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Innovation in Firms: A Microeconomic Perspective
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Introduction

How do we measure innovation?

As the importance of innovation as a driver of economic and social change grows, its nature, role and determinants are receiving increasing attention. Innovation is a broad concept which encompasses a wide range of activities and processes: markets, entrepreneurship, networks and competition, but also skills and organisations, creativity and knowledge transfers. Statistics covering various science and technology activities have been systematically collected by statisticians and researchers for more than 40 years, but only recently has the broader concept of innovation been formalised in a way that makes it possible to gather information about how firms innovate through large-scale statistical surveys. R&D surveys can provide information about some of the inputs to innovation, but have little information on the outputs of these processes, and tend to be more useful for measuring technology-based activities, which are only a subset of what is

The *Oslo Manual* and innovation surveys

To harmonise and ensure the quality of innovation surveys, the *Oslo Manual* was developed by the OECD in 1992. Since then, on the basis of the experience acquired, the *Oslo Manual* has been updated twice; while it was initially designed for firms in the manufacturing sector, it was later modified to include the services sector. At first it dealt with product and process innovations, but it was later extended to cover organisational and marketing innovations. The latest (third) edition of the *Oslo Manual* (OECD/Eurostat, 2005) defines innovation as the implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organisational method in business practices, workplace organisation or external relations. This implicitly identifies the following four types:

- *Product* innovation: the introduction of a good or service that is new or significantly improved with respect to its characteristics or intended uses. This includes significant improvements in technical specifications, components and materials, incorporated software, user friendliness or other functional characteristics.

The *Oslo Manual* and innovation surveys *(cont.)*

- *Process* innovation: the implementation of a new or significantly improved production or delivery method. This includes significant changes in techniques, equipment and/or software.
- *Marketing* innovation: the implementation of a new marketing method involving significant changes in product design or packaging, product placement, product promotion or pricing.
- *Organisational* innovation: the implementation of a new organisational method in the firm's business practices, workplace organisation or external relations.

In innovation surveys, firms are asked to give information about inputs, outputs and the behavioural and organisational dimensions of their innovative activities. On the input side, innovation surveys measure a firm's intangible assets, which include, beyond R&D expenditure, spending on training, acquisition of patents and licences, product design, trial production, and market analysis. On the output side, data are collected on whether an enterprise has introduced a new product or process, the share of sales due to significantly changed or new products ("new" can mean new to the enterprise, new to the market or new to the world). Other indicators capture the nature of innovative activities, whether R&D is done on a continuous basis and/or in co-operation with others, as well as categorical data on the sources of knowledge, the reasons for innovating, the perceived obstacles to innovation, and the perceived strength of various appropriability mechanisms.

Innovation surveys were first experimented in several European countries but have since been conducted in many others, including Australia, Canada, all EU countries (where the Community Innovation Surveys [CIS] co-ordinated by Eurostat are in their sixth round in 2008), Japan, Korea, Mexico, New Zealand, Norway, Switzerland, Turkey, as well as in Russia, South Africa and most Latin American countries. The United States is a notable exception, as no official innovation survey based on the *Oslo Manual* framework exists at this time.

included in the broader concept of innovation and often more relevant for manufacturing firms than for those in services. Likewise, patent data are useful for understanding certain innovation-related strategies, but they cannot measure the full extent of innovative activities and suffer from some well-known limitations. Given these constraints, it was felt that new surveys should be developed to collect more information about types of innovation, reasons for innovating (or not), collaboration and linkages among firms or public research organisations, and flows of knowledge, and that new

quantitative data should also be collected on the inputs and outputs of innovation. "Innovation surveys" were therefore developed to increase knowledge about innovation in firms with a view to developing effective innovation policies.

Microdata: what more can they tell us?

The OECD already publishes indicators based on aggregate data from innovation surveys such as the share of firms with new-to-market product innovation or the share of firms co-operating with universities. These indicators are very informative as regards the general situation of countries. They make it possible to identify gaps in national innovation systems (*e.g.* the proportion of innovative small and medium-sized enterprises [SMEs] may be smaller than in other countries).

Microdata-based indicators reflect the behaviour of individual firms and firms' heterogeneity. Some firms innovate, others do not. Among those that do, innovation performance is skewed (some are highly innovative, other are less so). Firms differ as well in the types of innovation that they perform (product, process, organisational, marketing). Improving our knowledge of firms' innovative behaviour and its determinants is crucial for designing effective innovation policies. To increase the number of innovative firms, for instance, it is necessary to understand what prevents certain firms from innovating, and among the impediments they face, the types of policies to which they would be more sensitive. Innovation policies that do not take into account the heterogeneity of firms risk missing their main targets. Those that ignore functional relationships that influence innovation at the firm level risk choosing the wrong target (*e.g.* subsidising R&D when the obstacle is market access).

Microdata-based indicators characterise firms by size, by industry, etc. Microdata also allow for combining responses to multiple questions and identifying firms' innovative profiles, which can then be aggregated at the country level. In addition, more sophisticated techniques, such as exploratory data analysis or econometrics, can also be used. The former make it possible to use the data to identify similarities and differences in certain characteristics or certain groups of firms; for instance, an analysis may show that in-house R&D, new-to-market product innovation and patents tend to be associated (performed jointly in the same firms), while process innovation is more closely linked to extra-mural R&D and investment in machinery. The econometric approach allows for estimating functional relationships between variables that may differ across sub-groups of firms; it can show, for instance, that firms that spend more on innovation tend to have a higher innovative turnover and increased productivity and it can qualify relationships across countries or by firm size.

Innovation survey data have been increasingly used to explore a number of questions related to the determinants, the effects and the characteristics of

innovation. Some of the topics examined in previous studies include the determinants of innovation, complementarities (in terms of the sources of innovation, knowledge acquisition, etc.), collaboration and co-operation strategies, the effects of innovation on economic variables such as productivity or export performance, and the impact of innovation polices (*e.g.* additionality *vs.* crowding-out effects of government support).

Exploiting the potential of microdata: a comparative project

The *OECD Innovation Microdata Project* was designed to examine a range of issues relating to innovation and firm performance using a common methodology. Research teams in 20 countries used similar data cleaning methods and econometric models on their national data sets to produce harmonised tabulations of results.[1] A series of topics of high policy interest was identified for the project's indicator and the econometric modules. The indicator work covered both standard innovation indicators, as well as more complex indicators of innovation strategies or "modes". The themes selected for econometric analysis (which also entailed the compilation of comparable indicators) included: the determinants of innovation and the impact on productivity; modes of innovation, including non-technological innovation; and the incentive effect of IPR on innovation. Below are some key findings.

The data used in this project come mainly from the 4th round of the CIS (CIS 4), or from national surveys carried during a similar time frame. It was decided to use the "core" CIS 4 coverage in terms of sectors and similar firm size thresholds as a benchmark in order to allow for comparability (countries using industrial classifications other than NACE performed concordances to map as closely as possible to the CIS 4 list of industries).

Beyond simple pointers

Twenty simple indicators were chosen to compare five broad dimensions: technological innovation; non-technological innovation; innovation inputs; innovation outputs; and key policy-relevant characteristics (internationalisation, collaboration, intellectual property rights). The results reveal firms' heterogeneity and reflect countries' structural differences in terms of sector specialisation and size composition. For example:

- The share of firms in each country having developed a product or process innovation ranges from over half of all firms in Austria, Germany, Luxembourg and Switzerland, to less than a third in France, Japan and Norway. Firm size is an important factor: differences among countries are much less pronounced when the focus is only on large firms (250 employees or more).
- The share of firms having introduced a marketing or organisational innovation varies widely across countries, ranging from around 60% of all

firms in Denmark, Germany and Luxembourg to around one-third in the Netherlands and Norway. The shares are quite similar for both service and manufacturing industries (unlike product and process innovations which are more prevalent in manufacturing than in services).

In addition, new "composite" indicators were developed to provide greater insight into innovation processes and help to better address policy needs.[2] How novel is innovation? How open/collaborative is it? Two examples of composite indicators are "output-based innovation modes", which aim to capture firms' novelty and creativity and "innovation status" which reflects firms' relative reliance on in-house and external sources of knowledge. The output-based innovation modes cross three variables from the surveys: Is the product new to the market or only new to the firm? Is the firm's market international or only domestic? Is the innovation based on in-house effort or not? This makes it possible to distinguish several categories of firms, of which the most innovative issue products new to the market, with an international market, based on in-house efforts (a category labelled "new-to-market international innovators"). In this category, the leaders (as a share of innovating firms) are Canada (manufacturing sector), Denmark, Finland, Luxemburg, the Netherlands and Sweden. Firms in Austria, France and Germany, instead, seem to rely more on innovation based on existing products (new to the firm). In terms of innovation status, in manufacturing the great majority of firms that collaborate also engage in in-house innovation, while in services collaboration plays a more central role.

Beyond the distinction between technological and non-technological innovation: a broader set of complementary strategies

While the concepts of technological (product, process) and non-technological (marketing, organisational) innovation are useful from a practical perspective, since the relevant data are readily available, they do not fully recognise that today's firms adopt mixed modes of innovation: certain types of innovation tend to go hand in hand in the same firms and complement each other, while other types tend to be independent or to substitute for each other; certain innovative activities (*e.g.* co-operation or patenting) are more closely related to certain types of innovation than to others. A set of activities or practices which tends to be grouped and implemented together by the same firms is here called a "mode of innovation".

This project applies an exploratory methodology – factor analysis – to innovation survey data to uncover different modes of innovation, and uses cluster analysis to group enterprises according to their use of such practices. This involves identifying a set of variables for measuring innovation-relevant activities and examining which of these variables "hang together" or "load up" so as to identify joint activities (*i.e.* activities often performed together in the

same firms) that lead to effective innovation. Such practices are likely to reflect both common conditions across countries and country-specific factors related to national innovation systems and country-specific socio-economic environments.

Four roughly common modes of innovation practices are found in the participating countries. These are interpreted as: *i)* new-to-market innovations based on own and diffused technologies (corresponding in many cases to in-house R&D in conjunction with acquired R&D and to IPR protection); *ii)* marketing-based following; *iii)* process modernising based on embedded technologies (acquisition of machinery, software, etc.) and training of staff; and *iv)* wider innovations linked to organisational and marketing innovations. In general, the highest degree of country specificity appears to emerge in conjunction with modes of innovation linked to new-to-market innovations, while process modernisers and wider innovation patterns exhibit greater consistency across the countries studied here.

Based on the innovation practices identified in each country, enterprises are clustered according to the extent to which they engage in the identified innovation practices. In other words, a cluster analysis groups together firms that exhibit similar values in their factor scores. In almost all countries, one group of firms scores high across all innovation modes. These are firms that engage in all types of innovation activities and combine all innovation modes. Other groups of firms are specialised in terms of their innovation strategies and score high in relation to one specific mode of innovation.

Following the identification of different modes of innovation in the participating countries, the modes are related to firm-level productivity. In addition to assessing productivity levels, broader factors – measures of human capital, conditions of competition and enterprise structure – are also considered. These appear to have stronger relationships with contemporaneous levels of productivity than the innovation practices identified here. Nonetheless, at least one of the summary innovation variables is linked to higher levels of productivity in most countries, and in most cases, a different innovation mode is involved.

Overall, the effects of specific modes of innovation and productivity across countries show no consistent pattern. Different modes of innovation are significantly related to the level of productivity measured at the end of the three-year period covered by the survey. This suggests that, even with the participating countries' data sets constrained to be as comparable as possible, there are major national differences in patterns of competitive and comparative advantage and thus potentially different patterns of response to similar policy instruments.

Innovation and productivity at the firm level

What are the channels at the firm level that make innovation possible and to what extent can they explain aggregate differences in productivity performance? This question is addressed by estimating a three-step structural model: *i)* the decision of firms to invest in innovation; *ii)* the knowledge production function, in which this investment, together with other inputs, produces innovation; and *iii)* the output production function in which innovation, together with other inputs, is related to labour productivity. Eighteen countries – European, non-European and one major developing economy, Brazil – participated in this part of the project. The analysis uses the same modelling and estimation strategy on comparable innovation survey firm-level data for a similar period (the early 2000s). The results show surprisingly similar and consistent patterns across countries, with some notable exceptions, especially the relationship between innovation policy and investments in innovation. The choice of the variables to be included in the model was dictated by the need to find a minimum common denominator for all countries. For the same reason, the basic model only uses variables available in innovation surveys. This implies that the measure of productivity used, log sales per employee, is a very simple one. In some cases and for some countries, it was possible to extend the analysis to control for other factors such as human capital and physical capital in the production function.

Which firms are more likely to be innovative (*i.e.* to have invested in innovation or to have introduced a product innovation in the reference year)? Results are strikingly similar across countries. In particular a firm that is large and operates in foreign markets is more likely to have reported innovation activity. Being part of a group is positively correlated with the probability of being innovative except in Canada and Norway. It is particularly important in Australia and Brazil, and it is very similar across EU countries.

Which firms invest more in innovation, *i.e.* which firms spend more on the intangible assets, such as R&D, ICT, training, etc., that are inputs in the innovation process? Co-operation is very strongly correlated with innovation expenditure except in Austria and Belgium. Public financial support is also associated with higher innovation expenditure, consistently so in many European countries.

Investing in innovation increases sales from product innovation in all countries except Switzerland. The impact on sales is over 40% in Australia, New Zealand and Norway and ranges from 14 to 35% for the other countries. The analysis provides mixed results on the effect of size on innovative sales.

Product innovation matters for labour productivity: in all countries except Switzerland, and sales from product innovation per employee show a positive and significant coefficient. The magnitude of the impact of sales of

innovations on productivity ranges from 0.3 to 0.9, with an average of 0.5, meaning that a 1% increase in firms' innovation sales per employee is associated with an average productivity increase of 0.5%. A negative impact on productivity is found for process innovation: a counter-intuitive result which could be due to adjustment costs or business cycle effects.

The incentive effect of IPR on innovation

Does the patent system stimulate or impede innovative activity? The analysis exploits information collected in innovation surveys to assess the impact of patents on firms' innovative behaviour ("incentive effect"). It focuses on patents, as results for trademarks were not found to be significant. The idea is that since the effectiveness of patent protection varies across industries, comparing the innovative behaviour of firms that benefit from more or less useful protection makes it possible to assess the incentive effects of IPR.

A structural model is estimated, in which firms anticipate the patent premium they can expect from the patent or trademark system when they decide on their innovative effort (the patent premium is the additional revenue that a firm obtains if it actually patents the innovation). The incentive properties of patents are therefore assumed to affect the firms' innovative effort only through this "anticipation channel".

According to the estimates, patents seem to be a significant structural driver of firms' overall innovative effort. There are large discrepancies among countries: patents are important in Belgium and Denmark but seem less so in Finland, Germany and Norway. In terms of the economic significance of the incentive effect, the smallest significant marginal effect is obtained for France and the largest for Denmark. Sample descriptive statistics reveal that the average industry share of patenting firms varies between 8% (Belgium) and 28% (Germany). Therefore, other things being equal, the "incentive effect of patents" would explain between 1.5 and 12 percentage points of the cross-country differences in the shares of firms involved in innovative activities. Since the base is around 50%, this represents a sizeable effect (ranging from 3 to 23% of the total share of innovation-active firms).

In the case of R&D, the estimated structural parameters are always higher than in the previous specification, which means that the R&D component of firms' innovative effort receives the greatest incentive from the patenting system. However, marginal effects are not always higher, which suggests that the average firm is not always able to benefit fully from these incentives. Patents stimulate the R&D efforts of firms in Finland, France, Germany and Norway more than in Belgium, Brazil or Denmark.

Exploiting innovation surveys: lessons learned

This analytical work has brought to light a series of limitations to exploiting innovation surveys, as currently designed, to address key policy questions. Some conclusions, based on the experience of the research teams involved in this project, are:

Need to better understand why certain firms innovate while others do not

- More detailed information is needed on non-innovators (skills, training staff, etc.). Currently, most innovation surveys filter out non-innovators early in the questionnaire, and thus collect little or no information on them. This makes it very difficult to understand why certain firms innovate while others do not, as the basic information regarding the differences between these two types of firms is not available. Policies aimed at changing non-innovative into innovative firms need such information.
- The variable "obstacles to innovation" is not always very useful for understanding the difference between innovators and non-innovators since responses may either indicate a perception (what they see as a barrier to innovation) or reflect their actual experience. Very often a barrier is encountered only if an activity is undertaken. Firms that engage intensively in innovative activity encounter obstacles along the way, while those that do not innovate, for whatever reason, may not. Questions relating to obstacles may therefore need to be reformulated in order to reveal the actual experience of respondents and the sequence of obstacles to innovation they have encountered.
- More information is needed on the sources of information for innovation (domestic/international), the role of users, and on linkages and collaboration in the innovation process. These topics are mentioned in the latest *Oslo Manual*, but few data have been collected so far.

Need to better assess the effects of innovation on firms' performance

- Survey questions on the effects of process innovation (*e.g.* cost reductions, greater productivity and flexibility, etc.) are needed in order to gain a more complete view of the effect of innovation on the economy. At present, only the share of new products in turnover is covered.
- The effects of innovation are dynamic and become apparent over time. This points to the need for panel data. Part of the sample of SMEs might be maintained in successive surveys so as to monitor the trajectory of innovative and non-innovative firms and the transition from non-innovator to innovator or the opposite. This would require a significant change in most countries' sampling procedures.

- Data from innovation surveys need to be able to be matched to data from other sources. Matched data sets should be constructed and statistical agencies' data access policies should accommodate the needs of users.

Need for better information on non-technological innovation (marketing, organisational)

- As this area only recently entered the core definition of innovation in the *Oslo Manual*, surveys are just starting to include questions on this type of innovation, and little is known at present about the effects of such innovations.

Notes

1. Note that not every country participated in all the modules of the project.
2. Composite indicators are defined here as indicators that combine answers to several questions in order to examine a number of policy-relevant factors and better capture the diversity of innovative firms.