# Annex C.

# MEASURING AND EVALUATING INNOVATION

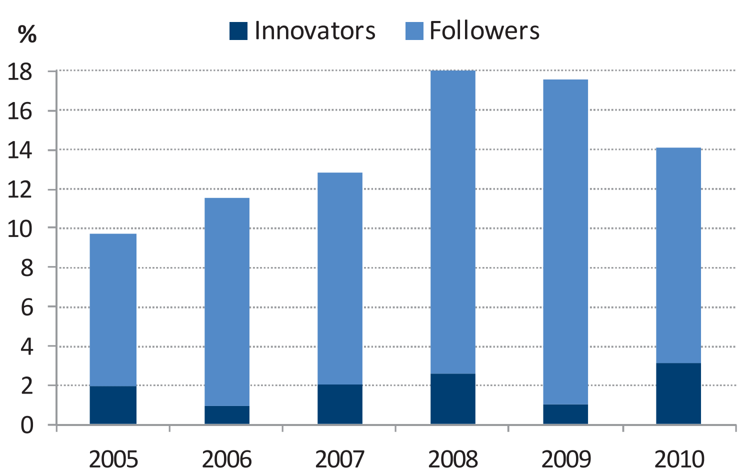
Indicators of innovation attempt to measure both efforts (e.g. R&D expenditures), outcomes (e.g. number of patents), and impacts (e.g. TFP growth or number of changes introduced in firms). Most common indicators of innovation efforts and outcomes are discussed in Chapter 1, Box 1.3, and some are presented in Chapter 2. This annex presents some of the recent efforts to develop indicators from survey data and discusses evaluation issues.

## Measurement of firm and farm level innovation

Business surveys of innovation can include information on the number of firms developing or applying a new product or process, or a marketing or organisational change; expenditures dedicated to the development of the innovation, or number of firms engaged in research co-operation. Chapter 1 of an OECD report on innovation in firms from the microeconomic perspective provides examples of possible indicators (OECD, 2009). Agricultural upstream and downstream industries are covered in those surveys, but unless they are specialised, their agriculture-related activities are not easy to identify. As shown in Box C.1, food industries can be identified. It would be difficult, however, to identify agricultural input innovation in the activities of biotechnology, as they also work for sectors other than agriculture, e.g. the pharmaceutical industry.

Questions on innovation adoption could be introduced in farm surveys, as done in the Dutch Farm Accountancy Data Network (FADN) (Figure C.1). Many countries already include questions about adoption of specific techniques (e.g. no-till) or production methods (e.g. organic).

**Figure C.1. Development in innovation diffusion in Dutch farms**

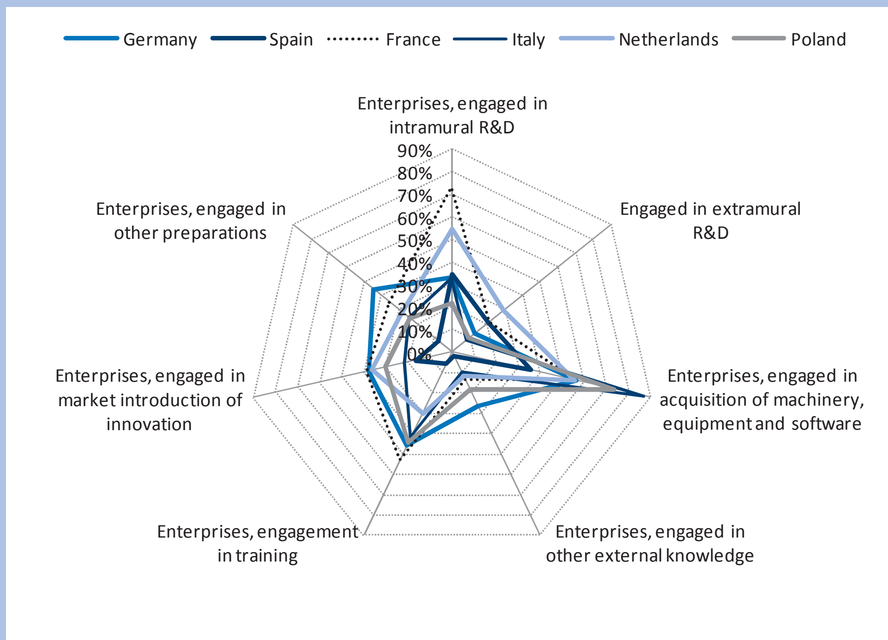



*Source:* LEI, Farm Accountancy Data Network. In: Galen, M.A. van (2012), *Innovatie en vernieuwing in de land- en tuinbouw in 2010 gedaald*, Agri-monitor 2012 (April).

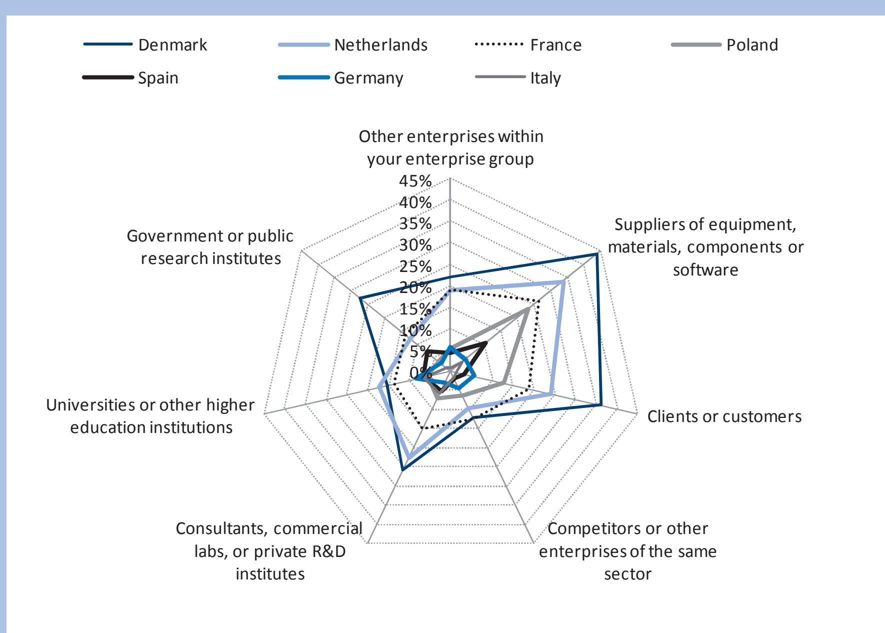
**Box C.1. Monitoring innovation in the food processing industry**

The figures below illustrate the type of information available in the innovation survey published by Eurostat. The first one illustrates the range of innovation activities performed in food and drink companies, from R&D and training to acquisition of machinery and marketing of innovation. The second one sheds light on the extent to which food and drink companies collaborate in product and process innovation with other companies or organisations.

**Share of enterprises engaged in innovation activities, by type of activity**




**Share of enterprises that collaborate in product and process innovation with other companies or organisations, by origin**




*Source:* Eurostat CIS, 2006-2008, calculations LEI. In: Van Galen, M. van, K. Logatcheva, T. Bakker, E. Oosterkamp and G. (2013), *Jukema, Innovatie in de levensmiddelenindustrie; Een internationale benchmarkstudie*, LEI Wageningen UR.

## Evaluating the performance of innovation systems and innovation policies

Innovation systems are becoming more complex, with more diverse actors and types of innovations. Linkages between actors and fields of innovation are becoming crucial for the functioning of the system. Yet measurement focuses on some aspects of innovation: R&D generating science and technology; and some performers, e.g. public R&D expenditures. Measurement is generally outcome-oriented, and does not consider networking and transmission of knowledge activities. Specific surveys would need to be designed to understand non-technical innovation and relationships.

Evaluation consists of measuring realised outcomes in relation to objectives (improving productivity, sustainability and competitiveness) and to inputs (staff, expenditures). It thus requires measuring both inputs (number of staff, or expenditures) and outcomes (number of published papers, or registered patents). Evaluation can be performed at individual level (researchers or extension officers), at team, laboratory, service or institution levels, at project level or at national level. Ideally, assessment should include both the creation and the adoption of innovation, e.g. the number of registered and exploited patents. System evaluation and impact assessment would help identify problems and solutions at national level, and benchmark performance across sectors and countries.

## Assessing the innovation-friendliness of the economic environment and the innovative capacity of the sector

The capacity of the environment to facilitate innovation and the capacity of the sector to be innovative is evidenced by the diffusion of innovation in the sector, and the impacts of innovation as discussed below. But it would be important to identify the specific drivers of innovation to assess their importance, and correct the various incentives in case of policy, market or system failures. As will be discussed in the following chapter, many policies and regulations influence innovation. The structural and socio-economic characteristics of farms and farmers, such as farm size, income and education level, are also important.

## Evaluating the economic impacts of innovation

Evaluation should help determine the economic effects of public investment in R&D and innovation, such as the contribution to growth, and the social impacts, such as better health outcomes (OECD, 2010a). Linking funding inputs with a wide range of possible outcomes presents many challenges outlined in Box C.2.

At macroeconomic level as for the agricultural sector, productivity growth is used as an indicator of innovation impact. The decomposition of total factor productivity (TFP) growth into technological change, technical efficiency change, and scale and mix efficiency change using farm-level data sheds light on the pathways to innovation in the sector (OECD, 2011a). Technological progress reflects advances in technology adopted by early innovators, which are the best performing farms that push the production frontier up. Technical-efficiency increase reflects later adoption of technology by individual farms, allowing them to move towards the production frontier. Scale efficiency increase (economies of scale) is represented by a movement along the production frontier due to a change in farm size. This means that the productivity of farms can be improved to a certain extent through economies of scale and the adoption of more technically-efficient production systems.[1] Mix efficiency changes refer to changes in productivity due solely to changes in the input or output mix (economies of scope). At national level, the agricultural sector will experience an increase in productivity if the least productive farms exit the sector, if the most productive farms push out the productivity frontier, or if less productive farms move closer to the productivity frontier (OECD, 2012b).

This may lead to either higher technical efficiency or higher scale efficiency. Indicators of partial productivity growth also provide an indication on the type of innovations, and their impact on the input mix.

**Box C.2. The main challenges for analysing the economic and non-economic impacts of public R&D**

*Causality*. There is typically no direct link between a research investment and an impact. Research inputs generate specific outputs that can affect society. This relation is always indirect and therefore difficult to identify and measure. It is also almost impossible to isolate the influence of a specific research output on a given impact, which is generally the result of several factors and thus difficult to control for. As a result, any “causality” between research outputs and impacts cannot be easily demonstrated.

*Sector specificities*. Every research field and industry creates output and channels it to the end user in a specific way. This makes it difficult to develop a single framework for assessment.

*Multiple benefits*. Basic research may have various impacts, not all of which can be easily identified.

*Identification of users*. It can be difficult and/or costly to identify all beneficiaries of research outputs, especially those of basic research.

*Complex transfer mechanisms*. It is difficult to identify and describe all the mechanisms for transferring research results to society. Studies have identified transfer mechanisms between businesses or between universities and businesses. The models are mainly empirical and often do not reveal the full impact on society.

*Lack of appropriate indicators*. Given the lack of the needed categories of beneficiaries, transfer mechanisms and end users, it is difficult to define appropriate impact indicators for measuring specific research outputs.

*International spillovers*. The existence of knowledge spillovers is well documented and demonstrated (Jaffe,1986; Griliches, 1979). As a result, specific impacts may result partly from international research rather than from national investments.

*Time lags*. Different research investments may take more or less time to have an impact on society. Particularly in the case of basic research, it may sometimes take longer for the research to generate its full impact.

*Interdisciplinary output*. Research outputs have various impacts, and it may be difficult to identify them all in order to evaluate the contribution of a specific output, let alone that of the research investment.

*Valuation.* In many cases, it is difficult to give a monetary value to impacts in order to make them comparable. Even if non-economic impacts can be identified, they may be difficult to value. There have been attempts to translate some of these impacts, e.g. the economic savings associated with a healthy population, into economic terms, but these have typically been partial and subjective.

*Source*: OECD (2008b), reported as Box 5.4 in OECD (2010a).

Estimates of the rates of return to agricultural R&D suggest a very high social value of agricultural R&D. Annual internal rates of return of investments on agricultural R&D estimated in the literature range between 20% and 80% (Alston, 2010). In the United States, the value of the productivity gains is estimated at least ten times higher than the value of the expenditures, regardless of the measurement method or the assumption about the shape and length of the R&D lag distribution, inter-regional or inter-institutional spillovers, or the roles of private R&D or extension (Alston et al., 2010). In Fuglie (2012) research capacity was found to be the primary constraint on productivity growth, while extension/education capacity was a binding constraint at very low levels of this variable. Once some minimal capacity in extension/education was achieved, it was research capacity that differentiated low TFP growth and high TFP growth countries. When relating R&D expenditures to productivity improvement, it is particularly difficult to take account of cross-sector and cross-country impacts, and to distinguish research with short-term market impacts from research with longer lags.

At macroeconomic level, TFP growth can be measured for the primary sector (agriculture, hunting, forestry and fisheries) using national accounts. The OECD publishes such estimates for a number of countries in OECD.stat.[2] Using FAO.stat information, the USDA has developed a world-wide database on TFP growth in agriculture (Fuglie, 2012). As part of the OECD Green Growth project on agriculture and food, efforts are being made to develop environmentally adjusted multi-factor productivity indicators (OECD, 2012b). As part of the OECD agricultural innovation project, the OECD network for farm-level analysis has undertaken to measure TFP for specific farm types to support OECD work on innovation and develop indicators of creation and diffusion of innovation. The report on farm performance indicators prepared as part of the innovation project is an exploratory analysis of factors determining farm performance using partial indicators (Kimura, 2013).

Innovation, however, concerns other aspects of production and marketing systems than technology, such as farm practices and organisation. It can also lead to quality improvements that are not necessarily transmitted into higher productivity. It should also be noted that productivity is not the sole objective of innovation systems, which are more broadly concerned with economic, environmental and social sustainability. It would be interesting to relate changes in environmental performance and food quality to innovation, but it would be difficult to assess relationship quantitatively in the absence of long-term indicators for those aspects.

The Standing Panel on Impact Assessment (SPIA) of the CGIAR commissioned consultants to review newly available data and methods to conduct rigorous assessment on the ways in which technological change can affect the various indicators of well-being (de Janvry et al., 2011). The report discusses both micro-economic impact analysis, and long-term and aggregate effects. Efforts are also undertaken in countries to test methods to evaluate various aspects of agricultural research. For example, the French Agriculture Research Agency (INRA) launched the ASIRPA project early in 2011 to contribute to the methodologies for evaluating the impact of public agricultural research. The project is based on a series of 14 representative cases that have been studied following a standardised method.[3] The US Department of Agriculture has undertaken a number of case studies, using evaluation methods going beyond standard techniques of economic evaluation (Heisey et al., 2010). Australia and Embrapa in Brazil publish annually net returns from agricultural Research expenditures (Allen, 2012, Lopes, 2012). Independent reviews and evaluation of impacts of Embrapa are carried out regularly, while in Chile and Mexico, this is done on an *ad hoc* basis. In Indonesia, the Assessment Institute for Agricultural Technology (AIAT) assesses research results, follows implementation and gets feed-back from users (Subagyono, 2012).

## Benchmarking

When assessing the performance of national AIS and innovation policy, it can be interesting to benchmark across sectors and countries.[4] This would require further developing international databases. Both the OECD and Eurostat have invested in comprehensive innovation databases. However, the coverage of agriculture is unequal. Countries with large agricultural research capacity like France or the United States are not included for some indicators, possibly because national indicators adopt different definitions. The coverage of the private industry is particularly weak. Few countries report information on private expenditures on agricultural R&D in the OECD database and the ASTI database only includes public expenditures. The most common and long series are public expenditures on agricultural sciences R&D, by sector of performance, but series for indicators by socio-economic objective start in 2003 (Table B.1). In addition, agricultural indicators are rarely included in indicators by source of funding.

Indicators listed in Table C.1 could help countries evaluate and benchmark their AIS. They could be expressed in constant terms for measuring trends. Research expenditures could be expressed as a percentage of sales or value added for research expenditures. It would also be interesting to know the share of different categories of R&D expenditures in total, e.g. share of government-funded R&D or share of project-based R&D in total R&D expenditures. Outcome indicators could be expressed in reference to inputs (funds or staff), e.g. patents per researcher.

**Table C.1. List of potential indicators of innovation**

| Examples of indicators | Possible data sources |
|---|---|
| ***Creation or import of new knowledge*** | |
| Public and private expenditure on agricultural R&D | OECD R&D Statistics |
| Number of staff in public and private agricultural R&D | OECD R&D Statistics |
| Number of patents registered in the area of agricultural biotechnology | OECD R&D Statistics |
| ***Adoption of new knowledge*** | |
| Public expenditure on agricultural extension and agricultural schools | OECD PSE database |
| Number of staff in agricultural extension services | National statistics |
| Public and private cost of extension services | National statistics |
| Contribution of technological change to total factor productivity | OECD Network for Farm Level Analysis |
| Adoption of specific innovation (e.g., production practices, including practices that generate non-marketable goods and services) | National Survey data |
| ***Diffusion of knowledge/ Combination of existing knowledge*** | |
| Contribution of technical efficiency change to total factor productivity | OECD Network for Farm Level Analysis |
| Distribution of farm productivity performance in the sector | OECD Network for Farm Level Analysis |
| Diversification in non-agricultural on–farm activities | OECD Network for Farm Level Analysis |
| Horizontal and vertical integration in the agri-food chain[1] | National Survey data |
| ***Enabling market and policy environment to innovate*** | |
| Linkage between farm support and productivity performance | OECD Network for Farm Level Analysis |
| Entry and exit in the agricultural sector | OECD Network for Farm Level Analysis |
| ***Induction of innovation*** | |
| Change in the rate of substitution of inputs | OECD Network for Farm Level Analysis |
| Reflection of R&D demand in public R&D agenda | National statistics |

1. This is often accompanied by transfers of technology and knowledge, and can also create the conditions for co-development of new technology and knowledge.

## Further issues

The OECD innovation strategy (OECD, 2010a) identifies some innovative indicators, highlights some of the gaps in current measurement and formulates a number of recommendations to take the measurement agenda forward. They include improving the measurement of broader innovation and its link to economic performance; investing in a high-quality and comprehensive data infrastructure to measure the determinants and impacts; recognising the role of innovation in the public sector and promote its measurement; promoting the design of new statistical methods and interdisciplinary approaches to data collection; and promoting the measurement of innovation for social goals and of social impacts of innovation (Box C.3).

Regarding agricultural innovation, there is still a lot to do to identify agriculture-specific information needed to calculate standard innovation indicators. The first challenge would be to improve the coverage of agricultural R&D performed by organisations that are not under the responsibility of the ministry in charge of agriculture, in particular non-agricultural specific institutions, as well as that of private R&D efforts. It would also be important to develop indicators covering the whole agri-food system. It would also be useful to understand the impact of innovation in inputs that are used by agriculture and other sectors, such as machineries, buildings, biotechnology, and nanotechnology.

Another issue with innovation indicators is the high aggregation level. It would be useful for assessment and comparison to distinguish short-term from long-term research, as they have different impact lags. Similarly, it would be interesting to distinguish institutional funding of research from project or programme-based research, as the respective shares vary a lot by country. To assess the impact of innovation on a specific commodity sector (crop, livestock) or objective (genetic improvement, productivity, sustainability, economic performance), one would also need to know the allocation of R&D funds in these different areas.

In terms of comparing across countries, R&D expenditures can hide differences in labour costs. Similarly, the distribution of staff qualification level can differ across countries. Similarly, comparing patents across countries would require careful examination of the type and size of innovation patented. If information on non-technological and relationship aspects of innovation were available, they would be difficult to compare across countries.

**Box C.3. A measurement agenda for innovation: Key actions**

**1. Improve the measurement of broader innovation and its link to macroeconomic performance**

Science, technology and innovation surveys need to be redesigned to take a broader view of innovation and improved measurements are needed to link science, technology and innovation policies to economic growth.

*Key actions*

- Measure and value intangible assets;
- Revisit the measurement framework for innovation to identify and prioritise areas for survey design and re-design; and
- Align survey and administrative data with economic aggregates.

**2. Invest in a high-quality and comprehensive data infrastructure to measure the determinants and impacts of innovation**

Sound policy advice needs to rely on a high-quality and comprehensive data infrastructure, including at the sub-national level. The backbone of such infrastructure is a high quality business register. The ability to link different data sets and exploit the potential of administrative records will improve understanding and reduce respondent burden.

*Key actions*

- Improve business registers;
- Exploit the statistical potential of administrative records;
- Improve the data infrastructure at the sub-national level; and
- Establish a data infrastructure which combines data linkages with good researcher access to the data, while protecting business and individual confidentiality.

**3. Recognise the role of innovation in the public sector and promote its measurement**

There is a need to account for the use of public funds, measure the efficiency of producing and delivering public policies and services, and improve learning outcomes and the quality of the provision of public services via innovation.

*Key actions*

- Develop a measurement framework for innovation in the public sector for the delivery of public services, health and education; and
- Devise indicators that capture the nature, direction and intensity of public support for innovation, at national and regional levels.

**4. Promote the design of new statistical methods and interdisciplinary approaches to data collection**

Design of policies for innovation needs to take into account the characteristics of technologies, people and locations, as well as the linkages and flows among them. New methods of analysis that are interdisciplinary in nature are necessary to understand innovative behaviour, its determinants and its impacts at the level of the individual, the firm and the organisation.

*Key actions*

- Develop interdisciplinary approaches to data collection and new units of data collection;
- Improve the measurement of innovative activity in complex business structures, organisations and networks;
- Promote the measurement of the skills required in innovative workplaces; and
- Promote the joint measurement of emerging and enabling technologies.

**5. Promote the measurement of innovation for social goals and of social impacts of innovation**

The current measurement framework fails to measure the social impacts of innovation. The development of measures that provide an assessment of the impacts of innovation on well-being, or their contributions to achieving social goals, needs to be promoted.

*Key actions*

- Develop measures of innovation that address social needs; and
- Devise measurement tools that bridge the economic and social impacts of innovation activities.

*Source*: OECD (2010a).

***Notes***

1. If at farm-level innovation is not the only way to achieve higher productivity, long-run productivity growth for the sector as a whole requires continuous innovation (OECD, 2011a).
2. A report on Technological Change and Structural Adjustment in OECD Agriculture (OECD, 1995) included agricultural TFP indicators for OECD countries calculated using agricultural accounts (excluding forestry and fisheries) published by OECD. Since then, the OECD no longer updates and publishes agricultural accounts for its member countries, but some continue to calculate them, e.g. Eurostat and the United States.
3. As part of this project, an International Conference on "Evaluating the impacts of an agricultural public research organization" will take place in Paris on 27-28 November 2012 to share experiences with academics and practitioners that are involved in research evaluation worldwide. www6.inra.fr/asirpa_eng/ASIRPA-project
4. OECD reviews of innovation policy use the OECD database to benchmark national innovation policy against that of other OECD countries.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