Agricultural Innovation Systems

A FRAMEWORK FOR ANALYSING THE ROLE OF THE GOVERNMENT

OECD

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OECD
BETTER POLICIES FOR BETTER LIVES

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Foreword

Agricultural Innovation Systems (AIS) are key to improving the economic, environmental and social performance of the agri-food sector. The long-term positive impact of agricultural research and development (R&D) on productivity growth is well established, and technologies and practices can help improve the sustainability of natural resource use. In recognition of their potential contribution to challenges facing the agri-food sector, AIS are the subject of renewed attention from policy makers.

In the last two decades, a number of countries have reviewed their national AIS and have engaged in reforms to improve its relevance to users' demand and broader policy priorities, as well as its cost-efficiency. The focus of reforms has been to strengthen co-ordination and governance, develop interactions within the system, and with other fields of innovation, improve cross-country co-operation, and strengthen mechanisms for the diffusion of innovation.

More recently, market developments, in particular high food prices, have focused attention on global challenges for agriculture and AIS. Agricultural production will need to increase faster to meet higher and more diverse demand for food, feed, fibre and fuel from a growing and wealthier population as well as for the development of bio-based, non-food products. Meeting these demands sustainably will require further increases in agricultural productivity and efficiency in the use of natural resources — land, water, biodiversity — in a context of growing competition between agriculture and other uses for finite land and water resources, and uncertainties associated with climate change. This will require changes in production methods, including the adoption of technological and other innovations, at every step of the agri-food chain.

The role of AIS in improving agricultural productivity and sustainability and the need to reinforce international efforts and co-operation to respond to global challenges such as food security and climate change is recognised at the international level (e.g. FAO, 2012; World Bank, 2006 and 2012).

In 2011 and 2012, agricultural innovation was discussed at G20 and G8 meetings, in the context of agricultural, development and food security themes. In the 2011 Action Plan on Food Price Volatility and Agriculture, G20 Agricultural Ministers "agree(d) to strengthen agricultural research and innovation through our (their) national agricultural systems, the CGIAR (Consultative Group on International Agricultural Research) and the Global Forum on Agricultural Research (GFA)" (agriculture.gouv.fr/IMG/pdf/2011-06-23_-_Action_Plan_-_VFinale.pdf). In 2012, the Mexican G20 Presidency asked International Organisations (IO) to prepare a report on "Sustainable Productivity Growth and Bridging the Gap for Small Family Farms". The IO report (G20, 2012) includes a number of recommendations on how to improve AIS which have been endorsed in the report of G20 Agricultural Vice-Ministers. In particular, agricultural Vice-Ministers agreed to "Undertake further analysis of current national approaches and best policy practices to increase sustainable agricultural productivity growth. As an initial step, and without creating new institutions, [they] call(ed) on the FAO, OECD and other relevant IOs to propose a consistent framework for analysis for [their] consideration before the end of 2012." In response to this request and in consultation with other international organisations, the OECD has undertaken further analysis to develop a framework for analysis to identify best policy approaches to increasing agricultural productivity growth sustainably.

This report contains an overview of agricultural innovation systems, outlining the main issues and trends (Part I), and develops a framework to analyse the role of government in fostering the creation and adoption of innovation in the agricultural and agri-food sector, i.e. primary agriculture, upstream and downstream industries (Part II). This framework adapts the agricultural and agri-food sector the OECD innovation strategy (OECD, 2010a, b; Box 1.4). It takes into account the specificities of innovation in agriculture, such as the impact of agricultural, environmental and rural policy, and the issues of adoption by farmers of innovations created upstream, and discusses measurement of innovation at the sector level. Previous OECD work on agricultural innovation (available at www.oecd.org/agriculture/policies/innovation), general innovation and green growth provided useful information. These include the following.

- OECD (2012a), *Improving Agricultural Knowledge and Innovation Systems: OECD Conference Proceedings*, OECD Publishing, dx.doi.org/10.1787/9789264167445-en.
- Country responses to a questionnaire on their Agricultural Knowledge Systems (AKS) institutions regarding its organisation, objectives, priorities and outcomes, as well as its internal/external networking and co-operation (Annex A).
- OECD (2012b), *Agricultural Policy Monitoring and Evaluation 2012: OECD Countries*, OECD Publishing, dx.doi.org/10.1787/agr_pol-2012-en.
- Interagency Report to the Mexican G20 Presidency, co-ordinated by the FAO and the OECD, on "Sustainable Productivity Growth and Bridging the Gap for Small Family Farms" (G20, 2012).
- OECD (2010a), *OECD Innovation Strategy: Getting a Head Start on Tomorrow*, OECD Publishing. Available at: www.oecd.org/innovation/strategy.
- 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.
- OECD (2010d), *Climate Change and Agriculture: Impacts, Adaptation and Mitigation*, OECD Publishing.
- OECD (2011b), *OECD Green Growth Studies: Food and Agriculture*, OECD Publishing. dx.doi.org/10.1787/9789264107250-en.
- OECD (2013), Policy instruments to support Green Growth – Main report, OECD Publishing, Paris, *forthcoming*.

Catherine Moreddu is the author of this report, which was declassified by the OECD Working Party on Agricultural Policies and Markets in March 2013.

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Executive summary

This report reviews recent trends in Agricultural Innovation Systems (AIS) and discusses the impact of a wide range of policies on the creation and diffusion of innovation in the agricultural and agri-food sector. It suggests a framework for analysing the role of governments in fostering increased innovation, with a view to helping to identify practical actions that governments could take to improve productivity growth, sustainable use of resources, and resilience to future market developments in national and global agriculture and agri-food systems.

The agriculture and agri-food sector is expected to provide healthy, safe and nutritious food for a growing and wealthier world population, feed for increasing farm animal populations, and fibre and fuel for a growing range of industrial uses without depleting available land, water and biodiversity resources. On current trends, these goals will not be met. Greater attention will need to be paid by governments and by the international community more generally to re-invigorate innovation, broadly defined, in the agriculture and agri-food sector.

AIS face many challenges — budget constraints, conflicting information on research priorities, very long time lags between research, adoption, and results — but also many opportunities. Commodity markets are strong, increasing the incentives for investment in agriculture, and international attention is re-focusing on the need to address global food insecurity in a sustainable way. A number of countries are engaging in reforms to increase the cost-efficiency and responsiveness to social needs of their AIS. Reforms have generally improved integration of AIS into general innovation systems, governance structures, priority setting and funding allocation mechanisms, the functioning of Intellectual Property (IP) markets, and opportunities for partnerships and cross-country co-operation.

Economy-wide policies can contribute to enable innovation, either because they directly create long-term conditions conducive to innovation (e.g. health, education, infrastructure, and other structural policies) or because they encourage the private sector to invest in the creation and adoption of innovations (e.g. transparent and predictable regulatory frameworks, and open and efficient output and input markets).

Agricultural policies are prevalent in many countries and can be particularly important for agricultural innovation. Removing distortions in input and output markets and measures slowing structural adjustment would foster farm-level innovation. Measures that facilitate investment, including protection of property rights, would also be beneficial. Agricultural regulations should be reviewed and where possible simplified. Regulations and incentives should be technology neutral and based on outcomes rather than processes. Improving rural and marketing infrastructure and the provision of services in rural areas is also important for agricultural innovation. In addition, as most innovations are created outside farms, particular attention should be paid to agricultural education and extension, and their role in facilitating timely adoption of innovation by farmers.

Innovation policy is central to improving AIS. The public sector plays a major role in the provision of knowledge infrastructure (e.g. communication technology, databanks, centres of technology convergence) and the financing of basic research, or research with long-term and public good aspects, in particular for agriculture and natural resource management. The public sector remains a major funder and performer of research and development (R&D) for agriculture. Governments also encourage innovation activities in the private sector, including fostering knowledge markets through IPR protection, engaging in public-private partnerships (PPP), providing information and sharing the outcomes of public research (spill-overs), and providing direct or indirect financial incentives.

The governance of national AIS could be improved both with better integration within the general innovation strategy, and with stronger co-ordination of the various AIS actors and related policies. It is particularly important to define clearly the respective roles of the public and private sectors, and areas of mutual interest and possible co-operation. Improvements to the institutional design of national AIS would include strengthening strategic planning and regular monitoring and evaluation mechanisms. Efforts should also be made to develop and facilitate access to information systems: databases, modelling and forecasting tools, gene banks, etc. Policy coherence at the national level is fundamental to improving the performance of AIS. In particular, objectives should be set clearly to improve the design of domestic and trade policy and regulations that can impact agricultural innovation.

International co-operation could also contribute significantly to improving the cost-efficiency of national AIS with the sharing of resources and outcomes, even allowing for some specialisation. In addition, co-ordinated efforts are increasingly needed to tackle global challenges and trans-boundary issues.

Part I.

Overview of agricultural innovation systems: Main issues and trends

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.

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

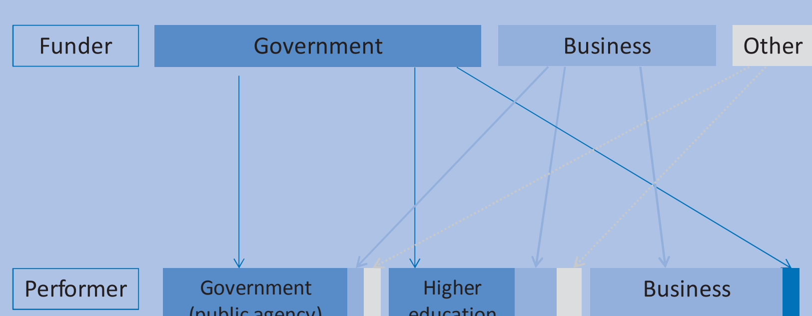
Source: *Frascati Manual* (OECD, 2002).

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

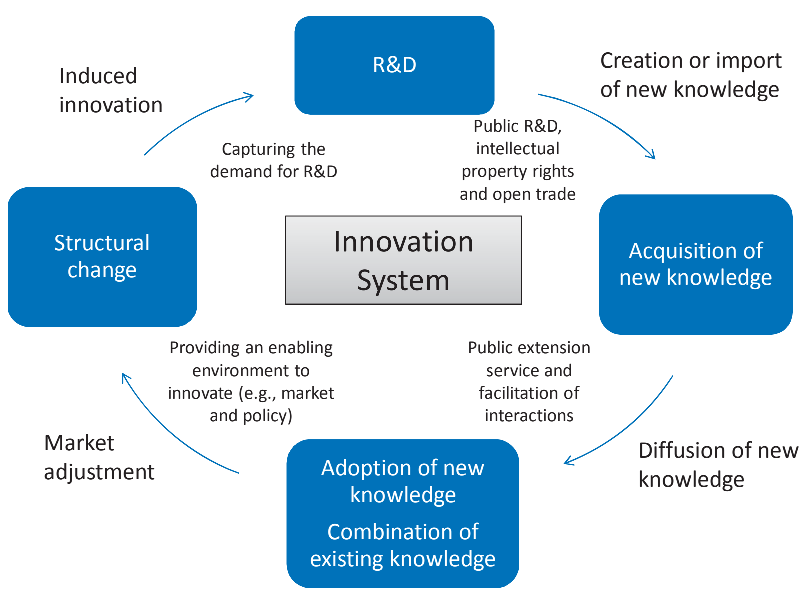
Many policies other than innovation policy *per se* affect innovation and stimulate the creation and adoption of innovation in both the public and private sectors. They include broader general "framework" policies, including macroeconomic and structural policies, and regulations on environmental or safety 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).

Chapter 2

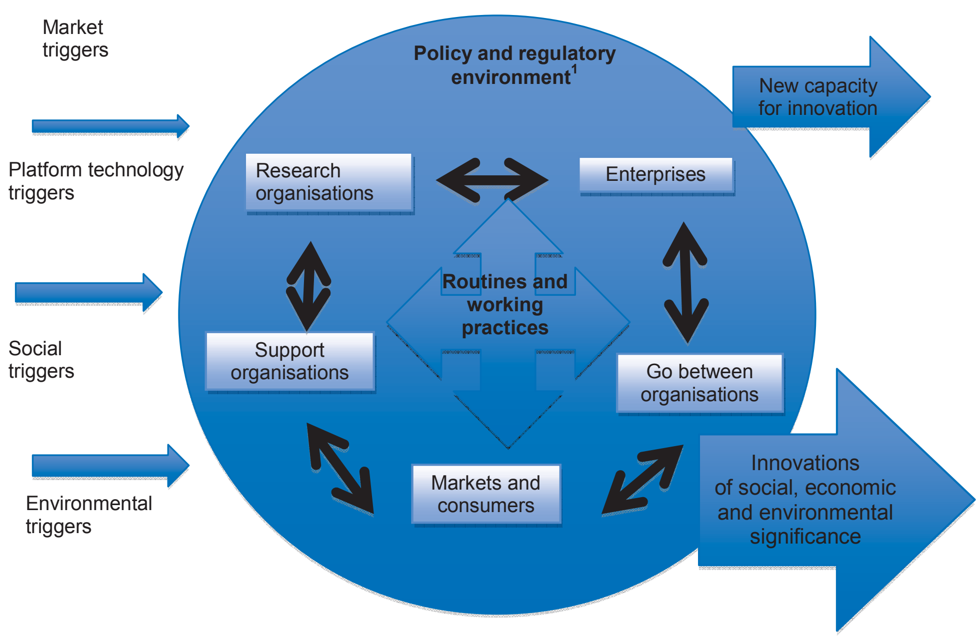
Overview of developments in Agricultural Innovation Systems

This chapter presents an overview of the main trends in Agricultural Innovation Systems (AIS). AIS are diverse, but there are common trends in developed and emerging economies. The scope of innovation has broadened and today AIS include more actors and more diverse institutions. At the international level, a greater number of countries (e.g. Brazil) are active players in agricultural R&D and technology transfers. As such, there is an increased need for interaction not only across components of the AIS, cut also with other innovation sectors and across countries. This is especially the case as budget constraints have been tightened in many countries, while demand for more innovation is growing. This requires stronger governance, planning, priority setting and evaluation mechanisms. This, in turn, has prompted many countries to review their AIS and its performance.

2.1 The diversity of Agricultural Innovation Systems actors and institutions

A number of organisations play various roles in guiding, enabling, funding, creating and diffusing innovation (Figure 2.1). Knowledge is produced and used through their actions and interactions. Hall (2012) describes a number of innovation organisations and actors from the public and private sectors, which respond to market, policy, environmental and social triggers and, together, produce innovation of economic, environmental and social significance. Box 3.1 provides a detailed list of organisations and their main functions. Innovation is produced in a wide variety of organisations. For example, public and private research organisations, higher education establishments and private companies create codified knowledge (or know-what), while enterprise organisations, including farms, are mainly users of this codified knowledge, but sometimes produce tacit knowledge (or know-how). Demand organisations, including consumers, government and international markets, influence research priorities and adoption of innovation, as well as consumers' acceptance. Support organisations facilitate physical and human investment in the creation and adoption of innovation, while go-between organisations help farmers and other enterprises apply innovation. The following paragraphs single out three important organisations — public agricultural R&D, education and extension organisations — and outline their diversity in various OECD countries and emerging economies.

Figure 2.1. Elements of a dynamic working system



1. The government is a major player in innovation. Its roles include setting the policy and regulatory environment, funding and performing research and related activities at central and local level, and providing information, innovation knowledge infrastructure and governance.

Source: Adapted from Hall (2012).

Box 2.1. Organisations in an Agricultural System of Innovation

Support organisations

- Banking and financial system
- Transport and marketing infrastructure
- Professional networks including trade and farmer associations
- Education system

Research organisations

Mainly producing codified knowledge

- National and international, public and private, agricultural research organisations
- Universities and technical colleges (public and private)
- Private research foundations

Sometimes producing codified knowledge

- Private companies
- NGOs

Enterprise organisations

Users of codified knowledge, producers of mainly tacit knowledge

- Farmers
- Commodity traders
- Input supply agents
- Companies and industries related to agriculture, particularly agro-processing
- Transporters

Demand organisations

- Consumers of food and food products in rural and urban areas
- Consumers of industrial raw materials
- International commodity markets
- Policy-making process and government agencies

Go between organisations

- NGOs
- Public extension services
- Consultants
- Private companies and other entrepreneurs
- Farmer and trade associations
- Donors

Source: Hall (2012).

Public **R&D** mainly takes place in research institutes under the ministry in charge of agriculture or in charge of science, technology and innovation, and in universities. Some agriculture-related research is also carried out in agencies attached to other fields, such as environment or health. The role of the ministry in charge of agriculture varies by countries. In some countries, like Canada, France, Denmark and Japan, it defines, co-ordinates, evaluates and funds the agricultural innovation strategy, while in others it executes a strategy defined and managed by the agency in charge of innovation, such as the National Innovation Council in Chile, the National Council of Science and Technology in Mexico, or the Ministry of Science and Innovation in New Zealand, in collaboration with relevant ministries. In other countries, specific agencies under the ministry in charge of agriculture supervise agricultural research and innovation (e.g. the Council of Agricultural Sciences at the Ministry of Agriculture in Estonia). In Brazil, the System of Agricultural Research and Innovation organises, co-ordinates and implements research. A semi-autonomous federal agency (public corporation) under the Ministry of Agricultural and Food Supply, Embrapa dominates agricultural R&D (Lopes, 2012). In Indonesia, the Agricultural Research Committee takes care of strategic planning, while the Indonesian Agency for Agricultural R&D is in charge of research (Subagyono, 2012).

Higher education is dominated by public, often regional, universities, which may receive some private funding. In some countries, there are both agricultural universities and agricultural departments in general universities. Public universities are generally under the umbrella of the ministry of education. In France and the Netherlands, higher education agricultural colleges are funded by the ministry in charge of agriculture. In many countries, more applied agricultural education is taking place in public and private, technical schools.

Extension systems display a wide diversity across countries or regions. They generally operate at sub-national level, and include very diverse actors: government agencies, education institutions, upstream and downstream industries, NGOs, consultants and farmers' organisations. They provide an increasing number of services ranging from technical and financial advice to implementation of policy. For example, Produce Foundations in Mexico were established to implement the *Allianza* programme. In the European Union, the Farm Advisory Service was originally introduced to help farmers implement cross-compliance, and covers now broader issues. It is co-funded at EU and national levels.

Table 2.1 identifies four main types of institutions and funding systems, which can co-exist in some countries. Some extension systems are totally financed by public funds and managed by the state, often through regional organisations. There are totally private systems (e.g. in the Netherlands or New Zealand) where farmers pay for a service and choose the service provider on a commercial basis. There are mixed systems where services are provided by state institutions and private consultant firms and farmers pay part or the whole cost. Finally, there are systems co-managed by farmers' organisations (e.g. France and Finland), with funding from the government, farmers' organisations and individual farmers (Laurent et al., 2006).

Table 2.1. Advisory services in OECD countries

	Main institutions	Source of funds	Countries
State-run	Public organisations at regional and national level	Wholly financed from public funds	Belgium, Italy, Greece, Slovenia, Sweden, Germany's southern regions, Spain, Portugal, Luxembourg, Japan, United States
Public private service	Increasingly provided by private consultant firms	Farmers partly or wholly pay for services; centralised and decentralised	Canada, Ireland, Czech Republic, Poland, Slovak Republic, Hungary, Estonia, Australia, Chile
Farmer organisations	Farmers' organisations	Membership fees and payments by farmers	Austria, France[1], Denmark, Finland, north-west regions of Germany, Norway
Commercial	Commercial firms or private individuals	Payment through project implementation or grants	England, Netherlands, north-east regions of Germany, New Zealand

1. In France, extension (farm advisory) services are provided primarily by the Chamber of agriculture, which are consular chambers (public institution that represents the interests of private actors) managed by representatives from the sector and funded by an additional tax on undeveloped land (50%), by contracts with different levels of governments and by clients.

Source: Adapted from Laurent et al. (2006), using responses to OECD questionnaire (www.oecd.org/agriculture/policies/innovation).

2.2 General trends in Agricultural Innovation Systems institutions

In recent years, many countries have reviewed their agricultural knowledge systems and moved away from supply-driven innovation towards a more interactive, demand-driven AIS approach, in response to concerns about: lack of adoption of innovation by farmers; the ability of AIS to meet emerging and pressing challenges; budget pressures; and issues related to the acceptance of innovation by consumer and civil society.

Mechanisms to develop a **strategy**, set priorities and co-ordinate agricultural research have been strengthened, and sometimes made more inclusive. In Australia, for example, a National Primary Industries R&D and Extension Framework was defined in 2009 with all stakeholders (National and State governments, CSIRO, Research and Development Corporations, Council of Deans), under the auspices of the Primary Industries Ministerial Council (Grant, 2012). The Indian Council of Agricultural Research plans, co-ordinates and promote agricultural innovation. It has established a Directorate of Knowledge Management in Agriculture within the ministry in charge of agriculture to ensure agricultural knowledge access for all (Venkatasubramanian and Mahalakshmi, 2012). In South Africa, the Agricultural Research Council (ARC) was created in 1990 through the amalgamation of 15 government specialised institutes and in 1992, it was formally separated from the Department of Agriculture (DoA) and established as a publicly owned and funded agency charged with basic research, technology development and technology transfer (OECD, 2006a).

Mechanisms to **monitor and evaluate** national AIS are being developed and implemented. In Australia and Brazil, net returns of R&D agencies are published annually. Independent reviews and evaluation of impacts are being carried out regularly for Embrapa activities in Brazil and on an *ad hoc* basis in Chile and Mexico. In Indonesia, the Assessment Institute for Agricultural Technology (AIAT) assesses research results, monitors implementation and reports feed-back from users. In Japan, the ten-year programme plan includes targets to facilitate assessment (Subagyono, 2012). The Collaborative Working Group on Agricultural Innovation and Knowledge Systems (CWG-AKIS) of the Standing Committee on Agricultural Research (SCAR) has carried out a preliminary analysis of Agricultural Knowledge Systems in a number of European countries (EU-SCAR, 2012). However, lack of data, targets and systematic evaluation of national AIS makes it difficult to compare performances across countries (Annex A). Research agencies, services and researchers are generally evaluated on a regular basis and discussion is on-going on the criteria used to evaluate them. They are often based on academic merits (e.g. number of publication in top journals) and this does not encourage more applied research and development activities, or non-core activities such as information dissemination and networking. The development of project- or output-based research, which is more prone to evaluation, has spread the culture of evaluation in the system.

Institutional changes have generally aimed at increasing **co-ordination** at national level both within the AIS and between the AIS, other related domains and the general innovation system. Some countries have merged or strengthened links between agricultural R&D and higher education institutions. Examples are: Denmark around the Universities; France with mixed technological units at the local level, mixed technological networks at national level, and the Agreenium research consortium which groups agricultural research agencies and agricultural colleges (schools) (Bergeret, 2012); the Netherlands which merged applied research and university into Wageningen UR; Flanders with the Platform for Agricultural Research founded in 2004; and Turkey with the Agricultural Research Advisory Board which brings together parts of the agricultural ministry, relevant science departments of universities, farmers' organisations, and Chamber of professional organisation (EU SCAR, 2012).

In most countries, agricultural R&D remains mainly funded by public expenditure (Figure 2.2). Public funding for agricultural research institutes is often national (federal), while research carried out in universities may be partly or totally funded by regional governments (e.g. United States). Public funds generally cover operational costs and basic research, as well as part or all costs of project-based research. Increasingly, public research institutes also receive funding from other sources, including charitable foundations, user fees, industry contracts, or producer levies. In many countries, public funds are increasingly granted for projects or programmes conducted in various types of government and non-government organisation, often with matching funds from other stakeholders, whether through competitive processes or not. Public-Private Partnerships (PPP) often fund projects with relatively short-terms prospects for marketable results. While in most countries, there are funds earmarked for agricultural projects, agriculture competes with general innovation projects for public funding in Chile and New Zealand (Falloon, 2012). The public research mandate has been broadened to include environmental, food and other issues, in particular in developed countries, reducing funds available for productivity-oriented research. While primary agriculture used to be the main focus of traditional agricultural knowledge systems, more attention is now given to innovation along the food chain and to non-technological innovations, e.g. institutional or marketing innovations.

The private sector is increasingly involved in R&D activities that have high potential market returns, such as biotechnology. Agricultural input industries account for about 45% of total agricultural R&D and are the major source of new crop varieties, crop protection chemicals, and livestock and animal breeds. Private R&D is concentrated in a relatively small number of large multinational firms with global R&D and marketing networks (Fuglie et al., 2011).

Among mechanisms to fund research, partnerships between public research and the private sector are being developed, including with local industries. To avoid crowding-out, mobilise extra funding and better understand users' demands, governments have encouraged public research to engage in **Public-Private Partnerships (PPP)** for specific projects. The cost of research infrastructure (e.g. gene sequencing) is increasing and collaboration is attractive to overcome investment constraints. These partnerships have been favoured by a strengthening of Intellectual Property Rights (IPRs), but also by the increasing share of public funds dedicated to "output-driven" projects replacing, to a still limited extent in most cases, funding granted on a permanent basis to research institutions. For example, most public expenditures on agricultural R&D in New Zealand now goes to Primary Growth Partnerships schemes, with 50-50 matching funds from the industry (Falloon, 2012). Government expenditure for these partnerships has tripled between 2010 and 2011.[1] In Australia, a significant proportion of government expenditure on rural R&D is conducted through research and development corporations (Grant, 2012). They were established in 1989 as a co-investment model under which an agricultural industry, and in particular individual farm business, agrees to contribute to R&D for the long term benefits of the sector. From 2008 to 2009, these R&D corporations spent a total of AUD 470 million on R&D, of which around 45% was matched by public funds. Australian Co-operative Research Centres (CRC) are also partnerships, with particular emphasis on applied research. They account for 6% of government expenditures on agricultural R&D accounted for in the PSE/CSE database. Chile also places a large emphasis on PPP and competitive funding for agricultural R&D. In the Netherlands, InnovationNetwork aims to develop new ideas and ground-breaking innovations by working on projects with an extensive network of parties (EU SCAR, 2012, Box 5.15).

International and cross-country co-operation is also being strengthened. The reform of the CGIAR, in particular the creation of a consortium, aims to strengthen its ability to co-ordinate activities within the 15 member centres and other partners within the framework of the GCIAR Research Programmes (CRPs). In addition, partnerships have become broader, funding has increased, and research agendas are now more results-oriented (CGIAR Consortium, 2012). A number of networks have recently been created to improve international co-operation, e.g. Global Research Alliance on Agricultural Greenhouse Gases and the Knowledge-Based Bio Economy (KBBE) Forum in 2009 (Fallon, 2012); and regional co-operation, e.g. INNOVAGRO for Latin America in 2011 (Deschamps, 2012). G20 Ministers have supported existing international initiatives to improve agricultural innovation, in particular in developing countries, and launched new ones (Chapter 5).

Developments in **extension services** include a decentralisation of public services and the emergence of private actors (Laurent and Labarthe, 2011). Lesser government involvement in the delivery of extension services has permitted the emergence of other intermediaries in this area. Innovation brokers have emerged in some countries. They articulate the demands of farmers for research and help them to access technology, or are associated with creating linkages in value chains (Hall, 2012; Klerkx, 2012). In addition, efforts have been made to improve the **sharing of information and knowledge**, using Information and Communication Technology (ICT), e.g. the Knowledge Platform for Rural and Marine Affairs in Spain (Garcia-Fernandez, 2012) and Agricultural Technology Information Centres in India (Venkatasubramanian and Mahalakshmi, 2012).

At the same time, **agricultural education** has been neglected in many countries and is less attractive to young people, although there have been exceptions such as France. Insufficient human capital in the sector, and growing disconnection between farmer knowledge and research and extension, often result in lack of adoption of innovation by farmers. Some countries like New Zealand or India have reformed their agricultural curricula to adapt them better to market demand.

2.3. Trends in agricultural R&D and extension funding

In most countries for which data are available (Box 2.2), the public sector plays a major role in agricultural R&D, and R&D performed by government and higher education institutions accounts for 45% to 95% of total expenditures on agricultural sciences (Figure 2.2). This share is higher for agricultural sciences and agriculture R&D than for total R&D (Annex Table B.1). The share of agricultural R&D performed in government and higher education institutions remained stable over the last two decades in the United States, at 45%, the Czech Republic at close to 70%, and Argentina, Iceland and Poland at around 90%. It decreased in some countries over the last decade, reflecting the stronger involvement of the private sector, but also the decrease in public R&D in Australia and Portugal (Annex Table B.4). This share increased in some transition economies, where public effort had decreased in the 1990s during the transition period, as well as in China, where the decline in business R&D is over compensated by the increase in public R&D, and in Korea where R&D performed by business and higher education organisations both increase.

Public expenditures on agricultural R&D (in constant terms as measured government budget appropriations or outlays for R&D, GBAORD, in constant 2005 USD-PPP) increased between the mid-1980s and the mid-2000s in more than two-thirds of countries, for which data are available in the OECD R&D database (Table 2.2). However, they decreased in the late 2000s in half of OECD countries covered. In some countries (e.g. Finland and Slovak Republic) where public expenditure declined, however, expenditures on agricultural sciences R&D performed by government and higher education increases, probably because they receive more funds from the private sector (Annex Table B.4). Moreover, the decline in public expenditures can also be accompanied by an increase in private expenditures, as in Australia and Portugal, although not large enough to prevent total expenditures from decreasing. Changes in the number of full-time equivalent staff working in government and higher education institutions on agricultural sciences do not reflect exactly changes in expenditures, probably because staff resources take longer to adjust than financial resources (Table 2.3).

Box 2.2. Main databases on R&D effort

Trends in R&D funding and staff mainly come from the OECD database on R&D statistics,[1] which are comparable across countries, and with Eurostat data.[2] R&D expenditures include Gross domestic expenditure on R&D by sector of performance (Higher education, Government, business and private non-profit), by field of science and socio-economic objective, as well as Government budget appropriations or outlays for research and development (GBAORD) by socio-economic objective. The definition of agriculture as a field of science and as a socioeconomic objective is given in Box 1.2.

OECD data are complemented by information from Eurostat for some EU member states and from the Agricultural Science and Technology Indicators (ASTI) database for some emerging economies.[3] Government expenditures on extension and advisory services are drawn from the OECD database on support to agriculture.[4]

1. Available on OECD.stat, available at www.oecd.org/statistics, under theme Science, Technology and Patent, sub-theme Research and Development Statistics.

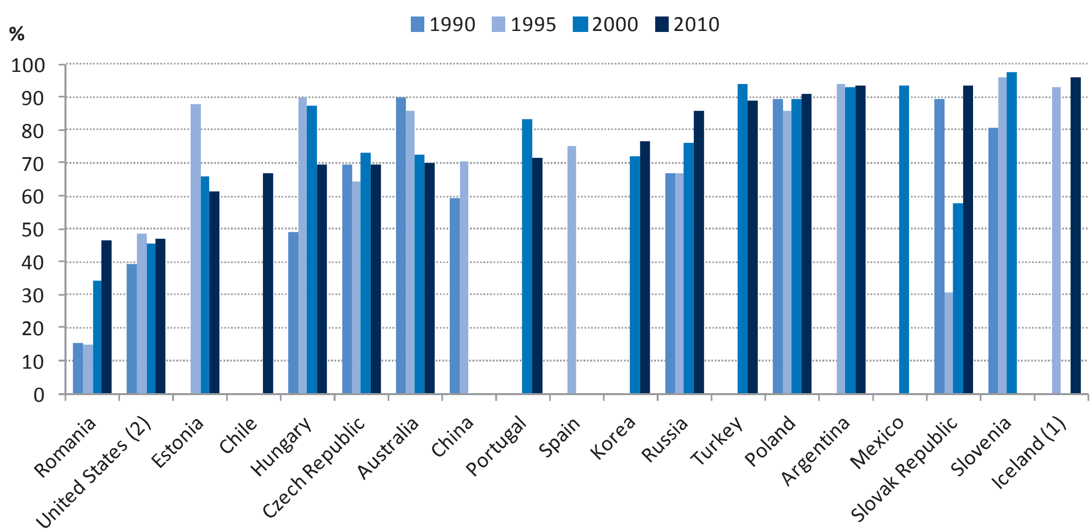
2. Available at epp.eurostat.ec.europa.eu/portal/page/portal/statistics/search_database, under Theme Science and Technology, sub-theme Research and Development.

3. Available at www.asti.cgiar.org.

4. PSE/CSE database available at: www.oecd.org/tad/agriculturalpoliciesandsupport/producerandconsumersupportestimatesdatabase.htm.

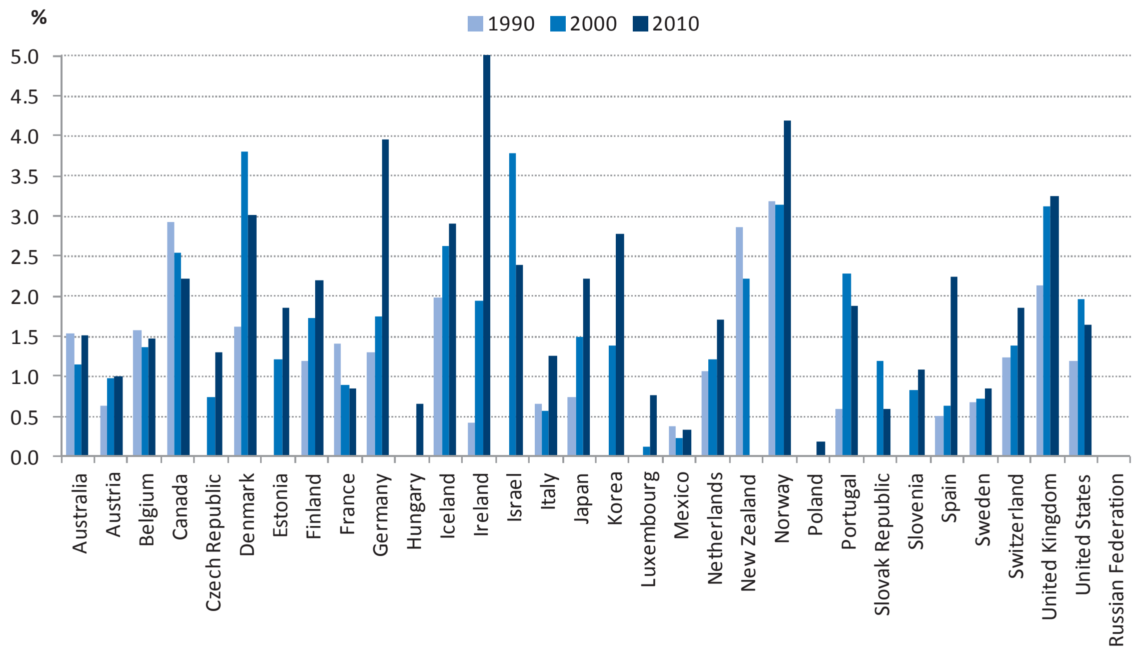
Figure 2.2. Share of expenditures on agricultural sciences R&D performed by government and higher education institutions

As a percentage of all R&D expenditures on agricultural sciences



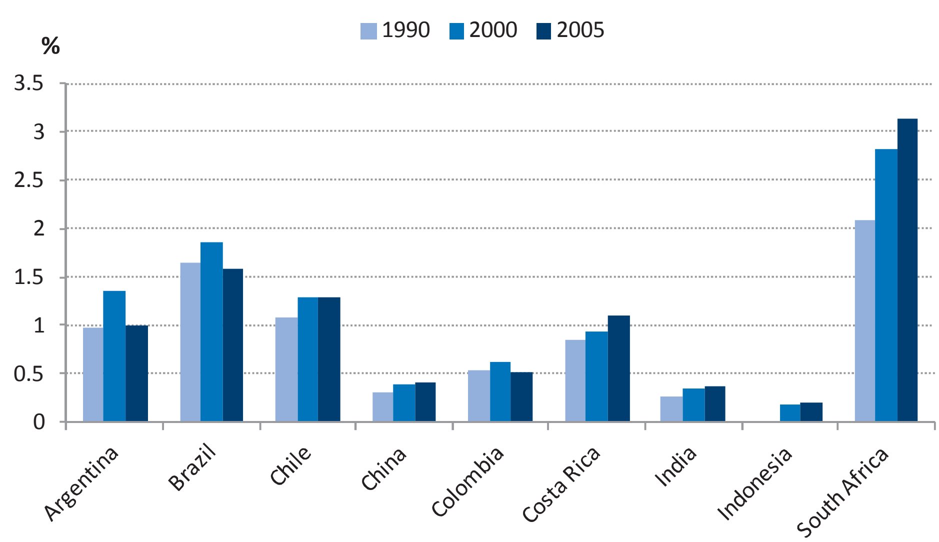
Note: * Irrespective of the origin of funds. See definitions of agricultural R&D in Box 1.2.
1. Eurostat. 2. USDA, R&D expenditures on agriculture as a socio-economic objective.
Source: OECD R&D database in OECD.stat. (Annex Table B.1).

Figure 2.3. Government budget appropriations or outlays for R&D (GBAORD) on agriculture as a % of agricultural gross value added



Note: See definitions of agricultural R&D in Box 1.2.
Source: OECD R&D database in OECD.stat. (Annex Table B.2).

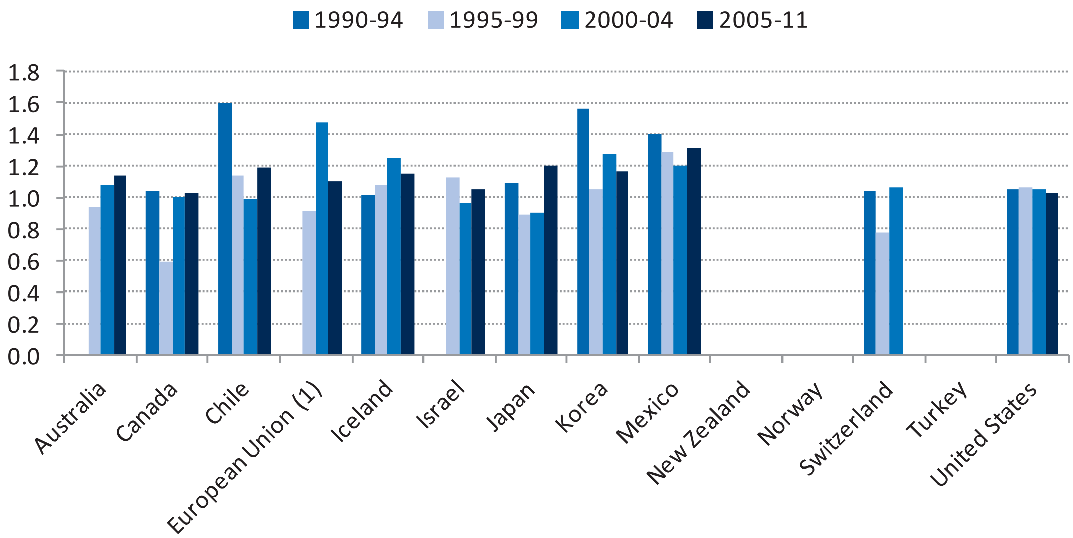
Figure 2.4. Public agricultural R&D expenditures as a percentage of agricultural GDP



Note: See definitions of agricultural R&D in Box 1.2.
Source: ASTI database.

Figure 2.5. Government expenditures on extension services

Annual % growth rate, by period, based on USD-PPP 2005



Note:

1. EU15 from 1995 to 2003; EU25 from 2004 to 2006; and EU27 from 2007 to 2011. For the European Union, 2000-03 instead of 2000-04; and 2007-11 instead of 2005-11.

Source: OECD, PSE/CSE database, 2012.

The share of public expenditures on agricultural R&D as a percentage of agricultural gross value added (GVA) [2] varies greatly among OECD countries, from less than 0.5% in Mexico to over 7% in Norway (Figures 2.3 and 2.4, Annex Tables B.2 and B.3). It generally increased since the 1990 in most OECD countries, with the exception of Canada, France, Israel, Mexico, New Zealand, and the Slovak Republic. With the exception of Brazil, Costa Rica and South Africa, it is below 1% in emerging economies, and even below 0.5% in China, India and Indonesia. In the food industry, R&D intensity, i.e. R&D as a percentage of net sales, is 1.7%, half that of all sectors (Table 2.4). It is higher in Japan and the European Union than in the United States. Biotechnology is the industry with the highest R&D intensity (over 20%). Annex Box C.1 contains more detailed information on innovation in agri-food enterprises in selected EU member states.

Government expenditures on **extension services** in OECD countries, where they exist, continued to increase at an annual growth rate of 1% or more (USD-PPP 2005). This rate slowed down in the European Union, Iceland, Korea and the United States in the second part of the 2000s compared to the first part, but increased in Australia, Chile, Israel, Japan and Mexico (Figure 2.5).

Table 2.2. Changes in government budget appropriations or outlays for R&D on agriculture

	1984-86	1989-91	1994-96	1999-2001	2004-06	2009-11	2009-11/ 1984-86	1994-96/ 1984-86	2004-06/ 1994-96	2004-05/ 1984-86	2009-11/ 2004-06
	2005 USD Million - Constant prices and PPPs						Annual growth rate in percentage				
Australia	240	209	256	253	327	312	1.2	0.6	2.8	1.8	-1.0
Austria	36	41	46	45	37	40	0.4	2.7	-2.1	0.1	1.9
Belgium	85	75	59	52	30	33	-2.4	-3.1	-4.9	-3.2	2.1
Canada[1]	675	584	544	543	501	429	-1.5	-1.9	-0.8	-1.3	-2.9
Czech Republic	n.a.	n.a.	n.a.	n.a.	58	69	n.a.	n.a.	n.a.	n.a.	3.8
Denmark	52	74	67	121	74	58	0.5	2.9	1.1	2.2	-4.3
Estonia	n.a.	n.a.	n.a.	n.a.	12	14	n.a.	n.a.	n.a.	n.a.	3.8
Finland	61	79	78	78	97	92	2.0	2.7	2.5	3.0	-1.0
France	633	755	609	404	334	319	-2.0	-0.4	-4.5	-2.4	-0.9
Germany	348	470	520	471	400	777	4.9	5.0	-2.3	0.8	18.8
Greece	77	61	48	44	48	36	-2.1	-3.9	0.1	-1.9	-5.0
Hungary	n.a.	n.a.	n.a.	n.a.	100	39	n.a.	n.a.	n.a.	n.a.	-12.2
Iceland	9	13	13	17	17	21	5.2	4.2	3.3	4.5	4.3
Ireland	35	24	54	69	73	106	8.1	5.5	3.5	5.5	8.9
Israel	n.a.	n.a.	87	88	85	87	n.a.	n.a.	-0.3	n.a.	0.4
Italy	320	270	197	202	395	338	0.2	-3.9	10.1	1.2	-2.9
Japan	n.a.	514	614	828	924	1 020	n.a.	n.a.	5.0	n.a.	2.1
Korea	n.a.	n.a.	n.a.	488	663	860	n.a.	n.a.	n.a.	n.a.	5.9
Mexico	n.a.	255	81	107	165	165	n.a.	n.a.	10.4	n.a.	0.1
Netherlands	144	164	160	148	236	175	0.8	1.1	4.8	3.2	-5.2
New Zealand[1]	n.a.	111	114	125	116	120	n.a.	n.a.	0.2	n.a.	0.7
Norway	83	111	107	108	134	143	3.0	2.9	2.6	3.1	1.4
Poland[2]	n.a.	n.a.	n.a.	n.a.	13	37	n.a.	n.a.	n.a.	n.a.	36.1
Portugal	41	76	81	154	139	98	5.6	9.7	7.1	11.9	-5.8
Slovak Republic	n.a.	n.a.	41	33	25	24	n.a.	n.a.	-3.8	n.a.	-1.3
Slovenia	n.a.	n.a.	5	9	7	13	n.a.	n.a.	3.6	n.a.	16.9
Spain	129	209	172	219	604	708	17.9	3.3	25.1	18.4	3.4
Sweden	48	46	36	40	61	43	-0.4	-2.4	6.7	1.3	-5.8
Switzerland[3]	78	59	26	45	48	43	-1.8	-6.7	8.7	-1.9	-2.4
United Kingdom	643	480	528	463	437	428	-1.3	-1.8	-1.7	-1.6	-0.4
United States	1 688	1 807	2 098	2 436	2 593	2 240	1.3	2.4	2.4	2.7	-2.7
Argentina[1]	n.a.	n.a.	212	190	266	503	n.a.	n.a.	2.6	n.a.	17.8
Russian Federation[4]	n.a.	n.a.	920	451	n.a.	229	n.a.	n.a.	n.a.	n.a.	n.a.

Note: n.a.: Not available. See definitions of agricultural R&D in Box 1.2. Agriculture as a socio-economic objective includes R&D expenditures directed at the food industry.
1. 2009-10 instead of 2009-11; 2. 2008 instead of 2009-11; 3. Average of 2009 and 2011 instead of 2009-11; 4; 2009 instead of 2009-11.

Source: OECD R&D database in OECD.stat. (Annex Table B.4).

Table 2.3. Changes in agricultural R&D staff

Annual growth rate of full-time equivalent person on agricultural sciences R&D performed in government and higher education institutions

	1995 to 2000	2000 to 2005	1995 to 2005	2005 to 2010	Notes
Australia	2.0	-3.3	-1.3	n.a.	1996, 2006
Austria	3.7	3.5	3.1	2.6	1998, 2002, 2006, 2009
Belgium	0.0	-2.5	n.a.	2.0	2009 instead of 2010
Czech Republic	-4.1	11.8	2.7	1.9	
Denmark	-2.1	-2.9	-2.0	2.8	1997, 2000, 2005, 2009
Estonia	n.a.	n.a.	n.a.	5.1	
Finland	1.8	1.4	1.7	-2.0	2009 instead of 2010
Germany	-1.7	-2.6	-2.0	0.8	2009 instead of 2010
Hungary	8.2	-3.2	1.8	1.3	2009 instead of 2010
Iceland	1.4	-1.9	n.a.	n.a.	
Ireland	n.a.	-5.1	n.a.	6.2	2002, 2005, 2009
Italy	n.a.	n.a.	n.a.	3.4	2009 instead of 2010
Japan	n.a.	24.5	n.a.	0.1	2001, 2005, 2007
Netherlands	n.a.	n.a.	n.a.	-8.4	2007, 2009
Norway	n.a.	1.4	n.a.	-2.8	2001, 2005, 2009
Poland	-2.1	-3.7	-2.7	-7.5	2009 instead of 2010
Portugal	1.0	-3.7	-1.4	-5.5	2009 instead of 2010
Slovak Republic	-17.4	12.0	-5.1	10.2	1996 instead of 1995
Slovenia	1.6	4.0	2.6	-11.8	1997, 2000, 2005, 2009
Spain	10.1	3.1	7.3	4.2	2009 instead of 2010
Romania	-16.0	16.4	-3.5	-6.8	1996, 2000, 2005, 2009

Note: n.a.: Not available. See definitions of agricultural R&D in Box 1.2.
Source: OECD R&D database in OECD.stat.

Table 2.4. Industry R&D as a percentage of net sales, by sector

Sector	Overall sector R&D intensity	EU sector R&D intensity	US sector R&D intensity	Japan sector R&D intensity
Beverages	1.1	0.5	0.8	0.8
Biotechnology	20.9	15.8	22.8	0.0
Food & drug retailers	0.4	0.3	0.4	0.4
Food producers	1.7	1.9	1.4	2.3
Total above	**2.3**	**1.2**	**3.7**	**1.5**
Software and computer services	0.6	10.6	10.5	5.8
Leisure goods	6.2	6.4	8.4	5.9
Chemicals	3.1	2.7	2.8	4.3
Total all sectors	**3.3**	**2.5**	**4.7**	**3.8**

Note: The survey includes the 1 400 largest R&D performers worldwide.
Source: The 2011 EU industrial R&D Investment scoreboard. European Commission, JRC/DG RTD (iri.jrc.ec.europa.eu/research/scoreboard_2011.htm).

Notes

1. See New Zealand PSE/CSE database at: www.oecd.org/tad/agriculturalpoliciesandsupport/producerandconsumersupportestimatesdatabase.htm.

2. Public R&D expenditures on agriculture may include some funding that is directed at food processing, which is not included in agricultural gross value added.

Part II.

The role of government in agricultural innovation

The OECD innovation strategy distinguishes policies and regulations to strengthen innovation in firms. This includes general framework conditions, incentives to entrepreneurship and support for innovation in firms, and policies that foster public and private investment in R&D and innovation. Chapter 3 examines general policies that affect the socio-economic and business environment for innovation, from macroeconomics to health and education policy, to business regulations. While the discussion remains general, their effect on innovation in agri-food firms and farms are examined more closely (e.g. credit, investment, tax, trade, health and education policy). Nevertheless, in some countries, specific conditions apply to the farm sector, as mentioned in Chapter 4 which considers the role of agricultural policies on innovation. Chapter 5 examines the different aspects of innovation policy in general terms and with specific references to agricultural innovation systems.

Chapter 3

Economy-wide policies and innovation

This chapter examines general policies affecting the socio-economic and business environment for innovation, from macroeconomics to health and education policy, including business regulations. Although the discussion remains general, how these policies affect innovation in agri-food firms and farms is more closely examined.

At the broadest level, strong socio-economic governance systems and stable **macroeconomic** policies, leading to high growth, low and stable inflation rates, play an important role in setting a favourable environment for investment in farms or agri-food firms seeking to introduce new products, to adopt new production methods or to undertake organisational changes (OECD, 2010a).[1]

Possible questions on the macroeconomic situation

- What are main structural challenges affecting economic and productivity growth prospects, including in the agri-food sector? What is the role of food and agriculture in the economy?

Possible indicators: GDP, private and government consumption, gross fixed public and private capital formation, foreign direct investment (FDI), domestic investment, inflation, total factor productivity (TFP), current account balance, exports and imports, unemployment rate, all expressed in year-on-year percentage changes; share of agriculture in the economy (GDP, employment), broken down by primary agriculture, upstream and downstream industries; imports and exports of the major agriculture commodities and food products.

Good governance systems and high-quality institutions provide economic actors with the assurance that the government is accountable, transparent and predictable. They are a fundamental pre-condition both to encourage public and private investment in the economy and to enable those investments to achieve the intended benefits, both for investors and the host country. Moreover, governance systems play an important role in addressing market failure, influencing the behaviour of firms as well as the efficient functioning of input and output markets.

The **regulatory environment** affects innovation in many ways. It influences the size and behaviour of firms, as well as input and output markets. The government plays an important role in setting standards and decreasing administrative burden. Regulations aim to respond to market failures and improve welfare. Regulations are inherently linked to reducing risks for economic agents and the environment, while innovation is about taking risks.[2] To balance risk and innovation, governments should promote innovation through market incentives and goal-based approaches when developing good regulation. They should also develop risk assessment and management tools. Inappropriate regulations may delay scientific advancements, prevent technology transfer and impose excessive transaction costs on organisations. Regulations affect **entrepreneurship** such as condition for entry and exit (bankruptcy), and regulatory burden influence firms' decision to invest in innovation. Heavy business regulation will limit changes in production and marketing systems. Low entry and exit costs help innovative start-up companies to develop. Definition and enforcement of property rights is essential to private investment. Measures to reinforce enforcement of contracts also contribute to improve the business environment and make it more conducive to innovation. Regulations in a number of policy areas affect innovation. Of particular importance for innovation is **Intellectual Property Right (IPR)** protection, which allows private investment in innovation to yield market returns and is discussed in Chapter 5. Agriculture-specific regulations and tax measures are discussed in Chapter 4.

Possible questions on governance and regulatory environment

- To what extent are rules and the regulatory process transparent, clear and predictable to domestic and foreign parties? How are regulatory impacts assessed when developing new and reviewing existing regulations? Do these assessments take into consideration impacts on rural areas or the agriculture sector?

Possible indicators: Doing Business Indicators (registering property, enforcing contracts).

Policies or regulations that ease the functioning of **financial markets** also facilitate investment in innovation, including those governing capital venture and foreign direct investment (FDI). Low interest rates in particular facilitate innovation in firms because they lower the price of investment and R&D capital (OECD, 2010a). Stock markets play an important role in entrepreneurship and innovation. Efficient financial markets can help allocate capital to innovative and high-return projects, including in the agricultural and agri-food sector. Improving financial reporting in firms would improve access to capital by helping investors to better assess future earnings and investment risks, thereby securing funding at lower cost of capital for innovative firms. Credit guarantees by government facilitate access of external finance as it acts as an insurance to lenders against risk of default, but evidence is scarce and mixed. Venture capital[3] is an important source of funding at the seed, start-up and growth phases of innovative firms in high growth sectors. Government support for venture capital should focus on areas where risks are higher, i.e. smaller firms, early stage of development and new areas for which other sources of finance are hard to access (OECD, 2010a). Business angels[4] also play an important role in financing early stages. The number of business angel networks is increasing in many OECD countries.

Possible questions on policies and regulations affecting financial markets

- What is the state of competition in the formal financial sector, including in rural areas? What types of financial products are offered to small, medium and large enterprises, including agricultural and agri-food firms?

Possible indicators: Enterprise survey data on firms seeking finance (by sector) and success rates; share of households with access to a bank account; survey data on the share of households that used formal financial institutions to borrow.

Tax policy is used to finance public expenditures, including for investment in R&D, and to address socio-economic objectives. It affects the decision of firms and households to save or invest in physical and human capital, and thus affect innovation. Some countries directly target innovation by offering preferential tax treatment to investments in private R&D or to young innovative companies. Tax policy can also provide incentives to move to different (greener) technologies and practices, granting for example tax rebates for environmental R&D (OECD, 2012c), or for the purchase of environmentally-friendly products (cars), or taxing more heavily polluting technologies (Polluter-Pays-Principle). In addition to its economy-wide impacts, tax policy affects the number and size of agri-food firms and farms, organisational structure, and the amount and relative mix of land, labour, and capital inputs. In some countries, specific tax provisions apply to agricultural income and assets (Chapter 4). R&D tax provisions can also be considered as part of innovation policies discussed in Chapter 5.

Possible questions on tax policy

- What tax arrangements apply to business, including agricultural and agri-food firms, that might encourage or discourage investment (income, property, sales, import and export taxes)? Are there specific tax incentives for investment in R&D?

Possible indicators: Tax rates; preferential rates; number of beneficiary firms.

Competition policy also affects innovation. On the one hand, competition encourages companies to innovate to catch up with, get or stay ahead of competitors; on the other hand, some market power may stimulate investment in innovation by facilitating the recovery of related expenses and facilitating financial risk management. Competition policy must strike a balance to provide adequate rewards to innovation and encourage collaboration, while ensuring competitive pressure that encourages firms to create, implement and diffuse innovation (OECD, 2006b). Competition policy should also allow for collaboration, which is essential in complex innovation areas like biotechnology. In particular, compulsory licensing as an anti-trust remedy should be considered with care, as it could discourage further innovation. Collaboration by producers can have either beneficial or harmful effects. Farmer co-operatives have the potential to serve pro-competitive purposes and to increase efficiency, while joint activities can harm consumers when it focuses on price- or quantity-setting and there is relatively little competition from close substitutes (i.e. cartels). Competition authorities thus have a beneficial role to play in the agri-food sector.

Possible questions on competition policy

- To what extent does competition policy promote and protect the competitive process? Are input and output markets competitive? What are the responsibilities of the agency in charge of the administration and enforcement of the competition law? Do these general rules apply equally to agricultural and agri-food firms?

Possible indicators: OECD Product Market Regulation (PMR) indicators; OECD competition law and policy indicator.

Openness to **trade and investment** is also conducive to innovation as it provides a larger market for innovators and consumers, and favours economic growth and job creation. It also facilitates the spread of knowledge, technologies and practices via imports of goods and services, investment flows, mobility of workers and cross-country collaboration in research and innovation (OECD, 2006b). International mobility of skilled researchers, multinational firms and open innovation are important channels for knowledge transfer. Weak restrictions on Foreign Direct Investment (FDI) can help cross-border innovation transfers (Jaumotte and Pain, 2005). The importance of international spillover for innovation does not mean countries should not invest in R&D. Spillover requires in particular well-trained specialists in every country. However, some specialisation and exploitation of complementarities could be efficient. Trade policies also influence innovation in upstream and downstream industries in the agricultural supply chain through their implications for the cost of sourcing inputs internationally and domestically.

Possible questions on trade policy

- To what extent do trade measures restrict trade? To what extent are customs and border procedures designed and implemented to provide consistency, predictability, simplicity and transparency?

Possible indicators: Trade openness (total exports and imports of goods and services as a share of GDP); Most-Favoured Nation (MFN) tariffs; trade as a share of GDP; index of the burden of customs procedures; OECD Product Market Regulation (PMR) Indicators.

Possible questions on investment policy

- Are the laws and regulations dealing with investments and investors clear, transparent, readily accessible and avoid imposing unnecessary burdens on businesses and on society? Does the government have mechanisms to periodically review the costs of investment restrictions (promotions) against their intended purpose? What mechanisms for dispute settlement have been established to ensure the widest possible scope of investor protection at reasonable cost?

Possible indicators: FDI stocks as a share of GDP; OECD FDI Restrictiveness Index; OECD Product Market Regulation (PMR) indicators; domestic and foreign investment inflows (agriculture, manufacturing and services); incremental capital output ratio (agriculture, manufacturing and services).

Investments in physical and knowledge **infrastructure**, from information, communication, water and electrification systems to transportation facilities, are important for overall growth and development as they improve the business and innovation environment, and facilitate domestic and foreign trade (see discussion on knowledge infrastructure in Chapter 5). They are vital to the delivery of and access to important social services, such as health and education, and play a critical role in better linking farmers to markets, encouraging investment in innovative techniques and products, reducing food waste, boosting agriculture productivity, and raising profits.

Rural development policy that improves **rural and marketing infrastructure**, in particular transport and communication infrastructure, would also facilitate the functioning of input and output markets: it would lower transport costs for purchased inputs and agricultural products, improve access to input and consumer markets and thus increase investment in agricultural innovation. Irrigation infrastructure is of particular relevance to agriculture, which is often a major user of irrigation water.

Broader rural development measures also affect agricultural innovation. Off-farm work opportunities in rural labour markets increase farmer's choice of production systems, mitigate income risk and facilitate farm investment. Rural policy also includes the provision of services such as banking, mail, and high speed communication, which are essential for business operations. The provision of ICT services is particularly important as it allows better access to information on markets and technologies, among other things. Rural policy can also attract innovative upstream and downstream industries, and play a role in enhancing local reputation, which can benefit agricultural products. By reducing inequalities in economic development and access to services across regions, rural development policies improve the diffusion of innovation.

Possible questions on infrastructure and rural policy

- How are infrastructure priorities identified and implemented? Does the government have clear guidelines and transparent procedures for the disbursement of public monies, including for agriculture-related infrastructure? Does it provide incentives to attract private investors to invest in infrastructure projects, such as secondary roads? Are there specific guidelines in place that govern public-private partnerships for infrastructure projects?
- Is specific consideration given to the needs of rural areas or the agriculture sector? How easy is it for producers and other actors in rural areas to access information about futures markets, input suppliers and customers and buyers?
- Are there mechanisms in place to ensure coherence across infrastructure, rural development and agricultural policies?

Possible indicators: Infrastructure competitiveness index (quality of port infrastructure); container port traffic; coverage of rural infrastructure: road density, irrigation, electricity, ICT (telephone, broad-band communication systems), wholesale markets; coverage of public services: banks, mobile phone, mail, education, health, etc. (% of territory or population covered; service per inhabitant).

Labour market policy affects employment composition, facilitates labour mobility across sectors, and influences production choices (i.e. rigid labour policies may restrict labour mobility). It can also play an important role in facilitating structural adjustment, including through farm consolidation, when offering off-farm job opportunities to excess labour in farming. Similarly, policies affecting markets for other factors of production will affect the type of innovation developed and adopted in terms of its impact on input mix. Farm innovation in particular will be affected by **land** policy and land ownership systems, such as inheritance laws, land tax provisions and regulations on land transactions, which can have specific provisions for farm land in some countries (OECD, 2005).

Possible questions on labour and land policies

- Are there specific initiatives to create new jobs and assist labour adjustment from declining to growing sectors? To what extent do migration rules and procedures ensure labour market demand is met?
- What are the rules governing land ownership and land transactions? Are there specific rules for agricultural land?

Possible indicators: index of employment protection legislation (EPL); emigration rate of tertiary educated as a share of total tertiary educated; share of rented agricultural land; number of transactions as a share of total agricultural area.

Education policy affects innovation in three main ways. First, a high level of general and scientific education facilitates acceptance of technological innovation by consumers and society at large. Second, innovation systems require well-educated researchers, teachers, extension officers, and producers to develop relevant innovations. Third, it is generally easier for producers with a good general, business and technical education to adopt some technological innovations. Fostering creativity and entrepreneurship in education is particularly important. Improving population **health** is also important: a healthy (and well-educated) workforce will also be more productive, have more employment opportunities and better income, and thus will be more flexible and prone to welcome innovation. More generally, investment in human capital is important for innovation.

Governments have a particularly important role to play in providing fair **information** to producers, consumers and society about the costs and benefits of innovations, which can be considered as part of innovation policy (Chapter 5). The following chapter illustrates the potential impact on innovation of **industrial or sectoral policy**, here agriculture.

Possible questions on education, health and information policy

- What are the characteristics of the education and training system? What is the place of science in formal education? Are there programmes to promote re-training?
- What are the characteristics of the public health system, in terms of coverage and accessibility? What mechanisms exist to evaluate public health expenditures and health outcomes?

Possible indicators: School enrolment in primary, secondary and tertiary education (% of gross); share of the labour force with tertiary education; labour force productivity (agriculture, manufacturing and services); total public expenditure on health and education as a share of GDP.

Consumer and environmental policies often have a strong regulatory component, aiming to protect consumers or the environment and facilitate acceptance of innovation by consumers and society (e.g. industry, health and environmental standards). These regulations have a strong impact on adoption of innovation. They may affect the adoption of specific production systems, through regulations on inputs, techniques and product characteristics. Some regulations on products and processes in particular can limit innovation if they are too prescriptive. This can be the case with restrictive measures that define production techniques too narrowly. Standards should encourage the private sector to innovate and apply the best technologies and approaches, without imposing specific ones, for example by targeting desired health or environmental performance, rather defining the method to obtain them. In developing an appropriate regulatory environment, experience has shown that generally, technology neutral, science-based approaches are most effective in diffusing innovation and least market distorting. Procedures to grant authorisation of inputs and outputs onto the market in particular should be transparent, based on independent scientific evidence and appropriate risk managements, and relatively short to facilitate innovation and acceptance by society. Environmental policy covers a number of issues with implications on agriculture, such as climate protection, preservation of biological diversity and sustainable energy policy, the conservation of forests, seas and soils, among others. Similarly, health regulations include food safety concerns.

Possible questions on consumer and environmental policies

- Do existing environmental policies, laws and regulations effectively ensure a sustainable use of natural resources, in particular by setting clear environmental standards, requiring independent environmental impact assessments and ensuring that the pricing of natural assets reflect their true scarcity value? Do they take into account the specificities of the agricultural sector?

Possible indicators: Total greenhouse gas emissions; land use and distribution data; water quality measures; share of total government expenditures allocated to the environment, broken down by category (i.e. spending on biodiversity, etc); private environmental expenditure; share of the population connected to public wastewater treatment plants; generation, export and import of hazardous waste; environmentally related tax revenues; energy sector support; pollution (CO_2 emissions from energy use, emissions of SOx and NOx); resource use (water abstractions, municipal waste per capita, material productivity, nitrogenous fertiliser use, pesticide use).

Notes

1. This chapter draws on the OECD innovation strategy (OECD, 2010a, b) for the general discussion, and on the progress report to the Mexican G20 Presidency that discusses best policy approaches to increasing agricultural productivity growth, sustainably, for the agricultural-specific discussion and the proposed questions and indicators.
2. Innovation in agricultural practices, however, help farmers control biological and climatic risks, e.g. irrigation or drought-resistant seed varieties.
3. Venture capital is a form of private equity. Returns on venture capital investment stem from a trade sale (sale to, or merger with, another company) or an initial public offering in which the company becomes authorised to sell its stock to the general public on a stock exchange. Venture capital funds will not only provide money but will mentor their investee firms (G20, 2012).
4. An angel investor is usually an experienced entrepreneur, who provides backing to very early-stage businesses or business concepts.

Chapter 4

Agricultural policies and innovation

This chapter discusses how agricultural domestic policies, trade policies and agriculture-related policies affect the adoption of innovation in this sector and facilitate the acceptance of agricultural innovation by consumers and society.

In addition to the general and business policy framework, which influences the creation and diffusion of innovation in private firms, including farms and agri-food firms, agricultural and rural policies affect more specifically farmers' willingness and capacity to invest and introduce innovation in production systems and the marketing of agricultural products. Some measures may also influence farmers' choice of product and input mix. Improving the innovative capacity of the farm sector would involve identifying obstacles to innovation, revisiting policies that hamper innovation, structural change and the functioning of output and input markets, and implementing measures to foster innovation and competitiveness.

Agricultural policy has various objectives, such as supporting or stabilising income, raising productivity and competitiveness, ensuring adequate supply of safe and healthy food, and improving the environmental and social sustainability of agriculture. Policy objectives and priorities vary by commodity, country and over time. Countries apply a diversity of trade and domestic policy measures and regulations to pursue their agriculture-related objectives. Policy measures include price support, maintained though domestic and trade measures, and direct payments to farmers based on input use, area or income, as well as investments in public services to the sector, including agricultural R&D, education, extension, and agricultural and rural infrastructure development. There is a wide diversity in the level and composition of support to agriculture across countries and over time and the extent to which different measures affect innovation at farm level (OECD, 2012a).

Among framework conditions, ensuring the agricultural trade and market environment is conducive to investment in agricultural innovation would imply reducing substantially trade and production distorting measures, improving market access, and disciplining export measures (G20, 2012). Policies and regulations that affect inputs markets are particularly important to foster farmers' access to innovative technologies. The market of land, capital or labour will influence the choice of technology. Innovation would be facilitated by the removal of impediments to the functioning of those markets and the implementation of appropriate competition, labour and investment policy to lower input costs, facilitate structural change, and strengthen investment in the agri-food sector.

4.1. Agricultural domestic policies

Domestic policies that support commodity **prices** and offer output-based payments, often encourage producers to invest in intensive commodity production,[1] but create market distortions (OECD, 2012b) and may prevent farmers from diversifying into other commodities or investing in added-value. **Commodity-specific area and headage payments** also focus investments into supported commodities. With **broader area payments**, market signals play a greater role in guiding farmers' choice of production, but the factor land is subsidised and this affects the choice of production system. Higher farm receipts facilitate investment, including for the development of more risky and innovative activities, but do not provide specific incentives to introduce changes.

More generally, the provision of any **income or investment support** is likely to positively affect farmers' capacity to invest. General income support, however, prevents competition and slows structural adjustment. To avoid crowding out market solutions and the slowing of structural adjustment, it should be targeted to specific market failures, such as under-provision of innovations to address problems related to the global commons. Targeted income support might help farmers overcome credit constraints and invest in technology, but it may also slow structural adjustment (see for example OECD, 2008a; 2011b).[2] Policies that facilitate structural adjustment could be envisaged to facilitate economies of scale, attract new entrants and thus foster innovation. Specific efforts could also help facilitate innovation and diversification of activities in small, pluriactive farms. Targeted assistance to investment on small-scale farms may also be warranted to overcome lack of market access to resources to innovate.

Farm input subsidies affects production practices, and thus innovation choice. For example, support to a specific input may encourage an input mix that will not necessarily be economically or environmentally sustainable. It would be more technology neutral to facilitate access to credit for the purchase of variable inputs. Similarly, credit support may be useful for farmers to invest in innovation in case of identified failure in credit markets. In any case, input subsidies should be temporary and regularly assessed not to impede the development of private markets (OECD, 2012c).

Innovation has a crucial role to play in ensuring the long-run **sustainability** of agriculture and the maintenance and enhancement of the underlying natural resource base – land, water and biodiversity (OECD, 2011b, 2013). A range of policy instruments should be employed that clearly target both the positive and negative environmental impacts of agriculture. Education, training and information initiatives, tailored to the specificities of local situations, can be helpful in many cases. Regulations and taxes should be employed, when possible, to preclude, or strongly discourage, negative environmental impacts (the "polluter pays principle"). Markets, such as the widely discussed carbon emissions and sequestration schemes, should be created where it is practical to do so. Government payments should be introduced where there is a clear demand for a good or service that is not remunerated by the market and where market creation is not feasible. In designing such payments, it is important to target explicitly the desired outcome to the extent feasible, so as to allow farmers to develop solutions best adapted to their circumstances. Policy measures should also help the sector adapt to climate change impacts, to mitigate greenhouse gases from agriculture, or to enhance carbon sequestration. This is, in particular, the case of many agri-environmental policies, such as those encouraging improved manure management to reduce run-off into water courses, adoption of anaerobic digesters, improved grazing land and livestock management, protection of fragile lands and restoration of degraded land, low or no-till systems that reduce soil erosion, afforestation of land for soil protection, flood/drought control or conserving biodiversity, and which can also have benefits in reducing GHG emissions. In addition, R&D on improved crop breeding and animal genetics and feeding systems can help to mitigate emissions and to facilitate adaptation to the impacts of climate changes. Innovation can also enable improved water management in agriculture (OECD, 2011f, 2012d).

Innovation involves some risk and there is a role for government in providing farmers with appropriate tools for managing risks. An effective policy framework for producer **risk management** should give due consideration to the full range of policies that affect farm risk and to the distinction between risks that a farm household can efficiently manage and those that require public support. Effective tools for risk management will be all the more important to ensure investments are made and innovations adopted as agricultural markets are expected to be more volatile in the future.[3] Government policies should take a holistic approach to risk management, assessing all risks and their relationship to each other, avoiding focussing on a single source of risk such as prices, and should not provide support to deal with "normal" risk. Governments can help farmers to assess and manage risks by providing information and training. Facilitating good "start up" conditions – information, regulation and training – should be the primary role of the government in the development of market-based risk management tools such as futures, insurance and marketing contracts. Agricultural risk management policies should focus on catastrophic risks that are rare but cause significant damage to many farmers at the same time. Contingency plans should define in advance the procedures, responsibilities and limits of the policy response. Subsidised insurance is one way of providing disaster assistance, but it tends to crowd out the development of private insurance markets and has not been successful in preventing additional *ad hoc* assistance being granted after the event (OECD, 2011c, 2011d).

Rather than supporting income, commodity production or input use, it would be more effective to develop specific measures to foster innovation, such as investment in R&D, agricultural education, training, technical advice, information systems covering market developments and most effective technologies adapted to demand, and transport, irrigation and marketing infrastructure.

Possible questions on agricultural domestic policies

- What are the main policy instruments in place? What are the resulting levels and composition of support to producers?
- What are the main obstacles to innovation in the agriculture and agri-food sector?
- What are the objectives of agricultural policy regarding innovation?
- Is impact on innovation at farm and industry level included in the evaluation of agricultural policy measures?
- Are there specific measures to improve adoption of innovation, e.g. credit for investment in farm-level innovation, incentives to adopt specific technologies, support to diversification of activities?
- Do some policy measures introduce disincentives to innovation (e.g. too tightly defined conditions, conditions based on processes, market distortions slowing structural adjustment)? What could be done to reduce policy-related obstacles to innovation?

4.2. Agricultural trade policies

Agricultural trade policy includes import restrictions (e.g. tariffs and tariff rate quotas), and export measures (e.g. export subsidies, export credit, export restrictions). Non-tariff measures, such as product and process regulations, and administrative border procedures, can also restrict market access and trade. Most trade measures maintain domestic prices at a higher level than border prices, and thus are an essential component of price support. Agricultural trade restrictions narrow markets for innovators and consumers. Reducing trade distortions would foster innovation by broadening market opportunities, and by increasing competition, which pushes farmers and agri-food industries to innovate to remain competitive. Trade also facilitates the spread of technologies and practices via imports of goods and services. Improving trade in farm inputs would also facilitate the adoption of new technology by lowering the price of variable inputs or farming equipment for example. Foreign investment in agriculture can help introduce new technologies.

Possible questions on agricultural trade policy

- What recent efforts has the government undertaken to facilitate cross-border agricultural trade, including within regional trade agreements, and by reducing regulatory and administrative border procedures and increasing consistency, simplicity and transparency? What steps has it taken to increase trade policy predictability?
- To what extent do inter-regional obstacles to trade affect the agri-food sector? How costly are these barriers? Do existing tariff and non-tariff barriers to trade contribute to hindering access to agricultural inputs and services or raising their costs?
- Are there specific restrictions on, or incentives for, foreign investment in agriculture?

4.3. Agriculture-related regulation

A number of regulatory issues are of particular importance for agricultural innovation, including IPR protection (discussed in Chapter 5), health and food safety regulations, and bio-safety regulations. For example, pesticides require government authorisation to be marketed, maximum levels of residues are set for the marketing of agricultural products, and regulations increasingly aim to improve animal welfare. But there are also safety rules regarding farm buildings and machineries. In some countries, labour and land regulations (and taxation) include specific provisions for agriculture (OECD, 2005). For example, relaxing restrictions regarding construction on farmland for farm buildings and agricultural related activities would facilitate investment in new activities. Another example is legal arrangements for farm enterprises, which can reduce risk for the farm family, and thus encourage innovation. In many countries, specific regulation applying to producer groups and co-operatives can reduce competition. Those institutions can influence positively or negatively adoption of innovation, depending on their behaviour.

In developing an appropriate sanitary and phytosanitary (SPS) regulatory environment, including implementation provisions, experience has shown that technology neutral, science-based approaches are most effective in diffusing innovation and least market distorting provided that care is taken to ensure agricultural specificities and societal choices are taken into account. Examples of regulatory practices in the European Union and the United States are given in Box 4.1 and Box 4.2. A variety of innovative approaches can help reduce the regulatory cost burden for governments. These include use of public private partnerships based on "best practices" in the way the SPS regulatory framework is managed, including the interface between private voluntary standards and compulsory compliance regulation. In general, the achievement of regulatory objectives mainly relies on adequate national practices supported by on-going harmonization towards best international practices, with the contribution, if necessary, of well-targeted capacity building in developing countries, including through mechanisms like the Standards and Trade Development Facility (STDF).

In this regard, the "three sisters", OIE (animal health), IPPC (plant health) and CAC (food safety), that are referenced in the WTO SPS agreement play an important role as standard setting organisations and early warning and response mechanisms. In complementing international harmonisation, regional co-operation can be a fruitful way to share practices.

Possible questions on policies and regulations affecting agricultural innovation

- To what extent are internationally harmonised standards used with respect to sanitary and phyto-sanitary requirements?
- How are regulations and standards affecting processes and products being established? Who provides scientific evidence? Who evaluates it? Who decides? How transparent is the system? How often are standards and norms being reviewed?
- Which mechanisms are used for approval of new inputs and products? (Same follow-up questions as above)
- What is being done to promote education and awareness (information) of innovation?
- Are there regulations specific to farm enterprises, land and labour, which provide obstacles to adoption of new technologies and production practices, investment in new machineries and equipment, changes in organisational or marketing practices?
- Is there an efficient system to register land property? How are property rights, and right of access to natural resources such as water, enforced?
- How is compliance to regulations enforced?

Box 4.1. EU regulatory practices

Smarter regulation in the European Union

Smarter regulations aim to simplify existing EU legislation in order to spur innovation and reduce the administrative burden for operators. Independent evaluations have been commissioned on several legislative areas including Genetically Modified Organisms (GMO), animal health, plant health and seeds. Impact assessment is now required for any regulatory proposal to improve the quality of proposals, ensure consistency between Community policies, and contribute to sustainable development. In terms of innovation, impact assessment takes the following questions into consideration:

- Does the option stimulate or hinder R&D?
- Does it facilitate the introduction or dissemination of new production methods?
- Does it affect IPRs, including patents, trademarks, copyrights and other "know-how" rights?
- Does it promote or limit academic or industrial research?
- Does it promote greater productivity or resource efficiency?

Source: Gerlitz (2012).

EU legislative framework for ensuring GM food and feed safety

The European Food Safety Authority (EFSA) is the agency responsible for the risk assessment regarding food and feed safety. In close collaboration with national authorities and in open consultation with its stakeholders, EFSA provides independent scientific advice and clear communication on existing and emerging risks. EFSA risk assessment procedures are based on international standards and are often defined in the scientific arena as the most comprehensive risk assessment procedures in the world. The three typical steps of the EFSA GM food/feed risk assessment process are: 1) Molecular characterisation; 2) Compositional analysis; 3) Food and feed safety analysis and risk evaluation; 4) environmental impact analysis.

The risk management phase is managed by the European Commission and member states. In order to obtain an authorisation for the production of GM food products, the interested parties have to submit an application to the competent national authorities, which has to acknowledge the receipt of the application and inform the EFSA without delay. Applications are sent to the European Commission and to the member states, who are consulted on the application over a three month period. EFSA must provide its opinion within six months of receiving the application. However, if additional data is requested during the scientific assessment the time limit is extended. The services of the Commission have to take due account of the comments of the public (within one month after the EFSA opinion) and submit a proposal agreed by the different depart of the Commission (inter-services consultation) to a committee composed of representatives of the member states and go through an examination procedure. When a qualified majority occurs in the Committee, the decision is adopted, published in the Official Journal of the European Union and included in the above-referred GMO register. Otherwise, the Commission must refer the issue to the Appeal Committee, which will have a two months timeframe to adopt a decision. Adoption is possible in the absence of a decision.

Authorisations, when granted, are valid for ten years and are renewable, for ten years each time. However, the decision can be reviewed and even withdrawn at any time if new elements occur that would justify such an intervention. In other words, the Commission with the fundamental scientific advice of EFSA maintains a substantial supervision power. Finally, all authorised products are entered in the EU register, which contains all relevant details and information.

Source: Updated from Valletta (2010).

Box 4.2. The regulation of genetically engineered (GE) products in the United States

Three agencies are involved in this regulation: the USDA's Animal and Plant Health Inspection Service (APHIS), the Environmental Protection Agency (EPA) and the Food and Drug Administration (FDA). APHIS is responsible for protecting agriculture against pests and diseases, the EPA is charged with ensuring the safe use of pesticides, and the FDA is responsible for food and drug safety. In several areas, the regulatory domains of each agency overlap. Indeed, products are frequently regulated by more than one agency.

Extensive coordination and collaboration among regulatory officials and agencies are crucial to this process. Within the United States, regulations have been updated numerous times to keep pace with scientific advancement. All product decisions are based on scientific evidence.

The USDA conducts oversight of nearly all field trials concerning GE plants. All field trials must receive USDA approval, and must be designed in a manner that guarantees biological confinement. When an applicant has enough information to demonstrate that a given organism will not pose danger to agricultural and human environments, and that it will not pose any plant-pest risks, he or she can petition the agency for "deregulated status." The agency will then conduct an environmental analysis process based on the supplied data, though it may request additional information, if needed. The public also has the opportunity to provide input during this process. Depending upon the conclusions drawn from this initial analysis, more complex and elaborate analyses may be required, as outlined under federal law.

This process demands information on a broad range of topics. Applicants must supply all relevant experimental data, including any data that may be unfavourable, as mandated by law. These data must also include comparisons to conventional crops. If a petition is approved and a product is deregulated, that product can be grown and marketed without further GE-specific oversight from APHIS. Deregulation, however, does not guarantee that the product will not undergo concurrent EPA or FDA review.

The EPA is responsible for the regulation of pesticidal microorganisms and any plant-produced pesticidal substances. If a plant were to produce the insecticidal toxin BT, for example, the EPA would regulate that substance as a pesticide. The agency also sets tolerance levels for the safe use of various conventional pesticides. If any herbicide is used in coordination with an herbicide-tolerant plant, the EPA will regulate the use of the herbicide in conjunction with that plant.

Regardless of whether a pesticidal substance is applied to, or produced by a plant, there is a wide range of information that must first be examined. Each product needs to be characterised, and its effects on human health, ecological impacts and environmental consequences must be evaluated. For certain insecticidal substances produce by a plant (e.g. BT proteins), the EPA also requires plans for resistance management, in the event that insects develop resistance to that insecticide. In addition, the EPA's responsibility with respect to these substances covers not only environmental effects, but impacts on food and feed safety, as well.

The FDA is responsible for ensuring that foods produced through GE are as safe as conventional foods. The types of issues addressed for GE products are the same as those addressed for conventional foods, including toxicity and allergens, food composition, nutritional value, and intended use. The FDA also conducts consultations with product developers. Formally, these consultations are considered voluntary, though it is very unlikely that a company would bring a product to market without first consulting the FDA. These consultations typically include significant dialogue between regulators and developers.

In short, all foods must meet same safety standard under the Food, Drug and Cosmetic Act, regardless of whether or not they are derived from GE organisms.

Source: Schechtman (2012).

Notes

1. As land supply has often a lower price elasticity than other inputs, output support provides an incentive to intensify production.

2. Kimura (2013) finds that low performers, in terms of the partial indicators used, are more dependent on support than the average of all farms, i.e. it accounts for a larger share of their farm receipts, and contributes to maintaining them in the sector.

3. The Policy Report on Price Volatility in Food and Agricultural Markets prepared by International organisations for the 2011 G20 suggests policy responses to tackle this issue. www.oecd.org/document/20/0,3746,en_2649_37401_48152724_1_1_1_37401,00.html

Chapter 5

Innovation policy and Agricultural Innovation Systems

This chapter outlines government's role in the governance of innovation systems. It also considers direct government involvement in the creation, diffusion and transmission of knowledge, and in encouraging knowledge flows and interactions at national and international levels. These aspects are discussed both in general terms and in reference to Agricultural Innovation Systems (AIS).

5.1. Governance of R&D and innovation systems

Strong governance of innovation systems is required to maximise benefits from public funds, including the definition of clear strategic priorities to guide public and private investments, and the identification of areas where government intervention is most needed in the food chain. Improving mechanisms for priority setting, co-ordination of efforts and co-operation, delivering public funds and evaluating outcomes would help improve policy coherence, create synergies and avoid unnecessary duplication of efforts.

National priorities are defined in national innovation strategies, plans or white papers. Within this context, missions of institutions and centres of excellence also define priorities. Governments should define priorities for public research as well as priorities for public funding of private research, taking into account private sector activities. Innovation policy should clarify the respective roles of the public and private sectors and seek to build partnerships. While private research is generally active in areas with short-term and/or large market returns, public resources are expected to focus on areas with strong public good elements and long-term benefits, e.g. more fundamental research, research on longer term issues such as climate change, provision of information, and areas where international spillovers are important.[1]

National priorities are linked with foreign priorities by competition, co-operation or specialisation relationships. Priority setting for regional or global challenges or large research infrastructures, in particular, requires co-operation to share costs. If significant, international funding can influence national priorities. Supra-national priorities can shape national priorities as in the EU case, where a number of co-ordination mechanisms are in place (e.g. European Research Area and Innovation Partnerships). A challenge at all levels for national innovation systems is to focus research priorities but remain diversified enough to face future challenges.

Polt (2008) characterises three dimensions to priority setting processes:

- types of priorities: thematic or generic;
- levels of priority setting: national, institutional, project or programme-based; and
- nature of priority setting process: top down/expert based versus bottom-up/participatory, degree of formalisation, and mechanisms for implementation and evaluation.

Mechanisms to define priorities should involve a wide range of stakeholders to better reflect users' and societal demand. Priority setting should also include formal and transparent co-ordination mechanisms, with well-defined roles assigned to each institution (e.g. co-ordination, consultation, expertise, discussion, decision). It should also rely on evidence from evaluation. More generally, the development of economic intelligence tools and strategic management information systems is essential for improving the governance of innovations systems.

Institutional reform should also aim to address the fragmentation of R&D organisation. Some consolidation and specialisation of institutions can help, but the most important is to assign overall co-ordination to a specific body, to clarify responsibilities between organisations and build bridges for co-ordination at all levels. Some governments have moved towards more formal consolidation of AIS institutions, such as merging or the creation of a superstructure or regional associations to strengthen links between research and education, or between different fields of research. Encouraging research centres to co-ordinate and pool some of their resources to avoid unnecessary duplication of efforts, in particular to focus on region-specific issues, should help exploit economies of scale and scope in innovation. The creation of centres of excellence that concentrate available resources, or the creation of issue-driven specialised initiatives, such as on climate change, can help focus energies.

Better integration of sectoral innovation systems in the general innovation system is important. Agricultural innovation is generally the shared responsibility of several ministries, mainly those in charge of agriculture, science and technology, or research and education, but also environment or health for specific issues. In some countries, the ministry in charge of agriculture plays a predominant role, and there are specific agricultural research institutions isolated from other fields of research. As agricultural innovation is increasingly linked with innovation in other fields of expertise, it would benefit from a strengthening of linkages or more advanced integration. Better integration would also help identify priorities in the economy as a whole.

Financing mechanisms are increasingly used to focus research on priorities. A challenge for governments is to find a balance between funds for basic research and funds for output-driven research, and between stable, institutional funding and project- or programme-based funding tied to specific objectives and missions.[2] Institutional funding, including for infrastructure, is critical for long-term research capacity while project-based funding is used to promote competition within the research system, but it has higher transaction costs. Both can be competitive or non-competitive (OECD, 2010a). Data on the share of a given type of funding is generally not available on a comparable basis across countries, in particular for the agricultural sector. However, national information of AIS indicates that a high share of project-based funding for agricultural research is found in Australia, Chile and New Zealand. The OECD has launched an international project on the public funding of R&D, which is described in Box 5.1.

Financing mechanisms can be also used to facilitate co-operation at national and international level. The restructuring of institutional mechanisms for financing public research, in part to facilitate funding of multidisciplinary research, has usually involved establishing or reforming the research councils or similar bodies that operate at the interface of government ministries and research-performing institutions. It has also been achieved through better co-ordination between funding agencies and government and through funds that create incentives for interdisciplinary collaboration or for research in certain priority areas (OECD, 2010a).

More emphasis on the quality and relevance of research activities, and on assessment of research performance and its contribution would improve the innovative capacity of the country. In all areas, budget constraints have increased demand for evidenced-based policies and evaluation of public investments. Evaluation of R&D government expenditures seeks to measure contribution to growth and social impacts, as well as contribution to help meet global challenges such as food security and climate change (Annex C).

The evaluation process could start within agencies and be complemented by outside, independent evaluation at regular intervals. As is often the case for specific programmes and projects, strategic plans should to the extent possible include targets and indicators of performance. It is important to improve the information base and analytical capacity required to assess the performance of innovation systems and identify future needs. Efforts should focus on developing indicators and methods to benchmark performance. Linking funding to performance criteria (number of publications, patents, peer review) could create strong incentives. But a number of specificities should be taken into account such as differences among sectors and disciplines, international spill-overs and time lags, as outlined in Annex Box C.2.

Box 5.1. Public funding of R&D: The first internationally comparable indicators

Only a few indicators on public R&D funding are currently used for international purposes (e.g. government R&D funding by socioeconomic objectives). However, more can be done with existing statistics to assist policy makers. To fill this gap, the OECD started in 2008 a project to develop new indicators on government R&D funding. A pilot exploratory phase involved six countries; it has been extended to include more than 15 OECD and non-OECD economies. Although this project does not include specific information on agricultural R&D, the information below illustrates the usefulness of developing similar indicators for the agricultural sector.

The general aim of the project is to make better use of the potential of government R&D data (GBAORD) to compare research funding systems across countries. The project focuses on:

- government R&D funding allocation (block funding vs. project-based focus);
- type of instruments used (investigator-led, policy-oriented, innovation-related);
- degree of autonomy of funding institutes (research organisation, policy-based ministry, etc.); and
- share of public funding to international organisations.

Preliminary results show:

- Country funding schemes vary widely. Austria, Germany and Switzerland mostly use institutional funding (around 70%), while Belgium and Ireland devote more than 50% of public funding to project-based funding, and Korea and New Zealand more than 70%.
- In the higher education sector, general university funds (GUF) are an important part of overall funding (considered as institutional funding), but Belgium, Canada and Ireland still provide substantial additional funding to project-based, peer-reviewed projects
- A large part of project funding is managed by independent agencies (such as research councils) except in the Czech Republic, Israel and Poland, where centralised research ministries or other sectoral ministries provide most of the project-based funding.
- The long-term trend of public R&D funding seems to favour project-based funding over institutional funding (Lepori et al., 2007), but over the short period studied so far (2000-08), countries' funding modes are relatively stable.
- Public funding of international organisations continue to be a minor component of national public R&D funding (usually less than 5%) except for Belgium and Switzerland, which devote more than 10% of public R&D funding to such organisations.

These findings are based on experimental indicators and should be interpreted with caution.

Source: OECD, Working Party of National Experts in Science and Technology (NESTI) microdata project on public R&D funding, 2009, reported in Box 5.3 in OECD (2010a).

Possible questions on governance of AIS

- What are the respective roles of the following actors in the agricultural innovation system: government, private sector, academia, non-profit organisations, producer organisations?
- What is the governance structure? Umbrella ministries, co-ordination, funding, performing, monitoring and evaluation agencies in the form of a flow chart.
- How is the AIS integrated into general innovation system? Are there features of the agricultural sector that require the AIS to be different from the general system?
- How are innovation priorities established and communicated? How are market and system failures identified?
- Are there mechanisms to co-ordinate national innovation priorities and their implementation?
- Who is in charge of evaluating staff, projects, overall system performance? How is performance measured and evaluated? What information is available?
- What criteria are used? What input and output indicators are available? What tools are used for benchmarking?
- Are the economic and social impacts of innovation evaluated? How (methods)? By whom? How frequently? How are evaluation results used in priority setting and decision making?
- How is information needed to measure and evaluate AIS collected?

Possible indicators: Diversity of stakeholders involved in strategic planning; Frequency of evaluation; number of indicators and models used in evaluation; content and timeliness of databases.

5.2. Investing in innovation

Role of public research

Innovation is more than science, but it is clear that innovation increasingly depends on scientific progress, especially at the frontier (OECD, 2010a). In particular, there is a strong link between science and innovation in emerging and growth sectors such as information and communication technologies (ICT), biotechnology pharmaceuticals, nanotechnologies and environmental technologies. The relationship between innovation and science also depends on the type of innovation, marketing and organisational innovation being the least dependent on science (defined in Box 2.1). Besides, the relationship between expenditures on scientific R&D and innovation is not linear and innovation is not only a question of money.

Public research plays an essential role in innovation. Public research institutions focus on basic research that often has a long term horizon and carries high risks with uncertain returns. Innovation improving long-term environmental effects, or focusing on poor farmers in developing countries, for example, have public good aspects. Public research is at the origin of major breakthrough innovation, e.g. recombinant DNA techniques, and the Internet, with long-term benefits for society. Moreover, public research allows private firms to develop more incremental and adaptative research that can be patented. For example, decades of publicly funded research in molecular genetics and biotechnology enabled private firms to develop new techniques with commercial potential and led to massive increases in private R&D investment by seed and crop biotechnology companies (King et al., 2012).[3] Dependence of innovation on public R&D, however, varies by sector. Public R&D also contributes to diversity and act as a competitive force to innovation, especially in areas where innovation is concentrated in a few large companies.

Public research has more diverse objectives than private research, and covers broader areas. In particular, it invests in areas that provide social benefits such as the environment and natural resources, human nutrition and food safety, and social and community development.

Moreover, because of the public good nature of public research, it encourages the diffusion and transmission of knowledge, and co-operation between researchers, and allows for interactions and linkages between different disciplines. There are clear mutual benefits between public research and higher education, including through exchange of students and staff.

Government and public research institutions at national and sub-national levels play an important role in terms of storage of information such as gene banks and scientific collections. Many countries are committed to increase access to research data deriving from public funding, although more efforts should be dedicated to improving harmonisation and user-friendliness of information systems.[4]

The government is a major actor in AIS as a performer and funder of agricultural research and development (R&D). In most developed countries, 70% to 90% of agricultural R&D is performed in public institutions, mainly higher education or research agencies (Figure 2.2). This share is generally higher for agricultural sciences than for total R&D (Annex Table B.1). In some countries, agricultural R&D is organised and funded at both national and sub-national levels.

Possible questions on investment in public R&D

- What are priority areas for public research? How are public funding decisions made? Does this involve any consideration of R&D underway overseas? What is the importance of R&D on transferable technologies?
- What are the strengths and weaknesses of your public R&D?
- What are the trends in public expenditures on agricultural R&D? What is the share of institutional versus project- or programme-based funding? What is the share of basic versus more applied R&D?
- Are there barriers to successful collaboration between government and non government researchers? To what extent does government policy encourage increased collaboration? What kind of funding mechanisms? What is the share of public support to agricultural R&D funding PPPs? In which areas? What lessons from recent experience?
- Do producers associations, industry, private sector or NGOs employ any unique mechanisms to raise funds for R&D and innovation?
- Does government fund networking activities? Which ones?

Possible indicators

- Trends in public expenditures, as a share of agricultural value added, as a share of total public and private expenditures on agricultural R&D, by topic.
- Share of expenditure on basic R&D; share of institutional funding.
- Number of patents created and exploited commercially. Number of patents as part of PPPs.

Direct and indirect support to private investment in R&D

In addition to funding and performing public research, the government also supports private investment in agricultural R&D if needed. Public funds are attributed directly through grants, often provided in a competitive manner, or indirectly through R&D tax provisions and credit guarantees to the industry. A number of financing mechanisms, such as consortia, competitive grants, matching grants and PPPs are used to focus research on specific topics and/or fund collaborative efforts (Box 5.2). Public-private partnerships (PPP) are increasingly used to exploit synergies between private and public research and funding capacities, mobilise private contributions to innovations that have a public goods nature and help increase the responsiveness of innovation policy to changing business needs.

In agricultural research, PPPs can include various actors from public and private research, but also upstream and downstream industries, co-operatives, NGOs and farmers. In addition to public and business sources, they can also receive funds from industry levies and charitable foundations. They are used to enhance both the creation and adoption of new technology, for example to develop solutions more adapted to specific contexts. For example, the Bill and Melinda Gates foundation finances PPPs including multinational and local seeds companies for the provision of improved seeds to farmers in developing countries.

Agricultural research PPPs have developed in recent years and some countries like New Zealand spend a significant share of public funds for research on project-based PPPs. They are also promoted by international organisations in developing countries (World Bank, 2012). However, there is a need for more evidence on the performance of agricultural research related PPPs, compared to other type of research, and on the conditions for their success. Specific concerns are about possible crowding out effects of private research and unequal sharing of costs and benefits. Exchange of experiences from all parties on practices for selecting, organising, funding and evaluating PPPs would help improve the design and selection of PPPs. Experience from PPPs for other purposes, such as investment in infrastructure and technology transfer could also be drawn upon.

Box 5.2. Common approaches to financing innovation activities in partnerships

Consortia are formal arrangements that bring together diverse partners around a specific and common problem requiring research investment, jointly define R&D strategies, arrange for financing, and implement the subsequent research-innovation project. Most consortia have a lead organisation, and each partner has a specific role and commits resources. Contributions from a range of actors, including private enterprises, cover various aspects of R&D (demand identification, R&D investment, technology transfer and adoption). Consortia are often funded through competitive grants (which match funds to resources mobilised by partners) for a limited period.

Competitive research grants are a common mechanism for funding basic, strategic, and applied research through competition based on scientific peer review. The aim is to focus scientists' efforts on high-priority research areas or new fields of expertise, improve the relevance and quality of agricultural research, promote research partnerships, and leverage research resources (from the public or private sector). Funds for competitive grant schemes usually come from the public sector and are managed by a public or semi-autonomous organisation.

Matching grants are used for financing near-market technology generation, technology transfer and adoption, or business-related innovation, often by including multiple stakeholders. Matching grants require a financial commitment from the beneficiaries (farmers, entrepreneurs) and therefore may be more effective than competitive research grants to enhance the dissemination and use of knowledge and technology. They are also better suited for funding overall innovation and for activities requiring private sector engagement (e.g. PPP). Both competitive research grants and matching grants involve short- to medium-term funding arrangements.

Public-private partnerships (PPPs) between public research and the private sector (e.g. producer organisations and the agri-food industry) are used to fund and carry out R&D activities. PPPs involve a contract between the different partners, which defines the purpose and the sharing of costs (e.g. funding, risk) and benefits (e.g. IPR).

Source: World Bank (2010 and 2012).

More innovative funding mechanisms, such as tax incentives, venture capital, and advance market mechanisms are also used. Over two-thirds of OECD members and many developing countries have tax incentives for R&D. Available evidence on the effectiveness of R&D tax credits is mixed, but they can be an effective mechanism to overcome market failures resulting in underinvestment in private R&D (Hall and van Reenen, 2000). Agricultural pull-mechanisms reward successful innovations *ex post*, as compared to push mechanisms which fund potential innovations *ex ante*. Examples of models for pull mechanisms are described in Box 5.3. Pull programmes are financially attractive because no resources are spent until the desired product is developed and approved by regulators. They can be structured so that total expenditure depends on adoption rates that create strong incentives for researchers to select appropriate projects and focus on developing products that farmers will want to use. Pull-mechanisms ought to focus on a specific market failure and development solution, embedded in Agricultural Innovation Systems in terms of regulatory environment.[5]

Box 5.3. Models for pull mechanisms

Standard prizes reward achievements in a technology development contest. It can be designed either as a winner-takes-all prize or one that also rewards the runners-up.

Proportional prize structures reward innovations in proportion to their impact. Such mechanisms could offer a fixed per-unit reward that depends on the total benefits achieved, so that the total award is flexible. For instance, a fixed payment per hectare planted in a new seed variety, where the total reward paid out would depend on adoption provides incentives to fund research aimed at improving the variety and adapting it to local conditions.

Advance market commitments (AMCs) offer a public-sector subsidy payment for goods and services that the AMC's intended beneficiaries want to buy. This increases the market size and makes returns more certain for producers. In exchange, the industry commits to providing the product at a sustainable long-term price for an agreed period after public support ends.

Source: World Bank (2012).

Possible questions on support to private investment in R&D

- What are the trends in private R&D and what are the relationships between private and public R&D?
- What mechanisms do you use to support private investment in agricultural R&D: competitive grants, tax provisions (which ones); credit guarantees?
- To which extent do you use procurement and pull mechanisms to fund research?
- What priority areas do you target through this type of support? Why?

Possible indicators: budgetary expenditures for each mechanism over time. Share of support to private R&D going to agricultural sciences and agriculture-related R&D.

Knowledge infrastructure

Governments also have an important role to play in innovation by providing knowledge infrastructure (OECD, 2010a). General knowledge infrastructure includes roads and communications, and general purpose technologies,[6] such as electricity, biotechnology, nanotechnology, and ICTs, which have strong element of public goods to allow open access to knowledge. Specific knowledge infrastructure includes databases, buildings and institutions.

ICT is a big driver of innovation. The role of ICTs and in particular high speed communication networks, such as the Internet and broadband networks, has been particularly important to facilitate exchange of information and collaboration between innovation actors and partners. Full coverage of communication networks is needed for the full potential to be realised: In the agricultural sector, ICTs facilitate access to information on markets, policies, technologies. They are also used to provide education (e-leaning) and extension services, and for data collection and storage. Geo-Satellite images help forecast yields, established early warning systems, monitor production, environmental impacts and policy implementation. At farm level, ICT technology is increasingly used to implement precision agriculture (remote sensing), to control the environment in glasshouses and to monitor milk cows. It is also used in the food industry to trace and track products in the food chain, from farm to kitchen, and to inform consumers by storing information in bar codes (Poppe, 2012).

Government action to promote ICT and overcome barriers to implementation include regulations (standards) and targeted support to projects with public good benefits. Governments also play a central role in the development and enforcement of reliable privacy and security frameworks needed to establish public trust in the technology.

More specific research infrastructure includes laboratories, libraries, databases containing information on plant and animal genes or biodiversity resources (gene banks and biological resource centres), modelling capacities, information on available technologies and their performance, and centres of technology convergence or excellence. As they favour cross-sector collaboration, centres of technology convergence, e.g. biotechnology, nanotechnology, information technology and cognitive sciences, are found to have a significant impact on innovation. For example, there is a strong correlation between the share of a region in country's biotechnology patents and its share in nanotechnology patents (OECD, 2010c).

Possible questions on knowledge infrastructure

- What kind of knowledge infrastructure does the government provide or subsidise?
- What is the policy regarding access to knowledge? What kind of information useful for innovation is publicly available (databanks)?
- Do government statistical agencies make information publically available for free? Are results of public R&D available for free, and shared internationally?
- Have any new institutions been created to share research results/intellectual property across countries/institutions?
- What other public research infrastructure is available? Poles of excellence, models, shared equipment and building, etc.
- Do you share knowledge infrastructure with other countries? How does your knowledge infrastructure link to equivalent entities abroad?

Possible questions: Number and content of free databanks? Number of poles of excellence, sharing agreements? Share of the country covered by broad-band ICT?

5.3. Fostering knowledge flows: The role of networks and markets

Innovation increasingly requires collaboration and exchanges. This section considers the role of circulation of knowledge, IPRs, and knowledge networks and markets in fostering innovation, and discusses the role of the government in fostering the development of knowledge networks and markets.

Circulation of knowledge

Circulation of knowledge is essential to generate new ideas, test, confront and mix them, adapt basic knowledge to different contexts and implement innovation. It allows for specialisation and resulting efficiency gains, without losing the benefits of multidisciplinarity. Circulation of knowledge is particularly important for open innovation, which involves partnerships with external parties (alliances, joint ventures, joint development, etc.), and for acquiring/selling knowledge (using contract R&D, purchasing, licensing). Open innovation is increasingly realised through corporate venturing: equity investments in university spin-offs or in venture capital investment funds (OECD, 2010a).

There is evidence of increased circulation of knowledge from data on trade in technology, i.e. transfers of techniques (patents and licences, disclosure of know-how); the transfer of designs, trademarks and patterns; services with a technical content, and technical assistance and R&D. Another indicator of knowledge flows is the share of patents applications with co-inventors located abroad. In the agricultural sector where specialisation between those who invent and those who adopt is particularly marked, specific attention should be given to the circulation of knowledge between providers and users (OECD, 2010a).

The role of intellectual property rights

IPRs are legal titles giving exclusivity on certain uses of intellectual assets to individuals, firms, universities or other entities. They include patents (for inventions), copyright (for material such as software, writing or the arts), design and trademarks (for brands, logos, etc.).

Intellectual property rights (IPRs) provide an important incentive to invest in innovation by enabling firms to recover their investment.[7] Through adequate IPR protection, rights-holders can exclude competitors from use of an innovation for a limited period of time or, in the case of open innovation approaches, promote access and sharing. A variety of collaborative mechanisms, such as licensing markets or pools and clearing houses, can facilitate access to and use of knowledge. IPRs contribute to the creation of innovation and are important for diffusing knowledge and creating value. The challenge for IPR regulations is to provide incentives for private investment in innovation, without compromising the sharing of knowledge and further innovation.

The strengthening of IPR protection in recent decades has also been associated with an increase in private sector investment in agriculture-related research and development and a surge in innovation leading to improved plant varieties, agricultural chemicals, and production technologies (e.g. OECD, 2011b). In part due to the incentives provided via IPR, many of these innovations have moved rapidly into commercial use. In some cases, the strengthened IPR regime has led to new collaboration via pooling of intellectual property, as was the case with the development of a nutritionally enhanced strain of rice known as golden rice (OECD, 2011e). At the same time, some concerns have emerged with respect to some aspects of the present approaches to IPR protection in agriculture. Fragmented ownership of intellectual property with respect to research inputs (technologies and materials such as genes), may hamper the innovation process or result in industry concentration to consolidate ownership of intellectual property (Blakeney, 2011). The threat of litigation may hamper scientific freedom to operate or may lead to liability for farmers using protected innovations such as biotech crops (Wright and Shih, 2010; McGloughlin, 2012).

Of particular importance for agricultural productivity, the WTO Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS) provides that patents shall be available – with a few exceptions – in all fields of technology for inventions that are new, non-obvious and useful.[8] An exception concerns plant varieties, which may be excluded and protected via a *sui generis* system such as the one provided under the convention of the International Union for the Protection of New Varieties of Plants (UPOV), or by any combination of those two options. In addition, in some cases, national law and regional or international accords afford IPR protection beyond the TRIPS minimum standards (e.g. availability of protection for new plant cultivars via patents and plant variety protection laws).

There are a variety of options available that may improve the system of IPR protection to provide further incentives for private investment in innovation without compromising the sharing of knowledge and further innovation. Some of these issues can be addressed by use of best practices in regulation and innovation policy frameworks such as with respect to collaborative approaches, public-private partnerships, or licensing of genetic inventions (e.g. OECD, 2011e and 2006c). The administration of the patent system is also important in terms of delivery of quality patents that provide an appropriate degree of protection (Dons and Louwaars, 2012).[9] Competition authorities play an important role in ensuring that patenting procedures are not abused and that patents are not used anti-competitively (OECD, 2010a).

Knowledge networks and markets

Knowledge networks and markets are arrangements which govern the transfer of various types of knowledge, such as IPRs, know-how, software codes or databases, between independent parties. Some are based on prices and money transfers; others on structural relationships or networks. Knowledge networks and markets include intellectual property (IP) markets (e.g. licensing markets, auction) and IP aggregating mechanisms (e.g. patent pools), non-commercial networks and knowledge communities (e.g. expert networks, consortia), and knowledge brokerage.

Policies for knowledge networks and markets aim to help different groups work together and share the result of early knowledge (OECD, 2010a). Governments should remove restrictions that limit interactions between different institutions and foster collaborative arrangements and ensure that researchers and public research institutions have incentives and opportunities for collaborating with industry, and vice-versa. In this context, research evaluation criteria should be adjusted to reflect the multiple missions of research institutions, including knowledge transfer where appropriate (OECD, 2010a). Funding mechanisms can provide incentives for collaboration (Box 5.2). Government can also play an active role in establishing and supporting collaborative mechanisms such as knowledge networks and consortia, non-commercial networks, knowledge communities, and knowledge brokerage.

To foster knowledge markets, governments should encourage IPR and collaborative mechanisms to facilitate access and use of intellectual assets. Improving market transparency and competition and supporting standard development can also help improve the valuation of intellectual assets, as well as develop mechanisms for the exchange of knowledge. Promoting the development of information systems would contribute to market transparency.

Possible questions on knowledge markets

- What are the rules governing IPRs? What are the practices regarding the sharing of Intellectual Property Rights (IPR) in PPPs? How does public research handle IPRs, patents?
- Do you provide advice/recommendations to private firms on how to handle IPRs? Which ones?
- Are there institutions and what institutions exist in your country to promote sharing of IPR? Are they in the private sector, the NGO sector or the public sector? Or are there license fees required to be paid for public sector innovations

5.4. Facilitating knowledge flows and interactions within national Agricultural Innovation Systems

Facilitation adoption: Agricultural education, training and extension, information

As outlined in Chapter 2, agricultural higher education, training, extension and advisory services are an integral part of innovation systems, as is agricultural R&D. They mainly facilitate the transfer of innovation, in particular the adoption of innovation by farmers, although agricultural higher education organisations, including technical colleges, also perform R&D. Agricultural and general education is found to have a positive impact on technical efficiency (Latruffe, 2010; OECD, 2011a). Training and extension services are critical to facilitate farmers' access to technology and knowledge. They also contribute to facilitate farmers' effective participation in innovation networks and ability to formulate their specific demands.

Revisiting **agricultural education** and training is required to improve the skills, understanding and innovative capacity of farmers, and to train agricultural specialists, scientists and service providers who can engage with other actors and implement the AIS approach. Making agricultural education attractive to young people is important to foster future productivity growth, but improving the profitability of the sector is essential to attract well-qualified new entrants. Aside from technical knowledge (e.g. production, processing, agribusiness, biotechnology), graduates require professional skills, such as leadership, communication, facilitation, and organisational capabilities that are crucial for performing in an AIS. Important reforms include reforming curricula and teaching methods to better match modern labour market needs and building capacity, and stakeholder partnerships for technical education and training.

Extension and advisory services need to respond to demands from an increasingly diverse farm population on a wide range of topics. They need to provide a combination of market-oriented services with other services, such as group organisations, access to technology and knowledge, policy implementation and project design to access private and public funds. The participation of farmers in defining problems and finding solutions would help to improve relevance. A challenge for extension systems is to adapt the service to different types of users and local circumstances. In a competitive system, extension officers also need to build trust with their clients. Attracting well-qualified advisors with diverse and flexible skills is a challenge. A challenge for the government would be to foster a demand-driven, pluralistic and decentralised advisory service that mixes both public and private providers. Public support could focus on public good aspects and farmers with limited access to private services. Supporting the provision of ICT tools would facilitate access to market, price, policy and weather information needed to guide producer decisions and help offer specific kinds of extension advice.

Public information is a resource for innovation. An important role for the government would be to facilitate the development of **information systems.** There is a growing need for information on a widening range of areas, such as weather, climate change, biodiversity, agronomic, environmental and climatic conditions, production practices and innovation, land, water and other input use, markets, economic situation, policies and regulations. Improving agricultural and innovation information systems in terms of coverage, consistency, timeliness and access would help guide: 1) decisions by producers regarding the adoption of innovation; 2) policy makers, analysts and more generally AIS in identifying problems and establishing priorities based on evidence and analysis; and 3) AIS in focusing on current and future demands. In addition to national and international statistical agencies, many private and public sources need to be mobilised, e.g. input firms, gene banks, or administrative data. The monitoring and evaluation of agencies, policies and projects can also generate useful information. Information systems should, in particular, facilitate the sharing of information between farmers, industry, policy makers, and other AIS actors. Given the long lags of research impacts, foresight projections of market developments and resource availability are essential to define longer-term priorities.

ICT has proven very useful in the sharing of information (web-based databases and advice, market information accessible on cell-phones). "Brokers" of information can play an important role in helping policy makers and AIS actors interpret increasingly complex information. There is also a growing need to share databases and infrastructures for research and experimentation. Open access to information from publicly funded activities should be the default rule and unnecessary restrictions should be removed. The challenge is to improve the coverage, timeliness and quality of information, as well as it accessibility to a wider public.

Possible questions on agricultural education, training and extension

- What are the strengths and weaknesses of agricultural education in your country? Is agricultural education attracting students? Is it adapted to labour market needs? What is the share of students remaining in the agricultural and related sectors (for example, after ten years)?
- What are the strengths and weaknesses of extension services in your country? Do they respond to farmers' needs (share of farmers using extension)? To policy objectives?
- Is there direct provision by the public sector? Is it targeted to specific groups of farmers, specific areas?
- Do you subsidise access to private extension? How? Is the rate of subsidy uniform? Is it differentiated depending on specific criteria (income, region, topic)?

Possible indicators

- Share of agricultural students in the public sector.
- Number and share of farmers undertaking training courses. With subsidies?
- Trends in public expenditures for the provision or access to extension services.
- Trends in public expenditures for the collection and diffusion of information.

Developing linkages

Reinforcing **linkages** between AIS components — research, development, extension, farmers, the industry, NGOs, consumers and others — would help connect research to demand; create synergies, facilitate technology transfer and increase the impact of scarce human and financial resources in many countries. Research outcomes would be more adapted to demand if farmers are involved at early stages of problem definition through to contributing to finding solutions.[10] As with general innovation, partnerships would also facilitate pluridisciplinary approaches that are increasingly needed to solve problems.

Policies should enable national and international partnerships, leverage skills and resources, diversify funding, and result in improved products and practices that meet the needs of the entire agri-food system. In all cases, new competencies related to communication, ICT, intellectual property rights, participatory planning, facilitation of partnerships-teamwork would help. Evaluation systems of individual researchers and research team should evolve to encourage partnerships and recognise communication and networking activities needed to work successfully.

"Bridging organisations", such as extension services, farm or trade associations, consultant firms or NGOs can help improve the demand articulation for innovations. However, research partnerships could move from participatory research and use of competitive research grants towards wider alliances and R&D consortia. In a market-oriented context, the strategic focus for institutional partnerships in the research system is expected to shift towards more resource leveraging and research linkages to producer organisations, agricultural input or processing industries, and supermarkets. This takes place usually within the framework of public-private partnerships (PPPs) and in the form of consortia. Various networks also contribute to bring together various AIS actors.

Possible questions on knowledge flows in AIS

- What institutions facilitate knowledge flows: network, consortia, platforms, etc.
- Do you have a strategy for engaging with and influencing key informal networks?
- How can knowledge flows between AIS actors be further developed?
- What is the role of producer groups?

Possible indicators

- Number of networks, consortia, platforms created.
- Number and diversity of participants.

5.5. Strengthening international co-operation in agricultural innovation

International co-operation is necessary when: 1) no single country can successfully address the problems alone; 2) individual countries may not be willing to bear the costs of addressing shared problems because they cannot appropriate the benefits; and 3) the uncoordinated efforts of many countries are likely to be more costly and less successful than co-ordinated, co-operative efforts (OECD, 2010a). This is the case for agricultural research aiming to pursue a number of pressing global issues such as food security, climate change, water scarcity, transboundary diseases, and price volatility in global markets. International co-operation in agricultural research is also appropriate when infrastructure costs are high (e.g. gene sequencing) and require investment beyond one country.

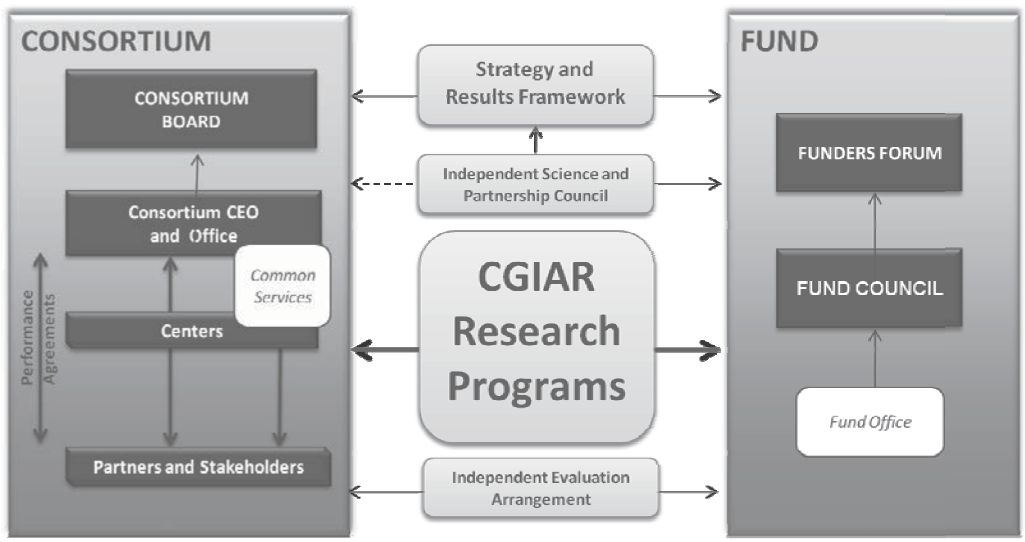
The benefits of international co-operation for national systems stem from the specialisation it allows and from international spill-overs. In countries with limited research capacity, scarce resources could then focus on better taking into account local specificities. International co-operation is taking place through technology transfer, financing mechanisms (e.g. international PPP), platforms and consortia, and exchange of staff.[11]

An increasing number of international initiatives aim to pursue global issues such as food security, development, environmental protection and climate change involve agricultural research. The Consultative Group on International Agricultural Research (CGIAR), the Global Forum for Agricultural Research (GFAR) and the Global Conference on Agricultural Research for Development (GCARD) play an important role in international co-operation for agricultural development.

The CGIAR is a long-standing partnership established in 1971. It was reinforced and reformed in 2009 to strengthen its ability to co-ordinate activities, broaden partnerships, and stabilise funding. Research agendas became more focused and results-oriented (CGIAR Consortium, 2012).[12] CGIAR research is now dedicated to 1) reducing rural poverty, 2) increasing food security, 3) improving human health and nutrition, and 4) ensuring more sustainable management of natural resources. It is carried out by 15 Centres that are members of the CGIAR Consortium, in close collaboration with hundreds of partner organisations, including national and regional research institutes, civil society organisations, academia, and the private sector. The 15 Research Centres generate and disseminate knowledge, technologies, and policies for agricultural development through the CGIAR Research

Programs (CRPs). CRPs are selected on the basis of: strategic coherence and clarity of objectives; delivery focus and plausibility of impact; quality of science; quality of research and development partners, and partnership management; appropriateness and efficiency of CRP management; accountability and financial soundness; and efficiency of governance. They are financed by a multi-donor trust fund. The CGIAR Fund provides reliable and predictable multi-year funding to enable research planning over the long term, resource allocation based on agreed priorities, and the timely and predictable disbursement of funds. CGIAR experience and recent reforms provide lessons for improving partnerships in agricultural research. They illustrate the importance of securing stable funding, focusing priorities, establishing co-ordination mechanisms (Figure 5.1), and setting clear criteria for selecting projects.

Figure 5.1. In the new CGIAR, partnership at all levels



Source: CGIAR Consortium (2012).

The GFAR was formally established in 1996 by an agreement among stakeholders of agricultural research to mobilise all stakeholders involved in agricultural research and innovation systems for development, and to catalyse actions towards to alleviate poverty, increase food security and promote the sustainable use of natural resources. The Forum's Strategic Objectives are: 1) to build consensus and strengthen advocacy for action on agricultural research and innovation priorities; 2) to promote global and regional partnerships for collaborative research and innovation; 3) to boost knowledge and improve communication of agricultural research and innovation; and 4) to strengthen the institutional capacities of GFAR and its stakeholders.[13]

Collaboration between GFAR and CGIAR includes membership in each other's institutions[14] and the organization of the Global Conferences on Agricultural Research for development (GCARDs) that have replaced the former CGIAR Annual meetings and GFAR triennial General Assembly. As a joint initiative of the GFAR and the CGIAR endorsed by the G20, the GCARDs are expected to play a key role in developing greater international coherence of agricultural science policies and promoting their implementation.[15]

A number of other initiatives were created or endorsed by the G20. The 2011 G20 Action Plan[16] includes the creation of the International Research Initiative for Wheat Improvement (Wheat Initiative) to improve productivity through R&D. This initiative is mainly science driven and aims to better coordinate international research on wheat genetics, genomics and agronomy related to wheat, both bread and durum wheat. The Action Plan also includes the creation of the Global Agricultural Geo-monitoring Initiative (GEOGLAM) aims to strengthen the international community's capacity to produce and disseminate relevant, timely and accurate forecasts of agricultural production at national, regional and global scales, by enhancing national agricultural reporting systems; establishing an international network of agricultural monitoring and research organisations and practitioners; and creating a monitoring system of systems based on both satellite and in situ observations.

The Chair of the G20 Conference on Agricultural Research for Development welcomed the principle of a Global Agricultural Foresight Hub, proposed by GFAR, to support the development of a neutral platform, linking international, regional and national levels.[17]

As part of the Mexican 2012 G20, Vice ministers of agriculture endorsed the organisation of regular meetings of agricultural Chief Scientists (MACS).[18] The 2012 MACS strongly supports Global Research Initiatives endorsed by the G20 and ongoing funding and collaborative mechanisms of the International Research Initiative for Wheat Improvement (IRIWI now named Wheat Initiative) and the Global Rice Science Partnership (GRiSP), the CRPs on Maize, and Livestock and Fish, as well as the Global Research Alliance on Agricultural Greenhouse Gases.

The transfer of innovations, technologies and practices is often an important component of international and regional initiatives. It is sometimes the main focus as with the Tropical Agriculture Platform (TAP)[19], which focuses on enhancing capacity-building and knowledge sharing to improve agricultural production and productivity. It aims at fostering the generation, sharing and utilization of agricultural technologies and practices for smallholders in developing countries, mainly using existing mechanisms.

Regional initiatives also play an important role in agricultural innovation as the involved countries have more in common (South-South co-operation), with emerging economies increasingly playing a leading role. For example, Brazilian research on tropical agriculture motivates countries with similar problems and challenges to seek information and support for technology transfer from the Brazilian agricultural research organisation Embrapa. Besides the traditional instruments of support, Embrapa outposts researchers in less developed countries of Africa or Latin America (Lopes, 2012). A number of regional institutions are engaged in co-operation for agricultural innovation.[20]

A number of networks have recently been created to improve international and regional co-operation. The Global Research Alliance on Agricultural Greenhouse Gases created in 2009 is a low/no cost approach to cross-country collaboration on research that help to address climate change challenges (Fallon, 2012).[21] The Knowledge-Based Bio Economy (KBBE) Forum is a partnership between New Zealand, Australia, Canada, and the European Commission also created in 2009. It aims to share knowledge and foster collaboration and joint activities to promote innovation in the bio-economy sectors (Fallon, 2012).[22] The INNOVAGRO Network was created in 2011 to boost innovation management processes in the agri-food sector by exchanging knowledge, information, co-operation and expertise, and taking advantage of all synergy available between the members (Deschamps, 2012). More specifically, the network aims to: facilitate co-operation and participation among member countries, implement collaborative actions; foster dialogue and analysis of innovation management processes; and communicate about successful innovation and technology transfer experiences. In 2012, the network consisted of 57 institutions, representing 16 different countries (14 from Latin America, as well as Spain and the Netherlands). These institutions range from high level research and innovation institutions to financial institutions, as well as public sector institutions, national systems, universities and Science, Technology and Innovation Ministries. The network thus provides a forum for discussion between AIS actors and policy-makers.

The OECD Co-operative Research Programme (CRP) on Biological Resources in Agriculture, which aims to strengthen the scientific knowledge that informs policy decisions on sustainable use of natural resources in agriculture, food, forests and fisheries, can also provide for a for dialogue between agricultural scientists and policy-makers. In recent years, The OECD CRP has organised a Conference on Challenges for Agricultural Research (Prague, April 2009) and funded the organisation of the OECD Conference on Agricultural Knowledge Systems (Paris, June 2011).[23]

EU experience can provide useful insights for innovation policy. In the European Union, some 85% of all public expenditure on R&D is still at the national level, but a number of initiatives aim to strengthen and fund collaborative undertakings. European Technology Platforms provide a platform for stakeholders, led by industry, to define research priorities and action plans on a number of technological areas (EU SCAR, 2012, Box 5.16). Joint programming initiatives were introduced by the European Commission in July 2008 as one of five initiatives aimed at implementing the European Research Area (ERA).[24] The objective of Joint Programming is to "increase the value of relevant national and EU R&D funding by concerted and joint planning, implementation and evaluation of national research programmes". Joint Programming intends to tackle the challenges that cannot be solved solely on the national level and allows Member States to participate in those joint initiatives where it seems useful for them. Holzinger et al. (2012) provide a detailed account of the JPI on Agriculture, Food Security and Climate Change (FACCE) set in 2009 and draws some early lessons for the governance of International partnerships on innovation (Box 5.4).

As part of the new EU innovation strategy, European Innovation Partnerships were created in 2010 to act as a framework bringing together major EU activities and policies and covering the whole spectrum from research to market. The European Innovation Partnership on Agricultural Productivity and Sustainability was launched in February 2012.[25] Moreover, the EU SOLINSA project was launched in 2011 to identify barriers to the development of learning and innovation networks for sustainable agriculture (LINSA).[26]

Box 5.4. General lessons for international innovation co-operation drawn from experience with implementation of EU Joint Programming Initiatives (JPI)

- Priority setting for international innovation governance needs some strategic policy intelligence in order to be sufficiently evidence-based. In this respect, the overall JPI process is less than satisfactory. Priority setting in the JPI is rather unsystematic and only in some cases based on systematic strategic policy intelligence. Individual JPIs might remedy the lack of an evidence base by their own activities (technology foresight, monitoring, etc.).
- Decision-making bodies of transnational research programmes should have a clear profile and clear tasks. In the case of JPIs the High Level Group for Joint Programming is the EU-level body that selects research themes for JPIs. The High Level Group is composed of policy makers with national interests. This makes independent scientific decision making on potential research projects difficult.
- The divergent interests and varying roles of supporting countries, transnational bodies (e.g. the European Union) and existing transnational research initiatives need to be weighed and balanced sensibly. STI policy is still predominantly the remit of nations. Different perceptions of the role of actors and stakeholders can lower the speed and performance of the process.
- Incentive mechanisms for participation should be designed to avoid free riding and moral hazard. A formal status more strongly tied to commitment might solve the problem of decision-making bodies becoming too large for strategic decisions. Moreover, transnational research programmes should ensure that potential participating countries can enter on equal footing.

Box 5.4. General lessons for international innovation co-operation drawn from experience with implementation of EU Joint Programming Initiatives (JPI) (*cont.*)

- Processes of linking national to international priority setting should be given high attention and should be carefully crafted so as not to leave national stakeholders (including the private sector) behind.
- Transnational research programmes depend on the commitment of participating countries. The JPI approach requires stability of commitment in terms of general participation, agenda setting, funding, etc. Commitment of participating countries is voluntary and might be affected by changes in national policy, elections, etc. This does not provide ideal conditions for international R&D projects.
- While flexibility and variability can be assets during the identification of joint research areas, coherence in the institutional settings (governance structure, agenda setting, framework conditions) of JPIs in general and their various bodies is important to avoid adding to the existing complexity of policy tools. This is especially true for funding arrangements.
- Platforms for mutual learning with other transnational innovation governance programmes are highly recommended. These have been only partially developed in JPIs.

Source: Holzinger et al. (2012).

Possible questions on mechanisms for international co-operation

- Do you encourage cross-country, international collaboration? How? In which areas?
- What policy, efforts are there regarding exchange of staff, domestically or internationally)?
- Are there any barriers to the international flow of knowledge through private mechanisms?
- Which international and regional networks are you involved in (e.g. CGIAR, GFAR, KBBE, High Level Task Force, etc.)?
- What mechanisms have been developed to encourage co-operation between actors at national level? Are there specific institutions, such as networks, consortia?

Possible indicators

- Share of foreign staff in national R&D; number of national R&D staff abroad; number of co-operation agreements.
- Number of partners in co-operation agreements.

Notes

1. The private sector is, however, increasingly interested in technology transfer in emerging and developing economies.

2. Institutional funding is generally a block grant that is not directed towards particular projects or programmes; project funding is a project- or programme-based grant which is attributed to a group or an individual to perform a research activity limited in scope, budget and time, normally on the basis of the submission of a project proposal (OECD, 2010a).

3. Between 1980 and 2010, R&D spending by US seed and biotechnology companies rose from USD 100 million per year to more than USD 2 billion in constant 2010 USD (Fuglie et al., 2011).

4. In 2006, the OECD Council endorsed a Recommendation on Access to Research Data from Public Funding, which includes guidelines and principles to produce publicly accessible knowledge (Box 5.2. in OECD, 2010a). In the agricultural context, this issue was discussed at the first G20 MACS meeting held in Mexico on 24-27 September 2012 and several initiatives were presented. sagarpa.gob.mx/g20/Paginas/Introduction.aspx

5. The Agricultural Pull Mechanism Initiative (AGPM), to be launched in 2012 by the G20, convenes experts across a variety of fields and collaborates with a diverse set of stakeholders, including governments, private companies, non-governmental organisations, and civil society organisations. It has developed a short list of potential pilot concepts and has formulated the architecture for the underlying pull mechanisms to overcome some of the constraints for the creation of an innovation that will generate wider social benefits.

6. General purpose technologies have been defined as technologies which are pervasive, have a widespread productivity impact on a range of industries, show continuous improvement and productivity growth and cost reduction in their own industry, and stimulate product and process innovation in application sectors (Box 5.5 of OECD, 2010a).

7. It should be noted, however, that IPRs do not apply to all types of innovations, organisational innovation for example.

8. The TRIPS Agreement covers patents, copyright and related rights, trademarks, undisclosed information (including trade secrets), geographical indications, industrial designs and topographies of integrated circuits.

9. This means that the patents awarded should be clearly defined with a scope in line with the nature of the invention and not overly broad.

10. For example, leaning and innovation networks for sustainable agriculture (LINSA) are being developed in Europe.

11. The Brazilian agricultural research organisation, Embrapa, uses the concept of Virtual Laboratory, or Labex, to increase its scientific and technological ties with advanced research organisations around the world. Instead of building its own platform abroad, Embrapa negotiates access to its partner organisations' existing facilities (Lopes, 2012).

12. See also www.cgiar.org and Fabre and Wang (2012).

13. www.egfar.org/.

14. GFAR is a member of the CGIAR Fund Council and the CGIAR Consortium is represented in GFAR's Steering Committee.

15. The GCARD first met in Montpellier in September 2011 to discuss how to promote scientific partnerships for food security. The second GCARD took place in Uruguay in October 2012.

16. Available at agriculture.gouv.fr/IMG/pdf/2011-06-23_-_Action_Plan_-_VFinale.pdf

17. The presidency summary can be found at: www.agropolis.org/news/G20_Conference_AgricultureResearch_Development.php

18. The first MACS took place in September 2012 in Mexico. The Agenda, Communique and material presented at the meeting are available at: sagarpa.gob.mx/g20/Paginas/Introduction.aspx

19. The TAP is an initiative requested by G20 Agriculture Ministers in 2011 and led by the FAO. It was formerly launched at the first G20-led Meeting of Agriculture Chief Scientists (MACS) in September 2012 in Mexico. For more information see www.tropagplatform.org.

20. They include the Forum for Agricultural Research in Africa (FARA), the Inter-American Institute for Cooperation on Agriculture (IICA), Association for Strengthening Agricultural Research in Eastern and Central Africa (ASARECA), Conference of African and French leaders of agricultural research institutes (CORAF), the Asia-Pacific Association of Agricultural Research Institutions (APAARI), and the Forum for the Americas on Agricultural Research and Technology Development (FORAGRO).

21. www.globalresearchalliance.org.

22. www.msi.govt.nz/update-me/archive/msi-archive/international-knowledge-based-bioeconomy-forum-kbbe-archived and http://ec.europa.eu/research/bioeconomy/international-cooperation/forum/index_en.htm.

23. More information on CRP, as well as the conference proceedings can be found at: www.oecd.org/agriculture/crp. The AKS Conference proceedings are referred to in this report as OECD (2012a).

24. www.faccejpi.com/faccejpi/Joint-Programming/What-is-Joint-Programming2.

25. ec.europa.eu/agriculture/eip/index_en.htm.

26. www.solinsa.net.

Chapter 6

The role of the government in improving agriculture innovation

This chapter draws a number of conclusions regarding the governance of Agricultural Innovation Systems (AIS) and the coherence of policies that affect innovation in agriculture and the agri-food sector. It suggests a framework to analyse the role of governments to improve agriculture innovation.

Innovation is key to improving the social, economic and environmental performance of the agri-food sector. Agricultural innovation systems (AIS) need to be strengthened to improve cost-effectiveness and responsiveness to multiple demands.

A number of conclusions regarding the governance of AIS and the coherence of the various policies affecting innovation in the agricultural and agri-food sector can be drawn from the analysis presented in this report. First of all, it is important to develop a national agriculture innovation strategy that takes account of changes in the sector and AIS and the nature of future challenges and opportunities in terms of sustainability, climate change and food security. This strategy for agriculture should be integrated into the wider national innovation strategy and take account of the whole range of policies and regulations that affect the capacity all sectors to create and adopt innovation. It should also include the development of indicators to explore impacts and evaluation criteria.

Innovation, and innovation strategies should be broadly defined and encompass the whole range of policies that can provide incentives or dis-incentives for greater innovation. For example, some measures can shape a long-term environment favourable to innovation (such as health, education, and other structural policies), and others can encourage the private sector to invest in innovation (such as transparent and predictable regulatory frameworks and open and efficient output and input markets). On the other hand, governance and institutional weaknesses or unreliable infrastructure systems discourage investments, including in innovation.

Innovation policy, and in particular investment in R&D, should remain at the centre of national innovation strategies. Public R&D still plays a major role in innovation systems, in particular AIS policy also encourages activities in the private sector, including by fostering knowledge markets through IPR protection, providing information and sharing the outcomes of public research (spill-overs), and providing direct or indirect financial incentives.

In the case of agriculture, sector specific policies should be an integral part of the agricultural innovation strategy. In many cases, particular attention should be paid to the importance of agricultural education and extension in facilitating adoption of innovation by farmers.

Policy coherence is essential to improve the performance of AIS and the agricultural and agri-food sector. In particular, objectives for the sector should be set clearly to improve the design of both agricultural policy and agricultural innovation policy, and to ensure consistency between them. Government should first identify and remove impediments to innovation. Improving the enabling environment would include ensuring a stable macroeconomic environment, open and well-functioning trade, investment and labour markets, setting appropriate regulations in a transparent way, and fostering human capital. Agricultural policies would facilitate farm-level innovation if impediments such as distortions in input and output markets and measures slowing structural adjustment were removed. Measures that facilitate investment, including property rights protection and appropriate risk management tools, would also be beneficial. Regulations should be simplified and based on scientific evidence through a clear decision-making process. Unnecessary regulations should be removed. Regulations and incentives should be technology neutral, based on outcomes rather than processes. Improving rural and marketing infrastructure and the provision of services in rural areas is also important for agricultural innovation. Overall, improving the competitiveness of the sector is crucial to attract young innovative people.

Government should continue to play a major role in AIS, in particular the provision of knowledge infrastructure, and the financing of basic research, and research with long-term and public good aspects. The governance of national AIS could be improved both with better integration within the general innovation strategy, and with stronger co-ordination of the various AIS actors and related policies. Improvements to the institutional design of national

AIS would include strengthening strategic planning and regular monitoring and evaluation mechanisms. Improving measurement and evaluation of innovation is crucial to identify market or system failure and improve performance. Efforts should be made to develop and facilitate access to information systems: databases, modelling and forecasting tools, gene banks, etc. Improving measurement and evaluation of innovation is crucial to identify market or system failure, and areas with regional or global public good characteristics. It would thus help define more clearly the respective roles of the public and private sectors, and identify areas for co-operation.

Co-ordination at the national, regional and international levels becomes crucial given the increasing number of actors in AIS, the complexity and the costs of innovation, and the common global interest in improving agriculture productivity growth rates and using scarce land, water and biodiversity resources more efficiently. Co-ordination between national and sub-national levels, and between the European Union and its member states, is also essential. Consolidation of institutions is an option with long term benefits, but most important is the need to establish stable and flexible co-ordination mechanisms. A combination of institutional and project funding is needed in agricultural research. Countries should consider introducing competition and output-driven projects. To strengthen linkages between public and private partners, governments can support the creation and functioning of networks; change reward systems in public research; and participate in public-private partnerships (PPPs). PPPs are attractive because they make the system more responsive to users' demand, encourage co-innovation, and harness private resources to address issues with some public goods aspects. Specific attention should be paid to making agricultural education and extension more effective. Governments should in particular foster competition in extension services and focus public efforts on public goods aspects. Improving IPR protection and Sanitary and PhytoSanitary (SPS) regulations would be crucial to fostering private sector's contributions to innovation. International co-operation is increasingly needed to tackle global challenges, such as climate change, green growth, food security, price volatility, and agricultural development, and transboundary issues such as pest and disease, and water management.

There is no "one size fits all" design for an efficient national AIS. Policy needs to be customised to different context, forms of innovation and phases of development of the AIS. However, sharing information on the performance of different systems would provide useful insights. In this regard, providing platforms for dialogue between AIS actors and policy-makers across-country would be beneficial.

The structure of this report suggests a framework for analysis of the role of governments in improving agriculture innovation, which in turn would contribute to more efficient use of natural and human resources and improved productivity performance (Box 6.1).

Drawing on theory and available evidence, the impact of specific measures on agricultural innovation would be examined. All through this report, boxes include a number of questions and possible related indicators that could be used to review policy incentives and disincentives. Table C.1 also suggests a number of innovation indicators to benchmark policy efforts and outcomes across countries and over time. The framework also considers governance issues, such as co-ordination, priority setting, measurement, monitoring and evaluation. Finally, it aims to assess policy coherence and provide suggestions for improvement.

Developing this framework provided an opportunity to review information on innovation efforts and outcomes available on a comparable basis across countries, and on the impacts of policies on innovation. A preliminary conclusion is that efforts should be made to improve existing indicators for the agri-food sector, to explore impact analysis at macro- and micro-economic levels and to develop evaluative criteria reflecting the diversity of policy objectives. This could be done when applying this framework to more indepth country reviews.

Box 6.1. Framework for analysing the role of the government in agri-food innovation

Economy-wide policies and innovation

Macroeconomic policies

Governance systems

Regulatory systems

Financial markets

Tax policy

Competition policy

Trade and investment policies

Infrastructure and rural development policies

Labour and land market policies

Consumer and environmental policies

Industrial policy and business regulations

Health, education and information policies

Agricultural policies and innovation

Policy objectives

Domestic agriculture policy

Agricultural trade policy

Agriculture regulations

Innovation policy and agricultural innovation systems

Innovation objectives

Governance of innovation systems

Investing in innovation

Fostering knowledge flows: the role of networks and markets (IPR)

Facilitating knowledge flows and linkages within national AIS

Strengthening international co-operation on agricultural innovation

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Annex A.

AGRICULTURAL KNOWLEDGE SYSTEMS (AKS) CONFERENCE, 15-17 JUNE 2011: QUESTIONNAIRE ON THE ORGANISATION, OBJECTIVES AND OUTCOMES OF AKS

Organisational issues

- What is the organisational structure of AKS (and its components: Higher education, Research, Development and Extension)? What major changes have occurred over the last decade?
- Who is responsible at government level for the AKS and its individual components? Please describe and comment on any major changes made during the past decade or currently being proposed.
- In what manner is AKS (and its components) financed both from public and private sources? What changes in funding the AKS activities have occurred during the past decade?

Objectives, priorities, and outcomes

- What is the government policy regarding the nature, scope and role of AKS (and its components)? What major policy developments have occurred during the past decade?
- What are the main objectives of AKS (and its components)? How have these changed during the past decade? What are the main instruments to achieve those objectives? How have these been developed during the past decade?
- How are priorities set for AKS as a whole (and for its components)? What major changes in priorities have occurred during the past decade?
- What major changes have occurred in programs, staff numbers and funding levels of AKS and its components during the past decade?
- What changes have occurred in student intake by area of study within AKS and level of degree/diploma? How do these changes relate to existing or expected future employment opportunities?
- What has been the impact of developments in the agricultural sector, markets, and policies, and consumer demand on priorities and functioning of AKS during the past decade?
- How has AKS contributed to agricultural and food policy formation, to public understanding of policy issues and to policy implementation during the past decade?

Relationships and networking

- How does AKS relate to the general scientific/educational community? How does AKS relate to any general science policy? How does AKS relate to the general higher education policy? Are there separate research institutes and higher education institutes dealing with agriculture or do AKS activities occur in general institutions?
- What opportunities for co-operation between AKS and other possible partners (e.g. the private sector) have been developed in research, extension and higher education?
- How have relationships between AKS and various client groups, (e.g. the public, consumers, food processors, farmers, input suppliers, public agencies) evolved during the past decade? Have new kinds of networks emerged? Have different kinds of networks emerged to address different issues?

Internal AKS co-operation

- How do the components of AKS relate to one another? What developments have occurred during the past decade?
- What opportunities for increased cooperation among the components of AKS have been identified and what mechanisms have been developed to encourage AKS cooperation during the past decade?

Cross-country co-operation

- What have been developments in international cooperation among developed countries and emerging economies, and with developing countries?
- What were the drivers of recent developments and is there scope for further co-operation?

Towards the future

- Please describe the outcome of any self assessments or evaluations of changes which have occurred in AKS and its components during the past decade? What lessons have been learned in order to guide the activities of AKS in the coming decade?
- What major challenge is your AKS expected to face during the coming decade?
- Please give a general overview of experience/proposals for greater co-operation/coordination/ integration among research/higher education/extension and suggest any conclusions from your country experiences, which you would wish to bring to the attention of the Joint Conference.

Information on the Conference and country' responses to the questionnaire are available at: www.oecd.org/agriculture/policies/innovation.

Annex B.

BACKGROUND TABLES

Table B.1. Share of expenditures on agricultural R&D performed by government and higher education institutions

As a percentage of all public and private expenditures on agricultural R&D

		1995	2000	2005	2010	Notes
Australia	Total R&D	50	45	39	36	1996, 2002, 2006, 2008
	Agricultural sciences	90	86	73	70	1996, 2002, 2006,2009
	Agriculture	n.a.	n.a.	76	71	2005, 2007
Chile	Total R&D	n.a.	n.a.	n.a.	50	2008
	Agricultural sciences	n.a.	n.a.	n.a.	67	2008
	Agriculture	n.a.	n.a.	n.a.	45	2008
Czech Republic	Total R&D	35	40	36	37	
	Agricultural sciences	70	64	73	70	
	Agriculture	n.a.	n.a.	59	n.a.	
Estonia[1]	Total R&D	n.a.	76	53	49	
	Agricultural sciences	n.a.	88	66	61	
	Agriculture[1]	n.a.	n.a.	98	98	2009 instead of 2010
Hungary	Total R&D	54	53	55	42	2009 instead of 2010
	Agricultural sciences	49	90	87	69	2009 instead of 2010
	Agriculture	n.a.	n.a.	90	76	2009 instead of 2010
Iceland[2]	Total R&D	n.a.	51	45	45	1999, 2005, 2009
	Agricultural sciences	n.a.	93	n.a.	96	1999, 2005, 2010
	Agriculture	n.a.		70	82	2005, 2011
Korea	Total R&D	25	25	22	23	
	Agricultural sciences	n.a.	n.a.	72	77	
	Agriculture	n.a.	n.a.	79	75	
Mexico	Total R&D	79	70	64	n.a.	2003 instead of 2005
	Agricultural sciences	n.a.	n.a.	93	n.a.	2003 instead of 2005
	Agriculture	n.a.	n.a.	92	n.a.	2003 instead of 2005
New Zealand	Total R&D	n.a.	n.a.	n.a.	n.a.	
	Agricultural sciences	n.a.	n.a.	n.a.	n.a.	
	Agriculture	n.a.	n.a.	n.a.	67	
Poland	Total R&D	61	64	68	71	2009 instead of 2010
	Agricultural sciences	89	86	89	91	2009 instead of 2010
	Agriculture	n.a.	n.a.	n.a.	n.a.	2009 instead of 2010
Portugal	Total R&D	64	61	50	44	
	Agricultural sciences	n.a.	n.a.	83	71	2009 instead of 2010
	Agriculture	n.a.	n.a.	79	85	2009 instead of 2010

Table B.1. Share of expenditures on agricultural R&D performed by government and higher education institutions (*cont.*)

		1995	2000	2005	2010	Notes
Slovak Republic	Total R&D	46	34	50	58	
	Agricultural sciences	89	31	58	94	1996 instead of 1995
	Agriculture	n.a.	32	41	93	
Slovenia	Total R&D	53	43	41	32	
	Agricultural sciences	81	96	97	n.a.	
	Agriculture	n.a.	95	79	83	
Spain	Total R&D	51	45	46	48	
	Agricultural sciences	n.a.	75	n.a.	n.a.	
	Agriculture	n.a.	n.a.	66	74	2003, 2009
Switzerland	Total R&D	n.a.	50	24	25	2000, 2004, 2008
	Agricultural sciences	n.a.	n.a.	n.a.	n.a.	
	Agriculture	n.a.	n.a.	21	n.a.	2004
Turkey	Total R&D	76	67	66	57	
	Agricultural sciences	n.a.	n.a.	94	89	
	Agriculture	n.a.	n.a.	n.a.	n.a.	
United States[3]	Total R&D	n.a.	n.a.	n.a.	n.a.	
	Agricultural sciences	n.a.	n.a.	n.a.	n.a.	
	Agriculture	39	48	45	47	2007 instead of 2010
Argentina	Total R&D	72	72	66	68	1996, 2000, 2005, 2007
	Agricultural sciences	n.a.	94	93	93	
	Agriculture	n.a.	n.a.	89	90	
Bulgaria[2]	Total R&D	n.a.	78	77	69	2009
	Agricultural sciences	n.a.	92	94	84	2009
	Agriculture	n.a.	n.a.	n.a.	89	2009
China[2]	Total R&D	53	40	32	27	1998, 2000, 2005, 2008
	Agricultural sciences	59	70	n.a.	n.a.	
	Agriculture	n.a.	n.a.	n.a.	n.a.	
Latvia[2]	Total R&D	79	60	59	64	1998, 2000, 2005, 2009
	Agricultural sciences	n.a.	95	61	96	1998, 2000, 2005, 2009
	Agriculture	n.a.	n.a.	n.a.	n.a.	
Romania	Total R&D	22	31	48	61	2009 instead of 2010
	Agricultural sciences	15	15	34	47	1996, 2000, 2005, 2009
	Agriculture	n.a.	n.a.	11	50	2009 instead of 2010
Russian Federation	Total R&D	31	29	32	39	
	Agricultural sciences	67	67	76	86	
	Agriculture	n.a.	n.a.	65	74	2006 instead of 2005

Notes: n.a.: not available.

1. Response to M&E 2012 questionnaire.
2. EUROSTAT.
3. USDA data. http://www.ers.usda.gov/Data/AgResearchFunding/

Source: OECD R&D database. Gross domestic expenditure on R-D by sector of performance and socio-economic objective in NABS2007 in OECD.Stat.

Table B.2. Government expenditures on agricultural R&D as a % of agricultural gross value added (GVA)

		1985	1990	1995	2000	2005	2010
Australia	R&D budget, all activities[1]	0.6	0.6	0.6	0.6	0.6	0.6
	R&D budget, agriculture[1, 2]	1.5	1.5	1.5	1.1	1.7	1.5
	R&D expenditures on agriculture[3]	3.9	4.2	4.7	3.4	4.3	3.6
	R&D expenditures on agricultural sciences[4]	0.4	0.7	0.7	3.8	3.4	3.4
Austria	R&D budget, all activities[1]	0.6	0.6	0.7	0.7	0.7	0.9
	R&D budget, agriculture[1, 2]	0.7	0.6	0.9	1.0	0.9	1.0
	R&D expenditures on agriculture[3]	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
	R&D expenditures on agricultural sciences[4]	1.1	0.7	0.7	3.8	3.4	3.4
Belgium	R&D budget, all activities[1]	0.6	0.6	0.6	0.6	0.7	0.7
	R&D budget, agriculture[1, 2]	1.9	1.6	1.5	1.4	1.1	1.5
	R&D expenditures on agriculture[3]	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
	R&D expenditures on agricultural sciences[4]	n.a.	n.a.	n.a.	5.0	7.9	11.2
Canada	R&D budget, all activities[1]	0.7	0.7	0.6	0.6	0.6	0.6
	R&D budget, agriculture[1, 2]	3.2	2.9	2.4	2.5	2.7	2.2
	R&D expenditures on agriculture[3]	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
	R&D expenditures on agricultural sciences[4]	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Czech Republic	R&D budget, all activities[1]	n.a.	n.a.	n.a.	0.5	0.6	0.7
	R&D budget, agriculture[1, 2]	n.a.	n.a.	n.a.	0.7	1.0	1.3
	R&D expenditures on agriculture[3]	n.a.	n.a.	n.a.	1.5	1.9	n.a.
	R&D expenditures on agricultural sciences[4]	n.a.	n.a.	0.9	1.0	1.6	1.7
Denmark	R&D budget, all activities[1]	0.6	0.8	0.8	0.9	0.8	1.1
	R&D budget, agriculture[1, 2]	0.9	1.6	1.5	3.8	3.3	3.0
	R&D expenditures on agriculture[3]	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
	R&D expenditures on agricultural sciences[4]	0.3	0.6	1.5	3.7	5.6	11.7
Estonia	R&D budget, all activities[1]	n.a.	n.a.	n.a.	0.4	0.5	0.8
	R&D budget, agriculture[1, 2]	n.a.	n.a.	n.a.	1.2	1.7	1.9
	R&D expenditures on agriculture[3]	n.a.	n.a.	n.a.	0.0	2.0	2.7
	R&D expenditures on agricultural sciences[4]	n.a.	n.a.	n.a.	n.a.	1.4	1.8
Finland	R&D budget, all activities[1]	0.8	0.9	1.1	1.1	1.2	1.3
	R&D budget, agriculture[1, 2]	0.9	1.2	1.8	1.7	2.5	2.2
	R&D expenditures on agriculture[3]	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
	R&D expenditures on agricultural sciences[4]	0.8	1.3	2.4	2.3	3.2	3.7

Table B.2. Government expenditures on agricultural R&D as a % of agricultural GVA (*cont.*)

		1985	1990	1995	2000	2005	2010
France	R&D budget, all activities1	1.6	1.5	1.2	1.1	1.1	0.9
	R&D budget, agriculture[1, 2]	1.2	1.4	1.3	0.9	1.0	0.9
	R&D expenditures on agriculture[3]	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
	R&D expenditures on agricultural sciences[4]	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Germany	R&D budget, all activities[1]	1.1	1.0	1.0	0.9	0.9	1.0
	R&D budget, agriculture[1, 2]	1.1	1.3	2.0	1.7	1.8	4.0
	R&D expenditures on agriculture[3]	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
	R&D expenditures on agricultural sciences[4]	0.9	0.9	3.6	3.1	4.3	5.6
Hungary	R&D budget, all activities[1]	n.a.	n.a.	n.a.	0.0	0.5	0.4
	R&D budget, agriculture[1, 2]	n.a.	n.a.	n.a.	0.0	1.7	0.6
	R&D expenditures on agriculture[3]	n.a.	n.a.	n.a.	1.8	2.4	3.0
	R&D expenditures on agricultural sciences[4]	n.a.	0.7	0.7	1.4	1.9	2.0
Iceland	R&D budget, all activities[1]	0.6	0.7	0.8	1.1	1.1	1.2
	R&D budget, agriculture[1, 2]	1.6	2.0	2.1	2.6	3.2	2.9
	R&D expenditures on agriculture[3]	2.0	2.6	2.7	4.2	7.3	4.1
	R&D expenditures on agricultural sciences[4]	n.a.	n.a.	3.0	4.4	5.1	4.5
Ireland	R&D budget, all activities[1]	0.4	0.3	0.4	0.3	0.5	0.6
	R&D budget, agriculture[1, 2]	0.8	0.4	1.1	1.6	3.7	5.0
	R&D expenditures on agriculture[3]	1.7	1.5	n.a.	n.a.	n.a.	n.a.
	R&D expenditures on agricultural sciences[4]	0.1	0.1	0.1	0.1	3.7	6.8
Israel	R&D budget, all activities[1]	n.a.	n.a.	0.9	1.0	0.8	0.7
	R&D budget, agriculture[1, 2]	n.a.	n.a.	4.3	3.8	2.9	2.4
	R&D expenditures on agriculture[3]	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
	R&D expenditures on agricultural sciences[4]	n.a.	n.a.	n.a.	n.a.	n.a.	0.9
Italy	R&D budget, all activities[1]	0.7	0.8	0.6	0.7	0.7	0.7
	R&D budget, agriculture[1, 2]	0.6	0.7	0.5	0.6	1.2	1.3
	R&D expenditures on agriculture[3]	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
	R&D expenditures on agricultural sciences[4]	0.5	n.a.	n.a.	0.7	1.3	1.5
Japan	R&D budget, all activities[1]	0.0	0.4	0.5	0.6	0.7	0.8
	R&D budget, agriculture[1, 2]	0.0	0.7	1.1	1.5	2.0	2.3
	R&D expenditures on agriculture[3]	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
	R&D expenditures on agricultural sciences[4]	1.0	1.1	1.5	1.3	5.4	5.9

Table B.2. Government expenditures on agricultural R&D as a % of agricultural GVA (*cont.*)

		1985	1990	1995	2000	2005	2010
Korea	R&D budget, all activities[1]	n.a.	n.a.	n.a.	0.7	0.9	1.1
	R&D budget, agriculture[1, 2]	n.a.	n.a.	n.a.	1.4	1.9	2.8
	R&D expenditures on agriculture[3]	n.a.	n.a.	1.9	2.0	2.1	4.0
	R&D expenditures on agricultural sciences[4]	n.a.	n.a.	n.a.	n.a.	1.9	3.1
Luxembourg	R&D budget, all activities[1]	n.a.	n.a.	n.a.	0.1	0.3	0.6
	R&D budget, agriculture[1, 2]	n.a.	n.a.	n.a.	0.1	0.2	0.8
	R&D expenditures on agriculture[3]	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
	R&D expenditures on agricultural sciences[4]	n.a.	n.a.	n.a.	0.4	2.9	n.a.
Mexico	R&D budget, all activities[1]	n.a.	0.2	0.2	0.2	0.2	n.a.
	R&D budget, agriculture[1, 2]	n.a.	0.4	0.1	0.2	0.3	0.3
	R&D expenditures on agriculture[3]	n.a.	n.a.	n.a.	0.8	n.a.	n.a.
	R&D expenditures on agricultural sciences[4]	n.a.	n.a.	0.1	0.6	n.a.	n.a.
Netherlands	R&D budget, all activities[1]	1.0	1.2	0.9	0.9	0.9	1.0
	R&D budget, agriculture[1, 2]	1.1	1.1	1.1	1.2	2.3	1.7
	R&D expenditures on agriculture[3]	1.6	n.a.	n.a.	n.a.	n.a.	n.a.
	R&D expenditures on agricultural sciences[4]	0.6	0.5	1.5	1.3	1.9	4.2
New Zealand	R&D budget, all activities[1]	n.a.	0.6	0.5	0.5	0.5	n.a.
	R&D budget, agriculture[1, 2]	n.a.	2.9	2.2	2.2	2.1	n.a.
	R&D expenditures on agriculture[3]	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
	R&D expenditures on agricultural sciences[4]	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Norway	R&D budget, all activities[1]	0.7	0.9	0.9	0.7	0.8	1.0
	R&D budget, agriculture[1, 2]	2.3	3.2	2.8	3.1	4.4	4.2
	R&D expenditures on agriculture[3]	n.a.	4.0	3.6	4.4	7.5	0.0
	R&D expenditures on agricultural sciences[4]	0.7	0.8	1.0	3.7	5.6	5.9
Poland	R&D budget, all activities[1]	n.a.	n.a.	0.5	0.4	0.3	0.4
	R&D budget, agriculture[1, 2]	n.a.	n.a.	n.a.	n.a.	0.1	0.2
	R&D expenditures on agriculture[3]	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
	R&D expenditures on agricultural sciences[4]	n.a.	n.a.	0.9	1.1	1.1	1.2
Portugal	R&D budget, all activities[1]	0.2	0.4	0.5	0.6	0.8	1.2
	R&D budget, agriculture[1, 2]	0.3	0.6	0.9	2.3	2.5	2.0
	R&D expenditures on agriculture[3]	0.4	0.7	1.2	2.7	3.0	2.8
	R&D expenditures on agricultural sciences[4]	0.4	0.7	1.3	1.9	2.3	2.1
Slovak Republic	R&D budget, all activities[1]	n.a.	n.a.	0.4	0.4	0.3	0.3
	R&D budget, agriculture[1, 2]	n.a.	n.a.	1.5	1.2	1.0	0.6
	R&D expenditures on agriculture[3]	n.a.	n.a.	n.a.	2.3	1.8	0.9
	R&D expenditures on agricultural sciences[4]	n.a.	n.a.	1.6	0.6	0.9	1.4

Table B.2. Government expenditures on agricultural R&D as a % of agricultural GVA (*cont.*)

		1985	1990	1995	2000	2005	2010
Slovenia	R&D budget, all activities[1]	n.a.	n.a.	0.6	0.6	0.7	0.7
	R&D budget, agriculture[1, 2]	n.a.	n.a.	0.4	0.8	0.8	1.1
	R&D expenditures on agriculture[3]	n.a.	n.a.	1.0	1.5	1.0	1.7
	R&D expenditures on agricultural sciences[4]	n.a.	n.a.	1.8	1.7	2.4	0.8
Spain	R&D budget, all activities[1]	0.3	0.5	0.5	0.7	0.6	0.9
	R&D budget, agriculture[1, 2]	0.4	0.5	0.5	0.6	1.7	2.2
	R&D expenditures on agriculture[3]	n.a.	n.a.	1.4	1.6	2.2	3.8
	R&D expenditures on agricultural sciences[4]	0.7	1.0	1.0	1.2	1.8	2.5
Sweden	R&D budget, all activities[1]	1.3	1.3	1.2	0.8	1.0	1.0
	R&D budget, agriculture[1, 2]	0.6	0.7	0.7	0.7	1.7	0.8
	R&D expenditures on agriculture[3]	0.5	n.a.	n.a.	n.a.	n.a.	n.a.
	R&D expenditures on agricultural sciences[4]	1.8	2.8	1.8	2.3	3.6	2.5
Switzerland	R&D budget, all activities[1]	0.6	0.5	0.8	0.7	0.7	0.8
	R&D budget, agriculture[1, 2]	n.a.	1.2	0.8	1.4	1.7	1.8
	R&D expenditures on agriculture[3]	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
	R&D expenditures on agricultural sciences[4]	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Turkey	R&D budget, all activities[1]	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
	R&D budget, agriculture[1, 2]	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
	R&D expenditures on agriculture[3]	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
	R&D expenditures on agricultural sciences[4]	n.a.	0.1	0.1	0.2	0.4	0.5
United Kingdom	R&D budget, all activities[1]	1.3	1.0	0.9	0.8	0.7	0.7
	R&D budget, agriculture[1, 2]	3.6	2.1	2.3	3.1	3.6	3.1
	R&D expenditures on agriculture[3]	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
	R&D expenditures on agricultural sciences[4]	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
United States	R&D budget, all activities[1]	1.3	1.2	1.0	0.9	1.1	1.1
	R&D budget, agriculture[1, 2]	1.1	1.2	1.6	2.0	1.9	1.7
	R&D expenditures on agriculture[3]	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
	R&D expenditures on agricultural sciences[4]	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Russian Federation	R&D budget, all activities[1]	n.a.	n.a.	0.7	0.5	0.4	0.6
	R&D budget, agriculture[1, 2]	n.a.	n.a.	0.7	0.6	0.1	0.3
	R&D expenditures on agriculture[3]	n.a.	n.a.	0.6	0.5	0.6	0.8
	R&D expenditures on agricultural sciences[4]	n.a.	n.a.	0.3	0.2	0.4	0.5

Notes: n.a.: not available.
1. GBAORD: Government budget appropriations or outlays for research and development.
2. Socio-economic objective agriculture.
3. Gross domestic expenditure on R&D performed by government and higher education on socio-economic objective: agriculture.
4. Gross domestic expenditure on R&D performed by government and higher education on agricultural sciences.
Source: OECD R&D database, OECD.Stat.

Table B.3. Public expenditures on agricultural R&D as a % of agricultural GDP

	1990	1995	2000	2005	2010
Argentina	1.0	1.5	1.4	1.0	n.a.
Brazil	1.7	2.1	1.9	1.6	n.a.
Chile	1.1	1.0	1.3	1.3	n.a.
China	0.3	0.3	0.4	0.4	n.a.
Colombia	0.5	0.5	0.6	0.5	n.a.
Costa Rica	0.9	0.7	0.9	1.1	n.a.
India[1]	0.3	0.3	0.4	0.4	n.a.
Indonesia[1]	n.a.	0.3	0.2	0.2	n.a.
South Africa[2]	2.1	3.0	2.8	3.1	2.0

Notes: n.a.: not available.
1. 1991 instead of 1990; 2003 instead of 2005.
2. 2008 instead of 2010.
Source: ASTI.

Table B.4. Change in gross domestic R&D expenditures on agricultural sciences by sector of performance

		2008-10	1994-96/ 1984-86	2004-06/ 1994-96	2008-10/ 2004-06	2008-10/ 1984-86
		Million 2005 Dollars - Constant prices and PPPs	Annual growth rate in percentage			
Australia	Total intramural	840	n.a.	1.8	-1.4	n.a.
	Business enterprise	273	n.a.	18.8	5.0	n.a.
	Government	385	n.a.	-1.1	-4.7	n.a.
	Higher education	204	6.7	6.6	1.7	8.0
	Private non-profit	2	6.9	39.3	0.6	30.5
Austria	Total intramural	n.a.	n.a.	n.a.	n.a.	n.a.
	Business enterprise	n.a.	n.a.	n.a.	n.a.	n.a.
	Government	47	1.0	-1.2	5.7	1.0
	Higher education	95	4.1	9.1	5.5	9.7
	Private non-profit	0	-4.3	-6.4	0.0	-3.2
Belgium	Total intramural	n.a.	n.a.	n.a.	n.a.	n.a.
	Business enterprise	n.a.	n.a.	n.a.	n.a.	n.a.
	Government	75	n.a.	n.a.	8.8	n.a.
	Higher education	153	n.a.	n.a.	1.4	n.a.
	Private non-profit	1	n.a.	n.a.	2.0	n.a.
Chile	Total intramural	122	n.a.	n.a.	n.a.	n.a.
	Business enterprise	22	n.a.	n.a.	n.a.	n.a.
	Government	44	n.a.	n.a.	n.a.	n.a.
	Higher education	38	n.a.	n.a.	n.a.	n.a.
	Private non-profit	18	n.a.	n.a.	n.a.	n.a.
Czech Republic	Total intramural	133	n.a.	3.5	1.5	n.a.
	Business enterprise	39	n.a.	3.2	3.4	n.a.
	Government	50	n.a.	0.0	-3.0	n.a.
	Higher education	43	n.a.	29.7	7.6	n.a.
	Private non-profit	1	n.a.	n.a.	39.2	n.a.
Denmark	Total intramural	n.a.	n.a.	n.a.	n.a.	n.a.
	Business enterprise	n.a.	n.a.	n.a.	n.a.	n.a.
	Government	0.4	n.a.	n.a.	-19.9	n.a.
	Higher education	162	30.1	-1.3	35.9	35.1
	Private non-profit	n.a.	n.a.	n.a.	n.a.	n.a.
Estonia	Total intramural	n.a.	n.a.	n.a.	n.a.	n.a.
	Business enterprise	n.a.	n.a.	n.a.	n.a.	n.a.
	Government	4	n.a.	n.a.	2.3	n.a.
	Higher education	7	n.a.	n.a.	1.5	n.a.
	Private non-profit	0	n.a.	n.a.	n.a.	n.a.
Finland	Total intramural	n.a.	n.a.	n.a.	n.a.	n.a.
	Business enterprise	n.a.	n.a.	n.a.	n.a.	n.a.
	Government	101	n.a.	1.8	0.4	n.a.
	Higher education	37	n.a.	3.6	7.9	n.a.
	Private non-profit	n.a.	n.a.	n.a.	n.a.	n.a.

Table B.4. Change in gross domestic R&D expenditures on agricultural sciences by sector of performance (*cont.*)

		2008-10	1994-96/ 1984-86	2004-06/ 1994-96	2008-10/ 2004-06	2008-10/ 1984-86
		Million 2005 Dollars - Constant prices and PPPs	Annual growth rate in percentage			
Germany	Total intramural	n.a.	n.a.	n.a.	n.a.	n.a.
	Business enterprise	n.a.	n.a.	n.a.	n.a.	n.a.
	Government	584	n.a.	1.0	3.4	n.a.
	Higher education	448	6.3	-1.0	3.2	2.8
	Private non-profit	n.a.	n.a.	n.a.	n.a.	n.a.
Hungary	Total intramural	135	n.a.	1.8	0.6	n.a.
	Business enterprise	39	n.a.	-6.7	24.9	n.a.
	Government	57	n.a.	27.8	-4.7	n.a.
	Higher education	39	n.a.	0.4	-0.3	n.a.
	Private non-profit	n.a.	n.a.	n.a.	n.a.	n.a.
Iceland	Total intramural	n.a.	n.a.	n.a.	n.a.	n.a.
	Business enterprise	n.a.	n.a.	n.a.	n.a.	n.a.
	Government	18	n.a.	3.4	-4.5	n.a.
	Higher education	6	n.a.	13.3	9.6	n.a.
	Private non-profit	0	n.a.	n.a.	n.a.	n.a.
Ireland	Total intramural	n.a.	n.a.	n.a.	n.a.	n.a.
	Business enterprise	n.a.	n.a.	n.a.	n.a.	n.a.
	Government	75	n.a.	n.a.	2.5	n.a.
	Higher education	24	0.7	20.4	13.9	18.0
	Private non-profit	n.a.	n.a.	n.a.	n.a.	n.a.
Italy	Total intramural	n.a.	n.a.	n.a.	n.a.	n.a.
	Business enterprise	n.a.	n.a.	n.a.	n.a.	n.a.
	Government	243	n.a.	n.a.	5.0	n.a.
	Higher education	238	n.a.	n.a.	0.7	-0.1
	Private non-profit	22	n.a.	n.a.	9.6	n.a.
Japan	Total intramural	n.a.	n.a.	n.a.	n.a.	n.a.
	Business enterprise	n.a.	n.a.	n.a.	n.a.	n.a.
	Government	1 775	n.a.	n.a.	-0.1	n.a.
	Higher education	739	0.9	0.4	-0.6	0.4
	Private non-profit	214	11.0	1.5	-1.6	4.9
Korea	Total intramural	1 066	n.a.	n.a.	3.5	n.a.
	Business enterprise	256	n.a.	n.a.	3.0	n.a.
	Government	543	n.a.	n.a.	1.4	n.a.
	Higher education	265	n.a.	n.a.	10.0	n.a.
	Private non-profit	2	n.a.	n.a.	n.a.	n.a.
Netherlands	Total intramural	n.a.	n.a.	n.a.	n.a.	n.a.
	Business enterprise	n.a.	n.a.	n.a.	n.a.	n.a.
	Government	201	n.a.	n.a.	n.a.	n.a.
	Higher education	169	15.0	0.0	-1.5	5.2
	Private non-profit	n.a.	n.a.	n.a.	n.a.	n.a.

Table B.4. Change in gross domestic R&D expenditures on agricultural sciences by sector of performance (*cont.*)

		2008-10	1994-96/ 1984-86	2004-06/ 1994-96	2008-10/ 2004-06	2008-10/ 1984-86
		Million 2005 Dollars - Constant prices and PPPs	Annual growth rate in percentage			
Norway	Total intramural	n.a.	n.a.	n.a.	n.a.	n.a.
	Business enterprise	n.a.	n.a.	n.a.	n.a.	n.a.
	Government	123	n.a.	n.a.	1.0	n.a.
	Higher education	27	4.3	3.4	-9.1	0.2
	Private non-profit	n.a.	n.a.	n.a.	n.a.	n.a.
Poland	Total intramural	270	n.a.	0.2	0.8	n.a.
	Business enterprise	26	n.a.	-1.8	-1.2	n.a.
	Government	185	n.a.	0.4	3.1	n.a.
	Higher education	60	n.a.	1.0	-3.6	n.a.
	Private non-profit	n.a.	n.a.	n.a.	n.a.	n.a.
Portugal	Total intramural	131	n.a.	n.a.	-1.9	n.a.
	Business enterprise	27	n.a.	n.a.	8.1	n.a.
	Government	42	5.5	-0.1	-8.6	-0.5
	Higher education	58	20.5	5.4	5.0	19.6
	Private non-profit	3	136.7	-2.5	-5.2	28.3
Slovak Republic	Total intramural	45	n.a.	-1.5	-1.0	n.a.
	Business enterprise	3	n.a.	22.2	-17.0	n.a.
	Government	32	n.a.	-5.7	11.5	n.a.
	Higher education	11	n.a.	12.9	5.9	n.a.
	Private non-profit	0	n.a.	n.a.	40.0	n.a.
Slovenia	Total intramural	11	n.a.	-0.7	-10.7	n.a.
	Business enterprise	2	n.a.	-9.0	48.4	n.a.
	Government	7	n.a.	-2.0	7.9	n.a.
	Higher education	3	n.a.	2.5	-17.3	n.a.
	Private non-profit	0	n.a.	47.8	-20.0	n.a.
Spain	Total intramural	n.a.	n.a.	n.a.	n.a.	n.a.
	Business enterprise	n.a.	n.a.	n.a.	n.a.	n.a.
	Government	581	0.8	7.6	5.7	5.8
	Higher education	124	25.6	-1.3	7.0	12.8
	Private non-profit	1	-5.4	5.4	12.5	0.6
Sweden	Total intramural	n.a.	n.a.	n.a.	n.a.	n.a.
	Business enterprise	n.a.	n.a.	n.a.	n.a.	n.a.
	Government	n.a.	n.a.	n.a.	n.a.	n.a.
	Higher education	117	-2.6	1.2	0.0	-0.7
	Private non-profit	n.a.	n.a.	n.a.	n.a.	n.a.
Switzerland	Total intramural	37	n.a.	n.a.	n.a.	n.a.
	Business enterprise	n.a.	n.a.	n.a.	n.a.	n.a.
	Government	n.a.	n.a.	n.a.	n.a.	n.a.
	Higher education	37	n.a.	n.a.	-1.4	n.a.
	Private non-profit	n.a.	n.a.	n.a.	n.a.	n.a.

Table B.4. Change in gross domestic R&D expenditures on agricultural sciences by sector of performance (*cont.*)

		2008-10	1994-96/ 1984-86	2004-06/ 1994-96	2008-10/ 2004-06	2008-10/ 1984-86
		Million 2005 Dollars - Constant prices and PPPs	Annual growth rate in percentage			
Turkey	Total intramural	384	n.a.	n.a.	7.7	n.a.
	Business enterprise	38	n.a.	n.a.	15.3	n.a.
	Government	163	n.a.	n.a.	8.5	n.a.
	Higher education	183	n.a.	7.2	5.1	n.a.
	Private non-profit	n.a.	n.a.	n.a.	n.a.	n.a.
Romania	Total intramural	96	n.a.	-2.2	-0.3	n.a.
	Business enterprise	51	n.a.	-3.7	-4.8	n.a.
	Government	11	n.a.	-1.1	-6.3	n.a.
	Higher education	34	n.a.	67.3	23.2	n.a.
	Private non-profit	1	n.a.	n.a.	112.6	n.a.
Russian Federation	Total intramural	450	n.a.	0.9	5.7	n.a.
	Business enterprise	64	n.a.	-2.4	-3.9	n.a.
	Government	350	n.a.	2.5	7.7	n.a.
	Higher education	36	n.a.	2.5	19.2	n.a.
	Private non-profit	0	n.a.	-7.0	82.2	n.a.
South Africa	Total intramural	81	n.a.	n.a.	-3.6	n.a.
	Business enterprise	71	n.a.	n.a.	-3.4	n.a.
	Government	8	n.a.	n.a.	-4.4	n.a.
	Higher education	2	n.a.	n.a.	-0.6	n.a.
	Private non-profit	n.a.	n.a.	n.a.	-3.4	n.a.
United States[1]	Total	10 632	0.1	1.6	-1.0	0.5
	Private	5 761	-0.3	1.8	-0.7	0.4
	Public	4 871	0.6	1.4	-1.3	0.5

Note:

1. USDA data on agricultural research funding in the public and private sector available at: www.ers.usda.gov/data-products/agricultural-research-funding-in-the-public-and-private-sectors.aspx. Accessed in February 2013.

Source: OECD R&D database. Gross domestic expenditure on R-D by sector of performance and socio-economic objective in NABS2007 in OECD.Stat.

Annex C.

MEASURING AND EVALUATING INNOVATION

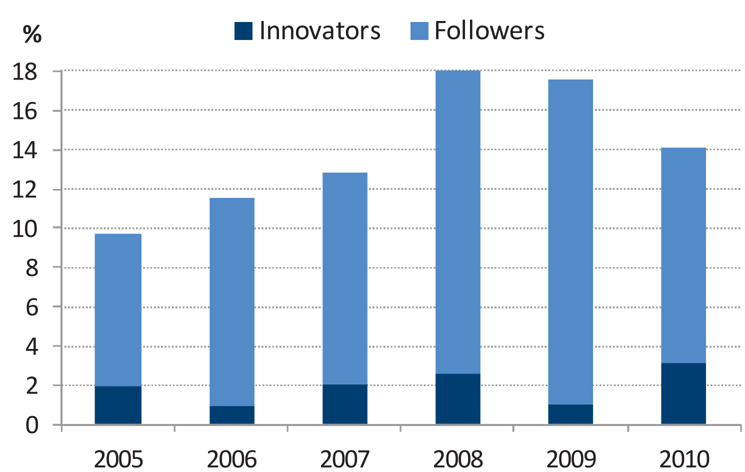
Indicators of innovation attempt to measure both efforts (e.g. R&D expenditures), outcomes (e.g. number of patents), and impacts (e.g. TFP growth or number of changes introduced in firms). Most common indicators of innovation efforts and outcomes are discussed in Chapter 1, Box 1.3, and some are presented 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

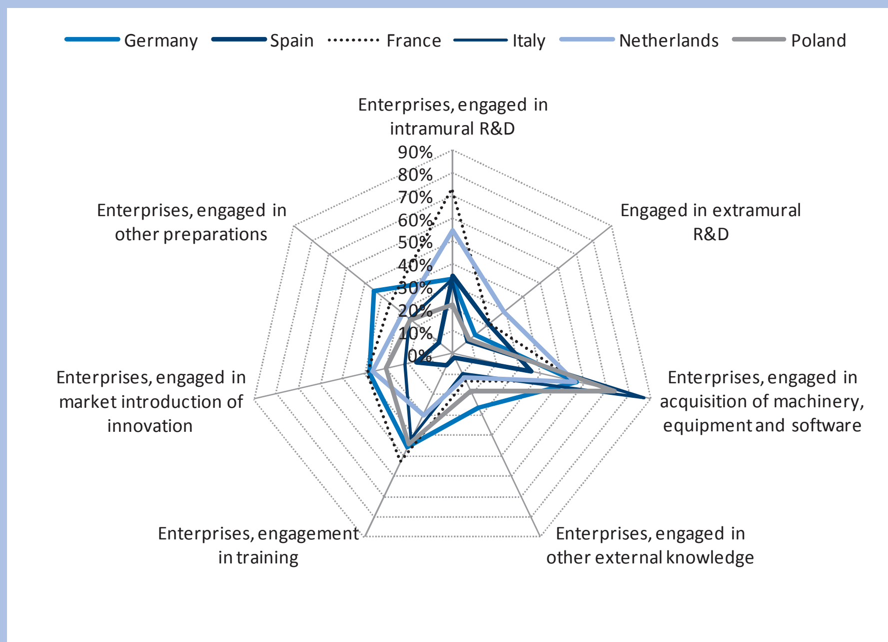


Source: LEI, Farm Accountancy Data Network. In: Galen, M.A. van (2012), *Innovatie en vernieuwing in de land- en tuinbouw in 2010 gedaald*, Agri-monitor 2012 (April).

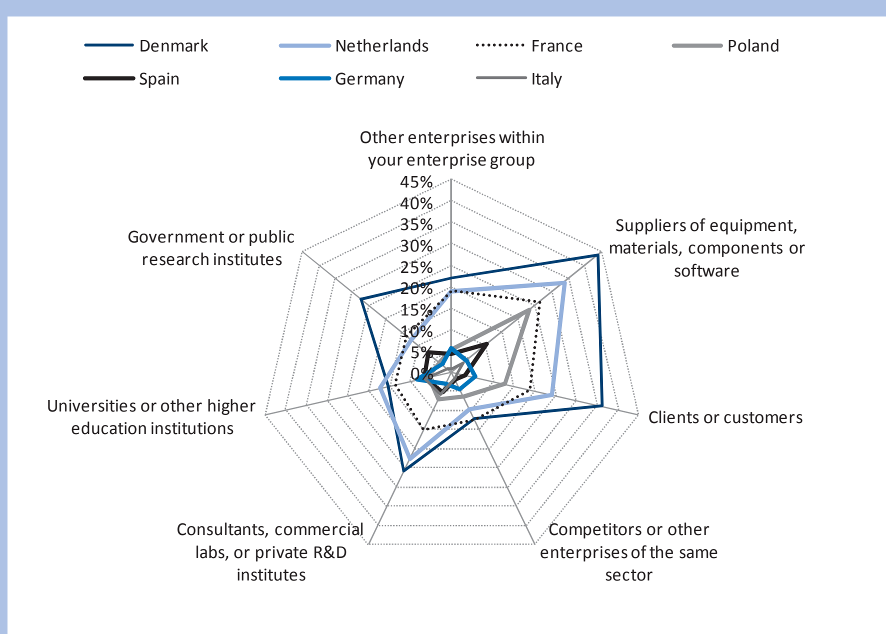
Box C.1. Monitoring innovation in the food processing industry

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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