. That is,

$$Y = AL^{\alpha}C^{1-\alpha}R^{\beta}D^{\gamma_1}F^{\gamma_2}$$

where Y stands for output, L for labor, C for capital and R,D and F for the own domestic and foreign R&D capitals, respectively. Elasticities γ_1 and γ_2 are assumed to be related to the firms' "absorptive capacity" and geographical location of their R&D activities through the relationships

$$\gamma_1 = \theta_0 + \theta_1 P + \theta_2 W^{UK}$$
$$\gamma_2 = \phi_0 + \phi_1 P + \phi_2 W^{USA}$$

where P is a dummy variable taking the value one if the firm has at least one patent, representing absorptive capacity, and W the proportion of firms' total patents where the inventor is located in the UK or the USA.

The paper "Entry and growth: Theory and evidence," by P.Aghion, R.Blundell, R.Griffith, P.Howitt and S.Prantl, considers the impact that opening up to foreign competition had on innovation activity in incumbent firms. The paper develops a model which shows that foreign entry should have a differential impact depending on the incumbent industries' distance to the technological frontier and ability to fight entry (e.g., access to sources of finance). The empirical results suggest that, in industries close to the technological frontier, an increase in foreign entry leads to an increase in the innovation rate in incumbent firms. However, in industries where incumbents are far behind the technological frontier, firms are not able to fight entry, and the innovation rates remain static or even decline.

3.3 The impact of innovation on productivity.

There are a considerable number of national firm-level studies analysing the relationship between innovation and productivity, but cross-country comparisons using micro data are still rare. The paper "Innovation and productivity across four European countries," by R.Griffith, E.Huergo, J.Mairesse and B. Peters, contributes to the literature by investigating the innovation-productivity nexus at the firm-level for the four European countries using the CIS 3 data. It applies a structural model that describes the link between R&D expenditure, innovation output and productivity (CDM model).

In what follows, we first briefly motivate the importance of the approach, present the theoretical framework and comment on the data, and explain the estimation method and results. Finally, we refer to other previous work from the project on this subject.

3.3.1 The role for firm-level R&D investment.

The poor productivity performance of European countries relative to the US has been an important focus for government policy. Value-added per capita in EU countries has long lagged behind the US despite widespread reforms across EU countries aimed at increasing growth[15]. EU (2003) emphasizes the fact that post-war growth in Europe was largely based on imitation, driven by capital accumulation, while what is needed now is for European countries to shift towards growth based on innovation. Academics and policy-makers have emphasised the importance of investment in research and development (R&D) as a contributor to long-term productivity growth. In response to these concerns, the European Union has set itself the target of increasing R&D expenditure to 3% of the GDP by 2010 (this is part of the "Lisbon Agenda").

Yet, despite the importance of the topics and the attention they have received, little is known about the links between R&D expenditure, innovation and productivity at the firm level. Does the EU's poor performance lie primarily in low investment in R&D[16], or is the main problem that EU firms do not exploit innovations as well? In this research, comparative data across European countries at the firm level are employed to estimate a structural model that directly links R&D to innovation outcomes and then links innovation to productivity. This allows for disentangling the contribution of R&D intensity from the productivity of innovative effort in its effects on overall productivity.

3.3.2 From R&D to innovation and productivity.

The model draws largely on Crépon, Duguet and Mairesse (1998). Traditionally, R&D is entered directly into the production function. From this the rate of return or elasticity of output with respect to R&D is estimated. What is done here is to model (i) firms' decisions to engage in R&D, (ii) the intensity with which they undertake R&D, (iii) the knowledge production function, allowing for different types of knowledge output including process innovation, product innovation, the extent of novelty of new products, and patents, and (iv) the output production function where knowledge is an input.

Let $i=1,\dots,N$ index firms, $j=1,\dots,J$ index industries, $c=1,\dots,C$ index countries, $s=1,\dots,S$ index size categories. The basic structure of the model is: firms decide whether and how much effort to put into innovation; knowledge is produced as a result of this investment (along with other inputs and uncertainty); output is produced using knowledge (along with other inputs). More formally, we can write this as follows.

Firms' innovative effort is described by the latent variable r_i^*

$$r_i^* = z_i'\beta + e_i$$

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15 See, for example, EU (2003).

16 R&D intensity in the four major EU countries (France, Germany, Spain and the UK) lies behind the US and Japan (as measured by GERD over GDP).

where z_i is a vector of determinants of innovation effort. However, we only observe effort (reported R&D expenditure, which is denoted as r_i) above a certain threshold level c. We therefore estimate a selection model for observed effort and use the predicted value to proxy innovation effort in the knowledge production function. The selection equation describing whether a firm is reporting R&D or not is given by

$$rd_i = \begin{cases} 1 & \text{if} \quad rd_i^* = w_i'\alpha + \varepsilon_i > c \\ 0 & \text{if} \quad rd_i^* = w_i'\alpha + \varepsilon_i \le c \end{cases}$$

where rd_i is the observed binary endogenous variable, being zero for non-R&D and one for R&D reporting firms, and w_i is a vector of variables explaining the R&D decision. On the condition that firm i reports R&D activities, we can observe the amount of resources devoted to R&D

$$r_i = \begin{cases} r_i^* = z_i'\beta + e_i & \text{if} \quad rd_i = 1 \\ 0 & \text{if} \quad rd_i = 0 \end{cases}$$

The error terms e_i and ε_i are bivariate normal with zero mean, variances $\sigma_\varepsilon^2 = 1$ and σ_e^2 and correlation coefficient $\rho_{e\varepsilon}$.

In contrast to Crépon et al (1998), the exercise is not concentrated on innovating firms, but rather considers all firms.[17] We model innovation effort in this way because we believe that all firms exert some innovative effort. For example, production workers may well spend a small part of their day considering how the process they are working on could be achieved more efficiently. However, below a certain threshold, a firm will not collect data explicitly on this effort and therefore will not report this effort. An alternative interpretation is as an instrumental variables equation, where the concern may be that innovative efforts are endogenous to the knowledge production function - that is, there may be unobservable (to the econometrician) characteristics of firms that make them both invest more in innovation effort and also make more productive use of this effort. This would induce spurious correlation and mean that the coefficients in the equation below would be biased upward.

The output of this effort produces knowledge g_i. In general, the knowledge production function takes the form

$$g_i = r_i^*\gamma + x_i'\delta + u_i$$

where the latent innovation effort enters and where x_i is a vector of determinants of knowledge production. Knowledge output is measured in the production of both process and

[17] According to the Oslo manual, R&D activities are only one of several innovation activities. The latter also comprises the acquisition of machinery and equipment in the context of innovations, the acquisition of other external knowledge, training activities related to innovations, market introduction of innovations, design and other preparatory activities for the production and delivery of new products (Eurostat and OECD, 1997).

product innovations. Effort is a public good within the firm, so it can be used to produce several outputs without depletion. Therefore, g_i is modelled as a vector of innovative outputs.

Finally, firms produce output using the following production function

$$y_i = \pi_1 l_i + \pi_2 k_i + \pi_3 g_i + v_i$$

where output y_i is measured as labour productivity. Besides labour l_i and physical capital k_i, knowledge – now measured in terms of the output of innovation activities – g_i enters the production function. One diverging point compared to the original CDM model is that the elasticity of productivity with respect to innovation is estimated not only for innovative but for all firms in the last part of the model.

3.3.3 Data, estimation and results.

The data is again CIS 3. The cross-section provides information for the period 1998-2000. In Germany, the UK and Spain, the CIS 3 covers all enterprises with 10 or more employees. In France, however, the target population for manufacturing covers only firms with 20 or more employees. To compare the four countries, the analysis is restricted to firms with at least 20 employees. The whole structure of the model, including the exclusion restrictions made for identification of the model, can be gathered from a table in the paper.

As mentioned before, the paper assumes that all firms exert some innovative effort, implying that the model is estimated for the whole sample and not only for the innovating firms. This further implies that the paper is only able to use variables which can be observed for all firms to explain the selection equation. Unfortunately, only a few variables are available for innovating and non-innovating firms in CIS 3 data. Thus, besides size and industry dummies, only two other variables enter the R&D selection equation. The first one is an indicator as to whether the international market is the firm's most important market. The second is exports as a share of total turnover at the beginning of the period (1998). More explanatory variables are available to explain the R&D intensity because R&D performers have to answer several additional questions in the CIS[18]. All equations are controlled for size and industry characteristics.

The model equations make it clear that a recursive model structure is assumed, i.e., possible feedback effects are neglected, e.g., effects of productivity on innovation effort. For estimation purposes, not all equations are estimated simultaneously, but a consistent although less efficient three-step estimation procedure is applied. In a first step, the generalized Tobit model, comprising the selection equation and the innovation effort equation, is consistently estimated by full maximum likelihood techniques. In the second step, the knowledge production function is estimated using the predicted value of the innovation effort as one explanatory variable. As already mentioned, innovation effort can be used to produce both new products and processes. Five different innovation outputs are considered and the applied

[18] The CIS questionnaires in France, Spain and Germany include a filter question, i.e., only firms with innovation activities are requested to answer a lot of other questions, like questions on cooperations, sources, etc. R&D performers are by construction firms with innovative activities.

estimation technique depends on the nature of the outcome variable (process innovation, product innovation, innovative sales share, sales share of products new to the market, the firm's holding any patents). In the last step, the output production function is estimated, allowing for the endogeneity of the knowledge input variable.

The econometric results show some interesting heterogeneity across the four countries. Using different innovation output indicators, it is found that the innovation output is significantly determined by the innovation effort in three out of the four countries (France, Germany, and the UK). The results for Spain are less clear in this respect. In contrast to that, productivity effects of innovation showed up only for France, Spain and the UK, but not for Germany.

3.3 4 More on productivity effects (comparisons, time, management).

Two previous papers set the stage for the coordinated work on this line of research. One, "R&D and productivity: A re-examination in light of the innovation surveys," by J.Mairesse and P.Mohnen, estimated the model with a sample of firms coming from the CIS 2 data provided by the OECD and Eurostat on the four European countries: France, Germany, Spain and the United Kingdom. The other, "Firm level innovation and productivity: Is there a common story across countries?", by N.Janz, H.Lööf and B.Peters, estimated the model with a CIS3 sample of German and Swedish knowledge-intensive manufacturing firms. Results of these papers are taken into account below.

The paper "Firm's age, process innovation and productivity growth," by E.Huergo and J.Jaumandreu, is a direct look at the impact of process innovation on productivity, with more detailed firm-level Spanish panel data. An extensive body of literature tries to assess the impact of innovation on productivity but without innovation data, which is usually not available. The problem is usually solved by employing reduced forms, directly relating productivity growth to R&D expenditures (often conveniently aggregated in a "knowledge capital" estimate). The recent availability of innovation data allows us to move towards more structural estimates.

The paper opens a new way of assessing the firm-level productivity effects of innovation directly using innovation counts. An econometric model is constructed relating total factor productivity (TFP) growth to innovation counts and their lags as well as the age of the firms (entry in the market is in some sense the first process innovation). The model is estimated using an unbalanced panel data sample of Spanish manufacturing firms with detailed data on the age of the firm and innovation counts for 1990-1998. A semiparametric model is used to control for age without imposing any functional form on its impact on productivity.

Results give many insights on the firms' productivity dynamics in relation to process innovations. Firms present high TFP growth up to the eighth year in the market, and then growth converges to a common rate (different according to activities). The introduction of process innovations boosts productivity growth for more than one year, but the firm must continue introducing process innovations in order to keep the common pace of productivity growth. Everything suggests that process innovation today brings future productivity growth, which tomorrow is generalised to all firms through spillovers. Process innovation then gives firms an important but only temporary advantage.

Results show that this is an interesting way of modelling the impact of innovation, worthy of being explored further. But the application of the employed methodology requires firm-level longitudinal data on productivity growth and innovation counts, which are rarely available.

The paper “Knowledge management, innovation and productivity: a firm-level exploration based on the French CIS 3 data,” by E.Kremp and J.Mairesse, addresses the question of the impact of firms’ knowledge management on innovation and productivity. The French CIS3, according to a pilot project by the OECD, included a series of questions about knowledge management in the firms. The questions concern the existence of a written policy of knowledge management, a culture of knowledge management sharing, a policy of retention of employees and executives and a policy of alliances and partnerships for knowledge acquisition. The idea is that knowledge is a resource that in modern markets requires explicit and specific management and practices. Using the recent data issued by the new questions, the paper explores both the diffusion of practices of knowledge management and their impact on innovations and firms’ productivity.

The answers to the questions reveal that knowledge management is more advanced in larger firms and firms operating in more technology-intensive sectors, as well as that the different actions included in the questions are highly complementary, their adoption tending to be very correlated. Given this correlation, the paper defines and uses mostly an indicator of knowledge management intensity constructed simply by adding up the “ones” corresponding to the use of any one of the policies (hence the indicator varies from zero to four). Using this indicator, a series of regression tests are carried out to assess the impact on the propensity to innovate and to patent, and the impact on innovative sales (share of sales resulting from new or improved products) and patented sales (share of sales resulting from patented products). A final regression is performed using labor productivity as a dependent variable.

Regressions include as control variables: firm size dummies, industry dummies, a dummy reflecting whether the firm belongs to a group, a dummy reflecting whether the firm uses new management methods, a dummy reflecting whether the firm uses Internet and ICT for external data sharing, and R&D intensity (log of R&D expenditure-to-sales ratio). The regression of (log of) labor productivity also includes as a control the physical capital intensity, measured by the (log of the) ratio of the gross book value to the number of employees. The paper uncovers statistically significant effects of knowledge management on both the propensity and intensity of innovation and patenting, as well as on labour productivity. All effects are additional to controls and robust to other specifications of the knowledge management measurement.

3.4 Innovation and employment at the firm level.

Innovation is widely considered to be a primary source of economic growth, and policies to encourage firm-level innovation are high on the agenda in most countries. The consequences of innovation for employment are of particular interest, but the relationship between innovation and employment is complex. On the one hand, the long-run macro-economic impact of innovation on employment is clearly not negative; many decades, and even centuries, of innovation in advanced economies have not been accompanied by ever-decreasing levels of employment. Yet, at the same time, the impact of innovation on employment at the firm level remains unclear. Individual innovations may destroy jobs, but innovation can also stimulate demand, and evidence suggests that, on average, innovative firms are more likely to survive and grow than firms that do not innovate. The firm-level relationship between innovation and employment is an important topic of research for several reasons. For example, the effects of innovation on employment at the firm level are likely to influence the extent to which different agents within the firm resist or encourage innovation. In addition, the incentives of managers and workers will determine the types of innovations that are introduced and their subsequent effects on prices, output and employment. Understanding these incentives and welfare effects at the micro level is essential for the effective design of innovation policy, and for predicting how other interventions, such as labour market regulations, might affect the rate of innovation.

The paper "Does innovation stimulate employment? A firm-level analysis using comparable micro data from four European countries," by R.Harrison, J.Jaumandreu, J.Mairesse and B.Peters, has developed the empirical investigation of the firm-level employment effects of innovation, making three main contributions to the literature. First, it uses a unique comparable firm-level data set across four large European countries. Firms in these countries operate in different economic and institutional environments, and our results identify several robust common effects as well as interesting cross-country differences in the firm-level relationship between innovation and employment. Secondly, the structure of the data allows us to apply a simple model of innovation and employment that disentangles many of the different effects at work. In particular, the mix of each firm's output growth between existing and newly introduced products is observed, enabling us to quantify the employment effects of product innovation. Finally, evidence is presented from roughly 19,000 firms, of which more than 6,000 are in the service sector. Almost all previous studies have focused exclusively on manufacturing, yet much of the employment created in these four economies in recent years has been within the service sector. Two more papers, "Employment effects of different innovation activities: microeconometric evidence," by B.Peters, and "Does innovation spur employment? A firm-level analysis using Spanish CIS data," by J.Jaumandreu, detail some aspects of the analysis for Germany and Spain, respectively.

The paper estimates equations relating firms' employment growth to the introduction of process innovations and to those parts of sales growth accounted for by unchanged and newly introduced products, respectively. In doing so, it attempts to control for potential sources of correlation between the variables included and the residual using suitable econometric methods. The results suggest that, while process innovations tend to displace employment, compensation effects are prevalent and product innovations are an important source of firm-level employment growth. In particular, we find no evidence of employment displacement effects associated with product innovation. These effects are measured at the firm level, but it is explained how they should be aggregated up to the industry level by taking into account rivalry between competitors and the effects of entry and exit. Due to data limitations, the paper has not contributed to the literature on skill-biased technical change, focusing solely on the level of employment without distinguishing between different types of workers.

The data used in this paper includes, for each firm in the sample, the employment and sales in the years 1998 and 2000, information about whether the firm has introduced process and product innovations during the period and, particularly useful for our purposes, the share of sales in 2000 stemming from new or significantly improved products introduced since 1998, as well as information on R&D and innovation investments, firms' sources of information and innovation aims.

In what follows, we discuss, as does the paper, the potential firm-level employment effects of innovation and the relationship between firm-level and industry and aggregated levels, and we relate the contribution of the research to the literature on the subject. Next, we move to a brief presentation of the model and the problems which its estimation presents, as well as an account of the descriptive evidence in the sample we use. Finally, reference is made to a more complete estimation of the relationships involved with panel data.

3.4.1 Employment effects of innovation at the firm level.

The potential firm-level employment effects of innovation can be summarised as follows[19]. It is convenient to distinguish between the effects of process innovations, which are directed at improving the production process and hence have a direct impact on factor productivity and unit costs, and the effects of product innovations, which are mainly undertaken to reinforce demand for the firm's products. In practice, of course, the distinction between the two types of innovation is not always so clear, since process innovations often accompany product innovations and vice versa. As indicated in Table 2, both types of innovation can be interpreted as the (partly random) result of the firm's investment in R&D and other innovative activities.

Pure process innovations are likely to reduce the quantities of (most) factors required to obtain a unit of output, including the required labour input. Thus process innovations tend to displace labour for a given output, although the size of this displacement effect will depend on the extent to which the process improvement is labour or capital augmenting. The effects of a single identifiable process innovation will be additional to those of any incremental improvements in efficiency, usually attributed to factors like learning and spillovers, which reduce input requirements over time[20].

Any increase in productivity resulting from a process innovation implies a reduction in unit costs. Depending on the competitive conditions facing the firm, this is likely to result in a lower price, which will stimulate demand, and hence produced output and employment, with the size of the effect determined by the elasticity of demand for the firm's products. The size of this compensation effect is also likely to depend on the behaviour of the agents inside the firm and the nature of market competition. For example, unions may attempt to transform any gains from innovation into higher wages, while managers may seek to use market power to increase profits[21]. Both behaviours can dampen or override the compensation effect.

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[19] In this section, we draw on theoretical discussions in several papers, including Nickell and Kong (1989), VanReenen (1997), Garcia, Jaumandreu and Rodriguez (2002) and the more theoretical works quoted therein; see also the survey by Chennells and Van Reenen (2002).

[20] Estimates of production functions frequently account for ongoing improvements in productivity using time trends or time dummies, when estimating in levels, or constants when estimating in first differences. See, for example, Hall and Mairesse (1995). Indicators of specific innovative investments or outcomes typically leave a large amount of unexplained additional productivity growth. See Huergo and Jaumandreu (2004) for an illustration of this point with detailed panel data.

[21] See Nickell (1999) for a discussion.

Product innovations may also have productivity effects, even if they are not associated with simultaneous process innovations. The new or improved product may imply a change in production methods and input mix, which could either reduce or increase labour requirements. The extent and direction of the effect must be determined empirically. However, the most important effects of product innovations are likely to be positive compensation effects resulting from increases in demand for the firm's products. The importance of any increases in demand resulting from product innovation will depend on the nature of competition and the delay with which rivals react to the introduction of new products. In addition, sales of new or improved products may cannibalise some proportion of the firm's existing sales, reducing the positive compensation effect of product innovation.

The service sector has become the largest part of most developed economies, and contrary to traditional wisdom, many areas of the service sector have demonstrated high levels of innovation and productivity growth[22]. However, innovation in services is often concerned with changes in organisation, delivery and variety, possibly linked to the adoption of Information and Communication Technologies (ICT)[23]. As a result, it is more difficult than in manufacturing to clearly identify new products (Triplett and Bosworth, 2004) and to distinguish product innovations from process innovations. Moreover, statistical concepts and measurement in services are currently in a period of change and refinement. As a result of these considerations, while we think it is important to include the service sector in the analysis, it is important to bear in mind that the same variables may be less precisely measured or have interpretations different from those in manufacturing.

3.4.2 Innovation and employment at the aggregate level.

The focus of this research is the firm-level relationship between innovation and employment in a sample of firms. An interesting question is how the employment effects of innovation that we observe at the firm level relate to aggregate changes in employment. There are two main reasons why the aggregate effect of innovation on employment cannot be directly inferred by multiplying the average firm-level effect by the number of firms.

First, the firm-level compensation effects that we observe do not distinguish between a pure market expansion component and a business-stealing component[24]. If innovation by firms results in business-stealing rather than market expansion, then the aggregate effect of innovation on employment will in general be smaller (either less positive or more negative) than the firm-level effect. We should note, however, that the average firm-level employment

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[22] See, for example, Evangelista (2000), or the recent study of the US service sector by Triplett and Bosworth (2004).

[23] Examples include Internet Banking and the introduction of scanners and computers in Retailing.

[24] See, however, the use of rivals' data in Garcia, Jaumandreu and Rodriguez (2002) to separate these effects.

outcomes that we observe already embody the effects of business-stealing by firms' rivals, even if we do not know the rivals' identity or observe them in the sample. Secondly, and related to this, we do not observe entering or exiting firms in our sample of continuing firms. Firm entry, which may be the result of innovation, is an important source of employment growth, while exit may be induced by successful innovation and business-stealing by rival firms. A full industry-level analysis would have to explicitly incorporate entry, exit and competition between rival firms. Evidence on the rivalrous effects of innovation could possibly be obtained through techniques similar to those used in the measurement of R&D spillovers, while data on entering and exiting firms would be needed to assess the role of entry and exit.

While the analysis does not relate directly to aggregate employment effects, it does provide essential information on the micro-mechanisms that underlie aggregate employment growth. As discussed in the introduction, this micro-level relationship between innovation and employment is an important topic of research in itself.

3.4.3 Previous literature on innovation and employment.

A number of previous papers have provided evidence on the relationship between innovation and employment at the firm level. The survey by Chennels and Van Reenen (2002), although focused on a related but different question, provides a useful overview[25]. Existing papers differ widely in terms of both methodology and data employed. Given the relationships summarised in the previous discussion, it is not surprising to find a broad range of modelling strategies, ranging from the assessment of correlations or estimation of reduced forms to more structural models. At the same time, different data provide various measures of innovation, some output-oriented, such as innovation counts, and others input-oriented, such as R&D intensity. Finally, papers differ widely in the extent to which they address issues of heterogeneity and endogeneity.

On the whole, product innovation emerges as clearly associated with employment growth, although the balance between displacement and compensation effects remains unclear (see, for example, Entorf and Pohlmeier, 1991; König, Licht and Buscher, 1995; Van Reenen, 1997; Greenan and Guellec, 2000; Smolny, 1998 and 2002; Garcia, Jaumandreu and Rodriguez, 2002; Peters, 2004). R&D is often found to be positively associated with employment growth (see, for example, Blechinger, Kleinknecht, Licht and Pfeiffer, 1998, and Regev, 1998), although not always (see Brouwer, Kleinknecht and Reijnen, 1993, and Klette and Forre, 1998). Process innovations and the introduction of new technologies show effects which range from negative to positive according to the specification (see, for example, Ross and Zimmerman, 1993, for a negative process innovation effect; Doms, Dunne and Roberts, 1995 or Blanchflower and Burguess, 1999, for positive technology impacts, and the various effects obtained for process innovations from many of the above papers).

[25] The survey is focused on the impact of technological change on the skill and pay structure of labour. This is an important related area of research, an early study of which is found in Berman, Bound and Griliches (1994). On the relationship between innovation and employment, see also the survey contained in Spiezia and Vivarelli (2002).

The focus of this research is the derivation and estimation of a simple theoretical model of employment and innovation that is applicable to the comparable cross-country data at hand. In particular, the data used allow us to observe firms' sales of new or significantly improved products as well as sales of unchanged products. Using a production function framework, various restrictions on the data can be derived, allowing us to distinguish some of the displacement and compensation effects of innovation on employment. The appropriate econometric techniques to control for potential sources of correlation between the variables included and the residual are used. Overall, the findings support the robustness of the product innovation effect on employment. In particular, there is no evidence of employment displacement effects associated with product innovation. The findings also shed some light on the reasons why the estimated effects of other technological measures vary across studies. In addition, evidence from the service sector as well as from manufacturing is presented, whereas almost all of the existing literature has focused exclusively on manufacturing.

3.4.4 Model and estimation.

Model

A firm can produce two types of products: old or only marginally modified products ("old products") and new or significantly improved products ("new products"). Outputs of old and new products at time t are denoted Y_{1t} and Y_{2t}, respectively. We observe firms at two points in time, at the beginning and end of the period. At the beginning of the period, all products are old products by definition, so Y_{21} is always equal to zero. If the firm does not introduce any new products during the period, then Y_{22} is also equal to zero. We assume that each type of product is produced with an identical separable production technology, with constant returns to scale in capital, labour and intermediate inputs. Each production technology has an associated efficiency parameter that can change over time. New products can be produced with higher or lower efficiency than old products, and the firm can influence the efficiency of production of either product through investments in process innovation. The production technology for product *i* at time *t* can be written as follows

$$Y_{it} = \theta_{it} F(K_{it}, L_{it}, M_{it}) \quad i = 1,2; T = 1,2$$

where θ represents efficiency and *K,L* and *M* stand for capital, labour and materials. The firm's cost function at time *t* can then be written

$$C(w_{1t}, w_{2t}, Y_{1t}, Y_{2t}, \theta_{it}, \theta_{2t}) = c(w_{1t})\frac{Y_{1t}}{\theta_{it}} + c(w_{2t})\frac{Y_{2t}}{\theta_{2t}} + F$$

where $c(w)$ is marginal cost (a function of input prices *w*) and *F* stands for some arbitrary fixed costs. According to Shephard's Lemma, we have

$$L_{it} = c_L(w_{it})\frac{Y_{it}}{\theta_{it}}$$

where $c_L(w_{it})$ represents the derivative of marginal cost with respect to the wage.

The growth of employment over the period can be decomposed into the growth of employment due to production of the old product, and the growth of employment due to production of the new product as follows (recall that $L_{21} = 0$).

$$\frac{\Delta L}{L} = \frac{L_{12} - L_{11}}{L_{11}} + \frac{L_{22}}{L_{11}}$$

Assume that the derivative of marginal cost with respect to the wage does not change over the period, so that $c_L(w_{11}) = c_L(w_{12}) = c_L(w_1)$. This will be the case, for example, if relative prices are constant over the period[26]. Using the previous results, we can then write an approximate employment growth decomposition as follows

$$\frac{\Delta L}{L} \cong -\left(\frac{\theta_{12} - \theta_{11}}{\theta_{11}}\right) + \left(\frac{Y_{12} - Y_{11}}{Y_{11}}\right) + \frac{c_L(w_2)}{c_L(w_1)} \frac{\theta_{11}}{\theta_{22}} \frac{Y_{22}}{Y_{11}}$$

where we use a linear approximation to obtain the first two terms.

This expression says that employment growth is the result of the change in efficiency in the production process for the old products, the rate of change of the production for these products, and the expansion in production attributable to the new products. The increase in efficiency of the old production process $\left(\frac{\theta_{12} - \theta_{11}}{\theta_{11}}\right)$ is expected to be larger for firms which introduce process innovations relating to the old product, although the efficiency of all firms may grow over time. If we assume that the derivative of marginal cost with respect to the wage is the same for old and new products[27], i.e., $c_L(w_1) = c_L(w_2)$, the effect of product innovation on employment growth depends on the difference in efficiency between the production processes for the old and the new products (the ratio $\frac{\theta_{11}}{\theta_{22}}$). If new products are produced more efficiently than old products, then this ratio is less than unity and employment does not grow one-for-one with the growth in output accounted for by new products[28].

[26] Notice that $c(.)$ is homogeneous of degree one and hence $c_L(.)$ is homogeneous of degree zero.

[27] Again this will be the case, for example, if relative input prices are the same for the two products. In fact, it seems quite likely that input prices would be the same for both products

[28] If the derivative of marginal cost with respect to the wage is higher for new products (i.e., $c_L(w_1) < c_L(w_2)$), then the estimated ratio will be biased upwards; in other words, the efficiency increase associated with new products will be underestimated.

Equation (1) suggests the following population relationship

$$l = \alpha + y_1 + \beta y_2 + u$$

where l stands for employment growth over the period, variables y_1 and y_2 stand for the rates of output growth $\frac{Y_{12} - Y_{11}}{Y_{11}}$ and $\frac{Y_{22}}{Y_{11}}$, respectively (output growth accounted for by the old and new products), and u for a random disturbance which is expected to have zero mean conditional on a suitable set of instruments, i.e., $E(u|z) = 0$. The parameter α represents (minus) the average efficiency growth in production of the old product, while β captures the relative efficiency of the production of old and new products.

In principle, equation (2) could be extended to allow process innovation to affect changes in the efficiency of production of old and new products as follows

$$l = (\alpha_0 + \alpha_1 d_1) + y_1 + (\beta_0 + \beta_1 d_2) y_2 + u$$

where d_1 and d_2 are dummy variables equal to one if the firm introduced any process innovations related to the production of old or new products, respectively, over the period. In practice, it is not known whether the process innovations of firms that introduce new products relate to their old or their new products, but it is possible to experiment with various alternatives. For example, it can be assumed that all such process innovations relate to old products, or all to new products.

Interpretation.

We should comment briefly on the significance and limitations of the previous equation, as well as the likely properties of u. On the one hand, this equation can identify two important effects. Firstly, under the assumption that the growth of output due to the introduction of new products is observed, the equation clearly identifies the gross effect of product innovation on employment. Secondly, observation of the introduction of process improvements in the production of the old products allows us to identify the productivity or "displacement" effect of process innovation[29]. On the other hand, the variable y_1 embodies three different effects which cannot be separated without additional (demand) data: the "autonomous" increase in firm demand for the old products, due, for example, to cyclical or industry effects; the "compensation" effect induced by any price variation following a process innovation; and the demand "substitution effect" resulting from the introduction of new products. As these components cannot be disentangled, y_1 will in practice be simply subtracted from l , thereby imposing the unitary coefficient.

[29] However, see below for a discussion of the problem that arises when the data refer to sales that are not properly deflated.

To compare the proposed equation with other specifications, notice that it can be transformed into a productivity growth equation by simply rearranging terms as follows (for simplicity we assume that all process innovations refer to the production of old products, i.e., $d_2 = 0$)

$$y_1 + y_2 - l = -\alpha_0 - \alpha_1 d_1 + (1-\beta) y_2 - u$$

This transformation shows that growth in output per worker will depend positively on process innovation and that the expected sign for product innovation depends on the value of the relative efficiency of the old and new processes. If β is equal to one, efficiency is the same across production processes and new products do not affect output per worker. If β is less than one, new products are produced more efficiently, and thus output growth due to new products increases output per worker.

Finally, the need for a suitable set of instruments results from the possibility that the key variables d and y_2 may be simultaneously determined and thus correlated with the error term u, although this is not necessarily the case. Notice that the equations involve rates of growth of the variables. We must clearly allow for the possibility that the error term contains unobserved shocks to productivity growth correlated with the introduction of process or product innovations (for example, investments, bursts in capacity utilization, labour and organizational problems). However, we exclude a priori the presence of long-run determinants of productivity growth differences in the error term that are correlated with product or process innovations. These would imply rather surprising long-run differences in growth rates, and it is unlikely that we would find suitable instruments in our data. Nevertheless, we should bear in mind that a positive correlation between the introduction of innovations and unobserved favourable productivity shocks would induce a downward bias in our estimates of both α_1 and β. In other words, we would estimate employment displacement effects of process innovation and the introduction of new products that are too large[30].

Estimation strategy.

Let us give a brief non-technical account of the problems involved in estimating an employment relationship equation as the proposed equation and the solutions adopted. To estimate the equation, we must substitute nominal sales, which are the magnitudes that we observe, for real production. The problem of unobservable prices is common in productivity analysis, but it is particularly relevant in this case since we are attempting to separately identify the productivity effects of old and new products, which may be sold at different prices. To estimate the relevant parameters consistently, then, we have to take into account three main problems.

[30] To see this, notice that a favourable unobserved productivity shock is a negative realization of u in the "productivity" equation, where u enters with minus sign. This would be trasmitted to d and y_2 through their dependence on productivity and, hence, their "reduced" forms would contain a positive shock, negatively correlated with the realization of u in the main equation.

First, the growth of sales due to new products is an endogenous variable, in the sense that it is correlated with the composite error term. The problem originates in our inability to measure the output ratio directly (a variant of the classical errors in variables problem), and we can try to solve it by instrumenting the sales rate with variables correlated with the real ratio and uncorrelated with the price differences. We discuss potential instruments extensively in the paper.

Secondly, the composite error term now will include the change in the prices of the old products, as long as we cannot control for them. This creates an identification problem. Any increase in proportional efficiency decreases marginal cost by the same proportion. If, for example, firms are pricing by setting some unspecified markup on marginal cost, then price variations are likely to be roughly proportional (with the opposite sign) to the increases in efficiency. In addition, firms endowed with some market power might pass on this cost decrease in different amounts. That is, we will only identify an effect of productivity changes on employment net of any compensating price movements. In our econometric estimates, we use a system of price indices computed at a detailed industry disaggregation as a proxy for the change in prices. With this arrangement, we are likely to identify the average real productivity effect, but an identification problem will remain to the extent that firms deviate from average price behaviour.

Finally, we must take into account the possible endogeneity of d and the sales growth due to the new products variable, as discussed above. The instruments that we use for the errors in the variable problem embodied in the sales growth may help to address this problem, but we also test for the endogeneity of d given the instruments available. We discuss these issues thoroughly in the paper and in the estimations detail.

3.4.5 Innovation and employment across four countries.

In this section, we briefly present the results of an initial exploration of the data. Innovators represent between about 40% (UK) and 60% (Germany) of firms in the samples. Innovators that only introduce process innovations generally constitute up to one in four of all innovators. The sizes of the national samples differ, but all samples are broadly representative by strata. Representativeness, however, diverges somewhat across countries, and therefore direct comparisons must be interpreted carefully. Details on the samples and variable definitions can be found in the paper.

The employment growth of innovators is consistently higher than the employment growth of non-innovators across the four countries, with the employment growth of product innovators slightly higher than firms that introduce only process innovations. Productivity gains also tend to be higher in the innovating firms (with the exception of Spain, where there is little difference in average productivity growth between innovators and non-innovators). Notice that the increase in employment of innovative firms is higher despite their larger labour productivity gains. This suggests that compensation effects resulting from the growth of output dominate displacement effects of innovation at the firm level.

The average increase in sales over the period 1998-2000 is high in all countries, reflecting both an expansionary phase of the industrial cycle and the fact that these are samples of continuing firms. Average sales growth is particularly high for Spain, even when deflated with the corresponding highest rate of price increase, but the Spanish economy was at the time experiencing high overall growth. Average industry price increases are negligible at that time in the UK and very low in Germany.

Sales growth is consistently higher for innovators than non-innovators, with no systematic difference between firms that introduce only process innovations and those that introduce product innovations. For product innovators, sales of new products are a very important component of total sales growth: sales in 2000 of new or significantly improved products introduced during the 1998-2000 period amount to more than one third of sales of the old products in 1998 for the German, Spanish and UK firms, and nearly 20% for the French firms. Sales of new products appear to partly cannibalise sales of old products, although the extent of cannibalisation varies across countries, and is markedly lower in France than in the other countries.

The proportion of sales of new products that are accounted for by products that are new to the market (as opposed to simply new to the firm) is almost one half for France, about one third for Germany and Spain, and only one quarter for the UK.

In the services sector, the proportion of innovators is lower in all countries than in manufacturing, but relatively high in Germany and particularly low in the United Kingdom and Spain. The proportion of innovators that introduce only process innovations is slightly higher than in manufacturing for all the countries.

In all countries, employment growth is somewhat higher for innovators, and is higher for product innovators than for firms that introduce only process innovations. This suggests that demand increases associated with new products play an important role in employment creation in service sectors.

The growth of nominal sales during the period is very high, but notice that average price increases are now also significant for all countries. As with employment growth, sales growth is higher for product innovators, but not particularly for firms that only introduce process innovations. The productivity growth of innovators is, however, sometimes higher (France, Spain) and sometimes equal or lower (Germany, the UK) than the productivity growth of non-innovators.

For product innovators, sales of new products are as large a part of total sales growth as in manufacturing, although there appears to be slightly less cannibalisation of old products by new products. As in manufacturing, the proportion of sales of new products that are accounted for by products that are new to the market (as opposed to simply new to the firm) is higher in Germany and Spain than in France and the UK

3.4.6 A decomposition of employment growth.

An interesting way to summarise the evidence obtained with the estimates is to decompose firms' employment growth into several components. Using the results of estimation, it is possible to distinguish the following components. For a given firm, the first component gives the change in its employment attributable to the (industry specific) productivity trend in the production of old products. The second component measures the change in employment associated with the net effect of process innovation in the production of old products. The third component gives the employment change associated with output growth of old products for firms that do not introduce new products. Finally, the fourth component measures the net contribution of product innovation, after allowing for any substitution of new products for old products. The last term is a residual unexplained component (u).

Table 3 reports the application of this decomposition to the whole samples of manufacturing and services firms, using the proportions and averages from the descriptive tables and the preferred regression results. Notice that the average residual component u is equal to zero by construction, and so the productivity trend in the production of old products can be obtained by subtracting the other components from average employment growth.

Before discussing the results of the decomposition, let us comment briefly on its interpretation. First, given that many of the estimated coefficients are similar across countries, differences in the results of the decomposition across countries will often be driven by differences in the average values of the variables. Nevertheless, the decomposition would not be possible without the estimated coefficients. Secondly, many limitations of the estimation results have been stressed above. In particular, process innovation effects are not separately identified from the effects of associated price changes, and firm-level compensation effects do not distinguish between pure market expansion and business stealing. Thirdly, recall that we are describing the average employment growth of a sample of continuing firms. Entering and exiting firms should be included to obtain a more complete picture of aggregate employment effects. And finally, the results are based on an expansionary period for all four countries, and so may not be representative of average firm-level effects at other stages of the cycle.

The table shows that, in Manufacturing, incremental productivity improvements in the production of existing products are an important source of reductions in employment requirements for a given level of output. The effect is smallest in France (-1.9% over two years) and largest in Germany (-7.5% over two years). However, growth in output of existing products over this expansionary period more than compensates for the productivity effect in all countries except Germany.

Individual process innovations account for only a small employment change in all countries, generally resulting in a small net displacement effect. This is partly because we are measuring process innovation effects in net terms after any price pass-through, but also because the number of firms that introduce only process innovations is small. Employment reductions resulting from process innovations may be important for individual firms, but they amount to only a small fraction of overall employment changes.

In contrast, product innovations play an important role in stimulating firm-level employment growth. The decomposition shows that the effect of new product sales, even net of the substitution for old products, is sizeable in all countries. It implies an average firm-level employment increase over the period ranging from 3.9% in the UK to 8.0% in Germany.

Overall, the importance of innovation in stimulating firm-level employment growth becomes clear when the different sources of employment change are compared. In Germany, where the combined effect of growth in existing output and trend productivity increases in production of existing products is slightly negative, product innovation is responsible for more than the whole average firm-level employment increase the during the period. Even in Spain and the UK, where increases in sales of existing products are responsible for a large proportion of net employment growth, product innovation was, on average, more important than the net effect of growth in sales of existing products.

The results for service sector firms are somewhat different. Average within-firm employment growth is almost double that in manufacturing during the period, and more than double in the UK. On average, product innovation accounts for a smaller, but still non-negligible, proportion of total employment growth than in manufacturing. In Spain and the UK the main source of firm-level employment growth is growth in production of old products, with a small counterbalancing effect of trend productivity increases only in the UK. In France, the contribution of product innovation is roughly the same as the net contribution of growth in sales of existing products. Total employment growth is lower in Germany, and growth in production of new products accounts for a larger share of employment growth than in the other countries.

3.4. 7 Using panel data to estimate the effects.

One of the objectives of this research project has been trying to structurally assess the effects of innovation on employment at the firm level. As we have already seen, without more complete data, some effects are difficult to separate. In addition, the model must take into account that the working of the "displacement" and "compensation" effects is likely to be strongly influenced by the wage and price reactions to innovation arising from behaviour of the firm agents. The paper "Innovation and jobs: Evidence from manufacturing firms," by A.Garcia, J.Jaumandreu and C.Rodriguez, uses more complete panel data in an exercise which tries to model all these aspects at the same time.

The paper estimates firm-level displacement and compensation effects in a model in which the stock of knowledge capital raises relative firm efficiency through the incorporation of innovations. Displacement is given by the elasticity of employment with respect to innovation in the (conditional or Hicksian) demand for labour, which is estimated alternatively from the specification of a production function and from the specification of the corresponding demand for labour. Compensation effects are estimated from a firm-specific demand relationship, which the stock of knowledge capital shifts through the introduction of product innovations, which possess a finite elasticity with respect to the product price. The combination of the estimated elasticities gives the displacement, compensation and total effects of innovations on employment. These effects may be respectively enlarged and weakened by the behaviour of firm agents if the incorporation of innovations starts wage and price changes aimed at appropriating innovation rents. The paper assesses the likelihood of these effects and quantifies them through the estimation of wage bargaining and margin determinants equations.

The model is applied with an (unbalanced) sample of nearly 1,300 Spanish firms, observed during the period 1990-98. The exercise is possible because the data set includes observations on the firms' output, inputs, R&D expenditures, innovations, demand-related variables and, a crucial and rather unusual feature, firms' individual input and output price changes and some idiosyncratic firm-market observations.

Results show that innovation displaces labour but also creates the firm-level conditions which compensate displacement. Process innovations reduce marginal costs and this reduction can be passed on to prices to expand demand with an employment effect that doubles the first effect. In addition, product innovations, which most of the innovative firms carry out at the same time (at a slightly smaller frequency) as process innovations, double the expanding effect obtained by unity of innovative expenditure. Positive potential net effects of process innovation are estimated to be reduced in the long run, when competitors match the innovations, but positive potential net effects of product innovation of a significant magnitude tend to persist in the long run.

Results also show, however, that the working of the compensation mechanisms can be dampened by the behaviour of the firm agents. In any case, average global actual net employment effects of innovations are estimated to be positive, even in the long run. A caveat to take into account is that innovation is only one of the sources of firm-level productivity growth and that other sources (embodied technical change, learning, spillovers, “outsourcing” of firm activities) can have more net negative effects on employment.

4. Conclusions and policy implications.

4.1 Innovation in Europe

The aim of an important part of the work undertaken by the project has been to characterize the comparability of the European CIS3 data and, once this was assessed, the exploration of the differences in innovation activity across countries, and the degree to which these differences are either country-specific, related to intra-country characteristics of the markets or, to the extent that industries globally diverge in their innovation indicators, due to the varying composition of economic activity across countries. This has been done by descriptively analysing the extent of innovative activity, several input and output indicators of innovation activities, and some related behaviour and policy variables for eleven manufacturing sectors, with CIS3 data, in the four large EU countries involved: France, Germany, Spain, and the UK.

Although CIS3 is an EU-harmonised statistic, some differences remain across countries, which implies that very specific comparisons must be made with care. In particular, statistical errors, the different wording and the different institutional framework for some questions and the various methods used to deal with non-response can lead to statistical differences in the numbers. The data used must then be checked in these respects, both at the national and international levels, as we have done with our particular samples, ensuring that the employed indicators present a useful and reliable picture taken as a whole. More long-term consequences, concerning the generation and handling of these data, are derived below.

The data show significant differences among countries in most innovation indicators at the aggregate level: with respect to firms' active participation in innovation, with respect to innovation intensities or efforts, with respect to innovation output and in both behaviour and technological policy variables (cooperation and public financial support, respectively). This fact raises the question of which effects drive the differences across countries amidst the work of at least three important forces: a trend towards incentive equalization derived from the development of an integrated European market; the own increasing European-wide dimension of each specific market, which is likely to influence its inter-country structure (e.g., dominant acquired positions, possibly due to economies of scale, previous sunk investments, technological advantages and so on, may induce intra-market inequalities); each country industry composition and its evolution. Our exercises have, however, shown that the influence of the latest factor is, in general, negligible.

As a summary of facts, we can say the shares of innovators do not seem to be strikingly different sector by sector, with the exception of Germany, where they are consistently higher across sectors. Specific high values are detected, however, for particular countries and sectors, which can be linked either to some European leadership of the firms in the sector (product innovation), or particular efforts to reduce costs and become more competitive (process innovation).

There is some additional heterogeneity, however, in innovation input measures. Germany often – but not always – shows the highest industry values while, at the other extreme, Spain consistently shows the lowest values (at the aggregate level, partly due to relative industry concentration in the low-technology sectors). Heterogeneity in input measures (e.g., firms' R&D intensity) across countries in the same industry can be considered to reflect relative European-wide market positions of the firms involved (and hence also sometimes the most domestic-market -or exporting towards third parties- orientation of some of them). They also seem to remark that, besides the production of innovations, very different contents may be involved.

More heterogeneity may be implied in behaviour, where cooperation shows, somewhat surprisingly, one the largest and most different variations. France and the UK, with proportions of firms which can be close, present the highest degrees of cooperation, while Germany is only intermediate and Spain the lowest one.

Average proportions of financially supported firms tend to be similar with the exception of the UK (whose proportion of supported firms in high-technology sectors is, however, not so dissimilar). Nonetheless, proportions of supported firms may be hiding important differences in the amount of funds received by firms and the process by which these funds are assigned.

With reasonably comparable data and significant differences among the values of the innovation variables (e.g., intensity, inputs and outputs, behaviour and public support), as well as forces which can explain many dimensions of the differences (by industries intra-country, intra-industry in European global markets, across countries…), the type of work represented by the lines of research in this project is possible and important. Cross- comparable samples, consisting of observations of many firms from different industries (and even manufacturing and services), treated with suitable microeconometric techniques, are the only way to generate reliable evidence in support of (empirically or theoretically) presumed regularities and to quantify them, to explore and understand the underlying behavioural mechanisms as well as to evaluate both the potential and results of economic policies. The assessments and quantifications, conclusions and questions which emerge in the rest of this summary are derived from this type of work.

A number of econometric results refer to the own variation of the innovation indicators. The main exercises of this type were conducted at the beginning of the project with firm-level CIS data referring to the period 1990-1992, comparing the expected innovative sales (and their components) and innovativeness for seven European countries (Belgium, Denmark, France, Germany, the Netherlands, Norway and Italy). The model points to significant differences among the countries with respect to a hypothetical "average Europe" (and between the high-R&D and low-R&D sectors). The expected share varies more across countries in the high-R&D sectors, while innovativeness varies more across countries in the low-R&D sectors. More specific results, referring to Germany in the period 1996-98, also give sensible indications. The probability of innovation is higher the greater internationalisation, product diversification and worker skills are. Size turns out to be important for product innovation, although perhaps not for explaining the probability of introducing market novelties. Simultaneity of the R&D intensity/innovative sales share equations is confirmed (intensity shows feedback from innovative sales). More works of this type, exploiting the work -in some sense "preparatory"- done with the samples in the last part of the project, seem~~s~~ to be one of the interesting avenues for future research.

4.2 Competition and innovation.

Competition heavily influences the way technology and innovation are originated and diffused. And the analysis of the dynamics of technology is one of the most important parts of this broad area of interest. The final stage of the research has been extensively and coordinately focussed on cooperation, which summarises many of the questions at stake (spillovers, “appropriability,” the relative roles of rivalry and cooperative outcomes, influence and role of public policy…). But the project has also produced evidence on the following questions related to the dynamics of technology: the relationship between ownership and convergence of technology, the probability of introducing process innovations according to the age of the firm, the identification of spillovers and conscious sourcing strategies by firms, and the impact of foreign competition and entry.

Cassiman and Veugelers (2002) found that firms’ ability to take advantage of incoming spillovers in the form of publicly available knowledge and limit outgoing spillovers and appropriate the returns to their innovative efforts both had a positive effect on the likelihood of firms undertaking cooperative R&D agreements. Moreover, incoming spillovers were found to be a more important factor in determining collaborative agreements with research institutions, and appropriability a more important determinant of vertical cooperative agreements up and down the supply chain.

In our coordinated econometric exercise, carried out with samples of the four countries, the results of our research support those in CV, in that we found a positive relationship between the likelihood of undertaking a cooperative agreement and both incoming knowledge spillovers and the extent to which firms find strategic methods important in appropriating the returns to innovative activity. However, it is also found that, on average, firms are less likely to engage in cooperative agreements in industries where legal protection methods such as patents are important for securing returns to R&D. At the same time, public support is positively related to the probability of undertaking cooperative agreements, particularly with regard to the likelihood of cooperation with the research base.

The econometric exercise carried out with UK establishments data~~,~~ to assess the impact of foreign ownership shows that 24% of frontier establishments are foreign-owned establishments, 2/3 of them US-owned, and the average total factor productivity growth (TFP) of non-frontier establishments is only about 65% of the TFP of frontier establishments, with the establishments remaining at the technological frontier for 4 years. Regressions obtain positive and significant effects both on the TFP growth of the frontier establishment and on the gap term. Consequently, establishments that are further behind the technological frontier experiment higher productivity growth, i.e., there is catch-up to the frontier. Regressions also obtain some evidence that catch-up is faster the larger the foreign presence within an industry.

The econometric exercise performed with a panel data sample of Spanish firms shows that the probability of innovating diverges by activity, and that small size per se reduces the probability of innovation. But it also shows that entrant firms tend to present the highest probability of innovation, while the oldest firms then show lower innovative probabilities. However, some sets of firms with intermediate ages also present a high probability of innovation, and exiting firms are instead clearly associated with lower levels of introducing innovations. This is consistent with an industry setting in which entering and young firms make the most numerous process innovations, growing bigger, and at the same time less active, as they mature. Some entering firms, however, have to exit as they are not able to innovate enough.

The last version of the sourcing exercise, performed with a panel of US and UK firms, tests the "technology sourcing" hypothesis that foreign research labs located on US soil tap into US R&D spillovers and improve home country productivity. Using panels matched to patent data, it is shown that UK firms which had established a high proportion of US-based inventors by 1990 benefited disproportionately from the growth of the US R&D stock over the next 10 years. It is also found that technology sourcing is more important for countries and industries which have "most to learn." Within the UK, the benefits of technology sourcing were larger in industries whose TFP gap with the US was greater. Between countries, the growth of the UK R&D stock did not appear to have a major benefit for US firms which located R&D labs in the UK.

The empirical results on entry suggest that, in industries close to the technological frontier, an increase in foreign entry leads to an increase in the innovation rate in incumbent firms. However, in industries where incumbents are far behind the technological frontier, firms are not able to fight entry, and the innovation rates remain static or even decline.

4.3 Innovation and productivity

There are a considerable number of national firm-level studies analysing the relationship between innovation and productivity, but cross-country comparisons using micro data are still rare. The research done on innovation and productivity has contributed to the literature by extensively investigating the innovation-productivity nexus at the firm level for the four major European countries using the CIS data: firstly with the CIS2 data, provided for the four countries by Eurostat, and then with the CIS3, coordinately using the different national samples.

The first outcomes obtained (CIS2 data) confirmed the usual results with respect to the most traditional effects: size influences the propensity to perform R&D but not its intensity; R&D plays a role in explaining innovation together with size (innovation output equations are not in intensity form) and the (corresponding) indicators of demand pull (in product innovation) and cost push (in process innovation); innovation outputs positively influence labour productivity.

The estimation of the equations for a set of four countries allowed for an exercise of decomposition. Decomposition was carried out for labour productivity, process innovation and innovative sales, as well as R&D intensity. Deviations of the dependent variable with respect to an average European value are explained according to the results of the regression (marginal effects are multiplied by the differences in the country-explanatory variables with respect to the European means), leaving an unexplained factor determined by the value of the country dummies.

Some particular results also emerged in the early Germany-Sweden comparison, already performed with CIS3 data. Demand pull (and not cost push) variables appeared as the ones important for explaining product innovation. In addition, the productivity effects of innovation were estimated to be high and fully significant. A more important particular insight, derived from the different setup of the model, is that productivity feedback effects on the innovative sales equation are important. One of the main conclusions of the research was that knowledge-intensive manufacturing firms seem pretty homogeneous across the two apparently different countries (Germany and Sweden), the main differences affecting only the relatively small German firms.

In the last stage of the project, effort has been made towards the coordinated estimation of the structural model that describes the link between R&D expenditure, innovation output and productivity. The econometric results show some interesting heterogeneity across the four countries. Using different innovation output indicators, it is found that the innovation output is significantly determined by the innovation effort in three of the four countries (France, Germany, the UK); the results for Spain are less clear in this respect. In contrast to that, productivity effects of innovation showed up only for France, Spain and the UK, but not for Germany.

Another, different strand of research, done with panel data, has stressed the forms of the impact of innovation on productivity, relating them to the age of the firms. Firms present high TFP growth up to the eighth year in the market, and then growth converges to a common rate (different according to activities). The introduction of process innovations boosts productivity growth for more than one year, but the firm must continue introducing process innovations in order to keep the common pace of productivity growth. Everything suggests that process innovation today brings future productivity growth, which tomorrow is generalised to all firms through spillovers. Process innovation then gives firms an important but only temporary advantage. Results show that this is an interesting way of modelling the impact of innovation, worthy of being explored further. But the application of the employed methodology requires firm-level longitudinal data on productivity growth and innovation counts, which are rarely available.

The French CIS3, according to a pilot project by the OECD, included a series of questions about knowledge management in the firms. The questions concern the existence of a written policy of knowledge management, a culture of knowledge management sharing, a policy of retention of employees and executives and a policy of alliances and partnerships for knowledge acquisition. The idea is that knowledge is a resource that in modern markets requires explicit and specific management and practices. Using the recent data issued by the new questions, regressions including control variables and a constructed knowledge management measurement have uncovered statistically significant effects of knowledge management on both the propensity and intensity of innovation and patenting, as well as on labor productivity.

4.4 Innovation and employment.

In exploring the relationship between innovation and employment, a simple model of employment and innovation has been derived and estimated using a unique source of comparable and representative micro-data on manufacturing and services firms across the four European countries. The results are illuminating about the relative roles of displacement and compensation effects in the firm-level relationship between innovation and employment growth. The results also provide a rare insight into the relationship between innovation and employment growth in service sectors. The firm-level relationship between innovation and employment is an important topic of research for several reasons. For example, the firm-level effects of innovation on employment are likely to determine the extent to which different agents within the firm resist or encourage innovation. At the same time, the incentives of managers and workers will determine the types of innovations that are introduced and their subsequent effects on prices, output and employment. Understanding these incentives and welfare effects at the micro level is essential for the effective design of innovation policy, and for predicting how other interventions, such as labour market regulations, might affect the rate of innovation.

The results are, in many respects, only a first look at this important topic. First, the lack of data for modelling the demand side of firms' activity imposes some obvious limitations when estimating the displacement and compensation effects of innovation. In particular, "business stealing" effects cannot be separately identified from pure market expansion, and compensation effects resulting from price pass-through cannot be fully assessed. Secondly, only the total level of employment and not its composition in terms of skills or type of worker has been considered. For example, our results suggest that workers on average have little to fear from product innovation, but we have not been able to address the possibility that new products are more complementary to skilled than to unskilled workers. Both these topics present important lines of research at the micro level, and suggest high returns to increasing the richness of available data sources.

But the main results reveal that, in manufacturing, although process innovation tends to displace employment, compensation effects are prevalent, and product innovation is associated with employment growth. The destruction of jobs through process innovation, as well as being relatively infrequent, appears to be partly counteracted by compensation mechanisms that increase demand through lower prices. At the same time, no evidence of displacement effects associated with product innovation is found, and compensation effects resulting from the introduction of new products are significant even when the cannibalization of old products is taken into account. In the service sector, there is less evidence of displacement effects from process innovation, and though less important than in manufacturing, growth in sales of new products accounts for a non-negligible proportion of employment growth. Interestingly, our results match well with the scarce evidence available, and provide explanations for both the strong positive effect of product innovation on employment and the unrobust effects of process innovation that are usually found.

Overall, the results are similar across countries, although there emerge some interesting differences which might also merit further investigation. For example, no evidence for a net displacement effect of process innovation in Spanish manufacturing is found, possibly due to greater pass-through of productivity improvements in lower prices. Product innovation appears to play a larger role in employment growth in Germany than in the other countries, and possibly a smaller role in the UK, while higher levels of firm-level employment growth over this period in Spain are largely explained by faster growth in the output of existing products.

Additional research with Spanish panel data which allow for modelling agents' reactions show that innovation displaces labour but also creates the firm-level conditions which compensate displacement. Process innovations reduce marginal costs and this reduction can be passed on to prices to expand demand with an employment effect that doubles the first effect. In addition, product innovations, which most of the innovative firms carry out at the same time (at a slightly lower frequency) as process innovations, double the expanding effect obtained by unity of innovative expenditure. Positive potential net effects of process innovation are estimated to be reduced in the long run, when competitors match the innovations, but positive potential net effects of product innovation of a significant magnitude tend to persist in the long run.

Results also show, however, that the working of the compensation mechanisms can be dampened by the behaviour of the firm agents. In any case, average global actual net employment effects of innovations are estimated to be positive, even in the long run. A caveat to take into account is that innovation is only one of the sources of firm-level productivity growth and that other sources (embodied technical change, learning, spillovers, "outsourcing" of firm activities) can have more negative net effects on employment.

4.5 Policy implications.

Aggregate productivity indicators systematically detected a slower growth of the EU economy in the 90's when compared with the US. This, although particularly based on the behaviour of certain sectors and their presumably general role in the economy (ICT's, some services), has been the cause of greater concern and discussion on the ability of the European economy to develop, diffuse and apply the new technologies, transforming them into an engine of growth. The "Lisbon strategy," a policy response to this challenge, embodied in a broad set of structural reform targets, with the global aim of making the European economy an advanced knowledge-based competitor by 2010. The development of these policies continues today, being a subject of primary attention. The results of this project, focussed on the description and understanding of several firms' innovative activities and decisions, have some general implications for these policies.

The premise is, as our results show, that innovative activity enhances productivity. This effect is quite robust to all markets, countries and ways of measurement, although its magnitude can differ broadly. The question is how to reinforce the best realisations of this fact.

First of all, as it has already been stressed, the European unified (manufacturing) markets which emerge from our characterisation are far from homogeneous, including –even for the same activity- different rates of participation in the innovative activities, different levels of resource commitment and different degrees of coordination of R&D activities. Sometimes the differences seem to be linked to the size of the firms, as a possible effect of the sunk costs associated with the innovative activities (too high for small competitors), but a less-than-perfect practical unification or globalisation of markets can probably explain many other situations. From this point of view, policies directed towards the reduction of inequalities in the intra-European dimension of the markets, by limiting segmentation and promoting the benefits of technological competition, seem to have an important margin for improving efficiency.

All our results show that the highly competitive situations tend to promote stronger rates of efficiency increase and a faster approximation to the technological frontier. Entering and young firms show faster productivity growth and create positive technological spillovers in their markets; proximity to foreign, technologically developed firms, either because of its penetration of domestic markets or the conscious sourcing pursued in foreign markets, stimulates technological development. This fact, combined with the intra-market inequalities which emerge from our previous description, points to a role for an active competition policy supporting entry, foreign investments, product development and the like.

Cooperation clearly emerges from our results as a way, still very unequally developed, to face the challenges of technological developments by enhancing profitable innovation. This is a timely subject. Both the OCDE and the European Union support the idea of developing stronger industry-science linkages. The British and German governments have defined precise policies to encourage collaborative activities. Other countries are considering doing the same. Our findings support the idea that both the presence of "incoming spillovers" and the ability to "appropriate" the returns from innovation stimulate cooperation, which means that the enlargement of collaborative practices can strengthen innovation and this can be policy-promoted. In fact, the results already show some positive association between cooperation and public support, which possibly stresses the presence of an already active supporting policy.

Innovation emerges from our study as positively influencing the employment of established firms. However, a distinction must be made between: a) the acute process innovations made in isolation to rationalise costly processes, which will mainly and inevitably cut jobs; b) the process innovations associated with price reductions which tend to create their own compensation mechanisms; and c) the strong positive effects detected to stem from product innovation. Labour market policy should be directed towards making the processes of the first type as painless as possible, making this compatible with the encouraging of the high flexibility necessary to ensure all the advantages coming from product and other process innovations. The positive effects are likely to need, for example, a high turnover of skills and new training facilities. Our results also stress the damage that a high degree of appropriability of the innovation returns may inflict on the employment effects, whether they come from either wages or prices. The promotion of technological competition can again be an important tool here for ensuring the spreading of the benefits.

To the extent that the project has developed some data-intensive work, we have accumulated some ideas for the improvement of the European innovation data generation and handling policies. They can be summarised as follows. First, comparability of the European innovation data may be enhanced by the exchange of experiences and knowledge between national statistical experts. In today's European statistical practices, this aspect of data generations clearly seems to be neglected. Second, the interaction with highly qualified users, such as a team of researchers, can be beneficial for the data generation process, both on a country basis as well as on a European basis. Third, the development of innovation micro data comparable over time –ideally, panel data- should be a concern at the European level, especially when this is already a concern in several of the countries involved.

Finally, to the extent that the project has been an experience of quantitative economic coordinated research involving researchers from four countries, we have developed some ideas on the usefulness of particular possible forms for European research support in our area. We can summarise it as follows. We have felt comfortable in the framework of a "scientific articles-based" project. It has been a natural way to align our long-run incentives with the project, an objective way to count results ("deliverables") and a way that will permit the quality of the work to be assessed in the long run (number of articles published in scientific journals). Second, it seems a good idea to have a project structured around a proposal of a set of quantitative studies, with comparable theoretical background, data, and econometric tools. A project of this type perhaps cannot be too big. Third, the project has implied important advances in the PhD process of several young researchers and their empirical training, helping the construction of a network which now shares knowledge and tools in practice. Fourth, the funding of the possibility of interaction with other researchers through the project meetings has been one of the keys in advancing in our work.

5. Dissemination results.

The European comparative data elaborated by the project were incorporated into the Spanish "White book on innovation," edited by the prestigious employers' association "Fundación Cotec para la Innovación Tecnológica." The comments were written by J.Jaumandreu, incorporating the results of the research carried out by IEEF.

The Spanish public entity "Fundación Española para la Ciencia y la Tecnología (FECYT)," motivated among other things by the experiences around IEEF, has decided to fund a series of projects aimed at transforming the Spanish innovation data into a panel data survey. With this goal, a technical committee which includes members of Cotec, FECYT, the Spanish statistical office INE and Spanish members of the project has been created.

Three of the investigations carried out by the Spanish members of the project have been edited in the series "Estudios" de Cotec, nº 26, under the title "Cuatro estudios microeconómicos sobre temas de innovación." A dissemination article was published in the review of the Ministry of Industry: "Innovación y empleo a escala de empresa," by A.Garcia, J.Jaumandreu and C.Rodriguez, Economía Industrial, 384, 111-118.

The structural model developed in the research on innovation and employment was used to assess the employment effects of product and process innovations in Germany in the recession period 2000-2002 on behalf of the Federal Ministry of Education and Research and will be published in the book "Innovationen in der deutschen Wirtschaft: Ergebnisse der Innovationserhebung 2003", by C.Rammer, B.Peters, T.Schmidt, B.Aschhoff T.Doherr and H.Niggemann, ZEW Wirtschaftsanalysen, Vol. 78.

An IFS Briefing Note drawing on our research presented new evidence on the UK's innovative performance and provided a summary of government business support programmes aimed at fostering innovative activity and technology transfer. This has been disseminated via the IFS website, at a workshop held at IFS on the 2nd of December on the topic of "Policy towards Innovation and Technology Transfer", and through an article published in the Independent on Sunday.

The workshop brought together members of the academic, business and policy-making communities to discuss the current direction of government policy in this area, and the role that different types of evidence can play in improving policy design. as detailed below,

The Briefing Note investigates the relative innovative performance of European countries. It discusses the underlying economic rationales for government intervention in the areas of innovation and technology transfer, and provides an accessible summary of government support in this area. Potential rationales for intervention include the idea that firms under-invest in R&D because they do not capture the full returns to such activity, (some of the benefits may accrue to other firms through knowledge spillovers), and the presence of financing constraints, (it is difficult to borrow against an idea). These issues are explored in more depth and from the business perspective in the case studies work discussed below.

Helen Simpson gave a presentation of the material covered in the IFS Briefing Note, entitled, "International evidence on innovative activity. Is the UK doing enough?" and discussion at an AIM (Advanced Institute of Management) conference on innovation. She also gave a presentation on ways of evaluating the effectiveness of the UK R&D tax credits to an audience of academics and officials at a DTI conference on evaluating business support programmes. Rupert Harrison gave a presentation to the Society of British Aerospace Companies on government policy on innovation in manufacturing industries.

R Griffith participated in a dinner at 10 Downing Street with senior policy advisers to the government to discuss policy objectives for the next term and meetings at HM Treasury to discuss policy targeting innovation and productivity in the UK.

R Griffith presented work on competition and performance at a meeting of the European Commission High Level Group of Experts on Globalisation and Outsourcing, hosted by EC member Mr. Erkki Liikanen on 14 April 2004.

6. References

(other than the papers, published and unpublished, generated by the project; see Annex B)

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Annex A:

Produced documents (deliverables) and presentations.

The initial plan promised a minimum of 9 scientific papers, divided among the different work packages. The real output issued by the project has been a total of 25 scientific papers, although some of them must obviously be considered the product of longer periods of work or maturation, and sometimes embody contributions of other researchers collaborating with the project. In what follows, we list the papers in the order in which they appeared in the previous reports, adding at the end the seven new papers corresponding to the last period of the project. All IEEF papers can be accessed at http://www.eco.uc3m.es/IEEF . Presentations report the main presentations of the papers by members of IEEF project.

[1] *Firms' Age, Process Innovation and Productivity Growth*, by Elena Huergo (Universidad Complutense de Madrid) and Jordi Jaumandreu (UC3M).

[2] *To Be or Not To Be Innovative: An Exercise in Measurement*, by Jacques Mairesse (GRECSTA-CREST) and Pierre Mohnen (MERIT, Maastricht University).

[3] *Accounting for Innovation and Measuring Innovativeness: An Illustrative Framework and an Application*, by Pierre Mohnen (MERIT, Maastricht University) and Jacques Mairesse (GRECSTA-CREST).

[4] *Innovativeness: A Comparison across seven European Countries*, by Pierre Mohnen (MERIT, Maastricht University), Jacques Mairesse (GRECSTA-CREST) and Marcel Dagenais (Université de Montréal).

[5] *Innovation and Innovation Success in the German Manufacturing Sector: Econometric Evidence at Firm Level*, by Norbert Janz and Bettina Peters (ZEW).

[6] *Foreign Ownership and Technological Convergence at the Micro Level*, by Rachel Griffith, Stephen Redding and Helen Simpson (IFS).

[7] *How does probability of process innovation change with firm age?*, by Elena Huergo (Universidad Complutense de Madrid) and Jordi Jaumandreu (UC3M).

[8] *Innovation and Jobs: Evidence from Manufacturing Firms*, by Angel García (Universidad de Oviedo), Jordi Jaumandreu (UC3M) and César Rodríguez (Universidad de Oviedo).

[9] *Knowledge management, innovation and productivity: A firm-level exploration based on the French CIS3 data*, by Elizabeth Kremp (SESSI) and Jacques Mairesse (CREST-INSEE).

[10] *R&D and productivity: A re-examination in light of the innovation surveys*, by Jacques Mairesse (CREST-INSEE) and Pierre Mohnen (MERIT, Maastricht University).

[11] *Firm-level innovation and productivity: Is there a common story across countries?*, by Norbert Janz (ZEW), Hans Lööf (Swedish Institute for Studies in Education and Research), and Bettina Peters (ZEW).

[12] *Technology sourcing by UK manufacturing firms: An empirical analysis using firm-level patent data*, by Rachel Griffith (IFS and University College), Rupert Harrison (IFS and University College) and John Van Reenen (University College and CEP).

[13] *Determinants for R&D cooperation: Evidence from Spanish manufacturing firms*, by Alberto López (UC3M).

[14] *Product market reforms and macro performance in the European Union*, by Rachel Griffith (IFS and University College) and Rupert Harrison (IFS and University College).

[15] *Entry and growth: Theory and evidence*, by Philippe Aghion (University College, Harvard University and IFS), Richard Blundell (University College and IFS), Rachel Griffith (IFS and University College), Peter Howitt (Brown University) and Susanne Prantl (IFS and University College).

[16] *Does innovation spur employment? A firm-level analysis using Spanish CIS data*, by Jordi Jaumandreu (UC3M).

[17] *Basic CIS 3 Statistics on Four European Countries (France, Germany, Spain and the United Kingdom)*, IEEF.

[18] *National differences in innovation behaviour: facts and explanations*, by Laura Abramowsky (IFS), Jordi Jaumandreu (UC3M), Elisabeth Kremp (SESSI) and Bettina Peters (ZEW).

[19] *Understanding co-operative R&D activity: evidence from four European countries*, by Laura Abramowsky (IFS), Elisabeth Kremp (SESSI), Alberto López (UC3M), Tobias Schmidt (ZEW) and Helen Simpson (IFS).

[20] *Knowledge flows and R&D co-operation: firm level evidence from Germany*, by Tobias Schmidt (ZEW).

.

[21] *Innovation and productivity across four European countries*, by Rachel Griffith (IFS and University College), Elena Huergo (Universidad Complutense de Madrid), Jacques Mairesse (CREST-INSEE) and Bettina Peters (ZEW).

[22] *Does innovation stimulate employment? A firm-level analysis using comparable micro data from four European countries*, by Rupert Harrison (IFS and University College), Jordi Jaumandreu (UC3M), Jacques Mairesse (CREST-INSEE) and Bettina Peters (ZEW).

[23] *Employment effects of different innovation activities*: *Microeconometric evidence*, by Bettina Peters (ZEW).

[24] *Research, Innovation and Productivity: A New Look,* Elisabeth Kremp (SESSI), Jacques Mairesse (CREST-INSEE) and Pierre Mohnen (MERIT, Maastricht University).

[25] *Impact of government funding on R&D and innovation*, Abraham Garcia (MERIT, Maastricht University) and Pierre Mohnen (MERIT, Maastricht University).

Presentations:

Paper [1] was presented at the Workshop on Demography of Firms and Industries held at the Universitat de Barcelona (November 2001). Paper [4] was presented at the 29th EARIE Conference in Madrid (September 2002) and at the DRUID Summer conference in Copenhagen, 2002. Papers [5] and [7] were presented at the 29th EARIE Conference in Madrid (September 2002). Paper [6] was presented at the CEPR/ESRC Labour Economics Workshop (October 2001), at UK Treasury (January 2002), at the University of Nottingham (January 2002), at the UK Royal Economic Society Meeting (March 2002) and at the CEPR Conference in Hydra, Greece (September 2002).

Papers [9],[10],[11] and [12], together with a version of paper [1], were accepted and presented at the Empirical Economics of Innovation and Patenting Conference (Mannheim, ZEW, March 2003). Papers [10], [11], [13] and [16] were presented and discussed at the European Summer School on Industrial Dynamics in September (Corsica). Paper [10] was also presented at the EPIP workshop on New Challenges to the Patent System (Munich, April 2003) and at the Druid Summer Conference (Copenhagen, June 2003). Paper [12] was presented at the Innovation Workshop on Complementarities and Endogeneity (Maastricht, MERIT, April 2003) and was presented at the workshop Comparative Analysis on Enterprise Data (London, September 2003). Paper [14] was presented at the Conference of the European Economic Association (Stockholm, August 2003). Paper [11] was also presented at the Annual Congress of the German EconomicAssociation (Verein für Socialpolitik, Dresden, September 2004), at the Innovation Workshop on Complementarities and Endogeneity (Maastricht, MERIT, April 2003) and at the workshop Comparative Analysis on Enterprise Data (London, September 2003).

Paper [20] was presented at the Druid Summer Conference (Copenhagen, June 2004), at the Conference Innovation, Entrepreneurship and Growth, (Royal Institute of Technology (KTH), Stockholm, November 2004) and at the Universities of Birmingham (December 2004) and Jena (November 2004). Paper [22] has been presented at seminars at Universidad Carlos III de Madrid, Tilburg University and Institute for Fiscal Studies; at the 31st EARIE Conference (Berlin, September 2004), the NBER productivity program meeting (Cambridge, December 2004) and the 15th EC2 Conference The Econometrics of Industrial Organization (Marseille, December 2004). Paper [23] was presented at the Conference Innovation, Entrepreneurship and Growth, (Royal Institute of Technology, KTH, Stockholm, November 2004), at the Universities of Wuerzburg (November 2004) and Odense (May 2004), at the 31th EARIE Conference (Berlin, September 2004) and at the economic seminar of the Centre for European Business Research (CEBR) (Copenhagen, May 2004). Paper [24] was presented at R&D, Education and Productivity, Conference in Honour of Zvi Griliches (Paris 2003), Schumpeter Society conference (Milan 2004), Innovations and Intellectual Property, Association d'Econometrie Appliquee, Singapore (July 2004), and at the 15th EC2 Conference The Econometrics of Industrial Organization (Marseille, December 2004).

Annex B:

Publication process

In what follows, we firstly list the already published papers and then the papers already submitted to some journal. For convenience, papers are ordered in each part as in Annex A.

Published papers:

Aghion,P., N.Bloom, R.Blundell, R.Griffith and P.Howitt (2005), "*Competition and innovation: an inverted U relationship," Quarterly Journal of Economics*, forthcoming.

Aghion, P. and R. Griffith (2005), *Competition and Growth* , MIT Press

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Janz, N., H. Lööf, and B. Peters (2004), Firm Level Innovation and Productivity – Is there A Common Story Across Countries?, *Problems and Perspectives in Management,* 2, 184-204.

Mairesse,J. and P.Mohnen (2001), "To Be or Not To Be Innovative: An Exercise in Measurement," *STI Review*, 27, 103-129.

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Mairesse, J. and P. Mohnen (2005), *R&D and productivity: A re-examination in light of the innovation surveys*, *Journal of Technology Transfer*, 30(1-2), .

Papers submitted:

[4] *Innovativeness: A Comparison across seven European Countries*, by Pierre Mohnen (MERIT, Maastricht University), Jacques Mairesse (GRECSTA-CREST) and Marcel Dagenais (Université de Montréal).

[6] *Foreign Ownership and Technological Convergence at the Micro Level*, by Rachel Griffith, Stephen Redding and Helen Simpson (IFS).

[8] *Innovation and Jobs: Evidence from Manufacturing Firms*, by Angel García (Universidad de Oviedo), Jordi Jaumandreu (UC3M) and César Rodríguez (Universidad de Oviedo).

[12] *Technology sourcing by UK manufacturing firms: An empirical analysis using firm-level patent data*, by Rachel Griffith (IFS and University College), Rupert Harrison (IFS and University College) and John Van Reenen (University College and CEP).

[13] *Determinants for R&D cooperation: Evidence from Spanish manufacturing firms*, by Alberto López (UC3M).

[15] *Entry and growth: Theory and evidence*, by Philippe Aghion (University College, Harvard University and IFS), Richard Blundell (University College and IFS), Rachel Griffith (IFS and University College), Peter Howitt (Brown University) and Susanne Prantl (IFS and University College).

[20] *Knowledge flows and R&D co-operation: firm level evidence from Germany*, by Tobias Schmidt.

[22] *Does innovation stimulate employment? A firm-level analysis using comparable micro data from four European countries*, by Rupert Harrison (IFS and University College), Jordi Jaumandreu (UC3M), Jacques Mairesse (CREST-INSEE) and Bettina Peters (ZEW).

[23] *Employment effects of different innovation activities: Microeconometric evidence*, by Bettina Peters (ZEW).

Annex C

Work packages and deliverables

Subject ordering of this report, work packages and deliverables			
Subject	Work packages	Planned deliverables	Final deliverables[1]
Using European innovation data			2 scientific papers: [17],[18]
Competition and innovation	WP2: Innovation, firm's demand and market shares 12 months report addition: Innovation and competition	Workshop Four or more scientific papers	2 workshops (Mannheim, London) 9 scientific papers: [5],[6],[7],[12],[13],[14],[15],[19],[20]
Innovation and productivity	WP1: Innovation and productivity	Workshop Three or more scientific papers	2 workshops (Paris, Marseille) 10 scientific papers: [1],[2],[3],[4],[9],[10],[11],[21],[24],[25]
Innovation and employment	WP3: Innovation, employment, wages and prices	Workshop Two or more scientific papers	2 workshops (both in Madrid) 4 scientific papers: [8],[16],[22],[23]

[1] Workshops organized by the leader of the work packages; papers [17] and [18] are not assigned because they are related to all work packages.

Annex D:

IEEF Meetings.

List of IEEF Meetings (see http://www.eco.uc3m.es/IEEF for details):

Initial Meeting: Madrid, 30-1 December 2001. Hosted by the UC3M.

Second Meeting: London, 25 November 2002. Hosted by the IFS.

Third Meeting: Mannheim, 13 March 2003. Hosted by the ZEW.

Fourth Meeting: Paris, 9-10 January 2004. Hosted by the CREST.

Fifth Meeting: Madrid, 24-26 June 2004. Hosted by the UC3M.

Sixth Meeting: Marseille, 16 Dec. 2004. Hosted by the GREQAM, Université Méditérannée.

List of participants at IEEF Meetings:

Laura Abramovsky	Institute for Fiscal Studies
Manuel Arellano	CEMFI
Elina Berghäll	Government Institute for Economic Research (VATT)
Isabel Busom	Universitat Autònoma de Barcelona
Antonella Caiumi	ISAE
Raquel Carrasco	Universidad Carlos III de Madrid
Michele Cincera	Universite Libre de Bruxelles
Chiara Criscuolo	CeRiBA, Office for National Statistics and University College
José Carlos Fariñas	Universidad Complutense de Madrid
Abraham García	Maastricht University
Antonio García Romero	Universidad Carlos III de Madrid
Rachel Griffith	Institute for Fiscal Studies and CEPR
Isabel Grilo	Enterprise DG, EC
Bronwyn Hall	University of Berkeley

Rupert Harrison	Institute for Fiscal Studies
Jonathan Haskel	CeRiBA, Office for National Statistics and Queen Mary & Westfield College, London
Mike Hawkins	Institute for Fiscal Studies
Elena Huergo	Universidad Complutense de Madrid
Norbert Janz	Aachen University of Applied Sciences
Jordi Jaumandreu	Universidad Carlos III de Madrid
Elizabeth Kremp	SESSI
Georg Licht	ZEW
Hans Lööf	Royal Institute of Technology, Sweden
Alberto López	Universidad Carlos III de Madrid
Matilde Machado	Universidad Carlos III de Madrid
Jacques Mairesse	CREST-INSEE
Ramón Marimón	Universitat Pompeu Fabra
Pierre Mohnen	MERIT, Maastrich University
Bettina Peters	ZEW
Steve Redding	London School of Economics
Cesar Rodriguez	Universidad de Oviedo
Tobias Schmidt	ZEW
Alessandro Sembenelli	Università di Torino
Helen Simpson	Institute for Fiscal Studies
Luc Soete	Maastricht University
Manuel Trajtenberg	Tel-Aviv University
Arie Van der Zwan	European Comisión
John Van Reenen	London School of Economics
Reinhilde Veugelers	Katholieke Universiteit, Leuven and CEPR

Programme of the 5th IEEF Meeting

Hosted by the Department of Economics, Universidad Carlos III de Madrid

Thursday 24th to Saturday 26th of June 2004

Thursday

Chair: *Jacques Mairesse (CREST)*

9.00-10.00 Invited paper: **The Names Game: Using Inventors' Patent Data in Economic Research**, by *Manuel Trajtenberg (Tel-Aviv University)*

10.30-12.00 IEEF paper: **National Differences in Innovation Behaviour: Facts and Explanations (Annex: Basic CIS3 Statistics on Four European Countries)**, by *Laura Abramovsky (IFS), Jordi Jaumandreu (UC3M), Elizabeth Kremp (SESSI)* and *Bettina Peters (ZEW)*

Discussion: *Isabel Busom (Universitat Autònoma de Barcelona)*

Isabel Grilo (Enterprise DG, EC)

12.30-13.30 Invited paper: **Impact of Government Funding on R&D and Innovation**, by *Abraham García (MERIT, Maastrich University) and Pierre Mohnen (MERIT, Maastrich University)*

Chair: *Norbert Janz (ZEW)*

15.30-17.00 IEEF paper: **Understanding Co-operative R&D Activity: Evidence from Four European Countries**, by *Laura Abramovsky (IFS), Elizabeth Kremp (SESSI), Alberto López (UC3M), Tobias Schmidt (ZEW) and Helen Simpson (IFS)*

Discussion: *Ramón Marimón (Universitat Pompeu Fabra)*

Reinhilde Veugelers (Katholieke Universiteit, Leuven)

17.30-18.30 Invited paper: **Encouraging Private Company R&D Spending: A Comparative Study of the R & D Tax Credits in France and the United States**, by *Bronwyn Hall (University of Berkeley), Jacques Mairesse (CREST) and Benoit Mulkay (INSEE)*

Friday

Chair: *Rachel Griffith (IFS)*

9.30-11.30 IEEF paper: **Does Innovation Stimulate Employment? A Firm-level Analysis Using Comparable Micro Data on Four European Countries**, by *Rupert Harrison (IFS), Jordi Jaumandreu (UC3M), Jacques Mairesse (CREST) and Bettina Peters (ZEW)*

Discussion: *Alessandro Sembenelli (Università di Torino)*

Luc Soete (Maastricht University)

12.00-13.00 Invited paper: **How Special is the Special Relationship? Using the Impact of R&D Spillovers on UK Firms as a Test of Technology Sourcing**, by *Rachel Griffith (IFS), Rupert Harrison (IFS) and John Van Reenen (London School of Economics)*

Chair: *Jordi Jaumandreu (UC3M)*

15.00-17.00 IEEF paper: **R&D, Innovation and Productivity in Four European Countries (France, Germany, Spain and the United Kingdom)**, by *Rachel Griffith (IFS), Elena Huergo (UCM), Jacques Mairesse (CREST) and Bettina Peters (ZEW)*

Discussion: *Manuel Arellano (CEMFI)*

Norbert Janz (ZEW)

17.30-18.30 Future plans for IEEF project

Programme of the 6th IEEF Meeting

Hosted by GREQAM, Université Méditérannée

Thursday 16th December 2004

8.30-10.00 **Does Innovation Stimulate Employment? A Firm-level Analysis Using Data on Four European Countries (France, Germany, Spain and the United Kingdom)**, by *Rupert Harrison (IFS), Jordi Jaumandreu (UC3M), Jacques Mairesse (CREST) and Bettina Peters (ZEW)*

Discussants: *Rachel Griffith; Elizabeth Kremp; Helen Simpson*

10.30-12.00 **Understanding Cooperative R&D Activity: Evidence from Four European Countries (France, Germany, Spain and the United Kingdom),** by *Laura*

Abramovsky (IFS), Elizabeth Kremp (SESSI), Alberto López (UC3M), Tobias Schmidt (ZEW) and Helen Simpson (IFS)

Discussants: *Bronwyn Hall; Elena Huergo; Bettina Peters*

14.00-15.30 **R&D, Innovation and Productivity in Four European Countries (France, Germany, Spain and the United Kingdom)**, by *Rachel Griffith (IFS), Elena Huergo (UCM), Jacques Mairesse (CREST) and Bettina Peters (ZEW)*R&D,

Discussants: *Jordi Jaumandreu; Elizabeth Kremp; Pierre Mohnen*

15.30-17.00 **National Differences in Innovation Behaviour: Facts and Explanations (France, Germany, Spain and the United Kingdom)**, by *Laura Abramovsky (IFS), Jordi Jaumandreu (UC3M), Elizabeth Kremp (SESSI)* and *Bettina Peters (ZEW)*

Discussants: Rachel Griffith; Elena Huergo; Jacques Mairesse