Chapter 1

Fostering innovation: The policy challenge

This chapter provides a definition of innovation, highlights its importance in fostering economic growth, and outlines the main challenges and opportunities faced by Agricultural Innovation Systems (AIS).

1.1. What is innovation?

As defined by the *Oslo Manual*, innovation is a broad concept (Box 1.1). It is more than research and development (R&D) and encompasses both the creation and adoption of innovation, which can be "new to the firm, new to the market or new to the world." At the farm level, many innovations are "process innovations" as they relate to production techniques, e.g. the adoption of improved seeds, irrigation technologies, and waste management technologies, and the development by farmers of practices adapted to their situation. Some process innovations for farmers such as improved seeds and animal breeds, agricultural machines, irrigation systems or buildings would be considered as "product innovation" for the upstream industry. The downstream industry also generates product innovation, such as food with new functional (health) attributes, or non-food products from agriculture for the chemical or pharmaceutical industry (bioeconomy). All along the supply chain, marketing and organisational innovations are increasingly important.

Box 1.1. Defining innovation

The latest (third) edition of the *Oslo Manual* 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 (OECD and Eurostat, 2005).

This definition captures the following four types of innovation and is used for measurement purposes.

- *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.
- *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.

An innovation can consist of the implementation of a single significant change or of a series of smaller incremental changes that together constitute a significant change. By definition, all innovation must contain a degree of novelty. The *Oslo Manual* distinguishes **three types of novelty: an innovation can be new to the firm,[1] new to the market or new to the world.**[1] The first covers the diffusion of an existing innovation to a firm – the innovation may have already been implemented by other firms, but it is new to the firm. Innovations are new to the market when the firm is the first to introduce the innovation in its market. An innovation is new to the world when the firm is the first to introduce the innovation for all markets and industries.

1. New to the farm in the case of primary agriculture.

Source: Box 1.2 in OECD (2010a).

1.2. Who are agricultural innovation actors?

Agricultural Innovation Systems (AIS) involve a wide range of actors, who guide, support, create, transfer or adopt innovation, and who advise and inform farmers and the public about innovations.[1] Governments provide strategic guidance, financial support to researchers and advisors in public and private organisations, and research infrastructure such as databases, laboratories and information and communication technologies (ICT). They also implement policies and regulations that affect the business and innovation environment, for example investment support, tax policy, agricultural and rural policies, and labour, consumer and environmental regulations. Researchers, private businesses and farmers create innovations. Advisors and other intermediaries (brokers, credit institutions, input suppliers) help diffuse innovation in farms and agri-food firms. Charities and non-governmental organisations (NGOs) play a role in funding innovation, and providing information and advice. Finally, markets and consumers provide signals on demand for innovation and acceptance of supplied innovation. All actors are involved to some extent in the provision of information. Chapter 2 provides more information on the diversity of AIS actors and institutions.

1.3. Why innovate?

In agriculture as in other sectors, innovation is the main driver of productivity growth. In particular, public expenditures on agricultural R&D are estimated to have significant impacts on agricultural total factor productivity (TFP) growth and competitiveness (see for example Alston, 2010; Alston et al., 2010; OECD, 2011a; Fuglie, 2012). At the national level, innovation helps create higher value added and improve competitiveness and economic growth. It also contributes to economic diversification, in particular in emerging economies.[2] At the farm level, introducing innovation should lead to a better allocation of resources, higher productivity, and thus income. Innovation can also improve the environmental performance of the farm. Introducing new techniques and products can be risky, e.g. if they are not adapted to specific circumstances, if they are difficult to implement, or if the marketing potential does not materialise. At the same time, some innovations have the potential to help farmers deal with production and income uncertainties (e.g. irrigation, animal medicines, pesticides, improved seeds, and innovative risk management tools).

Innovation in agriculture has been very successful in improving the productivity and quality of agricultural products, but it needs to be continuous to remain competitive. Further innovation is needed to adapt to input and output market developments, and changes in resource quality and availability. Innovation will have a key role to play in helping the agri-food sector produce more nutritious, diverse and abundant food, and provide raw material for non-food use, without depleting natural resources, and adapt to expected changes in natural conditions from climate change. In some regions, the challenge is to adapt agricultural production systems to more difficult natural environments (e.g. due to salinity, more frequent drought). Innovation in food industries target changes in food consumption habits linked to higher income, health concerns, higher participation of women in the labour force, and reduction of time available for meals.

1.4. Challenges and opportunities for Agricultural Innovation Systems

Changes in the demand for innovation present both challenges and opportunities for AIS. At the same time, agricultural innovation is broader in scope and more complex in nature than it used to be. While science and technology (S&T) is still a major component of AIS, innovation also includes institutional and organisational innovation. Agricultural innovation also covers more diverse areas, and has to respond to broader policy objectives. AIS increasingly draw on innovations developed for general or other purpose such as Information and Communication Technology (ICT), nanotechnology or biotechnology. As a result, agricultural innovation requires more interactions between diverse actors, from research, education, extension, farms, policy makers and regulators, NGOs, consumers and brokers; and between fields of science, and thus more co-ordination.

A specificity of AIS compared to other innovation systems is that major innovations on farming techniques such as improved seeds are generated outside farms, by public R&D organisations and upstream industries. Diffusion of innovation thus often requires intermediary actors such as extension services, to be adopted by farmers. Moreover, in many OECD countries, agricultural policies influence producers' willingness and capacity to invest in innovation, and the choice of production system. As for any innovation, adoption by consumers and society can be an issue. Moreover, agriculture is facing global issues, such as food security and climate change, which require international co-operation.

While investment in innovation is a main driver of economic growth, governments face budgetary constraints, including for funding agricultural R&D. It is therefore crucial to increase cost-efficiency, focus on priorities and avoid unnecessary duplication of effort at the national and international levels.[3] A strategic approach to innovation is thus required to improve governance and strengthen linkages (Chapter 2).

1.5. Measurement and evaluation issues

Measurement of innovation makes possible evaluation of the performance of innovation systems and the effectiveness of innovation policies with respect to their objectives. It also helps assess the capacity of the policy framework to create a socio-economic environment conducive to innovation, the capacity of a sector to adopt innovation, and the impact of innovation on the economy and society.

Innovation is difficult to measure because it is a continuous and complex process (OECD, 2010a). 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). As innovation is becoming more diverse and complex, it is increasingly difficult to measure the various facets of innovation. However, indicators can be developed to measure some innovation activities and elements of the innovation process.

One difficulty is to define the boundaries of agricultural R&D. Box 1.2 presents the classification of agricultural innovation developed in the Frascati Manual (OECD, 2002), and adopted by Eurostat and the OECD, among others. Another difficulty lies in identifying research on specific topics carried out in non-specialised institutions or companies.[4]

Box 1.2. Classification of agricultural innovation in the Frascati Manual

By fields of sciences

Agricultural sciences include agriculture, forestry, fisheries and allied sciences (agronomy, animal husbandry, fisheries, forestry, horticulture, other allied subjects), as well as veterinary medicine.

By socio-economic objectives

Agricultural production and technology cover all research on the promotion of agriculture, forestry, fisheries and foodstuff production. It includes research on chemical fertilisers, biocides, biological pest control and the mechanisation of agriculture; research on the impact of agricultural and forestry activities on the environment; research in the field of developing food productivity and technology. It does not include research on the reduction of pollution; research into the development of rural areas, the construction and planning of buildings, the improvement of rural rest and recreation amenities and agricultural water supply, research on energy measures and research for the food industry.

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Note: *The Frascati Manual* is currently being revised.

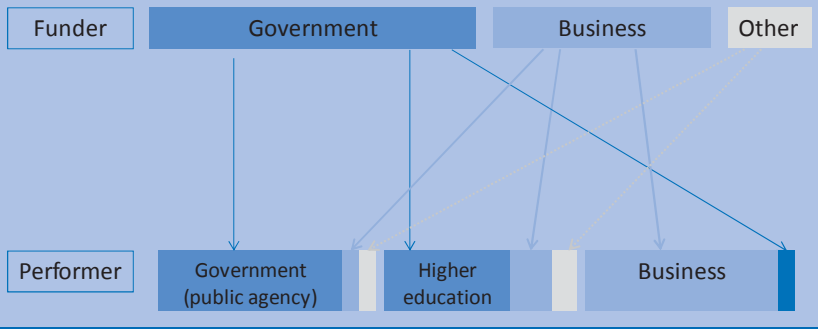
Source: *Frascati Manual* (OECD, 2002).

Box 1.3 briefly discusses the most common indicators of innovation, including those used to describe developments in agricultural R&D expenditures in Chapter 4 and Annex B. Annex C discusses evaluation issues and proposes a list of possible indicators comparable across countries which could help countries evaluate their AIS.

Box 1.3. Most common innovation indicators

Input indicators measure investment in innovation, such as R&D expenditures and number of staff. They are readily available in the EUROSTAT and OECD databases and as part of the ASTI project for emerging and developing countries.[1] Expenditures and number of staff are classified by funding sector (government, business, abroad, higher education), by performing sector (Higher education, government research, business, private non-profit), by field of science (agricultural sciences) and by socio-economic objective (agricultural production and technology) defined in Box 1.2. In addition, government budget appropriations or outlays for research and development (GBAORD) are available by socio-economic objective. These indicators are relatively well developed at national level, in particular regarding public efforts, but the coverage of agriculture, in particular private expenditures on agricultural R&D, is still limited despite efforts at the international level.

Using arbitrary shares, the figure below illustrates the relationships between funding sectors and performing sectors. Public money or private foundations fund both research performed in public organisations and private companies. In the United States in 2007, the private sector funded 60% of agricultural R&D expenditures and performed 54% of the total, of which 52% by agricultural input sectors and 48% by food sector (Figure 2 in King et al., 2012).



Box 1.3. Most common innovation indicators
(continued)

Information on the private sector is difficult to collect. Recently, an analysis of research investment in the private sector worldwide was carried out by the USDA (Fuglie et al., 2011). It examines more specifically the food processing, agricultural input and biofuel industries. The European Union publishes information on industrial R&D investment in the top 1 400 world companies, including food industries. However, agricultural input industries cannot be easily identified as companies do not work exclusively for agriculture (Table 2.4).

Indicators of *innovation outcomes* include the number of publications in academic journals, the number of patents registered, the number of databases and software created, and the number of innovations created or introduced in firms. The Thompson-Reuters Web of Knowledge includes all refereed papers published in scientific journals. The OECD collects and publishes statistics on patent counts by technology and the inventor's country of residence. They include patent applications to the European Patent Office (EPO); patents granted by the EPO; patents granted by the US Patent and Trademark Office (USPTO); patents filed under the Patent Co-operation Treaty (PCT), at the international phase that designate the EPO; and patents that belong to Triadic Patent Families defined by the OECD as a sub-set of patents all filed together at the EPO, at the Japanese Patent Office (JPO) and those granted by the USPTO, protecting the same set of inventions. Technologies include biotechnology and various environmental and climate change mitigation technologies, from which agriculture-related technologies can be extracted. Tracking the number of patents of a certain type over time and with regard to efforts can help measure progress in some areas. However, patents are more an indicator of invention rather than innovation since not all patents are commercialised, some types of innovation are not patentable (e.g. innovation on services and organisational innovation), and patents are not the only IPR system used in some countries. Moreover, patents can be used for very small increments as well as for major breakthroughs (OECD, 2010c), and adding-up very heterogeneous patents can be misleading. For similar reasons, bibliographic indicators should be interpreted with care.

Increasingly, efforts are being made to measure innovation at the firm level using innovation surveys, which include specific questions on innovation creation and adoption, or adding questions on innovation in farm surveys (Annex C).

There is no systematic measure of the impact of innovations on the economy and the impact of policies on innovation. For the agricultural sector, the relationship between TFP growth and R&D investment is well documented. The decomposition of TFP growth also sheds lights on the diffusion of innovation in agriculture. Technological change measures innovations that are new to the sector, while change in technical efficiency measures innovations that are new to the farm. While increasing agricultural productivity is generally an important objective of agricultural innovation policy, there are others such as increasing environmental and social sustainability, food quality and food safety, which require other types of indicators. Impact evaluation issues are discussed further in Annex C.

1. For more information on the Agricultural Science and Technology Indicators (ASTI) project, see Annex B of G20 (2012), Beintema and Stadt (2011), Stadt and Beintema (2012) and the ASTI website: www.asti.cgiar.org.

1.6. Government's role in innovation

Many policies other than innovation policy *per se* affect innovation and stimulate the creation and adoption of innovation in both the public and private sectors. They include broader general "framework" policies, including macroeconomic and structural policies, and regulations on environmental or safety standards (Chapter 3); sectoral policies (Chapter 4) and innovation policies (Chapter 5). The OECD innovation strategy (OECD, 2010a) defines policy principles for innovation discussed by OECD ministers in 2010 (OECD, 2010b) and summarised in Box 1.4.

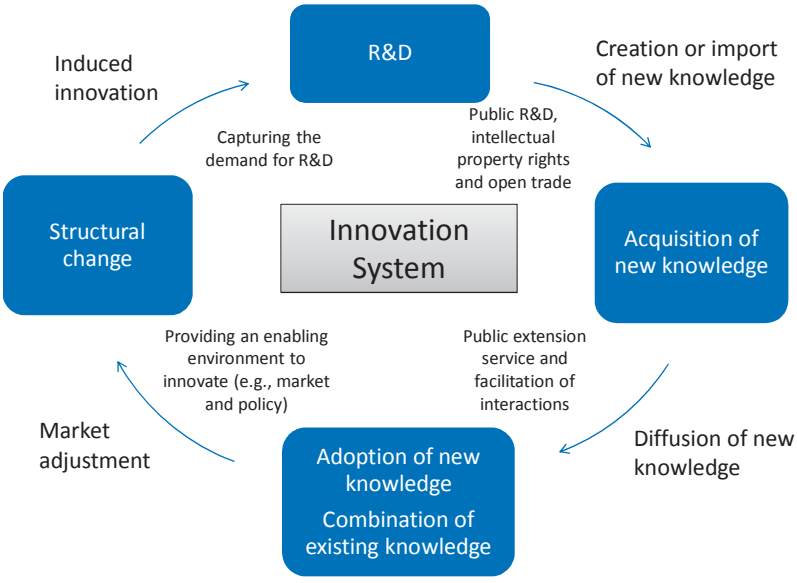
In the agricultural sector, rural, environmental, land, water and agricultural policies are particularly important for AIS as they influence structural adjustment, natural resources

quality and availability, investment capacity, and producers' choices of production systems, including through extension and regulations. Figure 1.1 illustrates the dynamics of innovation in agriculture.

Innovation policy includes investments in public R&D institutions to fund: staff and equipment, as well as projects and programmes; support to private R&D through tax rebates, competitive grants and funding of Public-Private Partnerships; the provision of knowledge infrastructure such as ICT, life science infrastructure (gene banks) and information systems; and regulations regarding Intellectual Property Rights (IPRs). Government policy also supports the creation and functioning of networks, centres of excellence, and provides platforms for partnerships.

Government involvement in agricultural R&D, education and extension is intended to respond to market failures, due to the public good nature of some research, the long lags between creation and adoption, and the fragmentation of various agri-food actors.[5] Agricultural R&D generates new technologies, and agricultural extension and advisory services help farmers adopt them. In many countries, agricultural policy measures also support investment in technology. In addition to strengthening and focusing public R&D to address market and system failures, efforts also aim to encourage the creation and adoption of innovation by the private sector, including through regulations to foster acceptance of innovation in the wider economy (consumer information and food safety regulations), the provision of risk management tools, and incentives for partnerships. This leads to better define the respective public-private roles in innovation, and to better integrate partners in innovation systems.

Figure 1.1. An illustration of the innovation dynamics in agriculture



Box 1.4. The OECD innovation strategy: Policy principles for innovation

1. Empowering people to innovate

- Education and training systems should equip people with the foundations to learn and develop the broad range of skills needed for innovation in all its forms, and with the flexibility to upgrade skills and adapt to changing market conditions, to foster an innovative workplace, and ensure that employment policies facilitate efficient organisational change.
- Enable consumers to be active participants in the innovation process.
- Foster an entrepreneurial culture by instilling the skills and attitudes needed for creative enterprises.

2. Unleashing innovations

- Ensure that framework conditions are sound and supportive of competition, conducive to innovation and mutually reinforcing.
- Mobilise private funding for innovation by fostering well-functioning financial markets and easing access to finance for new firms, in particular for the early stages of innovation. Encourage the diffusion of best practices in the reporting of intangible investments and develop market-friendly approaches to support innovation.
- Foster open markets, a competitive and dynamic business sector, and a culture of healthy risk taking and creative activity. Foster innovation in small- and medium-sized firms, in particular those that are new or at an early development stage.

3. Creating and applying knowledge

- Provide sufficient investment in an effective public research system and improve the governance of research institutions. Ensure coherence between multi-level sources of funding for R&D.
- Ensure that a modern and reliable knowledge infrastructure that supports innovation is in place, accompanied by the regulatory frameworks which support open access to networks and competition in the market. Create a suitable policy and regulatory environment that allows for the responsible development of technologies and their convergence.
- Facilitate efficient knowledge flows and foster the development of networks and markets which enable the creation, circulation and diffusion of knowledge, along with an effective system of intellectual property rights.
- Foster innovation in the public sector at all levels of government to enhance the delivery of public services, improve efficiency, coverage and equity, and create positive externalities in the rest of the economy.

4. Applying innovation to address global and social challenges

- Improve international scientific and technological co-operation and technology transfer, including through the development of international mechanisms to finance innovation and share costs.
- Provide a predictable policy regime which provides flexibility and incentives to address global challenges through innovation in developed and developing countries, and encourages invention and the adoption of cost-effective technologies.
- To spur innovation as a tool for development, strengthen the foundations for innovation in low-income countries, including affordable access to modern technologies. Foster entrepreneurship throughout the economy, and enable entrepreneurs to experiment, invest and expand creative economic activities, particularly around agriculture.

5. Improving the governance and measurement of policies for innovation

- Ensure policy coherence by treating innovation as a central component of government policy, with strong leadership at the highest political levels. Enable regional and local actors to foster innovation, while ensuring co-ordination across regions and with national efforts. Foster evidence-based decision-making and policy accountability by recognising measurement as central to the innovation agenda.

Source: Box 2 in OECD (2010b), Ministerial report on the OECD Innovation Strategy: Innovation to strengthen growth and address global and social challenges: Key Findings, available at: www.oecd.org/dataoecd/51/28/45326349.pdf or Box 8.1 in OECD (2010a), *OECD Innovation Strategy: Getting a Head Start on Tomorrow*, OECD Publishing. Available at: www.oecd.org/innovation/strategy.

Notes

1. Among the terms used to describe the features of systems producing agricultural innovation "Agricultural Innovation System (AIS)" has the broadest coverage of actors. The term "Agricultural Knowledge and Innovation System (AKIS)" is used in the European Union with the same meaning, although it is more restrictive in other contexts. Table 2.4 of OECD (2012a) describes the defining features of different knowledge systems.
2. Innovation in general plays a major role in explaining differences in income and productivity levels across countries (OECD, 2010a). In particular income gaps are closely associated with gaps in total factor productivity (TFP) and human capital.
3. Competing research efforts with similar purpose can be beneficial, fostering emulation and leading to different outcomes adapted to different conditions.
4. Further issues are to identify agricultural units to be sampled in firm innovation in surveys, to identify the relevant respondent for the unit, in the case of complex farms, and to provide relevant examples of innovations to respondents.
5. From a market failure rationale, there is now a move to a system failure rationale, which identifies bottlenecks, weak relationships and seeks to address them. System failures include: infrastructural failure (e.g. ICT and roads); institutional failure (e.g. laws, regulations, norms); interaction failure; and capability failure (Klein-Woolthuis et al., 2005).