Unclassified TAD/CA/APM/WP(2012)6/FINAL

Organisation de Coopération et de Développement Économiques
Organisation for Economic Co-operation and Development

05-Jun-2012

English - Or. English

TRADE AND AGRICULTURE DIRECTORATE
COMMITTEE FOR AGRICULTURE

TAD/CA/APM/WP(2012)6/FINAL
Unclassified

Working Party on Agricultural Policies and Markets

AGRICULTURAL POLICIES: MONITORING AND EVALUATION: PART I, CHAPTER 2. FOSTERING INNOVATION AND PRODUCTIVITY GROWTH IN AGRICULTURE

Contact Person: Vaclav Vojtech
(Email: vaclav.vojtech@oecd.org)

JT03322984

English - Or. English

Note by the Secretariat

This is the final version of Part I, Chapter 2 – Fostering Innovation and Productivity Growth in Agriculture of the report entitled ***Agricultural Policies: Monitoring and Evaluation 2012, OECD Countries***. It provides a special focus on policies related to innovation and productivity in agriculture.

It is circulated on OLIS as part of the following set of documents forming the 2012 report:

Executive Summary
[TAD/CA/APM/WP(2012)4/FINAL]

Part I, Chapter 1 – Developments in Agricultural Policy and Support
[TAD/CA/APM/WP(2012)5/FINAL]

Part I, Chapter 2 – Fostering Innovation and Productivity Growth in Agriculture
[TAD/CA/APM/WP(2012)6/FINAL]

Part II – Country Chapters
[TAD/CA/APM/WP(2012)7/FINAL]

Part III – Summary Tables of Estimates of Support
[TAD/CA/APM/WP(2012)8/FINAL]

Document [TAD/CA/APM/WP(2012)4/FINAL] contains the *Executive Summary* which will appear at the beginning of the report.

Document [TAD/CA/APM/WP(2012)5/FINAL] contains Part I, Chapter 1 *Developments in Agricultural Policy and Support.* It provides a description and an overall assessment of agricultural policy developments and support across the OECD area.

Document [TAD/CA/APM/WP(2012)7/FINAL] contains *Country Chapters* with contextual information, the evaluation of support and policy developments in 2011 for each OECD country.

Document [TAD/CA/APM/WP(2012)8/FINAL] contains Part III - *Summary Tables of Estimates of Support* of the report.

Part I, Chapter 2 has been declassified by the Working Party of Agricultural policies and Markets (APM) during its 57th session held on 29-31 May 2012.

TABLE OF CONTENTS

Tables

Figures

Boxes

CHAPTER 2.

FOSTERING INNOVATION AND PRODUCTIVITY GROWTH IN AGRICULTURE

1. Increasing productivity is a key objective of agricultural policies in many countries. It is an important means by which to improve the efficiency and the competitiveness of the agri-food sector. In countries with a comparative advantage in agriculture, it may also significantly strengthen the sector's contribution to economic growth.

2. At the global level, more food, fibre, fuel and feed are needed to meet the demands of a growing and richer population for more abundant and diverse diets, as well as for the development of bio-based, non-food products. Meeting these demands sustainably will require further increases in agricultural productivity and production systems must be improved to ensure more efficient use of available, finite natural resources. Higher productivity growth is also needed to increase production to better smooth supply shocks, which are expected to become more frequent due to climate change or resource limits more generally.

3. The challenge is to increase agricultural productivity growth sustainably, without imposing greater strain on natural resources, 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 farm-level and in the agri-food sector. There are many factors, including agricultural policy, that influence the adoption of innovation, the choice of production practices, and in particular the balance between productivity growth and sustainability.[1] Moreover, while the concept of sustainable productivity growth encompasses many objectives of agricultural policy and innovation systems, it is not necessarily the only one.

4. In response to these concerns, G20 leaders committed in the 2011 Cannes Declaration to sustainably increase agricultural production and productivity.[2] They "agree to further invest in agriculture, in particular in the poorest countries, and bearing in mind the importance of smallholders, through responsible public and private investment." They "decide to invest in research and development of agricultural productivity." Early in 2012, Mexico, as G20 President, invited international organisations to examine practical actions that could be undertaken to sustainably improve agricultural productivity growth, in particular on small family farms. In response to this request, twelve organisations prepared a report entitled "Sustainable Agricultural Productivity Growth and Bridging the Gap for Small Family Farms".[3]

5. This chapter aims to help policy makers in OECD countries and emerging economies pursue the global challenge of improving productivity growth sustainability by improving innovation systems and agricultural policies. It focuses on institutional, economic and policy aspects. The first section outlines the

1. The relationships between productivity growth and sustainability, and possible synergies, are discussed in OECD work on Green Growth (OECD, 2011b).

2. http://www.g20-g8.com/g8-g20/g20/english/the-2011-summit/declarations-and-reports/g20-cannes-summit-declarations-and-reports.1553.html

3. The report was coordinated by the FAO and the OECD, and is a collaborative undertaking by Bioversity, CGIAR Consortium, FAO, IFAD, IFPRI, IICA, OECD, UNCTAD, UN High Level Task Force on the Food Security Crisis, WFP, World Bank, and WTO.

issue by describing developments in agricultural productivity and resource use.[4] The second section discusses how innovation systems, agricultural policy, farm structure and other factors affect agricultural productivity and sustainability. The third section suggests how innovation systems could be strengthened to foster agricultural productivity growth efficiently and sustainably, while the fourth section focuses on agricultural policy. The need to improve policy coherence is stressed in the concluding section.

2.1. Agricultural productivity and sustainability: Trends and differences

6. Since the post-war period, there has been a strong growth in agricultural productivity driven largely by technological progress (OECD, 2011a). Together with the expansion of the resource base, this has enabled agriculture to provide food for a rapidly growing global population. This has, however, increased pressure on natural resources, raising concerns about the sustainability of past and future productivity growth, and the ability of the sector to respond to food security and climate change challenges sustainably. Moreover, improvements to productivity do not necessarily lead to increased production. They could result in reduced input use and lower environmental pressure whilst production remains broadly static or reduces.

Productivity measure: Trends and diversity

7. In recent years, efforts have been made to assess agricultural productivity performance at the global level using various partial and total factor productivity measures, building on existing databases and other information. Total factor productivity (TFP) — the ratio of output to input — is the most comprehensive measure of productivity as it reflects the efficiency to turn all inputs into outputs, whatever the input mix. TFP measures can be usefully complemented by partial factor productivity indicators, which shed light on how productivity growth is achieved. Higher partial factor productivity does not necessarily lead to higher TFP. For example, labour productivity, measured as output per person, increases with the adoption of labour saving technologies (e.g. machines) or with employment opportunities outside the sector that helps to reduce hidden unemployment. In the first case, TFP might not increase, while it will in the second case. As they compare volumes of outputs and inputs, most productivity indicators do not reflect quality or sustainability changes. They thus need to be complemented by other indicators, e.g. agri-environmental, or qualitative considerations. Higher land productivity (e.g. crop yields) has often resulted from more intensive use of variable inputs such as water, fertilisers and pesticides, but innovative practices and technologies, such as improved varieties, irrigation drip, no-till or integrated pest management, allow to save on these input applications while maintaining or increasing output per hectare (OECD, 2011b).

8. According to the most recent estimates by Fuglie (2012), total factor productivity (TFP) in developed countries grew at an average rate well above 1% per year in the 1970s and 1980s, and at faster rates of 2.2% in the 1990s and 2.4% in the 2000s (Table 2.1).[5] In developing countries, the annual growth rate of TFP averaged 2.2% in the last two decades, compared to around 1% in the 1970s and 1980s. TFP in transition economies has been recovering at an annual growth rate of 2.3% in the 2000s, following periods of decline or slow growth. At the global level, TFP growth tends to accelerate and to converge across major world regions at around 2% per year.

---

4. The 2012 OECD-FAO Agricultural Commodity Outlook (OECD, 2012a) provides a forward looking assessment of developments in productivity growth, resource use and commodity markets.

5. Fuglie uses data published by FAOSTAT to calculate TFP growth as the difference between output growth and input growth. The aggregate volume of output is Agricultural Gross Production in constant 2004-2006 USD, smoothed over time (see note to Table 2.1). The aggregate volume of inputs is calculated as the average of land, livestock, machinery, fertiliser and feed use, weighted by the shares of these inputs in agricultural production available in the literature.

9. The picture is more complex when looking at individual countries or sub-regions (Fuglie, 2010, 2012). In recent decades, some large countries, like Brazil, China, Indonesia, Russia and Ukraine, have achieved much higher growth rates than the average of their neighbours (3 to 5%), while TFP has decreased in neighbouring countries. China's high performance, in particular, hides the more modest performance of the rest of Asia (Alston *et al.*, 2010). With long-run TFP annual growth rates below 1%, Sub-Saharan Africa lags behind, but several countries like Cameroon, Kenya or Mali have achieved an annual TFP growth rate of 2-3% in the 2000s, mostly attributable to policy changes during the 1990s (Yu and Nin-Pratt, 2011). Their performance is comparable with the growth rates in East and South Asia and Latin America during the same period (Table 2.1).

10. Although this does not seem to be a general trend, TFP growth rates have declined in the last decade in some OECD countries with already high productivity levels, such as Australia, Canada, Korea and Mexico (Table 2.2).[6] Some studies also include the United States in this group (Alston *et al.*, 2010).[7] Experts have mentioned several possible explanations: bad weather conditions; policy changes such as the decoupling of support from current production and more stringent environmental regulation; and lack of innovation. In Australia, it is estimated that TFP growth rates have slowed down irrespective of recent bad climatic conditions (Sheng, 2011). One of the reasons given in Alston *et al.* (2010) for the slowdown in Australian TFP is a declining growth rate in expenditures for agricultural R&D.

Table 2.1. Developments in global and regional Total Factor Productivity

Annual growth rates by period (%)

	1961-70	1971-80	1981-90	1991-2000	2001-09
All developed countries	**0.99**	**1.64**	**1.36**	**2.23**	**2.44**
All developing countries	**0.69**	**0.93**	**1.12**	**2.22**	**2.21**
North Africa	1.32	0.48	3.09	2.03	3.04
South-Saharan Africa	0.17	-0.05	0.76	0.99	0.51
Latin America – Caribbean	0.84	1.21	0.99	2.30	2.74
Asia (except West Asia)	0.91	1.17	1.42	2.73	2.78
West Asia	1.21	2.21	0.95	1.70	1.34
Oceania	-0.14	0.47	-0.73	0.54	1.33
Transition countries	**0.57**	**-0.11**	**0.58**	**0.78**	**2.28**

Note: Estimated using using FAOstat data. The average annual growth rate in series Y is found by regressing the natural log of Y against time, i.e. the parameter B in $\ln(Y) = A + Bt$.

Source: Fuglie (2012).

11. In many OECD countries, labour productivity has increased faster than land productivity as labour was shed out of the sector. This has also been the case in Latin America and China, which recorded strong growth in both land and labour productivity (about 4.5% annual growth rate in China over 1990-2005, around 3% in Latin America). This contrasts with the rest of Asia and Africa, where labour productivity has increased less than land productivity, at rates of around 1% annually. At the global level, if China's performance is excluded there is evidence that the annual growth rate in land productivity is slowing down, from 1.9% in 1961-90 to 1.2% in 1990-2005 (Alston, 2010; OECD, 2011a).

6. Piesse and Thirtle (2010) note that an absolute increase in productivity translates into a smaller percentage change when initial levels are already high.

7. Annual variations in agricultural production and differences in data and measurement method may explain differences in TFP estimates.

12. Over the period 1961-2000, non-ruminant TFP growth has been very high in most regions of the world and it is projected to remain strong or become even stronger in the future (Ludena *et al.*, 2007).[8] In developed countries, TFP growth has been the highest in the crop sector, the lowest in the ruminant sector, and average in the non-ruminant sector. But TFP growth in the ruminant sector has been higher in developed countries than in most other regions. At the country-level, TFP growth has been measured for specific agricultural sub-sectors using farm-level data. For example, Nossal and Sheng (2010) found that Australian crop farms achieved higher TFP growth than cattle, sheep or mixed farms over 1978-2007, but were the most affected by recent declines, while the beef industry was more resilient.[9] Most recent figures show that between 1977/78 and 2009/10, TFP annual growth rates were 1.6% for cropping; 1.1% for mixed crop–livestock; 1.4% for beef, 0.5% for sheep, and 0.3% for the dairy industry. In recent years, the gap between the TFP growth rates of the cropping and livestock industries has been narrowing.

Table 2.2. Developments in Total Factor Productivity in OECD countries and emerging economies

Annual growth rates by period (%)

	1961-70	1971-80	1981-90	1991-2000	2001-09
Australia[1]	0.63	1.65	1.27	2.85	0.55
Canada	1.41	-0.36	2.67	2.55	2.14
Chile	1.70	2.20	1.09	1.71	2.58
Estonia	1.40	0.19	-0.69	1.29	4.70
Northwest Europe	0.85	1.48	1.55	1.80	2.75
Southern Europe	1.97	2.03	1.30	2.42	3.04
Israel	5.65	2.74	0.95	2.41	2.57
Japan	2.42	2.17	1.11	1.51	2.43
Korea	1.83	4.28	2.81	4.04	2.86
Mexico	2.65	2.17	-1.98	3.19	2.19
New Zealand[2]	1.47	1.39	1.84	3.20	3.14
Norway	0.92	0.91	1.18	0.56	2.37
Switzerland	0.43	1.06	0.06	1.74	2.02
Turkey	0.75	1.54	0.99	1.50	1.78
United States	1.21	1.80	1.21	2.17	2.26
Brazil	0.19	0.53	3.02	2.61	4.04
China	0.93	0.60	1.69	4.16	2.83
India	0.49	1.00	1.33	1.11	2.08
Indonesia	1.75	1.40	0.59	0.99	3.68
Russia	0.88	-1.35	0.85	1.42	4.29
South Africa	0.34	1.15	2.71	2.79	3.01
Ukraine	0.41	-0.18	1.12	-0.07	5.35

Note: Estimated using using FAOstat data. The average annual growth rate in series Y is found by regressing the natural log of Y against time, i.e. the parameter B in $\ln(Y) = A + Bt$.

1. Australian official figures on productivity growth are calculated by sub-sector.

2. Official figures published by Statistics New Zealand show TFP increasing in the late 1980s and then declining from the late 1990s onwards especially over the last decade.

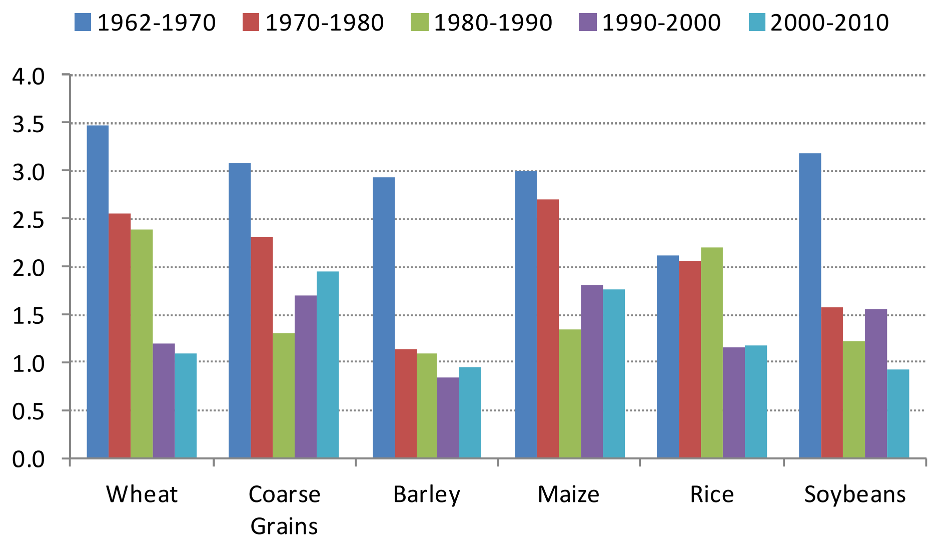
Source: Fuglie (2012).

8. Using FAOSTAT data to calculate Malmquist indices, Ludena *et al.* (2007) calculate TFP growth for the crop, ruminant and non-ruminant sectors at the global and regional levels. They decompose TFP changes into technological change and technical efficiency, defined in the following section.

9. Other examples are noted in Latruffe (2010) and summarised in Tables A.2 and A.3 of OECD (2011a).

13. Similar to TFP growth, developments in crop yields (production per ha) are contrasted across countries and regions, but also across individual crops. At the global level, the yields of major crops doubled or tripled between 1961 and 2010 (Annex Table 2.1). While crop yields continue to grow, the average global rates of growth in yield of most of the major cereals were lower in the last two decades than they were in the post-war period (Figure 2.1). Since the 1980s, growth in wheat and rice yields fell from 2.4-2.2% to slightly over 1%. Maize yields showed growth of slightly less than 2% over the last decade. Maize yields grew at a 1.8% annual rate, compared to around 3% in the 1960s and 1970s, while barley yields grew less than 1% per year. The annual growth rate of soybean yields has decreased from 1.6% in the 1970s and the 1990s to less than 1% in the 2000s. On average, coarse grains yields increased faster in the last two decades than in the 1980s, probably due to changes in aggregate composition over time (Annex Table 2.1).

Figure 2.1. Annual growth rates in world crop yields (%)



Note: Time series are de-trended, by decade, using a Hodrick–Prescott filter.

Source: FAOstat.

14. The levels and growth in the yields of major crops are contrasted across countries (Annex Tables 2.2 to 2.5). Cereals yields vary from less than 1 tonne per hectare in central Africa to over 9 tonnes per hectare for maize in North America and Western Europe, and rice in North Africa, with the highest yields for wheat and barley of about 6-7 tonnes per hectare on average being recorded in Western European countries such as France and Germany (Annex Table 2.2). In the European Union, cereal yields increased until 1998 and have since fluctuated around a flatter trend (OECD, 2011a). Annual growth rates of cereal yields are generally higher in emerging economies than in OECD countries, in particular for maize (Annex Tables 2.3 to 2.5).

15. While the yield of major crops has been extensively scrutinised, work on animal production is less prominent. OECD (2011c) reports higher yield growth rates in milk production than in cereal production in EU member states.

16. While there is no widespread evidence of a global decrease in productivity growth rates, slow or lack of progress in some developing countries is of concern and requires action. As productivity growth is

now the main driver of production growth at the global level,[10] it is crucial to strengthen the capacity of the sector to achieve the productivity growth needed to meet future demand in a sustainable manner, and the ability to create and adopt innovations needed to sustainably improve productivity growth further.[11]

Trends in resource use and availability

17. Agriculture is a significant user of some natural resources, in particular water and land, and needs to improve the sustainability of its resource use. Table 2.3 summarises the relative importance of OECD agriculture in its use of natural resources and contribution to environmental pressures (OECD, 2012e). Trends in resource use and constraints are then outlined and when appropriate and feasible, related to changes in policy and production. More analysis would be needed to relate changes in resource use and quality to changes in productivity.

Table 2.3. OECD Agriculture's use of natural resources, farm inputs and contribution to water and air emissions of importance to the environmental performance of agriculture, 2007-09

Percentage of OECD agriculture in total:	OECD average	Minimum – Maximum
Land area	35%	2% – 72%
Water use	45%	<1% – 87%
Pesticide use (sales)	*circa* 70%	*circa* 65% – 75%
Energy consumption	2%	<1% – 6%
Water pollutants, of which:		
Nitrates in surface water	..	<30% – 80%
Nitrates in groundwater[1]	..	<45% – >70%
Nitrates in coastal water	..	<2% – >30%
Phosphorus in surface water	..	<20% – >70%
Phosphorus in coastal water	..	<30% – >50%
Ammonia emissions	90%	71%-98%
Methyl Bromide use in total ozone depletion potential	75%	..
Greenhouse gas emissions, of which:	8%	3% – 49%
Nitrous Oxide emissions	70%	..
Methane emissions	40%	..
Carbon dioxide	1%	..

..: not available.

Note: Exceeding recommended drinking water threshold limits.

Source: OECD Agri-environmental Indicator database, www.oecd.org/tad/env/indicators. Reported in OECD (2012e).

18. Over the last half century, **land** area used in agriculture has increased in developing countries, but declined in developed countries. Competition for urban, industrial, environmental and recreational uses has been traditionally strong in many regions. Despite growing agricultural land use at the global level, as

10. Fuglie (2012) estimates that TFP accounted for three-quarters of global output growth in 2001-09, compared to less than 7% in 1961-70 when it was mainly driven by increases in land and other input use. In OECD exporting countries, growth in output is almost all due to TFP growth, not to higher input use.

11. The 2012 OECD-FAO Agricultural Commodity Outlook report (OECD, 2012a) presents projections of TFP and yields and estimates the impact of a 20% reduction in the yield gap, i.e. the difference between potential and actual yields, in developing countries.

much as 5 to 10 million hectares of agricultural land, representing around 0.3-0.6% of all agricultural land, are lost each year to severe degradation through overuse, poor land management, and nutrient mining[12] (FAO, 2009; Foresight, 2011), with varying degrees of irreversibility.

19. Over the last decade, agricultural land area has decreased in most OECD countries, except Chile, Finland, Sweden, Canada Estonia and Turkey (OECD, 2012e). In several EU countries and Japan, production has also decreased, possibly lowering environmental pressure on land through less intensive use. In many OECD agricultural exporting countries, such as Israel, Mexico, New Zealand and the United States, production has increased on a decreasing land area, mainly through higher input use (fertilisers, pesticides, water and energy).

20. **Water** is an important resource for agriculture, with large impacts on land and agricultural productivity. At the global level, agriculture accounts for around 70% of the world's total freshwater withdrawal (FAO, 2011). Cities and industries compete intensely with agriculture for the use of water and an increasing number of countries or regions within countries are reaching high levels of water stress and pollution (OECD, 2011g; OECD, 2012b).

21. At the OECD level, agriculture accounts for about 45% of all freshwater withdrawal (Table 2.3), but these shares vary considerably across countries and, in some, can reach 90%. Use of freshwater resources by agriculture grew slightly over the 1990s, but declined by -0.5% per year over the 2000s (OECD, 2012e). However, agriculture abstracts an increasing share of its water supplies from groundwater and some countries are under water stress. Changes in area irrigated have reflected changes in water use, increasing over the 1990s and decreasing slightly over the 2000s. Reflecting improvements in irrigation technologies and management practices, as well as agricultural and water policy reforms, efficiency of water application on irrigated land continued to improve over the 2000s but at a slower rate than in the previous decade. The largest improvements are recorded in Australia, where major policy reforms affecting agriculture included changing water property rights, creating water trading markets, and increasing water charges to farmers (OECD, 2010a). Israel's water policy reforms led to increased water prices paid by irrigators, and thus reductions in water application and improvements in irrigation technologies and management (OECD, 2010c).

22. Agriculture is often a major source of **water pollution**, from nutrients, pesticides, soils and other contaminants, leading to significant social, economic and environmental costs (Table 2.3) (OECD, 2012f). OECD agri-environmental indicators show that water quality across OECD countries has been either stable or deteriorating, in most cases over much of the last decade, compared to some easing of pressure from agriculture on water systems over the 1990s (OECD, 2012e). For a considerable number of countries, the level of nitrates, phosphorus and pesticides found in agricultural monitoring sites[13] exceeds national water threshold limits. However, the downward trend in nutrient surpluses and pesticide use over the past ten years for many OECD countries would suggest that pressure from agriculture on water systems has eased. OECD agricultural production continued to increase in the 1990s, but remained stable in the 2000s, with reductions in the nitrogen and phosphorus balance per hectare in both periods.

23. Much of the slowing of the rates of soil erosion on agricultural land has resulted from the increasing adoption of nutrient management practices encouraged by the decoupling of support from production and input related support (Figure 1.15) (OECD, 2012e); agri-environmental measures across many countries; and, in some countries, the introduction of a link between the provision of support payments and the requirement to meet a number of conditions related to environmental performance (cross

12. Depletion of nutrients in soil due to unsustainable farming techniques.

13. Sites where most pollution is likely to come from agriculture.

compliance) (Figure 2.1). In the United States, slowing rates of soil erosion are due primarily to adoption of conservation practices (conservation tillage, in particular) and retirement of highly erodible land.

24. Overall, OECD pesticide use diminished by 0.8% per annum over the period 2000-09, which contrasts with the small per annum increase over the 1990s (OECD, 2012e). Much of declining use of pesticides over the last decade was accounted for by the EU15 and the United States. For a growing number of countries, crop production has been increasing at a faster rate since 2000 than pesticide use. The apparent improvements in pesticide use efficiency for a growing number of OECD countries can be explained by a combination of factors which includes: the overall decoupling of support from production and input related support (Figure 1.15 in Chapter 1); the use of new pesticide products used in lower and more targeted doses; the expansion in organic farming; pesticide taxes; and the use of payments to encourage the adoption of pest management practices.

25. There is a large potential to reduce the amount of pesticides and nutrients in agriculture without reducing crop yields. In some intensive farming systems, up to 50% of available nutrient inputs (inorganic and organic nutrients) are not utilised by crops or pastures, leading to significant pollution from nutrient run-off (OECD, 2012f). The opposite is the case in large parts of the developing world, where crop farming leads to a net extraction of nutrients from the soil (OECD, 2012b). In Africa for example, shorter – or non-existent – fallow periods and poor cultivation practices, combined with low use of inorganic fertilisers and organic manure, have all resulted in reduced levels of soil fertility, reduced soil organic matter, and increased occurrences of acidified soils.

26. **Biodiversity** underpins agriculture and food security through the provision of genetic material needed for crop and livestock breeding. It also provides other important ecosystem services to agriculture such as pollinisation. The 20th century saw a great loss of biodiversity through habitat destruction, mainly due to deforestation (UN, 2001). Maintenance of biodiversity, e.g. through provision of natural habitat, pest predator habitat, shelter for pollinisation insects or wind shelter belts, is crucial for sustainability and resilience of farming systems as it builds the capacity to absorb shocks and continue to function within a changing set of circumstances. Agricultural biodiversity is largely created, maintained, and managed by humans through a range of farming systems from subsistence to those using a range of biotechnologies and extensively modified terrestrial ecosystems. As a major land user in most OECD countries, agriculture has a direct impact on species' habitats and indirect impacts on the existence of the species themselves (OECD, 2012e).

27. Farmland bird population is an indicator used to track the condition of farmland habitats.[14] In the OECD area, farmland bird populations declined continuously over the period from 1990 to 2008, but the decrease in bird populations was less pronounced over the 2000s compared to more rapid reductions in the 1990s (OECD, 2012e). Moreover, for many countries the decrease in farmland bird populations from 1990 to 2008, was much less pronounced than had occurred over the period from the mid-1960s to the early 1990s. This is partly associated with efforts beginning in the early 1990s to introduce agri-environmental schemes aimed at encouraging semi-natural land conservation on farms (e.g. field margins, buffer strips near rivers, and wetlands); changes in farm management practices, such as increasing the area under conservation tillage which has increased feed supplies for birds and other wild species in many countries; reduction in pesticide use for many countries lowering toxic effects on birds and their food supply (e.g. worms, insects); and changes in land use. Despite these positive improvements toward bird conservation on farmland across many OECD countries, the further intensification of agriculture and removal of natural and semi-natural habitats in many regions of the OECD, continues to exert pressure on bird populations and other flora and fauna associated with farming. It is also noticeable that bird species

14. Farmland bird population, however, can also be affected by other factors such as climate change, urban spread and transport infrastructure.

dependent on other habitats, notably forestry, have not experienced the same rate of decline as farmland bird species

28. **Climate change** is expected to impose additional constraints on agriculture, but also some opportunities, as it will affect land and water availability (IPCC, 2007; Müller *et al*., 2011; OECD, 2010d). In the near term, climate variability and extreme weather shocks are projected to increase, affecting all regions with negative impacts on yield growth and food security particularly in sub-Saharan Africa and South Asia in the period up to 2030 (Burney *et al*., 2010). Agriculture (including deforestation) accounts for about one-third of greenhouse gas emissions; for this reason, it must contribute significantly to climate change mitigation (IPCC, 2007). While crops can be adapted to changing environments, the need to reduce emissions will increasingly challenge conventional, resource-intensive agricultural systems (Royal Society, 2009). In OECD countries, agricultural emissions of ammonia and greenhouse gases (GHG) have decreased in the 2000s, while they were stable or increased in the 1990s (OECD, 2012c). The environmental efficiency gains in reducing the level and rate of release of agricultural GHG emissions over the past decade, as with ammonia, can be primarily linked to the uptake of improved technologies and farm management practices, as well as incentives to lower emissions provided by a range of policies introduced by OECD countries such as regulations on livestock housing to limit GHG emissions, and payments for biodigesters to limit methane emissions. Increasing numbers of farmers are adopting technologies (e.g. changing livestock feed composition to reduce methane emissions) and practices that are helping to reduce emissions, such as precision fertiliser application (lowering nitrous oxide emissions).

2.2. Some factors determining agricultural productivity

29. Many factors explain the large disparities in productivity across regions and farms, including the structural characteristics of the farm and its natural, market and policy environment (OECD, 2011a). Examining the relationship between these factors and productivity will help define paths to higher productivity growth at the farm, national and global levels.

The need for innovation

30. The relation between innovation and productivity is complex. At the farm level, theory identifies three ways to TFP growth: 1) technological progress, which reflects advances in technology adopted by early innovators, the best performing farms that push the production frontier up; 2) technical efficiency increase, which reflects later adoption of technology by individual farms, allowing them to move towards the production frontier; and 3) scale efficiency increase (economies of scale) represented by a movement along the production frontier due to a change in farm size (OECD, 2011a). 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. 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.

31. 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).[15] 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.

---

15. Innovation is defined in the Oslo manual as "the introduction of new or significantly improved goods or services, or the use of new inputs, processes, organisational or marketing methods (Eurostat-OECD, 2005).

32. 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.*, 2010b). 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.

33. In recent years, innovation systems have responded to the demand articulated by policy-makers, users and society as a whole, and developed and promoted innovations that allow for more sustainable use of resources, such as no-till farming, new crop varieties with higher yield potential and/or greater resistance to or tolerance of biotic and abiotic stresses, more efficient irrigation, water management systems, sensors for nutrient status in crops, remote sensing and Geographic Information Systems (GIS) to improve and monitor land use, and Short Message Service (SMS) messaging for enhancing advisory services to farmers.

Policies and regulations

34. Policies and regulations affect agricultural productivity in many ways. They influence directly farmers' choice of product and production methods and willingness and capacity to invest, adopt innovations, and achieve economies of scale. They may also affect farm productivity indirectly through their impact on markets and farm structural change.

35. Improving agricultural productivity and competitiveness is an important objective of agricultural policy in many countries, but evidence on the link with policy support, and of specific policies, on productivity growth is limited.[16] Most studies reviewed in Latruffe (2010) find a negative correlation between support to agricultural producers and technical efficiency. However, there are varying results regarding the link between support, and productivity and technological change. For example, support may be positively correlated with technological change as extra income might help farmers overcome their credit constraints and invest in new technology, but the relationship with efficiency change is not straightforward (Serra *et al*., 2008). As discussed in Section 2.4, the link between specific agricultural support policies and farm productivity depends on the type of measure (e.g. direct payment or investment support) and the way it is implemented.

Farm structural characteristics

36. Larger farms are generally found the most productive as they can to some extent achieve economies of scale, benefit from access to output and input markets, and suffer less from hidden unemployment than very small farms (Latruffe, 2010).[17] But there are also diseconomies of scale. Large, specialised farms may be less resilient than smaller family farms less dependent on external labour and

16. There is little empirical evidence of the impact of specific policies and regulations on productivity, but Latruffe (2010) reports a few examples. In addition, most studies estimate correlations rather than causality.

17. Using evidence from the literature on developed and emerging economies, Latruffe (2010) discusses the relationships between farm productivity and a number of farm characteristics: farm size, factor intensity, product specialisation, production and marketing practices, structure of the land, labour and capital (rented/own), and the characteristics of farm labour.

capital. However, smaller family farms have les borrowing capacity than their larger counterparts for investment and expansion. No clear relationship is found between technical efficiency and factor intensity indicators, such as capital-labour or land-labour ratios. Regarding the level of indebtedness, some researchers report that this has a positive impact on technical efficiency, suggesting that farmers who are indebted need to meet their repayment obligations and, therefore, are motivated to improve their efficiency. In terms of productivity change, borrowing may help farmers to invest in new technology.[18]

37. The impact of human capital has been widely investigated. A farmer's age or experience is not clearly related to technical efficiency. Education is generally found to have a positive effect on technical efficiency, but gender is usually not found to affect technical efficiency in developed countries. In developing countries, however, women might have lower access to farm inputs.

Market conditions

38. There are many two-way links between agricultural productivity and markets with agricultural market conditions affecting productivity in various ways. As Porter (1990) underlines, the presence of sophisticated and demanding buyers is important in creating and sustaining competitive advantage. Strong demand and higher output prices may attract investment in agriculture by high performers,[19] but lower output prices may push for technical efficiency improvements to remain profitable, as long as credit is available, or lead to the exit of less productive farmers. Input markets are equally important as they will affect the level and mix of input use. When energy, water and fertiliser prices in developed countries fail to account for externalities of their use, this can lead to overuse.

39. Past investments in agriculture and R&D have resulted in strong productivity gains. These have contributed to the declining trend in agricultural commodity prices, which may have then discouraged investment in agriculture and agricultural research in some countries. This trend has been reversed in recent years and agricultural prices are projected to remain higher than in the past decade as global demand for agricultural commodities is expected to continue to rise (OECD, 2012c). Stronger and more diversified demand comes from population growth - world population is expected to grow from 7 billion in 2011 to 9.1 billion by 2050 -, but also from income growth and the development of non-food markets. Income growth increases the propensity to consume food and to a more diversified diet that includes more meat and higher value-added products. The latter pushes the price of feed crops further up. This reinforces pressure on natural resources as meat production requires more land and water resources than crops. Growth in demand also comes from development of bioenergy and other non-food uses of agricultural production (OECD, 2012a). Higher agricultural prices and opportunities in differentiated markets should foster investments in agriculture in countries with a competitive advantage in the sector, leading to productivity growth.

Natural environment

40. Differences in performance across farms may be explained by the characteristics of the natural environment in which they operate (e.g. climate, soil quality, altitude or slope). They are usually found to have a significant impact on technical efficiency (Latruffe, 2010). For example, high quality soils are associated with high technical efficiency.[20] Climate and climatic events are also important determinants.

---

18. The OECD Network for Farm-Level Analysis is investigating the relationships between some farm structural characteristics and productivity indicators.

19. Higher prices also create incentives to raise production by using more inputs. This can lead to higher yields but not necessarily higher TFP, in particular if more marginal land is brought into production.

20. But farms in disadvantaged areas can achieve market competitiveness through low land costs or through lower labour and other input costs.

For example bad weather (heat stress) is found to be the main determinant of the slowing of cereal yields in France (Brisson *et al.*, 2010). They find that genetic progress has not declined, and suggest other agronomic factors may play a role, in particular the decline of legumes in crop rotations.

Resource availability

41. Differences in the availability of certain resources will affect partial factor productivity. Relative factor availability is a major factor to explain these differences in yield, with land productivity being higher in countries where land is relatively scarce relative to labour, and vice versa (Hayami and Ruttan, 1985). This explains largely differences in wheat yields between Western Europe and North America, for similar levels of TFP. The quality of the resource will also matter, e.g. soil quality. Water availability is also a major constraint.

2.3. Improving Agricultural Innovation Systems

The case for an Agricultural Innovation Systems approach

42. Agricultural knowledge systems display a large diversity corresponding to different country contexts. At present, they are in transition from the traditional linear and top-down approach – from research to innovation to adoption – to an innovation systems approach, which is more reactive and interactive, and where agents contribute together to finding innovative solutions, while avoiding duplication of effort. This movement is illustrated in Table 2.4, which displays the main features of various agricultural knowledge systems, from the narrowest to the broadest definition.

43. The "innovation system" concept embraces not only science suppliers, but involves the interactions of individuals and organisations processing different types of knowledge within particular social, political, policy, economic and institutional contexts (OECD, 1999; World Bank, 2006). The OECD Innovation Strategy (OECD, 2010b), however, recognises that science remains a key driver of innovation. In the agricultural context, while R&D remains an important component of agricultural innovation systems (AIS), and technological progress a major source of productivity growth, there is a growing recognition of the role of other actors — farmers, agricultural training and education, extension services, upstream and downstream industries, consumers, civil society, and information brokers — and of the need to strengthen the inter-linkages within the system (OECD, 2012c).

Table 2.4. Defining features in relation with the agricultural innovation systems

Defining feature	NARS	AKS	AKIS	AIS	NAIS
Actors	Research organisations, agricultural universities, extension service and farmers	Researchers, advisors and educators of Agriculture Knowledge Institutions, under the control of the Ministry of Agriculture	Farmer, research, extension and education	Wide spectrum of actors (research, extension, education, farmers, NGOs, industry, consultants, consumers, etc.)	Economic actors that generate and use knowledge
Outcome	Technology invention and technology transfer	Technology embedded in products	Technology adoption and innovation	Different types of innovation	Different types of innovation
Approach	Using science to create new technologies	Diffuse knowledge and develop new skills	Accessing agricultural knowledge	New uses of knowledge for social and economic change	Using and managing innovation at the national level
Mechanism for innovation	Technology transfers	Knowledge transfer through agricultural extension and education	Knowledge and information exchanges	Interaction an innovation among stakeholders	Interaction among the users
Role of policy	Resource allocation, priority setting	Diffuse knowledge to increase productivity	Linking research, extension and education	Enabling innovation	Foster co-operation between actors and enable a framework for innovation
Nature of capacity strengthening	Strengthening infrastructure and human resources	Teaching farmers new skills	Strengthening communication between actors in rural areas	Strengthening interactions between actors, institutional development and change to support innovation; creating and enabling environment	Strengthening interactions between all economic actors at a national level
Resources	Infrastructure and human resources	Infrastructure and human resources	Interaction platforms, e.g. networks	Interaction platforms, e.g. networks	Knowledge-based interaction platforms
Degree of market integration	Nil	Low	Medium	High	High

Notes: NARS: National Agricultural Research System; AKS: Agricultural Knowledge System; AKIS: Agricultural Knowledge and Innovation System; AIS: Agricultural Innovation System; NAIS: National Agricultural Innovation System.
While this table presents AIS as including more actors than AKIS, the two terms are sometimes used interchangeably to refer to the broader approach.

Source: Adapted from Deschamps, L. in OECD (2012c, Section 6).

44. Moving to an AIS approach would involve improving strategic thinking and interactions between research, training and education, extension services, farmers, the industry, and other actors. Stronger co-ordination would help to focus on priority areas, address the fragmentation of research institutions in some countries, strengthen links between agricultural and other fields of research which increasingly influence agricultural innovation, and facilitate the adoption of multidisciplinary approaches needed to tackle emerging issues. It is also expected to improve the synergy between public and private research, clarify their respective roles, and ensure appropriate funding.

45. While countries and international organisations generally acknowledge the benefits of moving towards an innovation system approach, and experiences so far have been positive, this move is taking place at a different pace across countries.[21]

Overview of agricultural education, R&D and extension systems

46. 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, M. in OECD, 2012c). In Indonesia, the Agricultural Research Committee does strategic planning, while the Indonesian Agency for Agricultural R&D is in charge of research (Subagyono, K. in OECD, 2012c).

47. 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. 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 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) usually 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. Box 2.1 describes several mechanisms used to select, carry out and fund research and innovation projects with multiple partners. 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).

---

21. A World Bank report on Agricultural Innovation Systems presents a number of positive experiences in developed and developing countries (World Bank, 2012).

Box 2.1. Common approaches to financing innovation

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).

48. **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.

49. **Extension systems** display a wide diversity across countries or regions. They are generally operating at sub-national level, and include very diverse actors: government agencies, education institutions, upstream and downstream industries, Non-Governmental Organisations (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 introduced to help farmers implement cross-compliance. It is co-funded at EU and national levels. Table 2.5 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 2.5. 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
Farmers 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. Advisory services are provided primarily by the Chamber of agriculture, which are public establishments managed by representatives from the sector and funded by a additional tax on undeveloped land (50%), by contracts with different levels of governments and by clients.

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

General trends in Agricultural Innovation Systems institutions

50. In recent years, many countries have reviewed their agricultural knowledge systems and moved away from supply-driven innovation towards a 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.

51. 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. 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. 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). At the international level, the Consultative Group on International Agricultural Research (CGIAR) established a number of institutions in 2009, including a Consortium to provide leadership to the CGIAR systems and co-ordinate activities among the 15 member centres and other partners within the framework of the CGIAR Research Programmes (OECD, 2012c, Section 8). The Global Forum for Agricultural Research (GFAR) and the Global Conference on Agricultural Research for Development (GCARD) also play a growing role in international co-operation.

52. 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. 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. 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.

53. 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 and the Agreenium research consortium which groups agricultural research agencies and agricultural colleges (schools); 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).

54. Agricultural R&D remains mainly funded by public expenditure, while the private sector is increasingly involved in R&D activities that have high potential market returns, such as biotechnology. 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 linear systems of 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.

55. Among mechanisms to fund research, partnerships between public research and the private sector are being developed, including with local industries. To avoid duplication of efforts, mobilise extra funding and better understand users' demands, governments have encouraged public research to engage into **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. Government expenditure for these partnerships has tripled between 2010 and 2011 (OECD PSE/CSE database, 2012). In Australia, a significant proportion of government expenditure on rural R&D is conducted through research and development corporations. 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). 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). 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 (Chapter 7). The EU SOLINSA project was launched in 2011 to identify barriers to the development of Learning and Innovation Networks for sustainable agriculture (LINSA).[22]

56. **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. 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, K. in OECD, 2012b); and regional co-operation, e.g. INNOVAGRO for Latin America in 2011 (Deschamps, L. in OECD, 2012b).

57. The 2011 G20 Action Plan[23] 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 supports the Tropical Agriculture Platform (TAP), which aims to foster the generation, sharing and utilisation of agricultural technologies and practices for smallholders in developing countries.

58. The Chair of the G20 Conference on Agricultural Research for Development, held in Montpellier on 12-13 September 2011, recognised that the Global Conference on Agricultural Research for Development (GCARD), which first met in Montpellier in March 2010 at the initiative of the Global Forum for Agricultural Research (GFAR) and the Consultative Group for International Agricultural Research (CGIAR), has a key role to play in developing greater international coherence of agricultural science policies and promoting their implementation. It welcomed the principle of a Global Agricultural Foresight Hub to support the development of a neutral platform, linking international, regional and national levels.[24]

59. 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, A.; Klerkx, L. in OECD, 2012c). 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

22. www.solinsa.net/

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

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

Affairs in Spain and Agricultural Technology Information Centres in India, described in OECD (2012c, Sections 10 and 11).

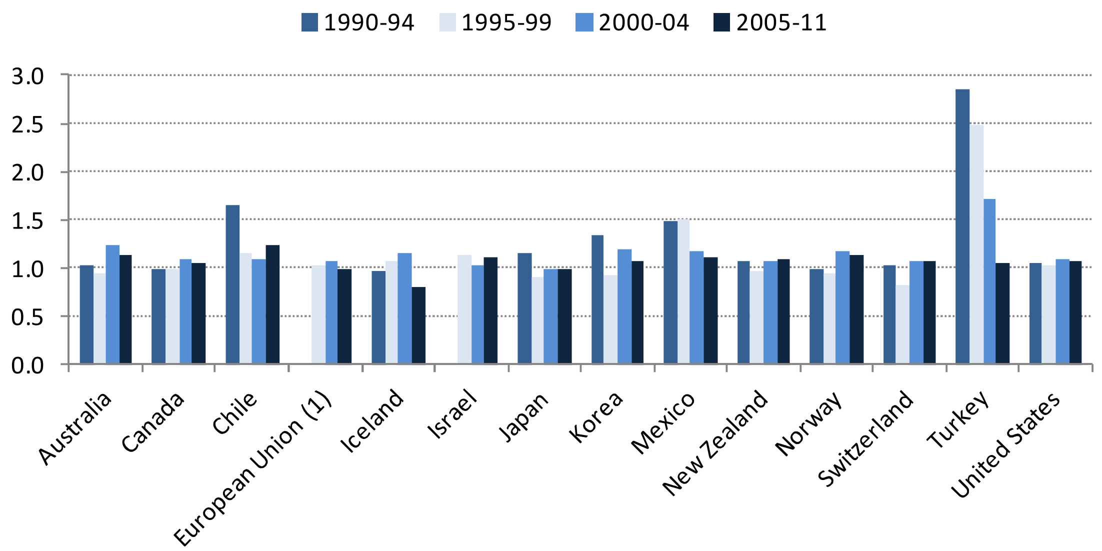
60. At the same time, agricultural education has been neglected in many countries and is less attractive to young people, although there have been exceptions such as France. Insufficient human capital in the sector, and growing disconnection between farmer knowledge and research and extension, often result in lack of adoption of innovation by farmers.

Trends in R&D and extension funding

61. OECD R&D indicators and the PSE/CSE database can help shed light on efforts in agricultural R&D across countries and over time. As measured by R&D indicators,[25] government R&D expenditure on agriculture accounts for above 1% of agricultural GDP in most OECD countries and reaches 4% in the United States. Although government expenditure on agricultural R&D grows slowly in some large OECD countries (0.2% per year in the United States, 0.5% in Japan in the 2000s), or decreases (e.g. in Australia), it continues to increase as a percentage of agricultural GDP in most OECD countries (OECD, 2011a). In the PSE database, government expenditures on agricultural R&D only refer to agriculture, and usually exclude forestry and fisheries. In some countries, however, they include parts of expenditures on agricultural statistics. As a result, the two data sources are very difficult to compare. As measured in the PSE/CSE database, government expenditures on agricultural R&D continue to increase in all OECD countries but often at a lower annual growth rate in the second part of the 2000s than in the first part. In two-third of the countries or regions, they are higher in the late 2000s than in the late 1990s (Figure 2.2).

Figure 2.2. Government expenditures on agricultural R&D

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



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.

62. Government expenditures on agricultural R&D in developing countries is generally lower as a percentage of agricultural GDP than in OECD countries, but there is a wide diversity across countries in

25. Agriculture includes crop, livestock, hunting, forestry and fishing.

terms of percentages and their developments (OECD, 2011a). In all low- and middle-income country regions as a whole, public expenditure on agricultural R&D increased from the 1980s, but there are important variations across countries within regions. Public R&D expenditures on agriculture in low-and middle income countries are generally lower as a percentage of agricultural GDP than in OECD countries, and there is wide diversity across countries. In East Asia and the Pacific, China accounted for about two-thirds of total public agricultural R&D spending in the low- and middle-income countries in 2002. China's agricultural research spending accelerated rapidly during the 1981–2007 period, especially since the turn of the millennium (FAO, 2012). In Sub-Saharan Africa, after a decade of stagnation in the 1990s, investment in agricultural research rose more than 20% between 2001 and 2008. However, most of this growth occurred in only a handful of countries (Beintema and Stads, 2011).

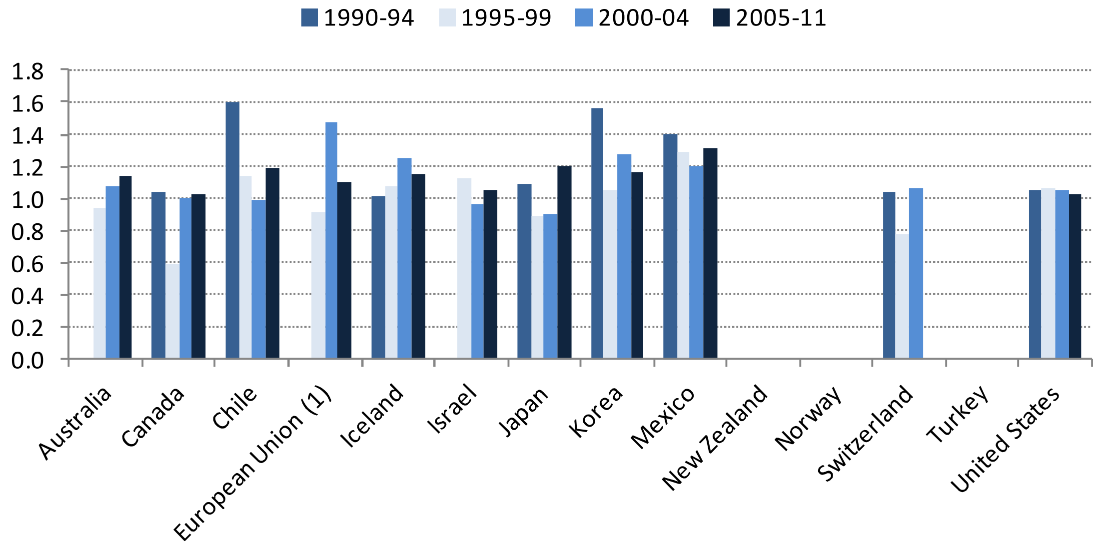
63. In developing countries, funding is often dependent on foreign aid and granted for time-limited projects; this may hamper the development of national R&D institutions and capacity building. However, research in some developed and emerging economies have spill-over effects and technology is being transferred to developing countries. An important challenge is to make research results better adapted to local conditions and to foster the adoption of technologies able to improve productivity growth sustainably in diverse conditions.

64. While government expenditure is the main source of funding for agricultural R&D, private sector investment has increased but generally focuses on high value and market-oriented production systems. Greater protection of intellectual property, rapid progress in molecular biology and the integration of global output and input markets have generated strong incentives for the private sector to invest in R&D. At the same time, the involvement of private research in natural resource management and in maintaining biodiversity is limited, with the exception of a few public-private partnership initiatives.

65. 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 2.3). The share of extension expenditures in the total of R&D and extension expenditures varies a lot by country, reflecting differences in government involvement (Figure 2.4). This share has increased in the European Union, Iceland, Japan, Korea and Mexico, remained stable in the United States and decreased in Australia, Chile, Israel, and Switzerland, following reforms of the system or the higher emphasis on R&D, and remained zero in Norway and the Netherlands.

Figure 2.3. Government expenditures on extension services

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

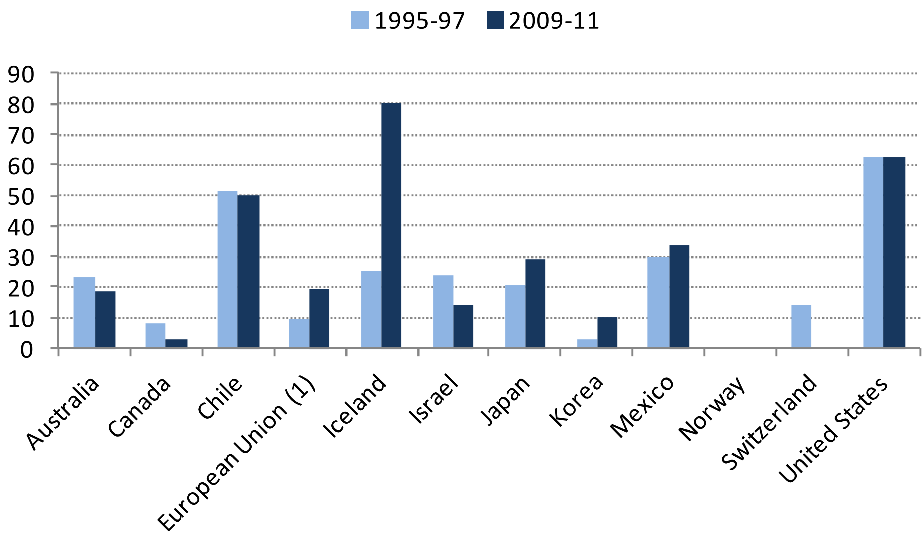


1. EU15 from 1995 to 2003; EU25 from 2004 to 2006; and EU27 from 2007 to 2011. For the European Union, 2000-03 instead of 2000-04; and 2007-11 instead of 2005-11.

Source: OECD, PSE/CSE database, 2012.

Figure 2.4. Share of government expenditures on extension services

As a % of total government expenditure on R&D and extension



1. EU15 in 1995-2003; and EU27 in 2009-11.

Source: OECD, PSE/CSE database, 2012.

Fostering national Agricultural Innovation Systems

66. There is no "one size fits all" design for an efficient national AIS, but sharing information on the performance of different systems would provide useful insights. Improvements to the institutional design of national AIS would include strengthening strategic planning and monitoring mechanisms; better

integrating all public and private partners; making the system more responsive to users' demand and encouraging co-innovation; improving the collection and sharing of information; strengthening agricultural education and extension systems; and improving IPR and Sanitary and PhytoSanitary (SPS) regulations. Co-ordination is also needed between the national, regional and international levels, in particular to identify areas with regional or global public good characteristics.

Strengthening strategic planning and monitoring mechanisms

67. The governance of national AIS can be improved both with better integration within the general innovation strategy, and with stronger co-ordination of the various AIS actors and related policies. This would improve policy coherence, create synergies and avoid duplication of efforts. Better integration in innovation systems is important as agricultural innovation is increasingly linked with innovation in other fields of expertise. It also helps identify priorities in the economy as a whole. AIS in various countries are more or less fragmented, and it is important to have a co-ordination body in place. Whether it is an independent agency, a government body or a department in a ministry, it should involve a wide range of stakeholders and consultations. Clear strategic priorities should be defined to guide public and private investments.

68. Mechanisms to monitor and evaluate the performance of innovation systems and policies should be strengthened. 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 AIS and identify future needs. Efforts should focus on developing indicators and methods to benchmark AIS performance.[26] The Report of International Organisations for the G20 on sustainable agricultural productivity growth recommends the strengthening of "*efforts at the national, regional and global levels to identify, assess, prioritize, monitor and evaluate investments in Agricultural Innovation Systems and identify the necessary resources to support the Agricultural Science and Technology Indicators (ASTI) initiative to a) collect and maintain a comprehensive database on expenditures on agricultural innovation; b) develop tools and methods to assess the performance and impact of innovation systems.*"

69. AIS policy should also 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.[27] A challenge for governments is to find a balance between funds for basic research and funds for output-driven research, and between stable funding and project-based funding. Competitive grants for selecting projects help improve relevance and efficiency.

26. The Agricultural Science and Technology Indicators (ASTI) initiative compiles and analyses primary data on institutional developments, investments, and capacity trends in agricultural R&D in low- and middle-income countries (www.asti.cgiar.org). OECD R&D indicators include public and private expenditures on R&D, number of staff and patents, but information on the agricultural sector, which follows the same definitions as in the ASTI initiative, is often incomplete.

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

Improving and sharing information

70. 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, genebanks, 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. ICT has proven very useful in this regard (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.

Reinforcing linkages within national AIS

71. Reinforcing linkages between AIS components — research, development, extension, farmers, the industry, NGOs and others — would help connect research to demand; create synergies, 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. Partnerships would also facilitate pluridisciplinary approaches that are increasingly needed to solve problems.

72. 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.

73. “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 (see below). Various networks also contribute to bring together various AIS actors.

74. 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 some specialisation to avoid 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.

Improving private sector engagement at national level

75. Private sector engagement in agricultural R&D is broadening to areas with medium to longer-term returns, and its role in mobilising resources, complementing public sector efforts and generating demand-driven outcomes needs to be taken into account in government innovation strategies.

76. Innovation policies should include incentives for private sector engagement in agricultural R&D. As discussed below, Intellectual Property Rights (IPR) protection plays an important role in this regards. It should also provide incentives for public research to engage in public-private partnerships, in particular in terms of funding mechanisms, institutions, regulation, capacity-building, and evaluation of research.

77. Significant efforts in capacity-building are required for effective public-private partnerships to take place with respect to advanced science and technology, complex regulatory systems, sophisticated markets and market infrastructure, and international trade considerations. Reforming innovation institutions and mechanisms may require a re-definition of the relationship between public and private researchers and their "clients". This would be useful in this regards to draw on successful experiences to develop guidelines, in particular concerning the sharing of costs and benefits.

78. In addition to consortia, competitive grants and matching funds (defined earlier in Box 2.1), more innovative funding mechanisms, such as tax incentives, venture capital, and advance market mechanisms, could be 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).

79. 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 2.2. 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.[28]

28. 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.

Box 2.2. 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).

Improve the system of intellectual property rights (IPR), where there is need

80. Protection of intellectual property rights (IPRs) is an important factor influencing the performance of agricultural innovation systems. The challenge for IPR regulations is to provide incentives for private investment in innovation, without compromising the sharing of knowledge and further innovation. 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.

81. 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 development of a nutritionally enhanced strain of rice known as golden rice (OECD, 2011h). 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).

82. 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.[29] 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).

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

83. 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, 2011h and 2006b). The administration of the patent system is also important in terms of delivery of quality patents that provide an appropriate degree of protection (Dons, H. in OECD, 2012c).[30] The sharing of information on genetic resources would facilitate research in this area as well as adoption.

Strengthening public and private extension and advisory services

84. Extension and advisory services are critical to facilitate farmer access to technology and knowledge. To enhance national extension systems, a strategy would be to establish and strengthen a demand-driven, pluralistic and decentralised advisory service that mixes both public and private providers.

85. 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. In coherence with the AIS approach, 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. 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.

Making agricultural education and training more attractive and relevant

86. 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.

87. Agricultural universities, faculties of agriculture, vocational and technical colleges, and farmer training centres all play a role in creating human capital needed to strengthen the sector. 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.

88. 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. Reinforcing the links between research, education and extension systems would help in this regards, with full participation of all actors in the innovation dynamics.

30. 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.

Management of sanitary and phytosanitary systems

89. Regulatory issues of particular importance for agricultural innovation include IPR (elaborated below), health and food safety regulations, and bio-safety regulations. Poor choices in regulatory policy settings or inappropriate application of tools may delay scientific advancements, prevent technology transfer and impose crippling transaction costs on organisations.

90. In developing an appropriate SPS regulatory environment, including implementation provisions, experience has shown that technology neutral, science-based approaches are most effective and least market distorting provided that care is taken to ensure agricultural specificities are taken into account. 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).

91. 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.

Strengthening co-operation at international level

92. Fostering sustainable agricultural productivity growth has become an international priority. It has been, in particular, a topic for G20 discussion. AIS at national and international levels are mobilised to tackle the issue, i.e. generate innovations that can lead to improvement in productivity growth and sustainability and are adapted to the diversity of farming systems across the globe. International co-ordination of efforts is required to balance costs and benefits of individual countries' contributions. The CGIAR system is well placed to undertake scientific R&D in partnership with national and regional AIS, encompassing a wide range of diverse needs and circumstances. Regional or theme-based networks and fora will also play an important role. It may be useful to identify all these efforts and evaluate their potential contribution.

93. Good co-ordination with international, regional and national research networks is important for countries to improve the performance of their AIS and to maximise international spill-overs. Enhancing the cross-border technology transfer potential of the international R&D architecture is pivotal to increasing productivity growth and addressing issues that are transnational, such as transboundary diseases, climate change, water scarcity, and price volatility in global markets, or that require investment beyond one country. The Global Research Alliance on Greenhouse Gases, for example, is a low/no cost approach to cross-country collaboration on research that help to address climate change challenges.[31]

94. Collaboration is increasingly needed in agricultural research, in particular when infrastructure costs are high. Moreover, in some countries with limited research capacity, scarce resources could focus on better taking into account local specificities. Regional initiatives facilitate the transfer of innovations, technologies and practices as the involved countries have more in common (South-South co-operation). Emerging economies are increasingly playing a leading role in this regard.

31. www.globalresearchalliance.org.

95. A prerequisite for better co-ordination would be to facilitate the exchange of information on the state of science and innovation and on-going efforts. Exchanges of experience on the performance of various institutional mechanisms for research and innovation would also help reinforce the global AIS.

Key issues for improving Agricultural Innovation Systems

96. At a time when agriculture needs to respond to multiple demands and public funding is limited, it is essential for countries to better co-ordinate their research agenda. They should collectively identify areas with global public goods characteristics and global spill-over effects that require international concerted efforts; areas where synergies exist at the regional level; and areas of national or sub-national interest. A better articulation between research and innovation at the international, regional, national and sub-national levels would limit duplication of efforts and ensure that no important area is left behind. The potential for innovation transfer should also be taken into account at all levels when defining priorities.

97. Revisiting the respective roles of the public and private sectors would also improve the performance of the AIS. Traditionally, public funds are expected to fund research which is not taken up by the private sector. Strengthening the participation of the private sector in agricultural research and innovation is essential to meet future demands. Innovative financing mechanisms are thus needed to provide incentives to engage the private sector in innovation with "public goods" characteristics and long-term benefits (such as climate change), and to ensure a socially-optimal sharing of costs and benefits.

2.4. The policy challenge

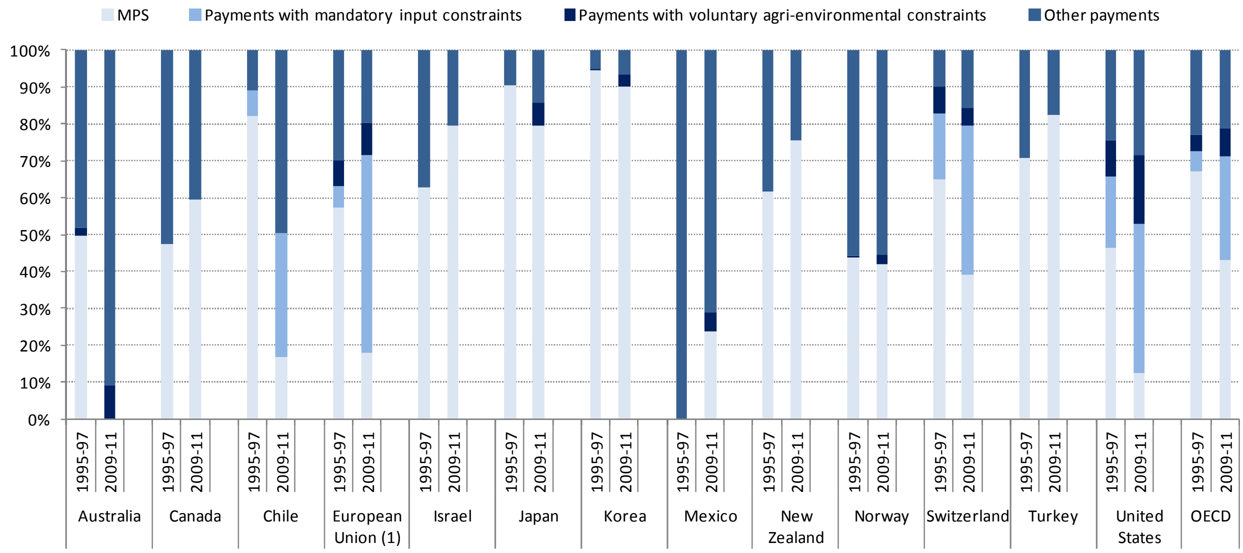
98. Agriculture is a sector where government intervention is pervasive, but the objectives, instruments and resulting support vary by commodity, country and over time. Agricultural policy includes measures that generate direct transfers to producers such as price support, input subsidies and area or income payments, as well as measures for the development of public services, infrastructure and institutions, which benefit farmers indirectly (general services). There is a wide diversity in the level and composition of support across countries (Chapter 1)

Trends in agricultural policies

99. Policy reform in OECD countries has reduced support levels, and the impact of support on commodity markets (Chapter 1). All other things equal, the relative decoupling of support from current production and input use is expected to have resulted in some extensification and contribute to maintaining in business farmers who would have otherwise left, but it has reduced distortions in the sector, as was intended. More stringent environmental regulations, the granting of payments conditional on the respect of regulations or the adoption of environmentally-friendly production practices (Figure 2.5.), and the development of other measures, such as market-based instruments, collective action and technical assistance, have improved the integration of environmental issues in farmers' decision-making since the early 1990s and the environmental performance of agriculture in OECD countries (OECD, 2012e). However, the extent to which this may have affected productivity is not clear. In developing and emerging economies, budgetary support focuses on subsidies to variable inputs and to farm, irrigation, transport and marketing infrastructure.

Figure 2.5. Payments with constraints on production practices

Per cent of total support to producers (PSE)



1. EU15 in 1995-97 and EU27 in 2009-11.

Source: OECD, PSE/CSE database, 2012.

100. In the OECD area, the emphasis on general services varies by country, as well as the priorities for government expenditures in this area. Expenditures on infrastructure, in particular for irrigation, are particularly important in Japan, Korea, Israel and Chile (Chapter 1). In emerging economies, investments in infrastructure are key components in most cases.

Agricultural policies fostering productivity growth sustainably

101. The first step to an agricultural policy more conducive to productivity growth and sustainability is to improve understanding and measurement of impacts. Sustainable productivity growth is not the only agricultural policy objective but understanding the impact of various measures will help design a more sustainable productivity-friendly policy mix.

102. This would involve revisiting policies that hamper productivity growth, innovation, structural change and the functioning of output and input markets, and implementing measures to foster innovation, productivity, sustainability and competitiveness. An important role for the government would be to facilitate the development of **information systems** for producers to make informed choices on the production systems and technologies that can achieve highest productivity in a sustainable way in their circumstances. This would require sustaining and improving efforts to collect at the national and international levels, information needed to make evaluation possible.

103. Improving the agricultural **trade and market environment** to make it conducive to investment in agriculture fostering productivity growth would imply reducing substantially trade and production distorting measures, improving market access, and disciplining export measures. It would also be important to removing impediments to the functioning of **input markets,** including land, labour, credit, fertilisers, pesticide, water and energy, to facilitate access to inputs and structural change. Regulations clarifying property rights on land would facilitate access to credit, and when monetary titles are attributed,

it would allow for the development of markets to rent and buy land.[32] Trading of production and payments entitlements would facilitate structural change and economies of scale, leading to higher productivity. Rural development policy that improve **rural and marketing infrastructure**, in particular transport 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 agriculture needed to foster productivity growth. Among other general services to agriculture, the provision of ICT services is important as it allows better access to information on markets and technologies, among other things.

104. Once impediments to market functioning are removed and general services provided, **agricultural policy measures** may be considered to address remaining market failures, for example in credit markets, contingency markets, in particular for the management of catastrophic risk, or the remuneration of positive externalities. These measures should avoid hampering the future development of market solutions (OECD, 2002).

105. **Broad-based measures** are in most cases unlikely to be effective and efficient in improving productivity growth as the combination of inputs and outputs achieving higher productivity sustainably is likely to depend on local or individual structural, climatic and agronomic circumstances. Governments are therefore encouraged to move away from general income support that prevents competition and slows structural adjustment, and from support that encourages a specific commodity across the board, i.e. irrespective of its productivity performance at the local level or the generalised use of a specific input, in favour of specific measures to foster innovation, productivity, sustainability and competitiveness. Targeted income support might, however, help farmers overcome credit constraints and invest in technology, but it may also slow structural adjustment (see for example OECD, 2008; 2011b). Policies that facilitate structural adjustment could be envisaged to facilitate economies of scale, attract new entrants and thus foster productivity growth.

106. **Input subsidies** should be temporary and regularly assessed, not to impede the development of private markets (OECD, 2012d). It would be more technology neutral to facilitate access to credit for the purchase of variable inputs as support to a specific input may encourage an input mix that will not necessarily be economically or environmentally sustainable. Similarly, credit support may be useful for farmers to invest in productivity and sustainability enhancing technology in case of identified failure in credit markets.

107. Effective **risk management** strategies are needed to foster investment in agriculture and facilitate the adoption of innovation. 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.[33] Government policies should take a holistic approach to risk management, assessing all risks and their relationship to each other, and 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

32. The Voluntary Guidelines on Governance of Tenure of Land, Fisheries and Forests in the Context of National Food Security were adopted in May 2012 by the UN Committee on World Food Security. The report by International organisations for the G20 encourages country-level implementation of these guidelines as a means for strengthening governance on issues related to land tenure, as appropriate.

33. 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. http://www.oecd.org/document/20/0,3746,en_2649_37401_48152724_1_1_1_37401,00.html

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, 2011e, 2011f).

108. To ensure the long-run **sustainability** of agriculture and the maintenance and enhancement of the underlying natural resource base – soil, water and biodiversity – 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 systematically employed 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. 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.

109. Improving **water management** in agriculture would concern five broad areas of action: 1) create incentives to signal to farmers (and other water users and consumers) the value of water and the cost of pollution; 2) invest in water infrastructure to foster more efficient farming practices and systems; 3) enable innovation to promote improved water management in agriculture; 4) strengthen institutions and governance to support efforts enhancing food and water security; and 5) build resilience to address long-term concerns with food and water security (OECD, 2010a, 2012f).

110. The challenge for policy makers is to prioritise objectives and find a mix of policy instruments that balances the different aspects of sustainable productivity growth and other objectives in different contexts.

Strengthening policy coherence

111. The entire policy and institutional environment affects agricultural productivity, sustainability and efficiency, from macroeconomic, structural, competition and trade policies to innovation, rural development and agricultural policies. Improving policy coherence is essential, in particular between agricultural, agri-food, innovation, trade, aid and development, and rural development policies. Clear strategic orientations for the agri-food sector and agricultural innovation systems (AIS) are needed for investment in the development and implementation of technologies and production systems allowing faster and more sustainable productivity growth and competitiveness. Incentives to improve productivity will yield better results if the economic and regulatory environment is conducive to investment, with clear property rights and enforcement mechanisms, and if marketing and trade channels are competitive. Rural development policies leading to better infrastructure and employment opportunities facilitate the integration of farmers and their family in rural labour markets and consumer markets, and thus foster improved labour and agricultural productivity.

112. Agricultural policy has various objectives, such as income support or stabilisation, raising productivity and competitiveness, and improving the environmental and social sustainability of agriculture. As the development and implementation of innovation adapted to agricultural challenges takes time, policy makers need to give a longer term perspective on the orientation of agricultural policies to farmers and other AIS actors, to allow for the development of innovations consistent with the objectives of agricultural policies.

REFERENCES

Alston, J. (2010), "The Benefits from Agricultural Research and Development, Innovation, and Productivity Growth", *OECD Food, Agriculture and Fisheries Working Papers*, No. 31. doi: 10.1787/5km91nfsnkwg-en

Alston, J.M., Beddow, J.M. and P.G. Pardey (2010a), "Global Patterns of Crop Yields and Other Partial Productivity Measures and Prices", Chapter 3 in Alston, J.M., B.A. Babcock, and P.G. Pardey eds (2010), *The Shifting Patterns of Agricultural Productivity Worldwide*, CARD-MATRIC Electronic Book, Center for Agricultural and Rural Development, The Midwest Agribusiness Trade Research and Information Center, Iowa State University, Ames, Iowa. Available at: www.matric.iastate.edu/shifting_patterns

Alston, J.M., M.A. Andersen, J.S. James, and P.G. Pardey (2010b), *Persistence Pays: U.S. Agricultural Productivity Growth and the Benefits from Public R&D Spending*, New York, Springer.

Beintema, N. and G.-H. Stads (2011), African agricultural R&D in the new millennium, IFPRI. Available at: www.ifpri.org/publication/african-agricultural-rd-new-millennium.

Blakeney, M. (2011), “Recent Developments in Intellectual Property and Power in the Private Sector Related to Food and Agriculture”, *Food Policy*, Vol. 36, pp. 109-113.

Brisson, N., P. Gate, D. Gouache, G. Charmet, F.-X. Oury and F. Huard (2010), "Whay are wheat yields stagnating in Europe? A comprehensive data analysis for France", *Field Crop Research*, Vo. 119, pp. 201-212.

Burney, J.A., Davis, S.J. and D.B. Lobell (2010), "Greenhouse gas mitigation by agricultural intensification", *Proc. Natl. Acad. Sci.*, 107(26): 12052-12057.

EU SCAR (2012), *Agricultural Knowledge and Innovation Systems in Transition — a reflection paper*, Standing Committee on Agricultural Research (SCAR) Collaborative Working Group on Agricultural Innovation and Knowledge Systems (CWG-AKIS), Brussels.

FAO (2009), World Agriculture Towards 2030/2050; How to Feed the World in 2050. www.fao.org/economic/esa/esag/esag-papers/en/

FAO (2011), *The state of the world's land and water resources for food and agriculture (SOLAW) - Managing systems at risk,* Food and Agriculture Organisation of the United Nations, Rome and Earthscan, London.

FAO (2012), *State of Food and Agriculture: Investment in Agricultural for Food Security* (forthcoming).

Foresight (2011), *The Future of Food and Farming: Challenges and Choices for Global Sustainability*, Final Project Report, The Government Office for Science, London.

Fuglie, K.O. (2010), "Total Factor Productivity in the Global Agricultural Economy: Evidence from FAO Data", Chapter 4 in Alston, J.M., B.A. Babcock, and P.G. Pardey eds (2010), *The Shifting Patterns of Agricultural Productivity Worldwide*, CARD-MATRIC Electronic Book, Center for Agricultural and Rural Development, The Midwest Agribusiness Trade Research and Information Center, Iowa State University, Ames, Iowa. Available at: www.matric.iastate.edu/shifting_patterns

Fuglie, K., P. Heisey, J. King, C. Pray, K. Day-Rubenstein, D. Schimmelpfennig, S.-L. Wang and R. Karmarkar-Deshmukh (2011), *Research Investments and Market Structure in the Food Processing, Agriculture Input and Biofuel Industries Worldwide*, Economic Research Report 130, Economic Research Service, U.S. Department of Agriculture, Washington, DC.

Fuglie, K.O. (2012), "Productivity Growth and Technology Capital in the Global Agricultural Economy", in Fuglie, K.O., S.L. Wang, and V.E. Ball eds (2012), *Productivity Growth in Agriculture: An International Perspective*, Oxforshire, UK: CABI International.

Hayami, Y., and V.W. Ruttan (1985), *Agricultural Development: An International Perspective*, Johns Hopkins University Press, Baltimore.

IPCC, M L Parry, O F Canziani, J P Palutikof, P J van der Linden, and C E Hanson (2007), *Climate Change 2007: Impacts, Adaptation and Vulnerability.* Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge, UK: Cambridge University Press.

Larue, S. and L. Latruffe (2009), *Agglomeration Externalities and Technical Efficiency in French Pig Production*, Working Paper SMART-LERECO No. 09-10, Rennes, France.

Latruffe, L. (2010), "Competitiveness, Productivity and Efficiency in the Agricultural and Agri-Food Sectors", *OECD Food, Agriculture and Fisheries Working Papers*, No. 30.
doi: 10.1787/5km91nkdt6d6-en

Laurent, C., M. Cerf, and P. Labarthe (2006), "Agricultural extension services and market regulation: learning from a comparison of six EU countries", *The Journal of Agricultural Education and Extension*, Vol. 12, pp. 5-16.

Laurent, C. and P. Labarthe (2011), "Économie des services et politiques publiques de conseil agricole", *Cahiers Agricoles*, Vol. 20, No. 8 5, September-October, pp. 343-351.

Ludena C.E., T.W. Hertel, P.V. Preckel, K. Foster, and A. Nin (2007), "Productivity growth and convergence in crop, ruminant, and nonruminant production: measurement and forecasts", *Agricultural Economics*, Vol. 37, pp. 1-17.

McGloughlin, M. N. (2012), “Prospects for Increased Food Production and Poverty Alleviation: What Plant Biotechnology Can Practically Deliver and What it Cannot”, in A. Altman and P. M. Hasegawa, Editor(s), *Plant Biotechnology and Agriculture*, Academic Press, San Diego, pp. 551-561.

Müller, C., W. Cramer, W.L. Hare, and H. Lotze-Campen (2011), “Climate change risks for African agriculture.” *Proceedings of the National Academy of Sciences*, Vol. 108, No. 11, pp. 4313-4315.

Nossal, K and Y. Sheng (2010), "Productivity growth: Trends, drivers and opportunities for broadacre and dairy industries", *Australian Commodities*, Vol. 17, pp. 216–230.

OECD (1999), *Managing National Innovation Systems*, OECD Publishing.

OECD (2002), *Agricultural Policies in OECD Countries: A Positive Reform Agenda*, OECD Publishing. http://dx.doi.org/10.1787/9789264199682-en

OECD and Eurostat (2005), *Oslo Manual: Guidelines for Collecting and Interpreting Innovation Data*, OECD Publishing.

OECD (2006a), *OECD Review of Agricultural Policies: South Africa*, OECD publishing.

OECD (2006b), *Guidelines for Licensing of Genetic Inventions*, OECD publishing.

OECD (2008), *Agricultural Policy Design and Implementation: A Synthesis*, OECD, Paris.

OECD (2010a), *Sustainable Management of Water Resources in Agriculture,* OECD Publishing, www.oecd.org/agriculture/water

OECD (2010b), *OECD Innovation Strategy: Getting a Head Start on Tomorrow*, OECD Publishing. Available at: www.oecd.org/innovation/strategy

OECD (2010c), *OECD Review of Agricultural Policies: Israel 2010*, OECD Publishing. http://dx.doi.org/10.1787/9789264079397-en

OECD (2010d), *Climate Change and Agriculture: Impacts, Adaptation and Mitigation*, OECD Publishing.

OECD (2011a), *Fostering productivity and competitiveness in agriculture*, OECD Publishing. http://dx.doi.org/10.1787/9789264166820-en

OECD (2011b), *OECD Green Growth Studies: Food and Agriculture*, OECD Publishing. http://dx.doi.org/10.1787/9789264107250-en

OECD (2011c), *Evaluation of Agricultural Policy Reforms in the European Union*, OECD Publishing. http://dx.doi.org/10.1787/9789264112124-en

OECD (2011d), *Agricultural Monitoring and Evaluation 2011: OECD countries and Emerging Economies*, OECD publishing. http://dx.doi.org/10.1787/agr_pol-2011-en

OECD (2011e), *Managing Risk in Agriculture: Policy Assessment and Design*, OECD publishing, http://dx.doi.org/10.1787/9789264116146-en

OECD (2011f), "Risk Management in Agriculture: What Role For Governments?", available at: http://www.oecd.org/dataoecd/56/63/49003833.pdf

OECD (2011g), *Water Governance in OECD Countries: A Multi-Level Approach*, OECD publishing.

OECD (2011h), *Collaborative Mechanisms for Intellectual Property Management in the Life Sciences*, OECD publishing, pp. 22-23.

OECD (2012a), *OECD-FAO Agricultural Outlook 2012-2021*, OECD Publishing. http://dx.doi.org/10.1787/

OECD (2012b), *OECD Environmental Outlook to 2050*, OECD Publishing. http://dx.doi.org/10.1787/9789264122246-en

OECD (2012c), *Improving Agricultural Knowledge and Innovation Systems: OECD Conference Proceedings*, OECD Publishing. http://dx.doi.org/10.1787/

OECD (2012d), *Agricultural Policies for Poverty Reduction: A Synthesis*, OECD publishing, http://dx.doi.org/10.1787/9789264167698-en

OECD (2012e), *Environmental Performance of Agriculture at a Glance*, 2nd edition (forthcoming).

OECD (2012f), *Water Quality and Agriculture: Meeting the Policy Challenge*, OECD publishing, www.oecd.org/agriculture

OECD (2012g), "Resource and Energy Use and Efficiency in the Agro-Food Sector: Preliminary Analysis" [COM/TAD/CA/ENV/EPOC(2012)6],

Piesse, J. and C. Thirtle (2010), "Agricultural R&D, technology and productivity", *Philosophical Transactions of the Royal Society B*, No. 365, pp. 3015-3047.

Royal Society (2009), *Reaping the benefits: Science and the sustainable intensification of global agriculture*, RS Policy document 11/09. London.

Serra, T., D. Zilberman, and J. Gil (2008), "Farms' technical inefficiencies in the presence of government programs", *The Australian Journal of Agricultural and Resource Economics*, Vol. 52, pp. 57-76.

Sheng Y. (2011), "Productivity pathways: Climate adjusted production frontiers for the Australian broadacre cropping industry", Presentation to the 8th Meeting of the OECD Network for Farm-level Analysis, Paris, 3-4 November 2011.

UN (2001), World Economic and Social Survey 2011. The Great Green Technological Transformation, Department of Economic and Social Affairs.

World Bank (2006), Enhancing Agricultural innovation – How to go Beyond the Strengthening of Research Systems, Washington D.C.

World Bank (2010), "Designing and Implementing Agricultural Innovation Funds: Lessons from Competitive Research and Matching Grant Projects", Report No. 54857-GLB. Washington, DC.

World Bank (2012), *Agricultural Innovation Systems: An Investment Sourcebook*. Washington, DC: World Bank.

Wright, B. D., and Shih, T. M. (2010), "Agricultural Innovation", *NBER Working Paper Series*, No. 15793.

Yu, B. and A. Nin-Pratt (2011), "Agricultural Productivity and Policies in Sub-Saharan Africa", IFPRI Discussion Paper 01150, December. Available at: www.ifpri.org/sites/default/files/publications/ifpridp01150.pdf

ANNEX 2A.

BACKGROUND MATERIAL

Annex Table 2.1. Developments in world crop yields, 1961-2010

	1961-63	2008-10	1962-70	1970-80	1980-90	1990-2000	2000-10
	Original time series						
	Tonnes per hectare		Average of annual percentage growth rate, by decade				
Wheat	1.1	3.0	3.8	2.7	3.0	1.3	0.9
Coarse Grains	1.4	3.5	2.7	2.2	1.7	1.7	1.8
Barley	1.4	2.7	3.6	1.6	2.6	1.0	0.9
Maize	2.0	5.2	2.2	2.6	1.4	1.8	1.6
Rice	1.9	4.4	2.8	1.9	2.6	1.1	1.1
Soybeans	1.1	2.4	3.2	1.3	1.0	1.7	1.5
De-trended time series[1]							
			Average of annual percentage growth rate, by decade				
Wheat			3.5	2.5	2.4	1.2	1.1
Coarse Grains			3.1	2.3	1.3	1.7	1.9
Barley			2.9	1.1	1.1	0.8	0.9
Maize			3.0	2.7	1.3	1.8	1.8
Rice			2.1	2.0	2.2	1.2	1.2
Soybeans			3.2	1.6	1.2	1.6	0.9

1. Time series were de-trended using a Hodrick–Prescott filter.

Source: FAOstat.

Annex Table 2.2. Differences in yields across regions, 2008-10

Tonnes/hectare

	Wheat	Barley	Maize	Rice	Soybeans
Africa	2.4	1.3	2.0	2.6	1.2
--Eastern Africa	2.0	1.5	1.5	2.5	1.1
--Middle Africa	1.6	0.7	1.0	0.9	0.6
--Northern Africa	2.5	1.2	6.3	9.5	2.9
--Southern Africa	2.8	2.6	4.4	2.6	1.9
--Western Africa	1.5	2.4	1.8	2.0	1.1
Americas	2.9	3.2	7.0	5.2	2.7
--Northern America	3.0	3.4	9.8	7.7	2.8
--Central America	5.1	2.4	3.0	3.8	1.8
--South America	2.6	2.7	4.3	4.7	2.6
Asia	2.9	1.7	4.5	4.4	1.4
--Central Asia	1.5	1.3	5.5	3.2	1.8
--Eastern Asia	4.7	3.6	5.4	6.5	1.7
--Southern Asia	2.6	1.8	2.4	3.5	1.1
--South-Eastern Asia	1.9	1.8	3.7	4.1	1.4
--Western Asia	2.3	1.6	5.5	6.1	3.4
Europe	3.8	3.4	6.1	6.1	1.7
--Eastern Europe	2.7	2.5	4.6	5.1	1.4
--Northern Europe	6.4	4.7	4.9		
--Southern Europe	3.4	2.9	7.4	6.6	3.0
--Western Europe	7.4	6.3	9.4	5.5	2.7
Oceania	1.6	1.8	6.7	6.4	2.0
World	3.0	2.7	5.2	4.4	2.4
Maximum	7.4	6.3	9.8	9.5	3.4
Minimum	1.5	0.7	1.0	0.9	0.6
StD	0.8	0.6	1.2	1.0	0.3

Source: FAOstat.

Annex Table 2.3. Developments in wheat yields in OECD countries and emerging economies, 1961-2010

Average of annual percentage growth rate, by decade[1]

	1962-1970	1970-1980	1980-1990	1990-2000	2000-2010
Australia	-0.3	0.6	2.4	0.9	-1.4
Canada	4.7	0.1	2.6	1.5	2.1
Chile	2.0	-0.5	3.8	4.0	1.7
European Union[2]	3.6	3.8	2.5	0.8	0.9
Israel	3.6	4.8	5.6	35.4	26.0
Japan	11.5	1.5	2.0	1.5	0.7
Korea	0.9	2.6	1.7	0.4	0.3
Mexico	8.3	3.3	0.7	1.7	1.2
New Zealand	-1.2	2.4	2.8	4.0	3.3
Norway	2.0	2.8	0.2	3.2	-0.3
Switzerland	4.7	2.1	1.7	0.8	-0.3
Turkey	2.9	4.0	1.0	-0.2	1.7
United States	2.2	1.6	2.1	1.3	0.8
Brazil	2.4	1.3	4.4	1.7	3.2
China	7.5	5.9	4.3	2.0	2.2
Russia	..	..	..	..	2.5
South Africa	4.0	3.2	3.3	4.5	2.4
Ukraine	..	..	..	..	1.2

1. Time series were de-trended using a Hodrick–Prescott filter.

2. Evolutive EU.

Source: FAOstat.

Annex Table 2.4. Developments in maize yields in OECD countries and emerging economies, 1961-2010

Average of annual percentage growth rate, by decade[1]

	1962-1970	1970-1980	1980-1990	1990-2000	2000-2010
Australia	1.6	2.3	3.3	2.5	0.6
Canada	1.0	1.0	1.3	1.3	2.3
Chile	4.0	1.8	7.2	2.4	1.1
European Union[2]	5.6	3.5	1.5	1.4	1.4
Israel	2.4	4.1	7.4	-0.7	6.3
Japan	0.7	-1.4	0.0	0.4	0.0
Korea	10.9	10.6	2.2	-0.9	1.9
Mexico	1.8	3.0	2.3	2.5	2.7
New Zealand	5.9	1.7	1.2	1.1	0.7
Norway	..	..	..	..	..
Switzerland	2.4	2.4	2.0	0.5	0.5
Turkey	2.4	3.8	5.0	1.4	5.3
United States	3.0	2.0	1.4	1.7	1.6
Brazil	0.9	1.6	2.4	3.7	3.3
China	5.7	4.4	3.6	1.4	1.0
Russia	..	..	..	..	3.6
South Africa	2.9	2.6	-0.3	2.7	6.0
Ukraine	..	..	..	..	4.3

1. Time series were de-trended using a Hodrick–Prescott filter.

2. Evolutive EU.

Source: FAOstat.

Annex Table 2.5. Developments in rice yields in OECD countries and emerging economies, 1961-2010

Average of annual percentage growth rate, by decade[1]

	1962-1970	1970-1980	1980-1990	1990-2000	2000-2010
Australia	0.5	-1.1	2.4	1.0	0.6
Canada	..	..	..	..	..
Chile	..	..	..	..	..
European Union[2]	-0.7	0.8	1.1	1.4	0.4
Israel	..	..	..	..	..
Japan	1.5	0.5	0.3	0.5	0.3
Korea	1.9	2.7	0.5	0.4	0.7
Mexico	2.1	2.5	1.8	1.3	0.3
New Zealand	..	..	..	..	..
Norway	..	..	..	..	..
Switzerland	..	..	..	..	..
Turkey	0.9	0.9	0.5	1.4	3.8
United States	2.0	0.5	1.7	1.1	1.2
Brazil	-1.3	0.1	3.2	3.9	3.7
China	3.5	2.9	2.8	1.0	0.5
Russia	..	..	..	..	4.8
South Africa	..	..	..	..	..
Ukraine	..	..	..	..	4.4

1. Time series were de-trended using a Hodrick–Prescott filter.

2. Evolutive EU.

Source: FAOstat.