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MONITORING PROGRESS TOWARDS GREEN GROWTH IN AGRICULTURE: PRELIMINARY RESULTS

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MONITORING PROGRESS TOWARDS GREEN GROWTH IN AGRICULTURE: PRELIMINARY RESULTS

EXECUTIVE SUMMARY

1. An integral component of any green growth strategy is a highly-reliable set of measurement tools and indicators that would enable policy makers to evaluate how effective policies are, and to gauge the progress being achieved in shifting economic activity onto a greener path. These tools and indicators, which will need to be based on internationally comparable data, must also be embedded in a conceptual framework and selected according to a clearly-specified set of criteria.

2. This report is a first step towards developing a framework to monitor progress on green growth in the agricultural sector in OECD countries. The goal is to identify relevant, succinct and measurable statistics to implement the *OECD Green Growth Strategy Measurement Framework* which provides a common basis for further developing green growth indicators in the agricultural sector in OECD countries.

3. Compiling a set of indicators to monitor progress being made in green growth in agriculture need not be onerous, as most green growth indicators overlap with existing indicators of agricultural policy support, agri-environmental and agricultural commodity indicators, or can be derived from economic and environmental statistics that have already been collected and compiled by the OECD, other international bodies and national statistical offices. But capturing the dynamics of green growth in agriculture and presenting them in terms of quantifiable indicators that could be unambiguously interpreted and easily communicated to policy makers is a challenging task.

4. Given the context-specific nature of many environmental issues; the varying preferences constituting green growth across countries; the multiple factors determining environmental outcomes in agriculture; and the lack of objective valuations of environmental externalities and public goods, establishing quantitative assessments of the cause and effect linkages between a country's policies and its green growth performance is a difficult task – and any comparisons across countries would need to be undertaken with great caution. That being said, comparison of trends over time could provide useful insights.

5. In this report, a preliminary selection of indicators has been made on the basis of existing work undertaken by the OECD and other international organisations, and they have been structured in line with the *OECD Green Growth Strategy Measurement Framework*. The choice of specific indicators was primarily governed by the idea of capturing key aspects of a low-carbon, resource-efficient agricultural sector.

6. In particular, the selection of the indicators was based on the following five guiding principles: they

- provide a balanced coverage of the two dimensions of green growth – "green" and "growth" – and of their main elements, with particular attention given to indicators capturing the interface between the two;
- reflect key issues of common relevance to green growth in OECD countries;
- are easy to communicate;
- are measurable and comparable across countries; and
- are in alignment with the OECD measurement framework for green growth.

These selection criteria are not new; they are rather variations of more specific aspects of OECD's basic guiding principles for indicators: policy relevance, analytical soundness and measurability.

7. On the basis of the above guiding principles, a preliminary selection of indicators was made for assessing the progress of green growth in the agricultural sector. The indicators were derived from the existing OECD databases (i.e. the Producer and Consumer Support [PSE/CSE] database; the agri-environmental indicators database; and patent statistical database), the FAO, the World Development Indicators database of The World Bank and EUROSTAT.

8. Obviously, a far greater range of indicators can be constructed from these databases, but, as a first task, the focus is on those key aspects of green growth in agriculture for which it is feasible to construct suitable indicators on a consistent basis, over time. The list also has been kept sufficiently flexible to enable countries to adapt it to different national contexts.

9. It should also be stressed that data for all indicators proposed are national averages, which often encompass wide variations within the country. Another caveat on selecting green growth indicators is that, as in most other domains of measurement, indicators are often proxies and context-specific and need to be read in conjunction with other indicators on the list.

10. Moreover, not all of the proposed indicators are relevant across all countries. Emphasis will vary depending on the overall development status and priorities and particularities of individual countries. National circumstances, such as structure of the sector, geography, institutions and the policy environment, will also influence the relevance, selection and interpretation of specific indicators.

11. Finally, the proposed list is neither exhaustive nor final. It represents a first selection made on the basis of the existing work and experience of OECD and other international organisations. Gaps exist, both in terms of data availability and quality, as well at the conceptual level.

12. The list of the proposed indicators will be further developed as new data become available and existing concepts evolve. In particular, progress in this area will benefit greatly from work that is currently being undertaken in the Secretariat on advancing the green growth measurement agenda, the completion and implementation of the United Nations' Integrated *System of Environmental and Economic Accounts* (SEEA) as well as the World Bank-led *Wealth accounting and Valuation of Ecosystem Services* (WAVES) partnership.

13. Further progress is required to select indicators for the following specific areas:

- environmental regulations;
- environmentally adjusted multi-factor productivity;
- water pricing and cost recovery; and
- green-related innovation in agriculture.

Chapter 1

Proposed green growth indicators for the agricultural sector – conceptual considerations

The OECD conceptual framework for monitoring progress towards green growth aligns the indicators with the four areas that capture the main features of green growth: the environmental and resource productivity of the economy; the natural asset base; the environmental dimension of quality of life; and economic opportunities and policy responses. Particular attention is paid to efficiency and productivity issues. The framework focuses on the environmental performance of production and consumption, and on the key drivers of green growth, such as policy instruments and innovation. The OECD conceptual framework for measuring green growth and the general principles used in selecting indicators relevant for monitoring progress towards green growth in agriculture are briefly described.

Introduction

14. Green growth is defined as fostering economic growth and development, while sustaining the natural assets base that provide the resources and environmental services on which our well-being relies (OECD, 2011a). Responding partly to the global economic downturn and partly in recognition of the increasingly apparent biophysical limits to growth, the green growth agenda represents a renewed focus on the fundamental drivers of growth, including the re-examination of the use of factors of production, environmental innovation and the removal of policy distortions. A green growth strategy can generate a "double dividend" effect – higher growth with lower adverse environmental impact – by improving the efficiency of resource use and increasing investments in natural capital to drive economic growth (OECD, 2011a).

15. Policies that promote green growth need to be supported with appropriate measurement tools to monitor progress and gauge how well policies are performing in shifting economic activity onto a greener path. Green growth indicators can assist in identifying policy opportunities that can both strengthen growth and improve environmental outcomes or in identifying policies that can address possible trade-offs between green and growth objectives.

16. Reporting and measuring progress of green growth play an important role in the policy work of the OECD, other international organisations as well as in several countries. The OECD, as part of its *Green Growth Strategy*, has developed a conceptual measurement framework and a set of indicators to help governments monitor progress towards green growth (OECD, 2011b*);* UNEP has developed indicators for green economy policy making (UNEP 2012a, 2012b and 2012c); the World Bank has developed a framework for measuring potential benefits from green growth policies (World Bank, 2012); and the *Roadmap to a Resource Efficient Europe* of the European Commission (EC, 2011).

17. Green growth indicators are used in the OECD for mainstreaming green growth into its core policy advice. Two areas where green growth indicators figure prominently: the OECD's Environmental Performance Reviews and the Economic Country Surveys. Member countries, such as the Czech Republic, Germany, Korea, Mexico, the Slovak Republic and the Netherlands, have already applied the OECD green growth measurement framework to their national contexts and produced their own indicator reports using national data. Similar work is underway in non-member countries, such as Colombia, Costa Rica, Ecuador, Guatemala, Paraguay, Peru and Kyrgyzstan.

18. The OECD green growth indicator report, *Towards Green Growth: Monitoring Progress – OECD Indicators*, has become a regular publication of the OECD that is updated as new data become available (OECD, 2011b; 2014). A green growth indicators database has been created, which contains selected indicators for monitoring progress towards green growth to support policy making and inform the public at large (http://stats.oecd.org/Index.aspx?DataSetCode=GREEN_GROWTH). The dataset covers OECD countries as well as BRIICS economies (Brazil, Russian Federation, India, Indonesia, China and South Africa), Argentina and Saudi Arabia for a time period from 1990 to the most recent years available.

19. The main objective of this report is to develop this framework for the agricultural sector and apply it to selected OECD countries.[1] The paper discusses analytical tools for monitoring and evaluating the relative effectiveness of green growth policies in agriculture. In particular, it discusses what is needed and then how to build on what we have in terms of economic performance indicators, policy indicators and agri-environmental indicators to evolve to a set of green growth indicators for agriculture.

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1. A similar exercise was performed jointly by the OECD and the International Energy Agency for the energy sector, where a set of indicators was proposed (OECD, 2011c).

The OECD green growth measurement framework

20. The cornerstone of the OECD approach to monitoring progress towards green growth is the use of a conceptual framework that reflects the integrated nature of green growth and describes the main aspects that need to be monitored. The OECD approach for monitoring progress towards green growth – which reflects a production framework of economic growth theory model, whereby inputs are transformed into outputs – draws on groups of indicators which capture major aspects of green growth. Particular attention is paid to efficiency and productivity issues. The focus is on the environmental performance of production and consumption, and on drivers of green growth, such as policy instruments and innovation activity (**Figure 1.1** and **Figure 1.2**).

21. For each group, a list of indicators has been proposed in the report, *Towards Green Growth: Monitoring Progress – OECD Indicators,* on the basis of existing OECD work and experience (OECD, 2011b; 2014). These four groups of indicators are complemented with generic indicators describing the socio-economic context and characteristics of growth.

Figure 1.1. OECD green growth measurement framework

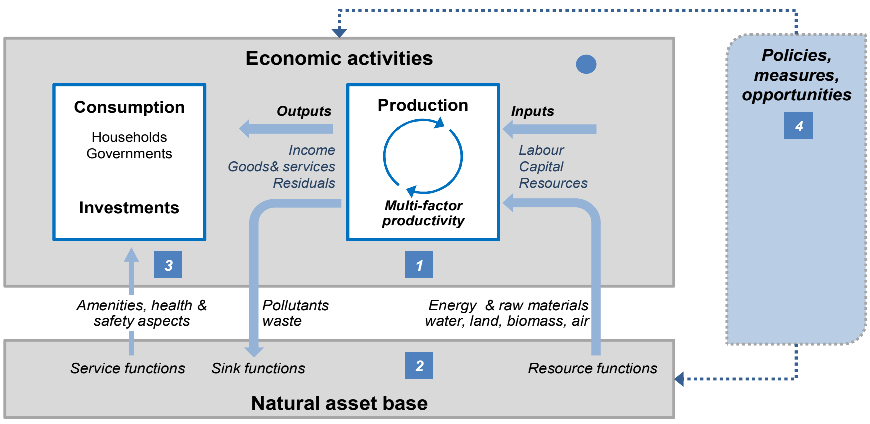
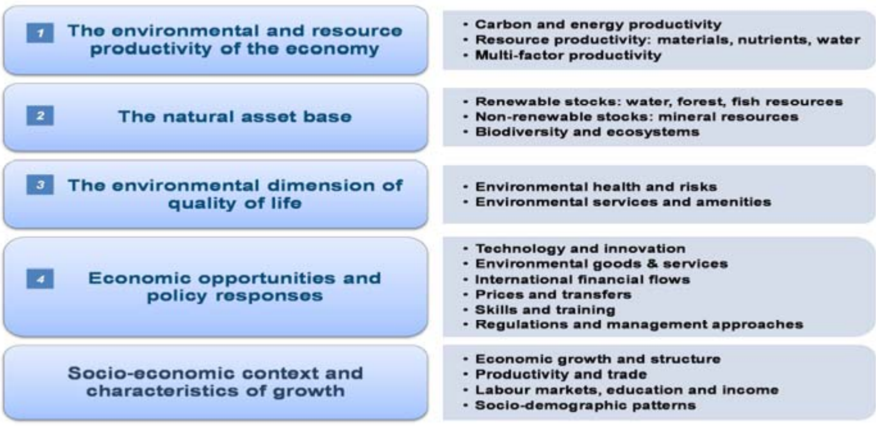


Figure 1.2. Green growth indicator groups and themes



Source: OECD (2011), *Towards Green Growth: Monitoring Progress – OECD Indicators*.

22. The measurement framework was used to guide the development of a proposed list of 25 green growth indicators for OECD countries (OECD, 2011b). These were presented in the 2011 indicators report to Ministers along with data for OECD and emerging economies. The 2011 indicators report has been updated and a new report has been published (OECD, 2014). The update also includes headline indicators for green growth.

General principles in selecting indicators relevant for policy making in agriculture

23. Although the concept of 'green growth' is relatively new, 'green growth' indicators themselves are not. Most overlap with existing sustainable development and environmental indicators or can be derived from economic, environmental and social statistics that have already been collected and compiled by national statistical offices and other national and international bodies. Statistical activities to monitor a country's progress on green growth can thus be streamlined with existing activities related to social, environmental and economic policy priorities (e.g. national sustainable development strategies, economic-environmental accounting and environmental monitoring).

24. The OECD Secretariat has considerable experience in monitoring and evaluating agricultural and agri-environmental policies and approaches. In this process, various databases and indicators have been constructed, which are relevant to monitoring green growth in agriculture. Moreover, several initiatives have been carried out to foster the adoption of sustainability indicators − which to some extent overlap with green growth indicators − into national and international policies. Data also have been collected and organised into so-called "environmental accounts" to help track the potential impact of economic and human activity on the environment (e.g. the UN integrated *System of Environmental and Economic Accounts*, SEEA).

25. Moreover, governments in several OECD countries are becoming increasingly aware of the importance of monitoring and evaluating their agricultural policies and are devoting considerable efforts to strengthening their monitoring and evaluation approaches. For example, evaluation of the EU's rural development programmes, which also include agro-environmental programmes − is required by legislation within an established framework which also comprises quantitative indicators. Less formal approaches are used by other member countries, which also use quantitative indicators (OECD, 2009). In addition, several OECD countries have already implemented the OECD Green Growth measurement framework, and some include agriculture-related indicators (e.g. the Czech Republic, Korea, the Netherlands, the Slovak Republic) (OECD, 2013b).

26. Notwithstanding the experience gained and amount of data collected, there are no existing indicators for the agricultural sector that, taken together, can track progress towards green growth and the process of monitoring and evaluating progress towards green growth in the agricultural sector is challenging: i) approaches that countries are taking towards green growth vary considerably; ii) environmental outcomes in agriculture are determined by multiple factors and there are methodological, measurement and data availability problems in evaluating the environmental impacts of polices; iii) many environmental issues are context-specific and there is no single overarching indicator of environmental performance; iv) not only are the links between the biophysical, economic and policy processes complex, but information on the state of the environment is difficult to collect and interpret; and v) there is a lack of objective valuations of environmental externalities and public goods. It is therefore difficult to establish quantitative assessments of the cause and effect linkages between policies and green growth performance in a country – and any comparisons across countries would need to be undertaken with great caution (OECD, 2012).

27. With this in mind, one important consideration in drawing up a set of green growth indicators for agriculture is to identify guiding principles. Ideally indicators would fulfil the following criteria:

Criterion 1: Capture the nexus between the environment and the economy

28. The interface between the economy and the environment is at the heart of green growth. As green growth concerns the interaction between environment and the economy, a key element in the choice of a green growth indicator is that it should contain information about the economic growth of the sector and its sources. A key principle is to achieve a balanced coverage of the two dimensions of green growth – "green" and "growth" – and of their main determinants, with particular attention given to indicators capturing the interface between the two. Capturing this nexus is an important – if not the most important – criterion for the selection of a green growth indicator.

29. Tracking trends in decoupling economic growth from environmental pressures is an important focus for monitoring and indicators measuring the relationship between growth and environmental impacts are crucial for monitoring green growth. However, while decoupling indicators show whether production has become greener in relative terms, they do not indicate whether pressures on environmental services are decreasing in absolute terms. Absolute decoupling indicators help to fill this gap, but need to be complemented with information on *absolute levels* of environmental services because of potential thresholds and non-linear changes in the environment. But in the absence of information on thresholds, little can be said about what the "optimal" rate of decoupling for a given country is or on whether the rate needs to be increased or decreased (OECD, 2014).

Criterion 2: Be measurable and comparable across countries

30. Measurability and applicability of the indicator for a reasonable number of countries and periods is an obvious criterion and one that is applied in all of the OECD's work on indicators. Definitions and data need to allow meaningful comparison both across time and countries or regions. Indicators should be based on data that are available or that can be made available at a reasonable cost, that are adequately documented and of known quality.

31. A related issue is the timeliness of data. One of the biggest challenges for agri-environmental data and indicators is that they are often not collected and disseminated with the same frequency and speed as the data and indicators on economic performance and on government transfers. An important consideration for an indicator is that it is (or can be) updated regularly.

32. Immediate measurability, however, is not a necessary condition for inclusion or exclusion of an indicator in the list of the proposed indicators, and some flexibility is required. If, for example, an indicator is considered analytically sound, policy relevant and can be made available at a reasonable cost it should be included in the list.

Criterion 3: Reflect key global environmental issues

33. Balanced against the need to capture the intersection between the environment and the economy, is the need for indicators to address those areas where the environmental concern associated with agricultural production is greatest. Climate change, biodiversity loss and sustainable management of water resources are generally regarded to be major policy challenges facing both OECD and non-OECD countries. For climate change and energy use, several countries have set quantifiable targets (e.g. reduced GHG emissions, increased energy efficiency and share of renewable energy) (OECD, 2013a). However, coverage of key global environmental issues should not be the sole selection criterion, especially if the indicator does not capture the link with economic growth.

Criterion 4: Ease of communication for different users and audiences

34. Unambiguous interpretation of the indicator in relation to green growth is a critical factor. Indicators need to be transparent and easy to interpret. Any change in the indicator must be easily understood as being either good or bad for green growth. Ensuring that the indicator is based on the best available science and is analytically sound are key features to assure that the indicator can be trusted.

Criterion 5: Alignment with the OECD Green Growth measurement framework

35. Obviously, the point of departure for designing a sector-specific framework for monitoring progress towards green growth in agriculture is the economy-wide framework and the list of the green growth indicators developed by the OECD Secretariat. As noted earlier, the measurement framework proposed by the Secretariat effectively captures the main dimensions of green growth. Thus, the indicators chosen should be consistent with the OECD framework on measuring progress towards green growth and should be able to track the economic and environmental performance of the agricultural sector.

36. In addition to the aforementioned guiding principles, two other criteria have been used in the current exercise:

- Adjustment of indicators, to relate them to the national green growth approaches and strategies discussed in the OECD study *Policy Instruments to Support Green Growth in Agriculture; A Synthesis of Country Experiences* (OECD, 2013a); and
- Indicators should, to the extent possible, be constructed from existing OECD work and data of other international organisations.

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Chapter 2

Contextual (generic) indicators

Interpretation and assessment of green growth indicators for agriculture need to take into account the socio-economic circumstances of individual countries. This Chapter provides information on the economic context and key characteristics of agricultural growth, particularly with regard to productivity, trade and commodity prices.

37. This group of indicators aims to provide information on the socio-economic context and key characteristics of agricultural growth. Several indicators are relevant, including: the relative importance of the sector in the economy in terms of GDP, employment and trade; socio-economic structure of the sector (education levels, age); commodity prices; structure of production (e.g. crops, livestock); and productivity (multifactorial, partial, yields), etc.

38. For the purpose of this exercise, the indicators proposed provide information on the economic performance of the agricultural sector, particularly with regard to agricultural economic growth and productivity, trade and commodity prices. Indicators reflecting socio-economic characteristics of the sector, such as education and age structure are included under the policy responses and opportunities group of indicators.

39. The following indicators are proposed (Table 2.1):

Table 2.1. Examples of contextual indicators

Theme	Indicators
Economic growth	Growth of total agricultural production (volume)
Productivity	Multifactor productivity
Trade	Relative importance of agricultural trade
Commodity prices	Trends in real international commodity prices
	Supplementary indicators
	Share of agricultural GDP in total
	Share of agricultural employment in total
	Growth of crop production (volume)
	Growth of livestock production (volume)
	Agricultural labour productivity growth rates
	Agricultural capital productivity growth rates
	Growth rates in yields

Measurability

40. Data on economic indicators proposed here are available across a wide range of countries and over time. Data on agricultural Gross Domestic Product (GDP) and employment, for example, are published by the World Bank and EUROSTAT, while data on international commodity prices are published by the IMF and FAO. Data on agricultural production volume are indices published by FAO. They show the relative level of the aggregate volume of agricultural production for each year in comparison with the base period 1999-2001.

41. Data on total factor productivity (TFP) and trade are published by OECD. Data on TFP are available for 20 countries from 1990 and are updated regularly. However, further efforts are needed to improve the availability and comparability of multifactor productivity by sector. In particular, for agriculture the estimates on multifactor productivity include hunting, forestry and fisheries. Moreover, due to the lack of data on investment by industry and by asset - which is a major requirement to obtain capital services series as a measure for capital input in the OECD productivity at the total economy level – the estimates of TFP at sectoral level is computed using net capital stocks.

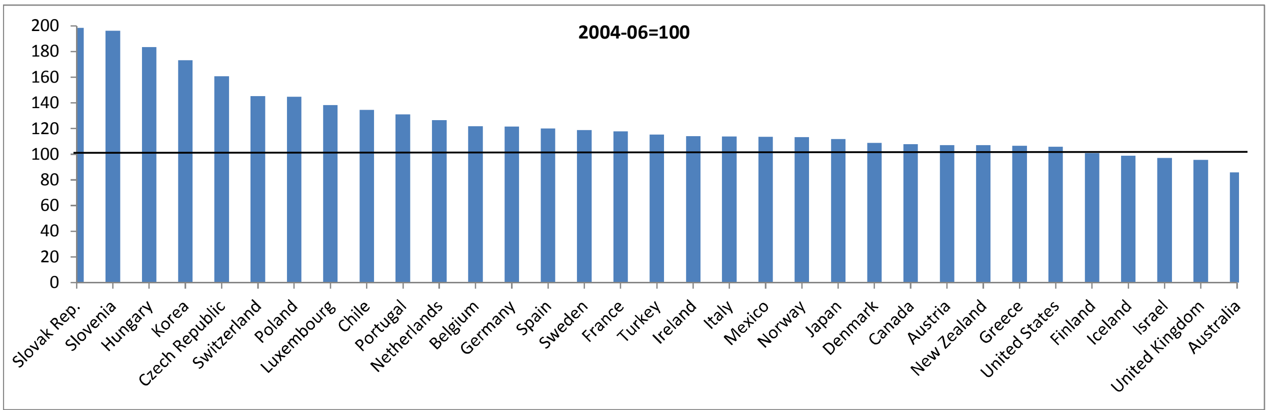
42. It should be noted that although a country's GDP (total and sectoral) is the most widely-used measure of economic growth, GDP and other standard economic indicators measure only the monetary value of goods and services without according specific consideration to the non-cost of the physical movement of materials associated with industrial development. GDP does not account for the depreciation of the produced asset for the depletion of natural assets and does not measure well-being (see, for example, Arrow et al., 2012; Nordhaus, 1974; Solow, 1974; and the report by the international Commission on *Measurement of Economic Performance* (Stiglitz, Sen and Fittousi, 2011) www.stiglitz-sen-fitoussi.fr/en/index.htm).

Trends

Relative importance of the sector

43. In most OECD countries, the direct economic contribution of the primary agricultural sector to the overall economy in terms of its contribution to GDP and employment creation is small. (**Annex Figure A.1**). On average, in the OECD area agriculture accounts for around 2.6% of GDP and 5% of total employment. However, the relative importance of agricultural trade has increased **(Figure 2.1)**. The indicator proposed here aims to capture the exposure of a country's agricultural sector to international competition.

Figure 2.1. Relative importance of agricultural trade in OECD countries, 2010



Note: Relative importance of agricultural trade is measured as the sum of agricultural imports and exports divided by the agricultural value of production (USD).

Source: FAOSTAT.

44. In addition, as world trade, investment and production are increasingly structured around so-called "global value chains" (GVCs) where the different stages of the production process are located across different countries, it is also useful to measure the importance of GVCs in agriculture (see **Box 2.1**). In agriculture, the GVC perspective links the primary sector to downstream activities ("agri-food business") and thus the indicators proposed cover both agriculture, and the food and beverage sectors. The indicators proposed are: i) the participation index, which captures the import content of exports; and ii) the "distance" to final demand, which measures the position of the country in the agro-food global value chain.[2]

2. The distance to final demand measures the number of stages between production and final demand and is an indicator of "upstreamness" in a global value chain. Longer distances indicate a specialisation in producing inputs closer to the beginning of the value chain, which includes higher-value activities, such as

Box 2.1. Measuring trade in value added

With the globalisation of production, there is a growing awareness that conventional trade statistics may give a misleading perspective of the importance of trade to economic growth and income. This reflects the fact that trade flows are measured gross and that the value of products that cross borders several times for further processing are counted multiple times.

World trade, investment and production are increasingly organised around global value chains (GVCs) (OECD, 2013a). A value chain is the full range of activities that firms engage in to bring a product or a service to the market, from its conception to its end use by final consumers. Such activities range from design, production, marketing, logistics and distribution to support to the final customer. They may be performed by the same firm or shared among several firms. As they have spread, value chains have become increasingly global.

Technological progress, cost, access to resources and markets and trade policy reforms have facilitated the geographical fragmentation of production processes across the globe according to the comparative advantage of the locations. Today, more than half of world manufactured imports are intermediate goods (primary goods, parts and components, and semi-finished products), and more than 70% of world services imports are intermediate services.

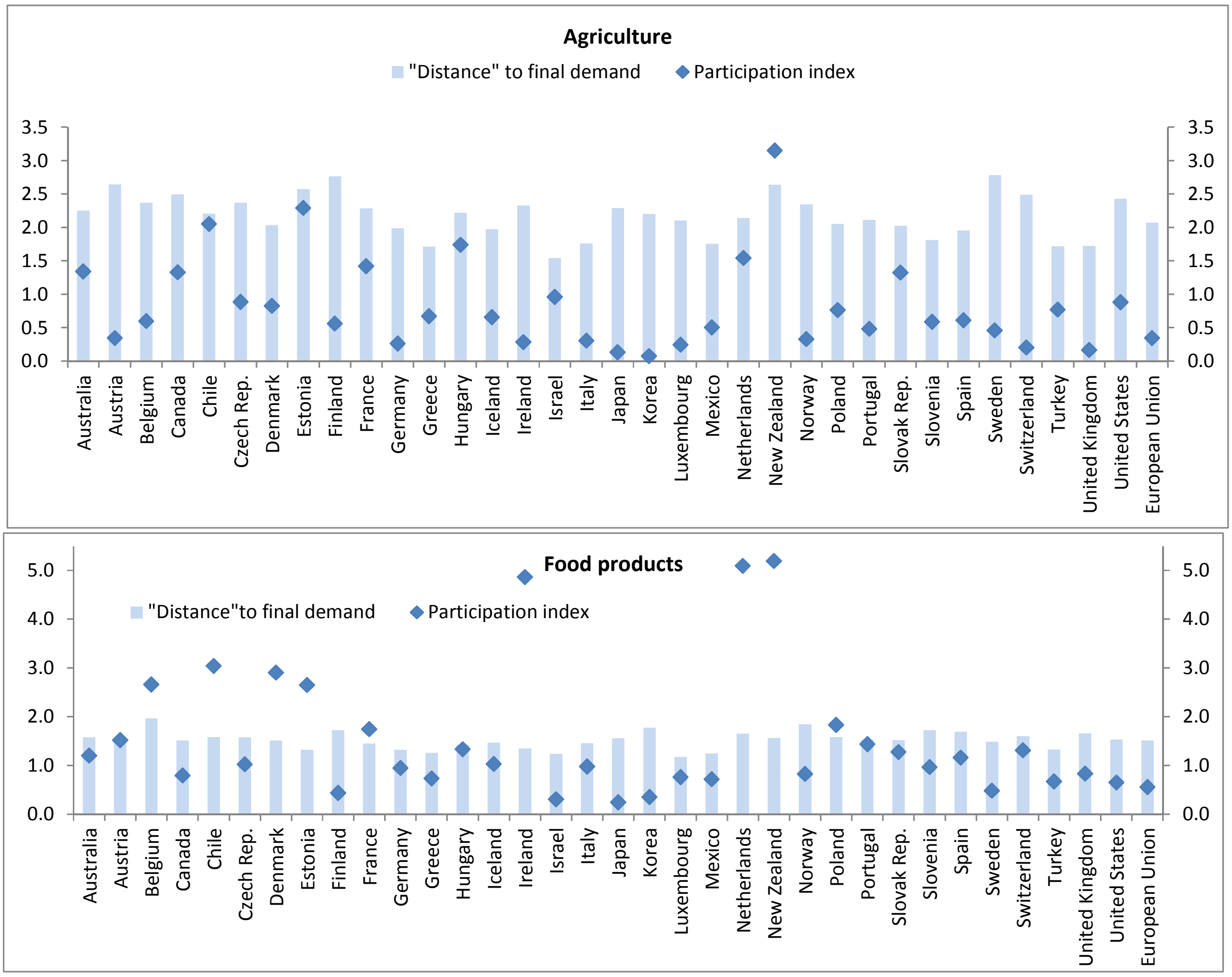
The emergence of global value chains has important implications for policy, including trade policy, and for measuring trade flows. Global value chains challenge the way statistics on trade and output are collected. Trade statistics in particular are collected in gross terms and record several times the value of intermediate inputs traded along the value chain. As a consequence, the country of the final producer appears as capturing most of the value of goods and services traded, while the role of countries providing inputs upstream is overlooked.

The joint OECD – WTO Trade in Value-Added (TiVA) initiative addresses this issue by considering the value added by each country in the production of goods and services that are consumed worldwide. TiVA indicators are designed to better inform policy makers by providing new insights into the commercial relations between nations (OECD, 2014).

45. In agriculture, New Zealand, Estonia and Chile are the three economies whose global value chain represents the highest percentage of exports; in the food products value chain, New Zealand, the Netherlands and Ireland are the three countries whose global value chain represents the highest percentage of exports (**Figure 2.2**). In terms of patterns of specialisation, Sweden, Finland and Austria are the countries with the highest index of upstreamness in agriculture, and Belgium, Norway, Finland, the Netherlands and the United Kingdom have the highest index in terms of food products.

R&D. The participation index is calculated as the sum of: i) the share of foreign inputs in overall exports, and ii) the share of gross exports that are used as inputs in other countries' exports.

Figure 2.2. Participation and position in global value chains for agriculture and food products in OECD countries, 2009

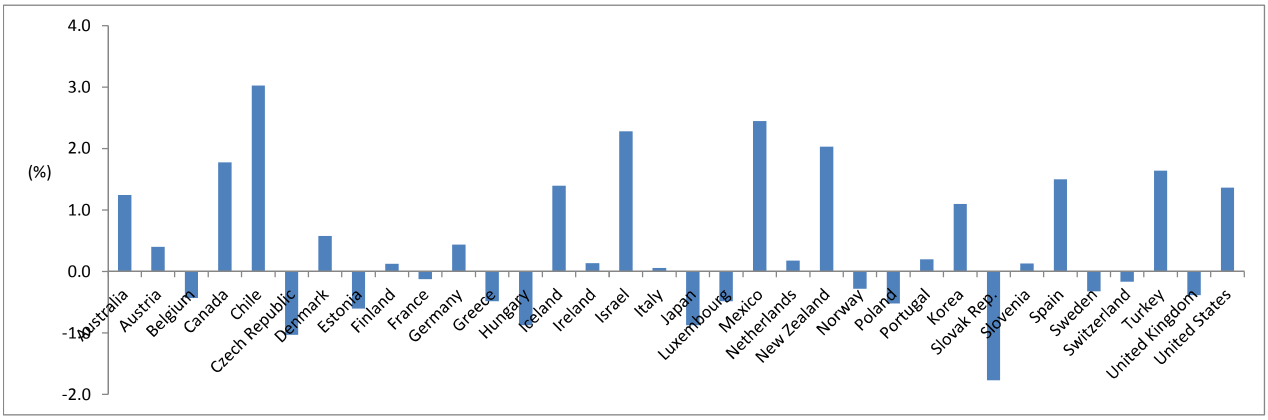


Source: OECD Global Value Chain indicators, May 2013.

Agricultural production

46. Agricultural production has increased for most OECD countries over the last two decades (**Figure 2.3).** Production growth was higher than 2% per year for three OECD countries (Chile, Israel and Mexico), while several countries experienced negative growth, albeit very small (e.g. less than 1% per annum). While in some countries, growth in total agricultural production resulted from growth in the production of both crops and livestock (e.g. Australia, Canada, Chile, New Zealand, Spain, United States, etc.) in some others either production of crops or livestock has declined (e.g. Austria, Belgium, Denmark, etc.) (**Annex Figure A.2**).

Figure 2.3. Average annual growth in agricultural production volume, 1990-2011 (%)



Note: The least-squares growth rate, r, is estimated by fitting a linear regression trend line to the logarithmic annual values of the variable in the relevant period, as follows: Ln(xt) = a + r * t and is calculated as [exp(r) – 1].

Source: OECD Secretariat calculations based on FAOSTAT.

47. Agricultural production is projected to expand over the next decade, but at a slower rate than in the preceding one (2003-12), down from 2.1% to 1.5% per annum (OECD, 2013b), with significant international differences across countries and commodities. This slower growth is expected to be exhibited by all crop sectors and livestock production. Rising costs, growing resource constraints and increasing environmental pressures are the main factors explaining these trends.

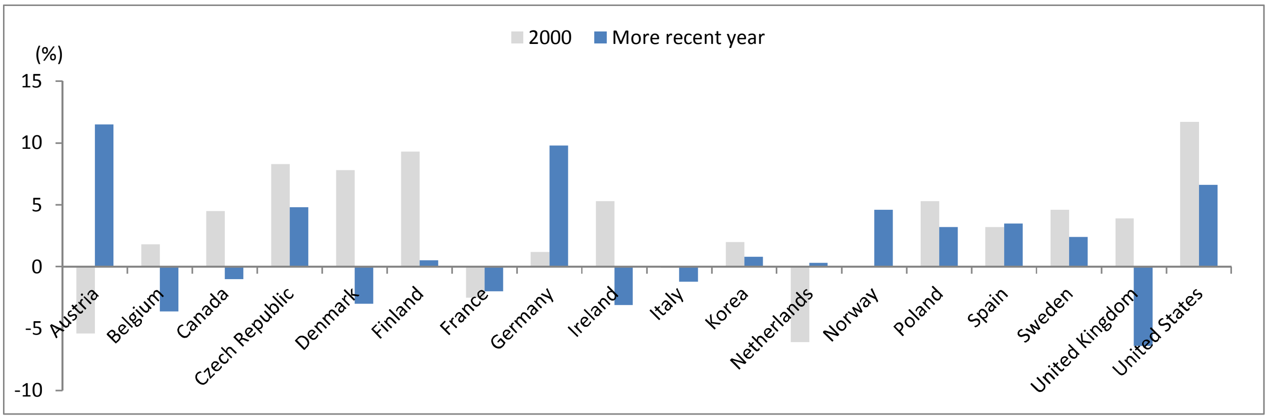
Productivity

48. Agricultural growth can arise from a number of sources: changes in real (adjusted for inflation) prices (or the "terms of trade" effect), increased agricultural land and greater yields. Higher real prices or improved terms of trade increase the value of the same quantity of output, while area and yield growth result in a larger quantity of output (real output growth). Yield growth itself can occur either from intensifying the use of existing technology (for example, using more fertiliser or labour per hectare) or from greater efficiency in overall input use (getting more output from a given level of inputs).

49. Greater efficiency in overall input use is known as growth in total factor (input) productivity or multi-factor productivity. TFP is often associated with new technology or farming practices (innovation). TFP will also increase if resources are shifted from producing lower valued outputs to higher valued outputs. It is widely agreed that increased productivity, arising from innovation and changes in technology, is the main contributor to economic growth in OECD agriculture.

50. TFP of agriculture (including forestry, hunting and fishing) has grown at a slower rate in the 2000s relative to the 1990s, in most of those OECD countries for which data are available (**Figure 2.4**). Five countries (Austria, Germany, the Netherlands, Norway and Spain) are the exceptions.

Figure 2.4. Total factor productivity of agriculture, annual growth rates (%)



Note: Includes forestry, hunting and fishing.

Source: *OECD Productivity Statistics* (database).

51. Single factor productivity measures, such as productivity of labour, capital and land (yields) are often used because the underlying data are more easily available. While useful, such measures can be misleading as they provide only a partial view of productivity. For example, partial measures, by considering output relative to only one input ignore the potential for new technology or efficiency improvements to raise productivity by saving other resources or shifting resources to produce more highly valued outputs. In addition, partial measures do not distinguish between the effects of a more intensive use of existing technology and the effects of adopting new technology.

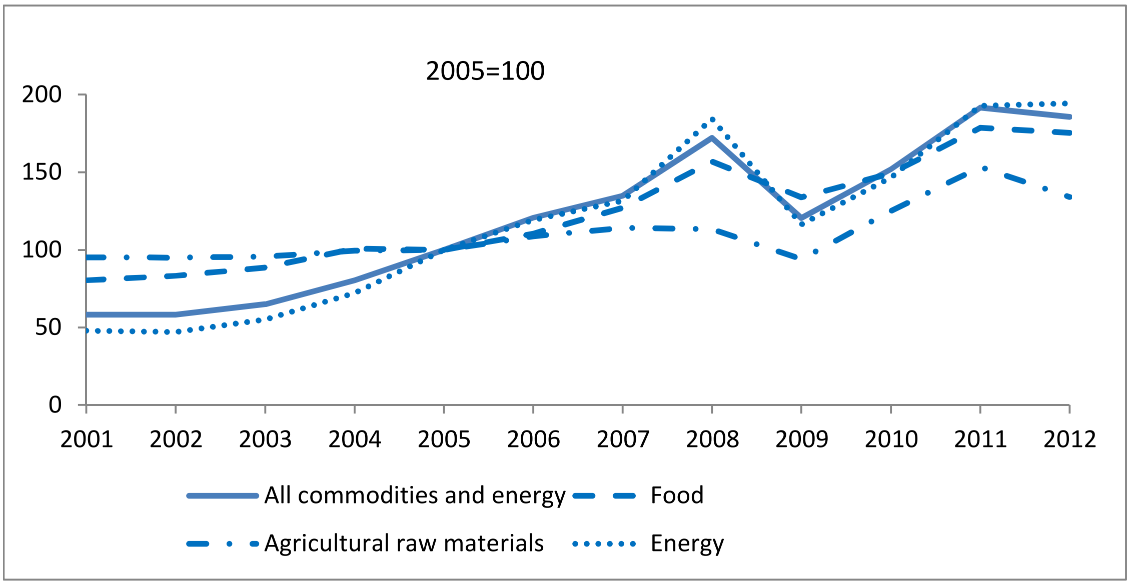
52. For these reasons, single factor productivity indicators are provided in the Annex as supplementary indicators (**Annex Figures A.3**, **A.4** and **A.5**). These data suggest that over the last two decades the highest increase in agricultural labour productivity was experienced in Slovenia, Korea and the Slovak Republic. Mexico, Germany and New Zealand registered the highest increase in investment productivity (agricultural production divided by net capital stock in agriculture), while the highest increase in yield was observed in Estonia and Portugal.

Commodity prices

53. Long-term trends in commodity prices in real terms provide signals about the scarcity or abundance of natural resources and affect economic behaviour. Commodity price increases could provide incentives for farmers to boost production and this may heighten environmental pressures, depending on the farming practices, systems and technologies adopted by the sector, as well as the environmental sensitivity of the location where production increases occur. Overly volatile price movements, on the other hand, tend to send unreliable signals that may or may not be conducive to more environmentally-benign growth.

54. Over recent years, international agricultural commodity markets have been strongly marked by higher and more volatile agricultural commodity prices. Commodity prices had reached historical peaks when the financial crisis started and they subsequently dropped sharply when the global economy contracted. Between 2009 and 2010, food prices rose globally by 15% and prices of agricultural raw materials by 31% (**Figure 2.5).**

Figure 2.5. Evolution of primary commodity prices, 2001-12



Source: International Monetary Fund, *Primary Commodity Prices Data*, 2013.

55. According to the OECD-FAO *Agricultural Outlook 2013-2022* in the next decade, agricultural commodity prices in nominal and real terms are likely to be higher and more volatile on average than they were in the last decade (OECD, 2013b). This rise in prices would result from growing world demand for food, in relation to rising population and incomes, particularly in emerging countries, an increase in the demand for meat, and the development of biofuels.

56. At the same time, production costs are projected to reach higher levels than in the previous decade, due to increases in energy, fertilisers and feed costs, as well as growing pressure on natural resources, especially land and water. Over the next decade, the crude oil price is projected to rise, which may translate into higher farm input prices (e.g. fertilisers, energy to pump water, pesticides). Overall, with the increase in output prices on the one hand, and rising farm input prices on the other, the expected environmental outcomes could be ambiguous depending on the intensity and location of production effects.

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Chapter 3

Environmental efficiency and natural resource productivity

Tracking trends in decoupling inputs to production from economic growth is an important issue for monitoring progress towards green growth. Indicators included in this Chapter attempt to capture the extent to which economic growth is becoming greener – that is, low-carbon and resource-efficient. The indicators presented pertain to: i) carbon and energy productivity, which characterises, among other things, interactions with the climate system and the global carbon cycle as well as the environmental and economic efficiency with which energy resources are used in agricultural production; ii) resource productivity, which characterises the environmental and economic efficiency with which natural resources such as water and nutrients are used in production; and iii) environmentally adjusted total factor productivity in order to give a more complete picture of the productivity of an economy by accounting for inputs from natural resources and for the generation of pollution.

57. Indicators in this group attempt to track the extent to which economic growth is becoming greener, that is, low-carbon and resource-efficient. Tracking trends in decoupling of inputs to production from economic growth is an important focus for monitoring.

58. Monitoring progress towards green growth can be through indicators focusing on environment-related "productivity," or its inverse, "intensity". Indicators in this group include indicators of productivity of natural resources and materials used in agricultural production (**Box 3.1**). Rising environmental and resource productivity would appear to be a necessary condition for green growth in agriculture.

59. Improvements in resource productivity (i.e. reducing the amount of resources used per unit of economic output) imply that less resources per unit of economic activity (e.g. agricultural GDP) will be required in the future. Monitoring natural resource and environmental productivity for agriculture is especially important because of the sector's significant role in using natural resources, making the productivity of soil and water resources of utmost importance.

Box 3.1. The resource productivity concept

Resource productivity refers to the effectiveness with which an economy or a production process is using natural resources. Resource productivity would ideally encompass all natural resources and ecosystem inputs that are used as factors of production in the economy. The term is however often used as a synonym for material productivity. Productivity measurement and analysis of natural resource and material flows complement the traditional indicators of capital, land and labour productivity. Used in parallel, these three types of productivity indicators afford a much deeper understanding of total factor productivity. While there is no disagreement on this general notion, a look at the productivity literature and its various applications reveals that there is neither a unique purpose for measuring productivity nor a single measure. It can be defined with respect to:

- The economic-physical efficiency (i.e. the value of output or value added generated per unit of resource inputs used).
- The physical or technical efficiency (i.e. the amount of resources input required to produce a unit of output, both expressed in physical terms, such as land for the production of cereals). The focus is on maximising the output with a given set of inputs and a given technology or on minimising the inputs for a given output.
- The economic efficiency (i.e. the money value of outputs relative to the money value of inputs). The focus is on minimising resource input costs.

The OECD puts "resource productivity" in a welfare perspective. It is understood to contain both a quantitative dimension (e.g. the quantity of output produced with a given input of natural resources) and a qualitative dimension (e.g. the environmental impacts per unit of output produced with a given natural resource input).

60. Improving resource productivity is often assumed to lead to a parallel reduction in environmental impacts to help avert the possibility of resource scarcity and environmental degradation. However, unless such improvements outweigh economic growth, a risk exists that the associated negative environmental impacts might still increase. Protecting and managing the natural resource base cannot, therefore, rely on improvements in resource productivity alone: it will also be necessary to de-link economic growth from environmental pressures (**Box 3.2**). While productivity indicators and their inverse − decoupling trends − show whether production has become *greener* in *relative* terms, they do not show whether environmental pressure has also diminished in *absolute* terms. From an environmental perspective it is thus useful to also monitor the presence of absolute decoupling.

Box 3.2. Decoupling concepts

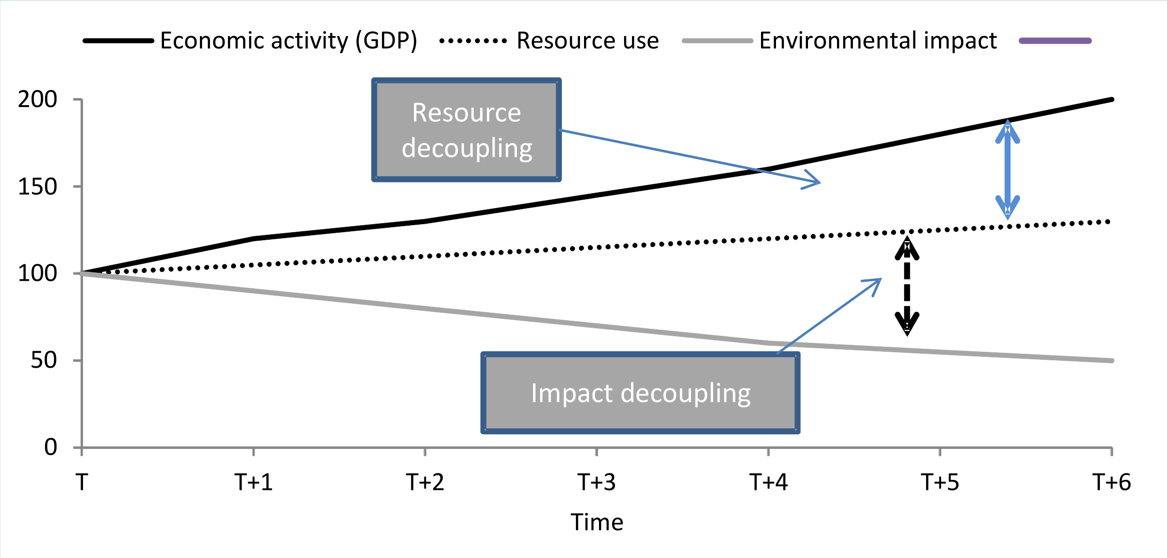
The de-linking − commonly called decoupling − of environmental impacts from economic growth is a core goal of the OECD Green Growth Strategy. The concept of resource decoupling was officially endorsed by OECD Environment Ministers in 2001 and is considered a main objective in the "Environmental Strategy for the First Decade of the 21st Century" (www.oecd.org/dataoecd/33/40/1863539.pdf). The OECD Secretariat was mandated to undertake the task of developing a set of indicators for measuring progress across all three dimensions of sustainable development. They include indicators to measure the decoupling of economic growth from environmental degradation that might also be used in conjunction with other indicators in the Secretariat's economic, social, and environmental peer review processes (OECD, 2002).

There are two different forms of decoupling, commonly referred to as *absolute* and *relative* decoupling. Decoupling is said to be relative when the relevant environmental parameter (e.g. resources used, or a measure of environmental impact) is increasing at a lower rate than the relevant economic variable (e.g. GDP) − that is to say, the economy is growing faster than the resource use, while the absolute quantity of the resource input is still increasing (i.e. the elasticity is positive, but less than unity). Such relative decoupling appears to be fairly common. Decoupling is said to be absolute when the economic variable is growing, while the environmental variable is stable or decreasing.

The decoupling concept, however, does not automatically capture the environmental impacts associated with economic growth. The relationship between resource use, environmental pressures and environmental impacts is complex − taking resource use as a proxy for environmental impacts can be misleading: first, the entire life-cycle of resources, from their extraction, through their use in the production of goods and services and subsequent use phase, to the waste phase, gives rise to environmental impacts; second, any given natural resource material can take numerous different pathways through the economy, which, in turn, can change with time (as a result of technical or social developments, for example); third, differences in regional conditions and use patterns also need to be considered. Furthermore, the extent of the environmental impacts varies in accordance with the resources used.

For these reasons, as shown in **Figure 3.1,** two dimensions of decoupling as applied to green growth have been distinguished in the literature − *resource* decoupling and *impact* decoupling: the former addresses the link between economic growth versus resource use, while the latter refers to the link between economic growth versus environmental impacts (i.e. increasing economic output while reducing negative environmental impacts) (UNEP, 2011). In terms of methodology and data collection, impact decoupling is usually very demanding at the aggregate level (national or sectoral), as many environmental impacts, which may have quite different trends, need to be considered, and the weighting procedures necessary for aggregating the impacts might be seen as subjective. Moreover, a negative relation between these two concepts of decoupling might occur, as reducing environmental impacts does not necessarily have a mitigating impact on resource scarcity or production costs, and may, indeed, even sometimes increase them. In fact, a significant volume of theoretical and empirical studies exists, which examines whether or not increased efficiency leads to environmental improvements − the so-called "rebound effect" or Jevons' paradox. In general, the magnitude of the rebound effect is driven by the degree of substitution between factors of production (e.g. energy, capital) (Sorrell, 2009; Sorrell, Dimitriopolous and Sommerville, 2009).

Figure 3.1. Stylised representation of resource and impact decoupling



61. Moreover, productivity or intensity indicators need to be gauged in the specific (country) context regarding the country's level of development or endowment of natural assets. Specific indicators selected in this group should track the productivity of those natural resources that are of most importance to domestic agricultural production. Thus, specific indicators selected in this group will vary across countries. For example, indicators related to the intensity of water use in agriculture may be considered irrelevant by those countries possessing abundant water resources.

62. But some indicators will be common across countries, in particular those that are global in nature, such as climate change. The atmosphere's capacity to absorb Green House Gases (GHGs) is a global asset and the environmental efficiency of GHG emissions is relevant independent of the country or region in question. Similarly, energy is a critical input into agricultural production and energy productivity is important around the world.

63. Another limitation of partial indicators is that rising productivity may also be the result of the substitution of natural assets for other inputs (labour, capital, energy) or an overall rise in the efficiency of the production process from improved technology or organisation (i.e. a multi-factor productivity increase). Some care must therefore be taken when interpreting partial productivity measures, although the caveats relating to environmental productivity do not differ from those relating, for instance, to traditional partial productivity indicators (e.g. labour productivity). Overall, changes in the natural resource and environmental productivity indicators need to be carefully interpreted. Table 3.1 displays the proposed indicators in this area.

Table 3.1. Proposed environmental efficiency and natural resource productivity/intensity indicators

Theme	Indicators	Criteria			
		Capturing the nexus between the environment and the economy	Ease of communication for different users and audiences	Reflecting key global environmental issues	Measurability and comparability across countries
Carbon productivity	Agricultural GDP per unit of agricultural GHG emissions	***	***	***	***
	Supplementary indicators				
	Share of agriculture in total GHG emissions	***	***	***	***
	Productivity of GHG emission from agriculture by source (soil, ruminants, manure management)	***	***	***	***
Energy productivity	Agricultural GDP per unit of energy use	***	***	***	***
	Renewable energy produced by agriculture	***	***	***	*
Water productivity	Irrigation water per irrigated area	***	***	***	*
Nutrient flows and balances	Nutrient (N and P) intensities per area of agricultural land	***	***	***	***
	Nutrient balances in agriculture (N and P) per agricultural output and area	***	***	***	**
	Intensity of commercial fertilisers	***	***	**	***
Material (biomass) productivity	Indicators to be developed				
Multifactor productivity	Environmentally adjusted total factor productivity	***	**	*	*

*** = high; ** = medium; * = low.

Carbon productivity

Policy context

64. Agricultural production not only uses environmental resources as inputs, but also puts pressure on the environment by emitting pollutants such as GHGs, therefore contributing to climate change. Agriculture is highly exposed to climate change, which may have an impact on yields, location of production and costs of production - with potential risks for food supply, food prices and farm incomes.

65. But the relations between agriculture and climate change are complex. Agriculture not only contributes to GHGs, but it also provides a carbon sink function under certain management practices. Moreover, agriculture is subject to the impacts of climate change. While farming is a source of GHGs, principally methane (CH_4) and nitrous oxide (N_2O), which are part of the primary driving force behind climate change, equally climate change may also impact on farm production.

66. Although agriculture does not have specific commitments under the United Nations Framework Convention on Climate Change (UNFCCC) to reduce GHG emissions, many OECD countries are developing agricultural climate change programmes aimed at reducing GHGs, promoting carbon sinks, and making agriculture more resilient to the impacts of climate change.

67. Climate change is a major global issue that could have significant effects on green growth and sustainable development. A key challenge in relation to agriculture and agricultural GHG emissions is that of reducing the overall level and rate of emission release per unit volume of agricultural production.

Monitoring progress

68. The progress of green growth in agriculture can be assessed against trends in agricultural GHG emissions and the level of decoupling achieved between GHGs and economic growth in agriculture. The proposed indicator relate to the carbon productivity of agriculture defined as the amount of agricultural

GDP per unit of carbon equivalents emitted by agriculture.[3] Increasing carbon productivity is a key to addressing the twin challenge of mitigating climate change and managing economic growth.

69. Supplementary indicators might include: i) Share of agriculture in total GHG emissions; ii) productivity of agriculture GHG emissions by source: soil denitrification, fermentation of ruminants, manure decomposition and rice cultivation.

Interpretation

70. GHG productivity is already used as an indicator in OECD and other international publications relating to green growth. It is widely accepted and easy to interpret.

Measurability

71. UNFCCC inventories are the main data source. Measurability of indicators is good, as data on GHG emissions are reported annually by Annex I countries to the Secretariat of the UNFCCC. The data cover all OECD countries, except Chile, Israel, Korea and Mexico. Emissions are expressed in CO_2-equivalents, as different GHGs have a different global warning potential.

72. The main sources of agricultural GHG emissions are:

- Methane (CH_4) emissions, through enteric fermentation in ruminant animals (cattle, sheep and goats);
- Nitrous oxide (N_2O) emissions, produced by soil denitrification;
- CH_4 and N_2O emissions, from manure decomposition.

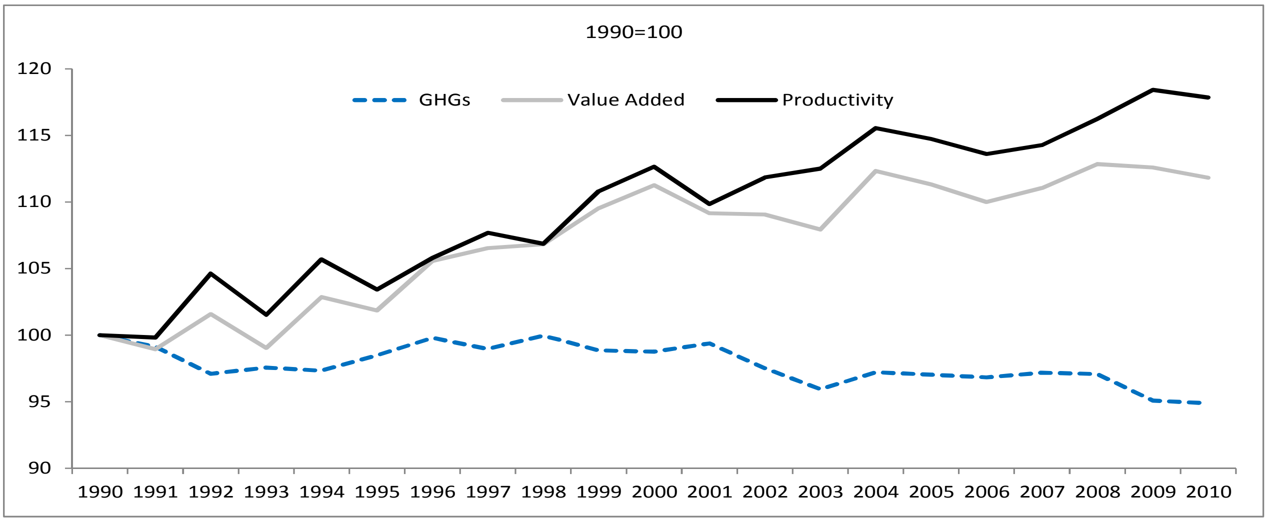
73. These biochemical processes generally depend on climatic, agronomic and technological conditions which can affect agricultural soils and manure storage facilities. Methane and nitrous oxide emissions are closely related to livestock production. Since these different GHG, have different global warming potential, the data are expressed in terms of emissions of CO_2-equivalent in order to make them comparable.

Results

74. Primary agriculture in the OECD area accounts, on average, for 8% of total GHGs in the OECD area (**Annex Figure A.6**). Soil de-nitrification is the main source of GHGs from agriculture (46%), followed by fermentation of ruminants (37%) and manure management (15%) (**Annex Figure A.7)** Over the period 1990-2010, total OECD agricultural GHG emissions decreased slightly (**Annex Figure A.8)**. Over the same period, agricultural production steadily increased, suggesting that for the OECD area as a whole there has been an improvement in the environmental efficiency of agricultural GHG emissions (**Figure 3.2**). In several cases, absolute decoupling of GHG emissions from agricultural production is observed (**Figure 3.3)**. Productivity of GHGs produced by soil de-nitrification, fermentation of ruminants and manure decomposition increased steadily over the 1990-2010 period; productivity of GHGs produced by rice cultivation, on the other hand, exhibited somewhat more variable trends (**Annex Figure A.10**).

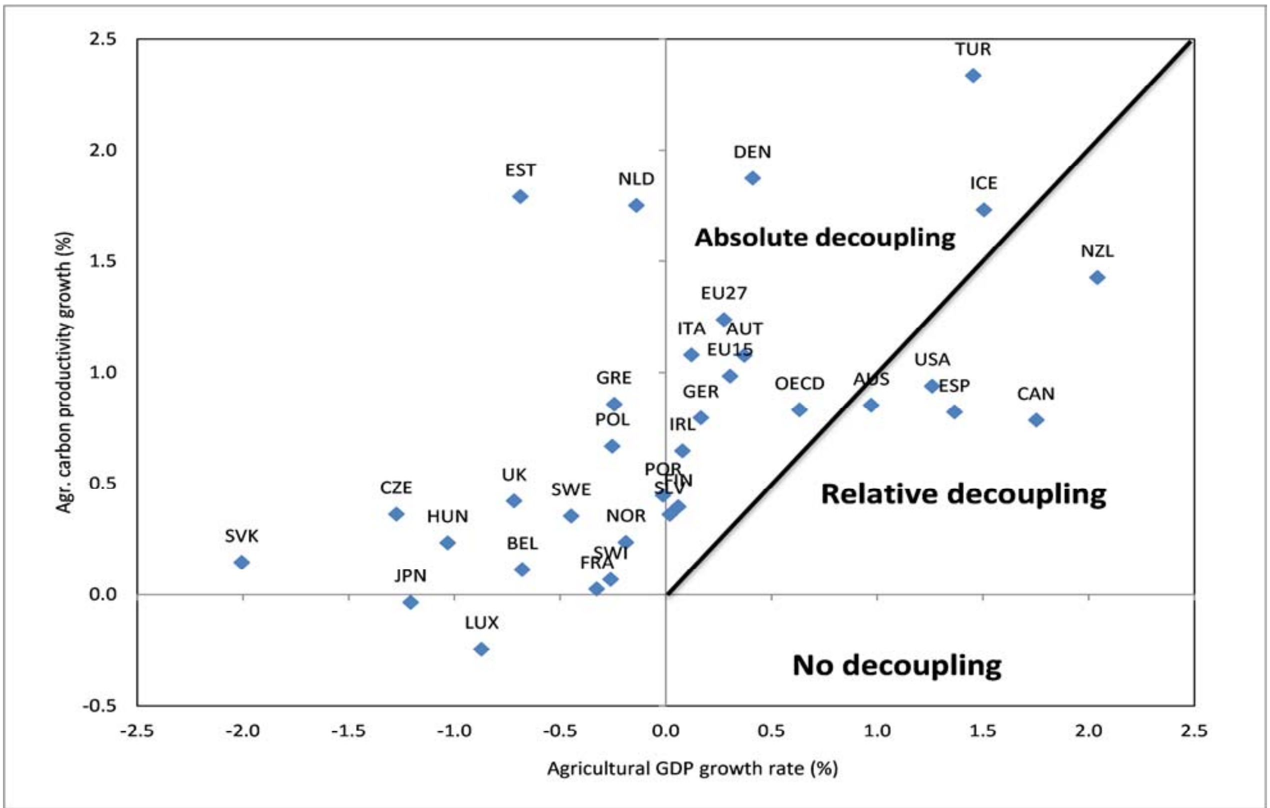
3. Agricultural GDP refers to gross agricultural production value in constant 2004-06 USD as reported in FAOSTAT.

Figure 3.2. GHG emissions, GDP and productivity for agriculture in the OECD area, 1990-2010



Source: UNFCCC *Greenhouse Gas Inventory Data*; FAO, *FAOSTAT* database.

Figure 3.3. Agricultural economic growth and GHG emissions and their effects on decoupling, 1990-2010



Source: UNFCCC *Greenhouse Gas Inventory Data*; FAO, *FAOSTAT* database.

Energy productivity

Policy context

75. Energy is a crucial factor in the ability of agriculture across the OECD area to achieve competitiveness and sustainability. But the links between agriculture and energy are complex, as agriculture is both a consumer and a producer of energy. Farming consumes energy directly through the use of machinery (e.g. operating machinery and equipment), and the heating of stables and greenhouses, and it also consumes energy indirectly, in terms of the energy required to produce fertilisers, pesticides, farm machinery and other inputs. But agriculture is also an important potential source of clean, renewable energy.

76. Support to agricultural energy use is widespread across OECD countries, mainly through reduced standard rates of fuel tax for on-farm consumption. Support is also common across the OECD area for bioenergy, through the provision of a combination of tax incentives and payments for bioenergy production, feedstocks using agricultural raw materials (e.g. maize), and waste (e.g. straw).

77. The key challenge for agriculture with regard to energy is to improve energy use efficiency on-farm, through lowering energy consumption per unit of agricultural production, and also to seek opportunities to increase the production of environmentally neutral biofuel feedstocks (i.e. requiring less energy to produce than the energy generated and having minimal impact in terms of water pollution and air pollution).

Monitoring progress

78. Progress towards green growth can be assessed against: i) the energy productivity of agriculture (the ratio of agricultural GDP per unit of direct use of energy – solid fuels, oil, gas, electricity, renewables, heat and industrial waste);[4] and ii) trends in the volume of renewable energy produced by agriculture.

Interpretation

79. These indicators should be studied in conjunction with those concerning GHG emission productivity, R&D and patents related to energy efficiency and renewable energy, energy prices and taxes, and carbon pricing and biofuel support.

Measurability

80. The data on energy productivity pertain to direct on-farm energy consumption by primary agriculture, which includes energy consumption for: electricity, heating fuel and machinery fuel used in crop production; grain drying, animal production; poultry; transportation of farm products and personal use (for example, heating the farmhouse and driving to town). Indirect use of energy (i.e. energy consumed in the production, packaging and transport to the farmgate of fertilisers, pesticides, farm machinery and buildings) is not included. Data also cover energy used in forestry, which is assumed to be non-significant in most countries relative to agriculture.[5]

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4. Agricultural GDP refers to gross agricultural production value in constant 2004-06 USD as reported in FAOSTAT.

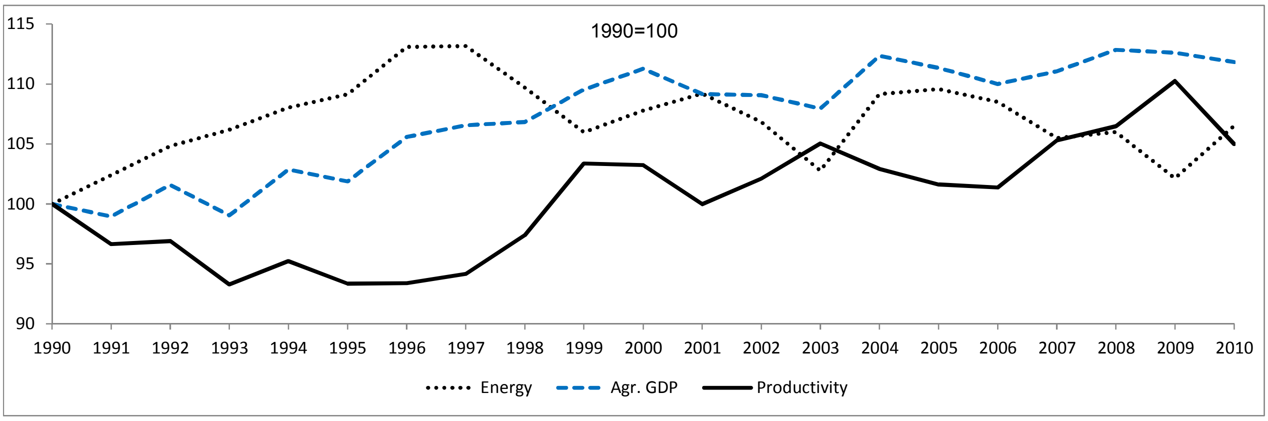
5. The project *Life+ Agriclimatechange* aims to develop a software tool to assess energy consumption as well as GHG emissions in farms (*htwww.agriclimatechange.eu/index.php?lang=en*). This common comprehensive tool is intended to be applicable throughout the whole of the European Union and it was

81. Comprehensive data on renewable energy produced by agriculture are not readily available and are not reported in the present document.

Trends

82. Across the OECD area, energy use in agriculture increased over the 1990-2000, on average, at a higher rate than agricultural GDP, suggesting that a relative decoupling took place. This trend was reverse since 2000, and absolute decoupling was experienced as the growth rate in agricultural production outpaced the growth in energy productivity (**Figure 3.4**).

Figure 3.4. Direct on-farm energy productivity, OECD area, 1990-2010



Source: OECD, *Agri-environmental Indicators* database; FAO, *FAOSTAT* database.

Water productivity

Policy context

83. Farming accounts for around 70% of the water used in the world today (45% in the OECD area) and if no new policies are put in place to avert it, demand for water in agriculture could rise by over 30% by 2050. Increased pressure from urbanisation, industrialisation and climate change will provide agriculture with more competition for water resources. Several OECD countries, particularly those which face scarcity of water resources, have policy strategies to address water management in agriculture (OECD, 2010).

Monitoring progress

84. The one indicator proposed relates to trends in irrigation water per hectare of irrigated area. The share of irrigated area in total agricultural area is proposed as a supplement. In addition, these indicators should be read in connection with indicators on available renewable freshwater resources and indicators on water abstractions by major use (OECD, 2014).

85. The two indicators proposed have a number of limitations which need to be taken into account when examining absolute levels and trends when making comparisons across countries (OECD, 2013). In particular, complete and consistent time-series data are available for only a handful of OECD countries

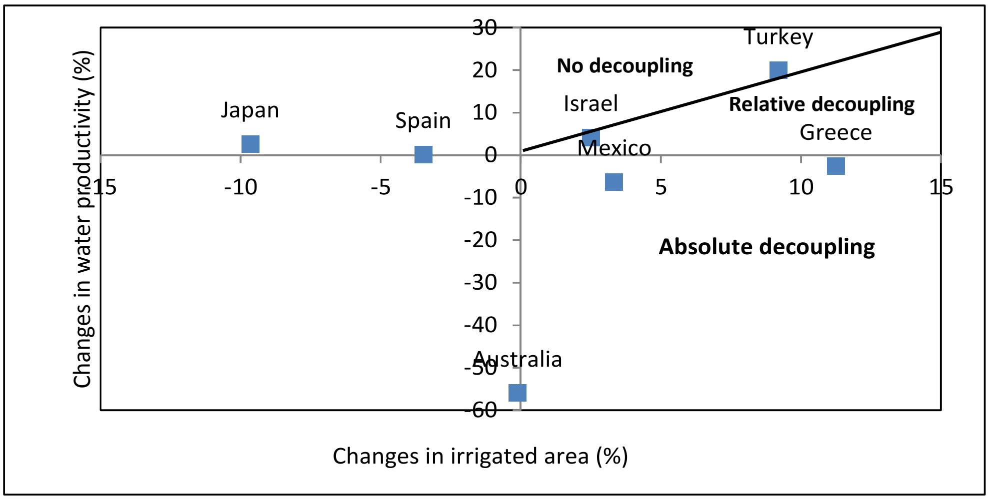
implemented from September 2010 and December 2013. Action plans were designed and implemented for farms located in the four countries which participated in the project (France, Germany, Italy and Spain).

(**Figure 3.5**), partly because these data are not usually calculated annually, but are derived from five- or even ten-year surveys.

86. Methods of collecting and calculating the data vary across and within countries and are also subject to errors of measurement. Sources of data for irrigation freshwater withdrawals include sample surveys of irrigators, and are sometimes estimated using information on irrigated crop acreages along with specific crop water-consumption coefficients or irrigation-system application rates. In other cases, irrigation water withdrawal data may reflect water allocations, which may differ substantially from actual withdrawals, depending on annual climatic conditions (see OECD, 2013).

87. The term "agricultural water withdrawals" refers to "water abstractions" for irrigation and other agricultural withdrawals (such as for livestock) from rivers, lakes, reservoirs and groundwater (shallow wells and deep aquifers), and "return flows" from irrigation, but excludes precipitation directly onto agricultural land. "Water withdrawal" is different from "water consumption", which relates to water depleted and not available for re-use.

Figure 3.5. Decoupling trends of agricultural water use (%)



Note: Changes refer to the average of 2005-10 and 1990-95.

Source: OECD, *Agri-environmental Indicators* database.

88. In some OECD countries, irrigated agriculture accounts for a significant share of agricultural water withdrawals. Overall, the total OECD area irrigated decreased over the 2000s at -0.4% per annum, compared to slight increase over the 1990s (OECD, 2013). The reduction in the area irrigated over the past decade largely reflects decreases reported in Australia, Japan, Italy, Greece and Spain (**Annex Figure A.12)**. Reductions in agricultural production, improvements in efficiency with the remaining areas irrigated and prolonged drought in some regions are main sources of the decline in irrigated area.

Nutrient flows and balances

Policy context

89. Nutrients, such as nitrogen, phosphate and potash, are essential in maintaining and raising crop and forage productivity. Applied annually, most of these nutrients are absorbed by the crops, but when applied in excess, they can be lost to the environment through volatilisation, leaching into groundwater, emission from soil to air, or runoff into surface water. Where nutrients are in deficit, soil fertility can

decline, while an excess of nutrients necessary for plant growth entails the risk of polluting soil, air and water, through eutrophication.

90. Across the OECD area there is a widespread incidence of surplus nutrient application and nearly all OECD countries, to varying degrees, apply an extensive range of policy instruments (payments, taxes, regulations, farm advice, etc.) to address nutrient pollution of water and air in terms of ammonia emissions (OECD, 2013). The challenge in agriculture is to seek ways to increase production while minimising farm nutrient losses and subsequent damage to the environment.

Monitoring

91. Two types of indicators are proposed to monitor progress towards green growth: i) changes in agricultural nutrient balances and intensities and; ii) changes in intensities of inorganic (commercial) fertilisers. In particular, the following indicators are proposed:

- Changes in nitrogen (N) intensity (gross N balance per ha of agricultural land) related to changes in agricultural production.
- Changes in phosphorus (P) intensity (gross P balance per ha of agricultural land) related to changes in agricultural production.
- Changes in commercial fertiliser intensities, calculated by dividing the annual consumption of commercial fertilisers with the area of arable land.

Interpretation

92. These indicators are proxies of the risk of environmental pressures associated with agricultural production - declining soil fertility (in the case of a nutrient deficit), or the risk of soil/water/air pollution (in the case of a nutrient surplus). Nutrient balances and intensities provide an indication of the level of potential environmental pressures from nutrients, in particular on soil, water and air quality in the absence of effective pollution abatement.

93. When interpreting these indicators it should be noted that they describe potential environmental pressures, and may hide important sub-national variations. Cross-country comparisons of change in nutrient surplus intensities over time should take into account the absolute intensity levels during the reference period. They should also be read together with information on agricultural land use and farm management approaches.

Measurability

94. The gross nutrient balances (N and P) are calculated as the difference between the total quantity of nutrient inputs entering an agricultural system (mainly fertilisers and livestock manure), and the quantity of nutrient outputs leaving the system (mainly uptake of nutrients by crops and grassland).

95. Nutrient balances are expressed in terms of changes in the physical quantities of nutrient surpluses (deficits) to indicate the trend and level of the potential physical pressure of nutrient surpluses into the environment. The nutrient balance indicator is also expressed in terms of kilogrammes of nutrient surplus (deficit) per hectare of agricultural land per annum to facilitate the comparison between countries of the relative intensity of nutrients in agricultural systems.

96. Data on nitrogen and phosphorus balances are available for almost all OECD countries from 1990 until 2009 (OECD, 2013). Data on apparent consumption of commercial fertilisers are published by the International Fertiliser Industry Association (IFA) and the FAO.

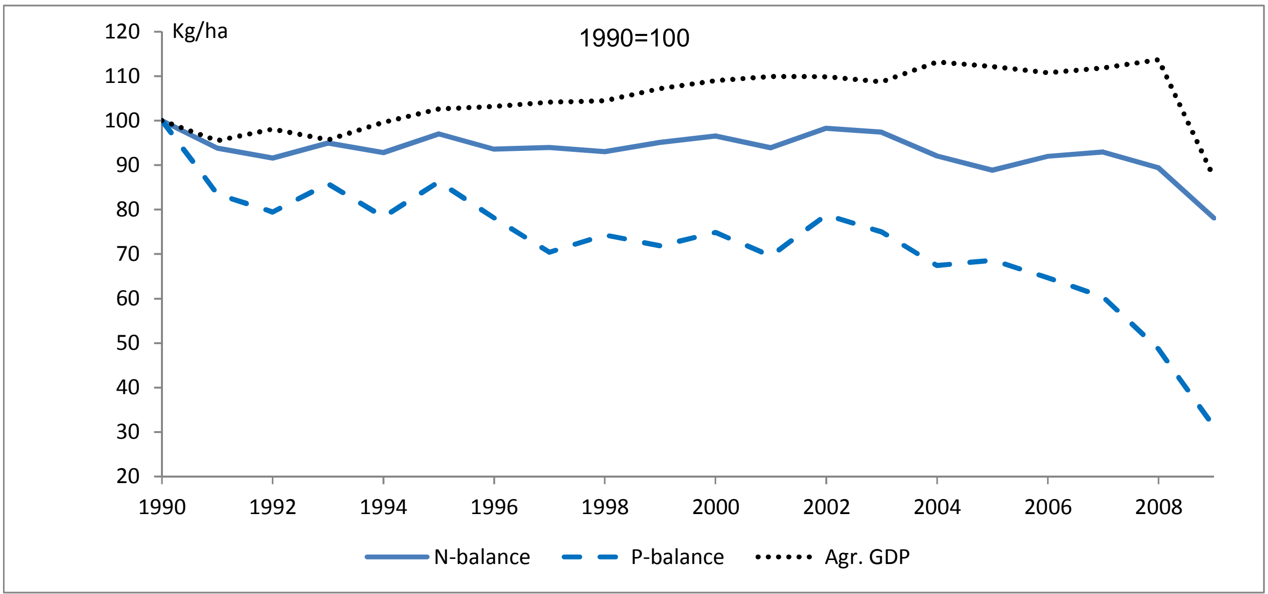
Main trends

97. For many OECD countries, nutrient surpluses have been declining over time relative to agricultural output. Overall, OECD agricultural surpluses N and P have been on a continuous downward trend from 1990 to 2009, both in absolute tonnes of nutrients and in terms of nutrient surpluses per hectare of agricultural land. The rate of reduction in nutrient surpluses in the OECD area was more rapid over the 2000s compared to the 1990s, signalling a process of relative decoupling of agricultural production from N- and P-related environmental pressure (**Figure 3.6** and **Figure 3.7**).

98. A similar picture emerges from the trends in inorganic fertiliser intensities, particularly since 2000; their consumption has been trending downwards, while crop production has been increasing (**Figure 3.8** and **Figure 3.9)**.

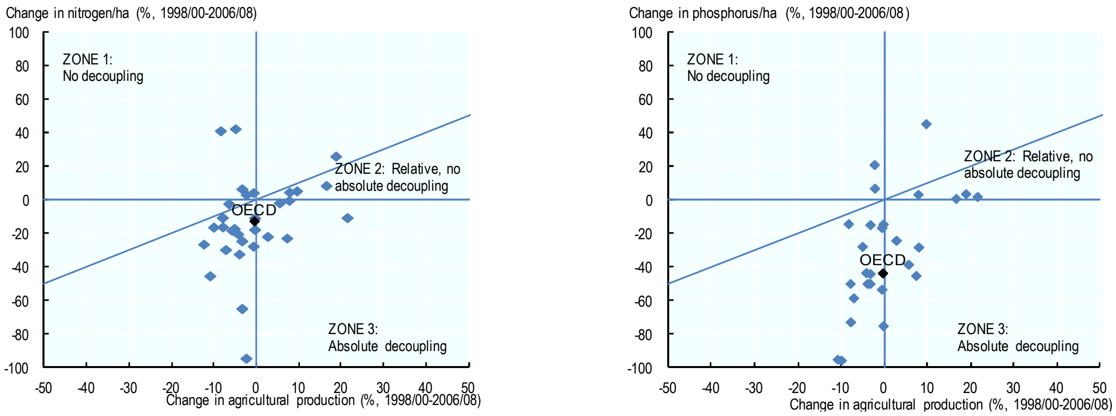
99. These developments reflect both improvements in nutrient use efficiency by farmers and slower growth in agricultural output in many countries. The lowering of nutrient surpluses has reduced the risk of environmental pressure on soil, water and air, but sizable variations within and across countries in terms of the intensity and trends of nutrient surpluses indicate various degrees of decoupling.

Figure 3.6. Agricultural nutrient balance intensities and agricultural production, OECD area, 1990-2009



Source: OECD, *Agri-Environmental Indicators* database.

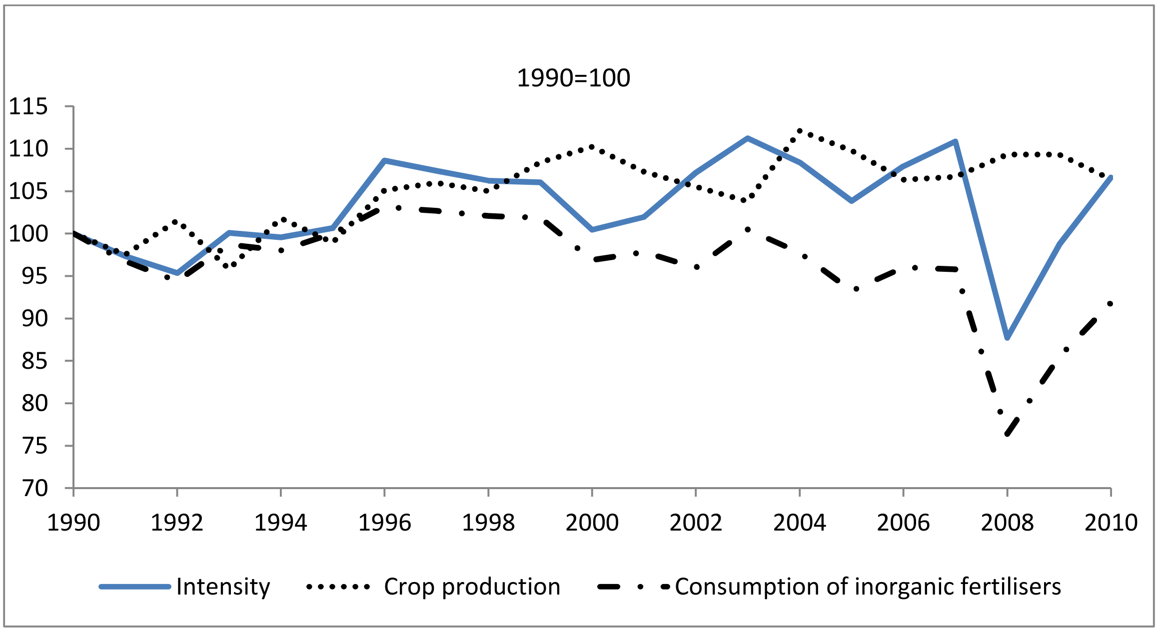
Figure 3.7. Nutrient decoupling trends, OECD countries



Source: OECD, *Agri-Environmental Indicators* database.

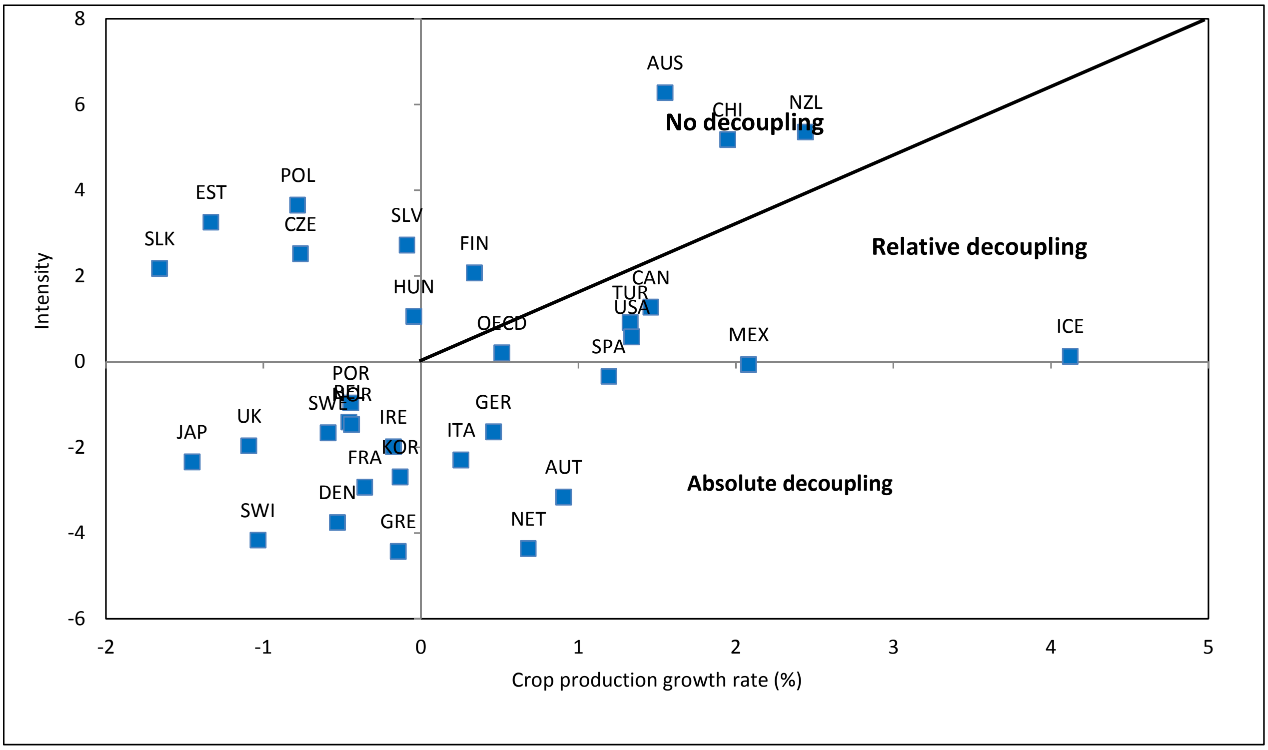
StatLink http://dx.doi.org/10.1787/888932925407

Figure 3.8. Apparent consumption and intensity of inorganic fertilisers, and crop production, OECD area, 1990-2010



Source: FAO, *FAOSTAT*; International Fertiliser Association (IFA).

Figure 3.9. Decoupling trends of inorganic fertilisers, 1990-2010 (1990=0)



Source: FAOSTAT; International Fertiliser Association (IFA).

100. Despite the overall improvement in lowering nutrient surpluses, nitrogen and phosphorus intensity levels per hectare of agricultural land remain at very high levels in terms of their potential to cause environmental damage. By 2008-09, around two-thirds of OECD countries had an annual national nitrogen surplus in excess of 40 kgN/ha nitrogen, with Belgium, Israel, Japan, Korea and the Netherlands reporting surpluses in excess of 100 kgN/ha (**Annex Figure A.13**). Similarly for phosphorus, about one-third of OECD countries had a surplus in excess of 5 kgP/ha, over the same period, with Israel, Japan, Korea, the Netherlands, and Norway, having surpluses in excess of 10 kgP/ha.

Material productivity (biomass)

Policy context

101. As noted earlier, natural resources and the materials derived from them form the material basis of the economy. Using them efficiently is essential not only to sustain economic growth, but also to minimise the negative impacts on the environment. Resource productivity and efficiency are high on the international policy agenda and are the focus of a number of national and international initiatives, such as the Kobe 3R Action Plan, the UNEP International Resource Panel and the EU 2020 Flagship initiative on resource efficiency. The OECD has two Council Recommendations related to advancing work in this area.

Monitoring

102. Monitoring natural resources, the way they are used in economic activity and contribute to economic outputs, and how their use impacts on the environment requires a comprehensive data on natural resource flows and indicators that monitor progress.

103. Indicators based on Material Flows Analysis[6] are useful to measure progress with resource productivity, and provide insights into the economic efficiency and environmental effectiveness with which materials are used in the production and consumption chain, up to final disposal. One commonly used indicator is material productivity (or intensity), relating economic output to the amount of materials (or raw materials) used as inputs. It is defined as GDP per Domestic Material Consumption (DMC) or per Domestic Material Input (DMI).[7] It can be derived from Economy-Wide Material Flow Accounts[8] that cover the economy as a whole and distinguish between various material types and groups. Water as resource is not covered in such accounts and needs to be reported separately.

104. Applying this approach to agriculture would require data on material flows broken down by industry, or alternatively data on major material inputs into agricultural activity and on material outputs from agricultural activity, including processed products. Such data are not yet available for all OECD countries, and relevant indicators have yet to be defined.

Environmentally adjusted total factor productivity

Policy context

105. Central to examining green growth in agriculture is the inclusion of environmental externalities in growth accounting. Agricultural production affects natural resources and influences eco-systems and biodiversity. Many of these environmental effects exhibit the characteristics of negative or positive externalities or public goods, for which private markets do not exist or are poorly functioning. These effects are usually neglected in traditional growth accounting frameworks or in estimations of common indicators of economic performance, such as total factor productivity (TFP). By omitting these developments, traditional TFP – which is often interpreted as a measure of economic efficiency, competitiveness and a long-term determinant of material living standards – may be biased and lead to incorrect policy conclusions. Some of these problems can be addressed by deriving a measure of total factor productivity that is adjusted for the use of natural resources and other environmental services.

Monitoring progress

Interpretation

106. As noted earlier, MFP is a well-defined measure of productivity, but it is usually computed as a residual and is more difficult to communicate than partial productivity measures, such as labour

6. Material Flow Analysis (MFA) studies how natural resources and materials flows into, through and out of a given system (usually the economy) and how these flows interact with the economy and the environment. It is based on methodically organised physical flow accounts that provide data on the material inputs taken from the environment into the economy (e.g. resources extracted or harvested from the surrounding natural environment or imported from other countries), the transformation and use of inputs within the economy (from production to final consumption) and the material outputs from the economy to the environment as residuals (waste, pollutants) or to other countries in the form of exports. The data are compiled from available production, consumption and trade data, and from environment statistics (on waste, emissions, etc.).

7. DMI measure the material inputs into an economy, accounting for the domestic extraction of materials and imports. DMC measures the amount of materials consumed in an economy (i.e. the direct apparent consumption of materials). It is composed of two elements, namely the domestic extraction and the physical trade balance (which equals imports minus exports). DMC equals DMI minus exports.

8. MF accounts are part of the family of physical flow accounts described in the Central Framework of the System of Environmental Economic Accounts (SEEA). The SEEA has been adopted as an international statistical standard (UN, 2014). The reporting on economy-wide MF is mandatory in the EU.

productivity. Accounting for natural resource inputs and for emissions such as negative outputs it would add an additional element of complexity. Nevertheless, this is considered to be conceptually correct way of examining the measurement bias that may arise from not recognising environmental services in traditional TFP measures.

Measurability

107. This indicator is not currently measurable and the OECD has started research to advance work in computing this indicator. The objective is to examine whether TFP growth has been under- or overstated as a consequence of omitting undesired outputs and natural resource inputs from the calculation (**Box 3.3**). In a first stage, this work focuses on integrating natural resources, such as land, timber, and sub-soil resources into a set of inputs, and on integrating undesirable output (selected emissions) into the set of outputs. Some exploratory work has also been undertaken by the Secretariat for calculating environmentally adjusted TFP for the agricultural and energy sectors.

Box 3.3. OECD's on going work on adjusting total factor productivity estimates to account for environmental services

The OECD has started research, developed a calculation method and applied it to selected countries. The work builds on the literature on productivity measurement with undesirable outputs (Pittman, 1983; Repetto et al., 1997). It integrates selected natural resources (land, timber, subsoil assets) as input factors and selected pollutant emissions (carbon dioxide, sulphur and nitrogen oxides) as undesirable "bad" outputs in the production function. The absence of data on resources such as water and fish stocks, preclude their inclusion in the analysis at this stage.

The framework is based on a standard production function, whereby output is derived using labour and capital input factors. This function is complemented by natural capital and the negative effect of undesirable bad output on production. Two adjustments are made to the standard production function. First, natural capital inputs (including minerals, oil, gas, coal and timber) are aggregated into a natural resource index and enter the production function as a third input factor. Second, 'bad outputs', essentially air pollutants, such as sulphur oxides and nitrogen oxides and CO_2 emissions are added to output to derive effective output.

The biggest challenge is data availability regarding the use of environmental inputs in production and the associated costs, in particular, the cost of the depletion and degradation of natural resources and their use in consumption and production. As a first step, the techniques to compute the monetary value of natural resources are consistent with the 2008 SNA and the 2012 Central Framework of the SEEA. No attempt is made to estimate the value of other environmental services, particularly for "non-uses" such as regulating services. The SEEA *Experimental Ecosystem Accounts* will, in the longer term, provide further guidance on techniques for valuations.

Although subject to limitations in its practical implementation, this extension of productivity measurement can allow for a more accurate assessment of economic performance. Preliminary results of the OECD's work show that the adjustment of the traditional productivity growth measure for bad outputs is small. While this partly hinges on the fact that for lack of more comprehensive data only a limited set of bad outputs are considered in this paper, namely CO_2, SO_X and NO_X emissions, the relatively small adjustment of the traditional productivity growth measure is good news for two reasons. First, it implies that ignoring the bad outputs considered in this paper results in a relatively small bias of productivity measurement, and thus analysis based on traditional measures should be relatively reliable in this regard. Second, it also implies that the acceleration in productivity growth that would help to substantially reduce the bad outputs considered in this paper, without reducing output growth, should be possible to achieve.

Source: Brandt et al. (2014).

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Chapter 4

The natural asset base and the environmental quality of life

Chapter 4 focuses on the group of indicators relating to the natural asset base and the environmental quality of life. Natural resources are a major foundation of economic activity and human welfare, and their efficient management and sustainable use are fundamental to achieving economic growth and maintaining environmental quality. Progress can be monitored by looking at indicators that describe the natural asset base. The main issues of importance to green growth in agriculture included in this Chapter pertain to availability and quality of freshwater, and of biological diversity and ecosystems, including species and habitat diversity and the productivity of land and soil resources.

Due to data and methodological issues, no indicator to capture the impact of the environment on people's quality of life is proposed.

108. The group of indicators on ***the natural asset base*** aims to monitor whether the natural asset base is being kept intact – a condition for sustainable growth – because, as noted earlier, rising productivity may be associated with an increase in environmental pressures. Indicators in this group should be aligned with indicators of environmental and resource productivity, and focus on natural assets that matter the most to agricultural production. Consequently, indicators will vary across countries according to their natural asset base.

109. A major methodological question is the extent to which one type of asset can be substituted for another. Can for example, an increase in land used for agricultural production offset the loss of a natural forest? As many natural assets are not (fully) priced, asset prices cannot adequately reflect society's preferences, which leads to under- or over-exploitation of these assets.

110. In principle, and for the purposes of indicator construction, social shadow prices could be estimated, which can be used to value the net investment of each natural asset. However, for natural assets, such as water and soil, calculation of social shadow prices is not straightforward due to externalities and imperfect information about resource rents. In such cases, the physical evolution of natural assets could provide a starting point, although this alone would convey limited information about progress towards green growth. Indicators of stocks and flows of natural resources and environmental services need to be read along with information on resource management policies.

111. The group of indicators ***environmental quality of life*** attempts to capture the direct impact of the environment on people's lives, in terms of: i) people's exposure to various pollutants and the associated health effects; and ii) the access that different groups have to environmental services (e.g. water, sanitation, green space, etc.). Indicators in this group should be selected to reflect the most pressing environmental health risks associated with agricultural production. This should be mirrored in the presentation of information on environmental services or amenities.[9] However, there are serious issues related to data availability and methodology in constructing rigorous indicators in this area. The most obvious proxy indicators for agriculture relate to: i) health risks to people associated with exposure to pesticides (e.g. number and rate of acute work-related poisonings due to pesticide exposure);[10] and to health risks to people associated with water pollution from agriculture. But in both cases data are incomplete (OECD, 2013). In any case, it can be argued that in OECD countries, environmental quality of life issues related to agricultural production are critical only in certain regions of countries. For these reasons, no indicator is proposed under this heading.

Monitoring progress of natural asset base

112. The main issues of importance to green growth include availability of freshwater and biological diversity and ecosystems, including species and habitat diversity as well as the quality of land and soil resources. More specifically, the following indicators are proposed:

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9. The OECD's economy-wide green growth indicators work includes two indicators under this group: percentage of population exposed to air pollution; and percentage of population using improved sanitation and waste water treatment facilities (OECD, 2014).

10. See, for example, Minnesota Department of Health, Acute Work-Related Pesticide Associated Illness and Injury Reported to Poison Control Centers, www.health.state.mn.us/divs/hpcd/cdee/occhealth/indicators/pesticide.html

Table 4.1. Proposed indicators for monitoring the natural asset base

Theme	Indicators	Criteria			
		Capturing the nexus between the environment and the economy	Ease of communication for different users and audiences	Reflecting key global environmental issues	Measurable and comparable across countries
Renewable stocks	Freshwater resources				
	Share of agricultural freshwater withdrawal in total	***	**	***	*
Biodiversity and ecosystem services	Land use resources				
	a) Land cover types, conversions and cover changes				
	Trends of arable land and cropland	***	***	***	***
	Trends of permanent pastures	***	***	***	***
	b) Soil resources				
	Share of agricultural land affected by water erosion classified as having moderate to severe water erosion risk	***	***	***	***
	Wildlife resources				
	Farm birds index	*	*	*	**

*** = high; ** = medium; * = low.

Renewable stocks: Freshwater

Policy context

113. As noted earlier, agriculture is the world's largest user of water. The main challenges are to ensure a sustainable management of water resources in agriculture (and other uses) by avoiding over-exploitation and degradation. Using more efficient technologies and applying the user pays principle as well as adopting an integrated approach to the management of freshwater resources are all essential elements (OECD, 2010).

Monitoring

114. The indicators presented here relate to the trends in agriculture freshwater withdrawals and their shares in total freshwater withdrawals.

Interpretation

115. When interpreting this indicator, it should be kept in mind that it only gives insights into quantitative aspects of water resources. Moreover, the indicator is at the national level and may conceal significant territorial differences and should be complemented with information at sub-national level. The indicator should be read in connection with indicators on cost recovery ratios, water productivity and water quality.

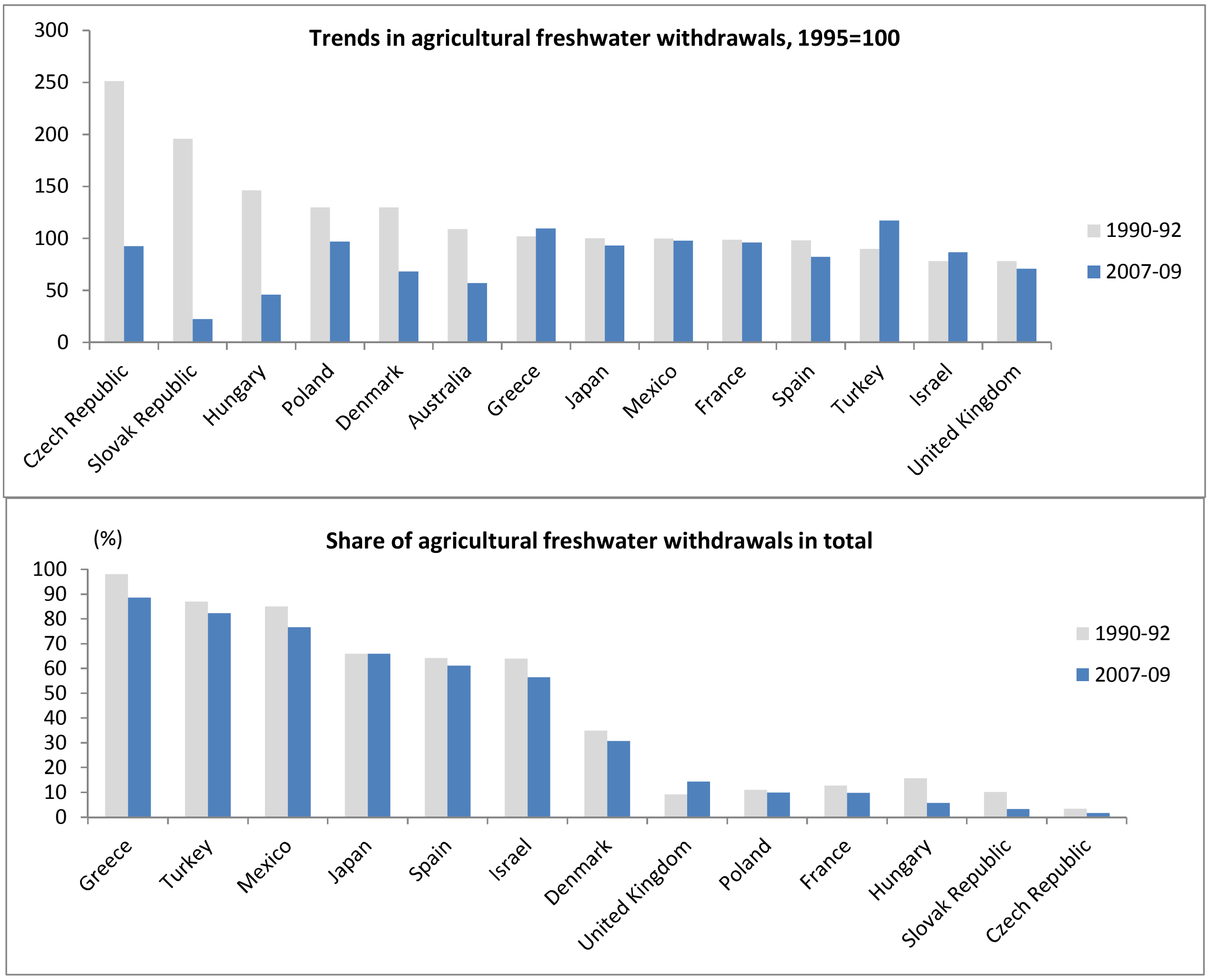
Measurability

116. As pointed out earlier, indicators related to agriculture water resources are very limited. Information on freshwater resources can be derived from water resource accounts. This is available for several OECD countries, although the definitions and estimation methods employed may vary considerably from country to country and over time. More work is needed to improve the completeness and historical consistency of data on water abstractions, and the methods for estimating renewable water resources.

Trends

117. Overall, in most countries withdrawals of freshwater resources by agriculture have declined in most OECD countries for which data are available (**Figure 4.1**). Moreover, agriculture's withdrawal of freshwater, expressed as a share in total withdrawals, has decreased in recent years as compared with the early-1990s, but it remains a major user of water, accounting for over 40% of total withdrawals in nearly half of the OECD member countries.

Figure 4.1. Agricultural water withdrawals in selected OECD countries



Source: OECD, *Agri-Environmental Indicators* database.

118. The declining OECD trend in agricultural water withdrawals over the past decade – notably in Greece and Israel – was driven by a mix of factors, varying between countries, including: a near stable or reduction in the area irrigated (**Annex Figure A.12**); improvements in irrigation water management and technological efficiency; drought; release of water to meet environmental needs; and a slowdown in the growth of agricultural production (OECD, 2013).

Biodiversity and ecosystems

Policy context

119. Loss of biodiversity has been identified as one of today's most pressing global environmental issues and its conservation is a key concern, both nationally and globally. Agriculture is crucial for preserving biodiversity as it is a major user of land and water resources on which certain genetic resources and wild species are highly dependent.

120. The way in which agricultural land is used and managed influences land cover and soil quality in terms of nutrient content and carbon storage; it affects water and air quality; determines erosion risks, plays a role in flood protection, and affects GHGs. The main challenge is to ensure a sustainable management of land and soil resources so as to reconcile competing demands and conflicting interests and to preserve the land's essential ecosystem functions.

121. OECD countries employ a variety of policies and approaches designed to reconcile the need to enhance farm production and yet reduce harmful biodiversity impacts, especially those on wild species (e.g. birds) and ecosystems (e.g. wetlands). In addition, most OECD countries are signatories to international agreements of significance for agro-biodiversity conservation, such as the *Convention on Biological Diversity;* the *Convention on the Conservation of Migratory Species of Wild Animals*; and the *Ramsar Convention* for the protection of wetlands.

Monitoring

122. Despite the general recognition that, beyond its critical role regarding the environment, biodiversity is also relevant to growth and despite the important role that agriculture plays in preserving biodiversity, development of a suitable indicator is beset with serious methodological and data difficulties. In the absence of such an indicator, the following proxy indicators **-** which relate to land use and cover, soil resources and wildlife resources **-** are proposed in order to assess progress towards green growth:

- *Land resources*: changes in agricultural land use and land cover types – arable crops, permanent crops and pasture areas.
- *Soil resources*: agricultural land affected by water erosion classified as having moderate to severe water erosion risk.
- *Wildlife resources*: farmland bird index.

123. Indicators on changes in agricultural land use and cover should be read in conjunction with changes on other types of land in the economy (e.g. forest, built-up areas, etc.), in order to obtain a more comprehensive picture of competing uses of land and potential pressures on ecosystems and biodiversity.

Interpretation

124. Changes in land use and cover are established environmental indicators that are generally well understood. The proxy indicators on how agricultural land is used and how this changes over time is proposed as a good proxy of the pressures on land-competing uses, as well as pressures on biodiversity.

Although it is a proxy and does not *directly* measure biodiversity, it is considered as the best measure currently available to broadly monitor pressures on ecosystems and biodiversity.

125. On wildlife resources, birds can act as 'indicator species', providing a barometer of the health of the environment. Being close to (or at the top) of the food chain, they reflect changes in ecosystems rather rapidly compared to other species. The proposed farmland bird index indicator measures populations of a selected group of breeding bird species that are dependent on agricultural land for nesting or breeding. In general, a decrease in the index means that the balance of bird species trends is negative, representing biodiversity loss. Likewise, an increase in the index implies that the balance of bird species trends is positive, implying that biodiversity loss has halted. However, caution should be exercised in interpreting this indicator as an increasing farmland bird index may not always equate to an improving situation in the environment. In all cases, detailed analysis must be conducted to interpret accurately the indicator trends, while the composite index trend of farmland birds can hide important changes for individual species.

126. It should be kept in mind that these indicators only provide a partial picture of the impacts of agriculture on biodiversity. Furthermore, when making comparisons across countries, several factors should be taken into account including the levels of economic development, the structure of agricultural production, countries' agricultural trade patterns and geographical factors.

Measurability

127. Data on agricultural land use and cover exist for all OECD countries, although with varying degrees of quality. But for non-agricultural land, internationally harmonised statistics on conversions from one type of land use to another are not yet available.

128. Data on threatened species are available for all OECD countries with varying degrees of completeness. The number of species known or assessed does not always accurately reflect the number of species in existence, and the definitions – which should follow IUCN standards – are applied with varying degrees of rigour in individual countries. Historical data are generally not comparable or are not available. Bird population indices are available for Europe and North America (Canada and the United States).

129. The indicator on agricultural land area classified as having moderate to severe water erosion, which is based on models, is subject to several limitations, making cross-country comparisons problematic. Moreover, comparable data are available for only eight OECD countries and in a number of countries where soil erosion or degradation is a widespread concern there is little or no regular updating of national soil erosion monitoring (e.g. Australia, New Zealand, Portugal, Spain and Turkey) (OECD, 2013). For these reasons, results for this proposed indicator are not reported at this stage.

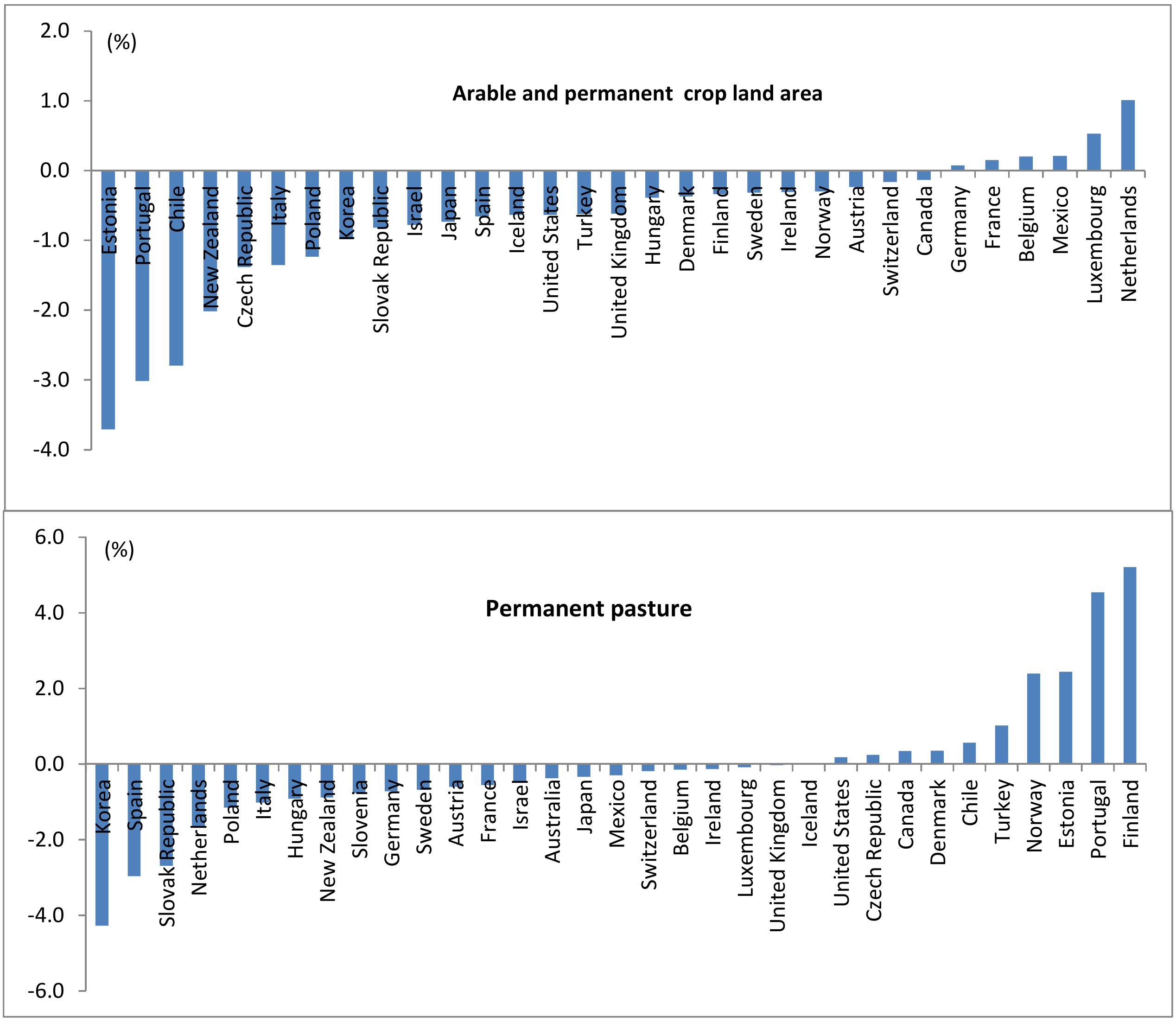
Trends

130. In nearly all OECD countries the agricultural land area has decreased over the 1990-2010 period in terms of both arable and crop land, and permanent pasture area (which accounts for two-thirds of all OECD agricultural land) has declined in most countries (**Figure 4.2**). Agricultural land has mainly been converted to use for forestry and urban development (OECD, 2014; 2013). Despite this overall trend, agriculture remains the major land use for many countries, representing over 40% of the land area in two-thirds of OECD countries.

131. Concerning permanent pasture, which represents a major share of agricultural semi-natural habitats, has declined most OECD countries; it has mainly been converted to forestry, although in some countries pasture has also been converted for cultivation of arable and permanent crops (e.g. Finland and the Netherlands).

132. The overall OECD trend masks some important differences between countries with a significant increase in permanent pasture area in countries which already had a high share of pasture in total agricultural land (e.g. Chile), and a sharp reduction in other countries where the permanent pasture share is also significant (e.g. Austria, the Netherlands and New Zealand).

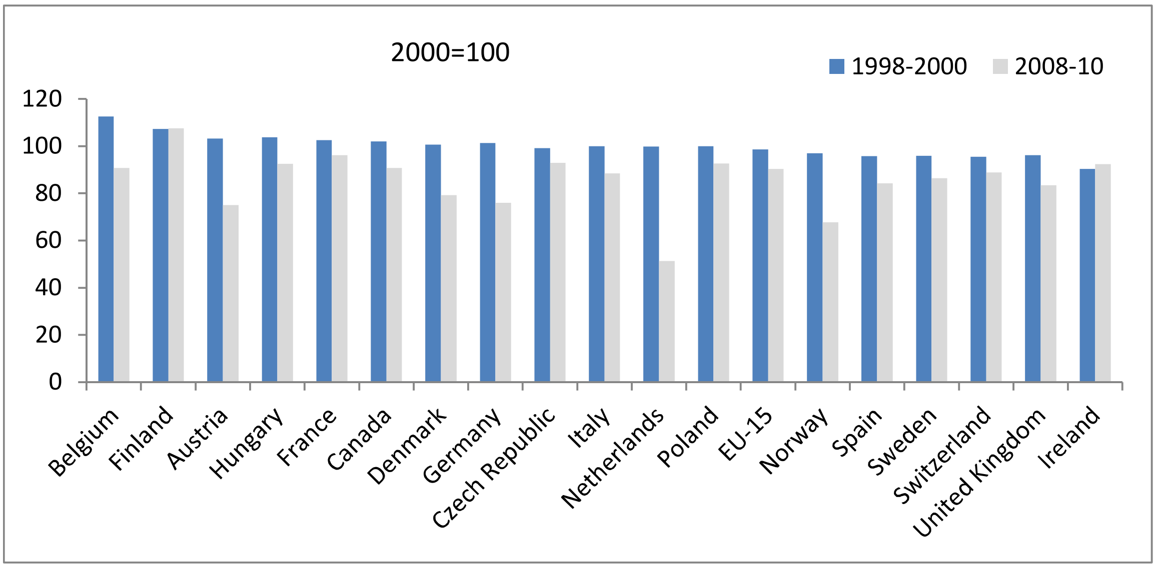
Figure 4.2. Trends in agricultural land cover, 1990-2010 or most recent year



Source: FAO, *FAOSTAT* database.

133. Trends in OECD farmland bird populations declined continuously over the period from 1990 to 2010 for almost all countries (**Figure 4.3**). But interpreting the consequences of changes in permanent pasture land areas for farmland birds and other wildlife species is complex. Without knowledge of the quality of the land change and its subsequent management, it is difficult to assess these developments. Given the magnitude of the decline in permanent pasture across most OECD countries over the past decade, however, it is likely that this has been one of the factors influencing the overall decline in farmland bird populations.

Figure 4.3. Farmland bird index, OECD countries



Source: OECD, *Agri-environmental Indicators* database.

134. More generally, the assessment of land use changes both between agriculture and other uses of land (e.g. forestry, urban use) and within agriculture (e.g. between pasture and arable crops), is incomplete in this report. This is because of the paucity of datasets to provide a complete analysis of these changes, including data on how different land types are managed and thereby influence the wild flora and fauna that use farmland as a habitat.

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Chapter 5

Policy responses and economic opportunities

The category of indicators included in this Chapter aims to discern both the effectiveness of policy in delivering green growth and the economic opportunities which arise from such growth. These indicators should also help to identify potential synergies and trade-offs among different policy objectives, and among green growth goals.

It combines two types of indicators: i) policies of importance to green growth; and ii) economic opportunities arising from green growth. The main issues of importance to green growth dealt with in this Chapter are: transfers, taxes and prices; investment in human capital; and technology and innovation. Ideally, indicators regarding economic instruments should be complemented by indicators on regulation. However, data availability and comparability of regulatory measures across countries hamper the construction of such indicators.

135. This broad category of indicators aims to discern both the effectiveness of policy in delivering green growth and the economic opportunities which arise from such growth. These indicators should also help to identify potential synergies and trade-offs among different policy objectives, and among green growth goals. It combines two types of indicators: i) policies of importance to green growth; and ii) economic opportunities arising from green growth. In the OECD Framework on monitoring progress towards green growth, these issues are treated together, as they can be relevant for all elements of the proposed green growth framework: the natural asset base, productivity and environmental quality of life.

136. Identifying indicators in this group is perhaps the most problematic task. A wide range of opportunities and policy responses is possible, including those related to: government transfers, prices and taxes, regulations, technology and innovation, management approaches, and training and skills development. These thematic areas will be of varying relevance across countries.

137. On policy responses, indicators should capture the policy measures contained in the Green Growth Policy Toolkit for food and agriculture, on the basis of which an assessment may be made of the extent to which countries are implanting these policies (OECD, 2013a). The OECD PSE/CSE database contains rich data and indicators on various agricultural support policies, which are of direct relevance to green growth. This database can be used, for example, to construct indicators of the extent to which agricultural support policies are becoming less harmful/more beneficial to the environment. It can also be used to calculate indicators on market distortions associated with agricultural policies, as well the share of public investments in R&D.

138. Indicators on government transfers to producers should be complemented with indicators reflecting regulatory measures put in place by governments to reduce the negative effects of agriculture on the environment. The construction of such indicators is, however, constrained by important conceptual issues and data gaps (i.e. information is often of a qualitative nature).

139. Identifying indicators on the aspect of economic opportunities arising from green growth is perhaps the most challenging, not only from the point of view of data availability, but also on conceptual grounds. The main opportunities which could arise relate to: i) technology development and innovation, which, as was noted earlier, are key determinants of agricultural growth and productivity, and are crucial for moving towards a resource-efficient, low-carbon agricultural sector; and ii) green entrepreneurship, training and the development of skills - all of these are important factors in aiding the adoption of farming system innovations to minimise the environmentally detrimental effects of agricultural production (among the foremost of these are integrated pest management, integrated plant nutrient systems and no-till/conservation agriculture).

140. But constructing indicators to monitor technology and innovation relevant to green growth in agriculture is not a straightforward issue, due to the difficulty in providing an unequivocal definition for “green” innovation or technology, both at the sectoral and economy-wide level. There is no systematic measure of the impact of innovation on the economy or of the impact of policies on innovation. As innovations become more diverse and complex, it becomes increasingly difficult to measure the various facets of innovation.

141. In addition, conventional indicators capture only part of the innovation process. For example, input indicators measure investment in innovation, such as R&D expenditures and the number of staff. Output measures include the number of publications and quotations in academic journals, or the number of patents registered. However, patents are an indicator of invention rather than innovation, since not all patents are commercialised and it is not possible to patent some types of innovation in the agricultural sector. The limits of bibliographic indicators are obvious.

142. Moreover, data on the level of technology and innovation in agriculture, as measured by conventional indicators (such as expenditure on green technologies) and the number of patents are not available for most countries. In general, aspects related to green innovation and investments in agriculture are inadequately captured by the currently available indicators and merit further development.

143. In the same vein, indicators for the creation of "green jobs" are subject to conceptual difficulties and are not part of the OECD green growth headline indicators. For example, an indicator on employment creation generated by green technologies (e.g. renewable energy technologies) should take into account all employment effects (direct and indirect) − work is currently underway in the Secretariat to advance measurement of this aspect of green growth.[11] Overall, monitoring of this area is considered to be the weakest in terms of data availability and relevant quantifiable indicators.

144. With the aforementioned considerations in mind, indicators are proposed for the following main issues of importance to green growth:

- *Transfers, taxes and prices* - that provide important signals to producers and consumers are tools to internalise externalities and to influence the behaviour of market participants towards more environmentally-friendly patterns.

- *Investment in human capital* – which facilitates the uptake and dissemination of technology and knowledge and contributes to meeting economic growth and environmental objectives.

- *Technology and innovation* – important drivers of growth and productivity in general, and of green growth in particular.

145. Table 5.1 shows the specific indicators proposed for each of the above categories:

11. This aspect of indicators will benefit from the on-going work to refine the OECD Green Growth indicators.

Table 5.1. Proposed indicators for monitoring green growth policies and opportunities

Theme	Indicators	Criteria: Capturing the nexus between the environment and the economy	Criteria: Ease of communication to different users and audiences	Criteria: Reflecting key global environmental issues	Criteria: Measurable and comparable across countries
Policy responses	Government transfers to producers				
	Trends of potentially the most environmentally harmful producer support	***	***	***	***
	Environmentally related taxes in agriculture				
	Share of agriculture in energy taxes	***	***	***	**
	Share of agriculture in transport taxes	***	***	***	**
	Share of agriculture in pollution taxes	***	***	***	**
	Effective tax rates on energy for agriculture	***	***	***	**
	Water pricing and recovery	***	***	***	**
	Supplementary indicators				
	Trends of total support to farmers	**	***	**	***
	Trends of the potentially most environmentally beneficial producer support	***	***	**	***
Economic opportunities	Empowering people to innovate				
	Farmers with agricultural training	***	***	n.a.	**
	Trends of payments on agricultural training and education	***	***	n.a.	***
	Supplementary indicators				
	Age structure of farmers (share of young and elderly farmers in total)	**	***	n.a.	***
	Enrolment rates of farmers in tertiary education	**	***	n.a.	**
	Conservation technical assistance	**	***	**	**
	Investing in green innovation				
	Trends of agricultural R&D payments in total support to agriculture	**	***	n.a.	*
	Share of agricultural green innovation (patents) in total green innovation (patents of importance to GG)	***	***	***	**
	Supplementary indicators				
	Share of payments on agricultural R&D in total support to agriculture	***	***	*	***
	Share of R&D (private and public) on agriculture in total R&D expenditures	***	***	*	**

*** = high; ** = medium; * = low; n.a. = not applicable.

Monitoring policy responses

Policy context

146. One of the central challenges in achieving green growth is to ensure that all the costs associated with economic activity are reflected in production and consumption decisions (i.e. that they are internalised either through prices or via some other mechanism). Governments have at their disposal a wide range of potential policies that influence the productive efficiency and environmental performance of agriculture.

147. Government policies, for example, have for a considerable time provided transfers (or support) either directly or indirectly to the agricultural sector in OECD economies. This is in addition to a wide

array of regulations – especially when taking into account the whole food chain – some of which are economy-wide, some being more specific to the sector. On the other hand, the role of market-based instruments, such as taxes and charges and tradable permit systems in promoting green growth in agriculture is not, however, as prominent as in other sectors (e.g. transport).

148. The policy challenge is to find cost-effective ways to account for environmental externalities that are not factored into producer and consumer decisions. This implies addressing at least three policy sets: removing those transfers that distort production decisions and trade flows, and harm the environment (or cause extra pressure on natural resources); enforcing the polluter-pays-principle; and finding ways to incentivise producers to generate economic and environmental services (benefits). The types of transfer measures which are likely to create the greatest barriers to improving economic efficiency (and thus potential for growth) and increasing environmental performance should be prime targets for policy reform to enhance green growth.

Monitoring progress

149. The following indicators are proposed:

- Trends of the potentially most environmentally harmful support to farmers
- Trends of the level and relative importance of environmentally-related taxes on agriculture (%)
- Water pricing and cost recovery

150. The shares of the potentially most environmentally harmful support in total support, the composition of environmentally-related taxes in agriculture (energy, transport, pollution and resources) and effective tax rates on energy use are proposed as supplementary indicators. In addition, the indicator on the potentially most environmentally harmful support should be read in connection with indicators of the level of total producer support, while the indicator on agriculture's contribution to environmentally-related tax revenues can be read in conjunction with indicators on GHG emissions.

151. The potentially most harmful support to farmers comprises (OECD, 2013a):

- market price support;
- payments based on commodity output, without imposing environmental constraints on farming practices; and
- payments based on variable input use, without imposing environmental constraints on farming practices

Measurability

152. As noted above, data for the indicators on government transfers to producers are published annually by OECD (PSE/CSE database) for OECD countries and also for certain non-OECD members. For the European Union, the data refer to the EU as a whole and no data are available for individual EU member countries.

153. The *System of Environmental-Economic Accounting: Central Framework* provides a definition of environmentally-related taxes (UN, 2014). In the SEEA, the tax base is used to define whether a tax is

environmental. Specifically, an environmental tax is a tax whose tax base is a physical unit (or a proxy of it) of something that has a proven, specific, negative impact on the environment.[12]

154. The SEEA Framework groups environmental taxes into four categories:

- *Energy taxes*: taxes on energy products used for both transport and stationary purposes (i.e. fuel oils, natural gas, coal and electricity).
- *Transport taxes*: taxes related to the ownership and use of motor vehicles.
- *Pollution taxes:* taxes on measured or estimated emissions to air and water, and the generation of solid waste. An exception is taxes on carbon, which are included under energy taxes, as discussed above. Taxes on sulphur are included in this category.
- *Resource taxes*: typically includes taxes on water abstraction, extraction of raw materials and other resources (e.g. sand and gravel).

155. Effective tax rates on energy are taken from a recent OECD study (OECD, 2013c). This study provides the first time a systematic comparative analysis of the structure and level of taxes on energy use in all OECD countries. It also presents effective tax rates on energy use in terms of both energy content and carbon emissions for the full range of energy sources and uses in each country. Fuel quantities are expressed in terms of energy value (in gigajoules – GJ), reflecting that what all the products have in common is that they are sources of energy. The quantities of the various energy sources are expressed in terms of the carbon emissions associated with their use (in tonnes of CO_2).

156. Concerning water pricing, there is an important data gap which prevents comparison of trends across countries and over time. Comprehensive data on water pricing and cost recovery are not available. Overall, this aspect of monitoring green growth is considered to be the weakest in terms of data availability and relevant quantifiable indicators.

Interpretation

157. Since the mid-1980s, as part of its work on monitoring and evaluating agricultural policy developments, the OECD Secretariat has measured, on an annual basis, the level and composition of support (monetary transfers) associated with agricultural policies in OECD countries (and, to an increasing extent, also for non-OECD countries), using a standard methodology. The classification of support into different categories is based on how policies are actually implemented and not on the objectives or impacts of those policies.

158. It should be emphasised that neither the total PSE nor its composition in terms of different categories of policies can be interpreted as indicating the actual impact of a policy on production and markets (OECD, 2013a). Clearly, the actual impacts (*ex post*) will depend on the many factors that determine the aggregate degree of responsiveness of farmers to policy changes – including any constraints

12. The approach taken to the definition of environmental taxes in the SEEA differs from the approach commonly found in the economics literature where environmental taxes are defined with reference to taxing negative externalities (i.e. Pigouvian taxes). These types of taxes are based on an assessment of the motive for setting rates of tax (i.e. the extent to which a particular tax rate will reduce the negative externality). Pigouvian taxes do not include taxes collected for fiscally motivated reasons. Since determining the precise motivation for taxation presents a difficult measurement issue, the focus in the SEEA is to consider the underlying tax base.

on production. For example, while it is true that market price support mechanisms and payments based on output are potentially the most harmful for the environment, whether they actually are harmful depends on a host of other factors, including whether production quotas are attached to them and whether they incorporate strong cross-compliance requirements, or are constrained by agri-environmental regulations independent of the support payments. Similarly, payments based on area, animal numbers, farm receipts or income, and historical entitlements are only potentially neutral in their effects on the environment, but may be harmful − or even beneficial − depending on specific programme designs and other regulations (OECD, 2013a).

159. Information on environmentally-related taxes is available from the OECD-EEA database on instruments used for environmental policy and natural resources management (www2.oecd.org/ecoinst/queries/). Information on energy taxes is available from the IEA. EUROSTAT also publishes environmentally-related taxes by economic activity, following the SEEA Framework for European countries at NAC Rev 2 level (data include forestry). Data on effective taxes only account for taxes imposed at the federal level.

Trends

Government transfers to producers

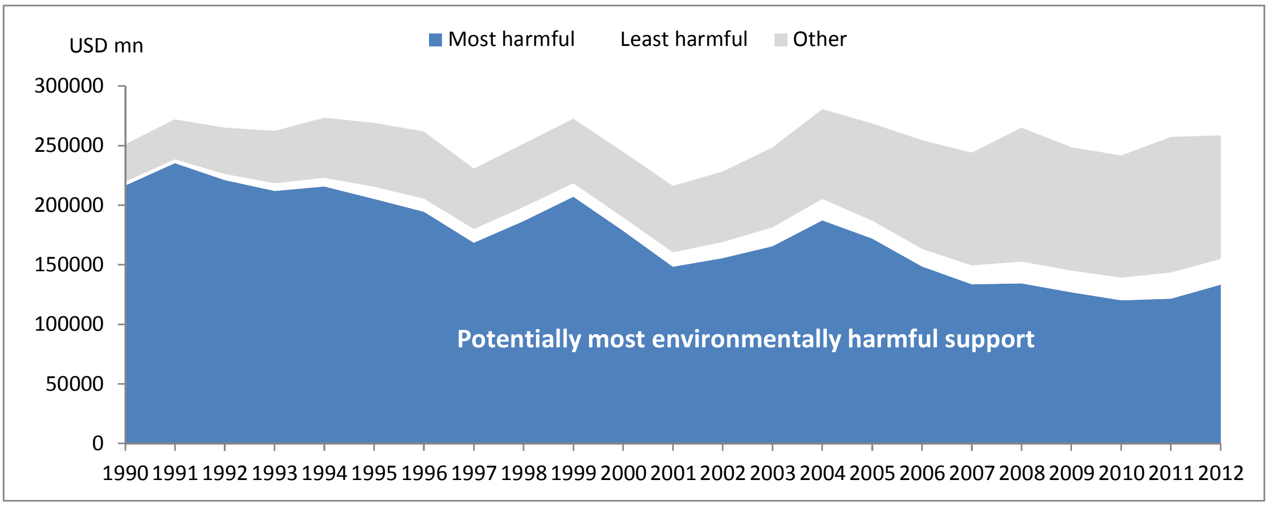
160. OECD countries have made a concerted effort to reduce the most environmentally harmful types of agricultural supports and have achieved a decrease from over 85% of the total in 1990-92 to 49% in 2010-12 (**Figure 5.1**). The largest decrease of the share of the potentially environmentally most harmful support was observed in Australia and in the European Union (**Figure 5.2**). This share increased only in New Zealand, which is explained by the fact that the country has consistently the lowest level of support (i.e. the percentage Producer Support Estimate is 1%) and the country’s agriculture is driven by market signals.[13]

161. While some countries have taken clear steps to decouple support from output and price levels, other countries have not yet begun to address the problem. The potentially most environmentally beneficial support increased its share in total support to producers, but, on average, accounts for only 8% over the OECD area.[14]

13. In New Zealand most domestic prices are aligned with the world prices and payments are only provided for animal disease control and relief in the event of large scale natural disasters.

14. For a detailed definition of the potentially most environmentally beneficial support see OECD, 2013a, Table 3.1.

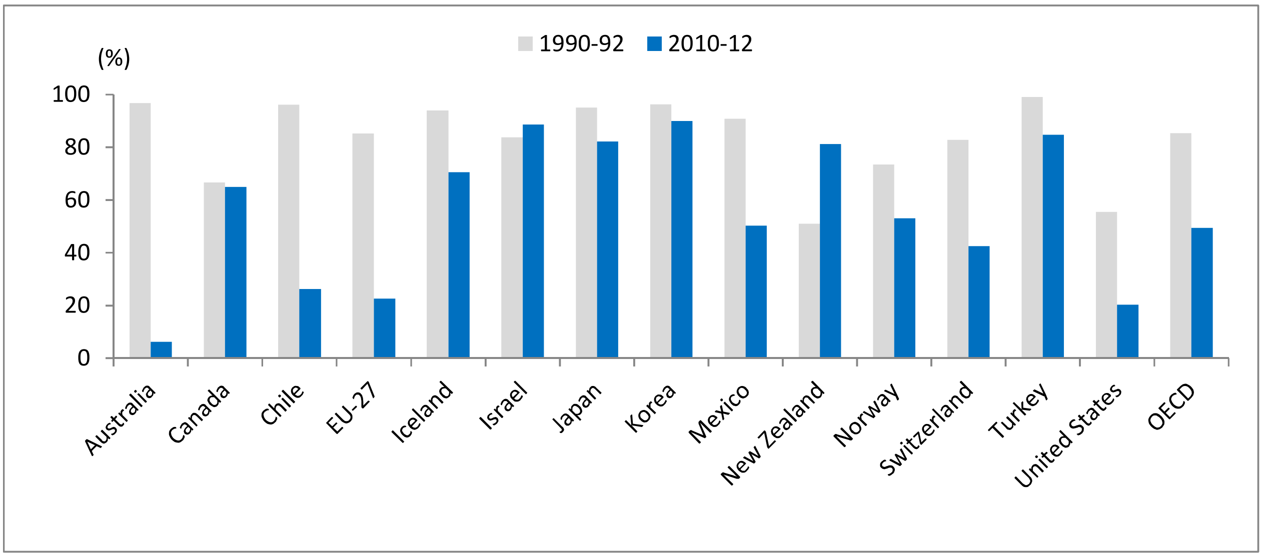
Figure 5.1. Evolution of producer support by potential environmental impact in the OECD area, 1990-2012



Source: OECD, *PSE/CSE* database, 2013.

Figure 5.2. Potentially most environmentally harmful producer support in OECD countries

Share in total producer support (%)



Note: 1995-97 for Israel.

Source: OECD, *PSE/CSE* database, 2013.

Environmental taxes

162. Environmental taxes (or charges) are policy measures imposing a tax relating to pollution or environmental degradation, including taxes on farm inputs (or outputs) that are a potential source of environmental damage. Environmentally-related taxes, by influencing the behaviour of producers and consumers, constitute an important instrument for governments to internalise the environmental externalities of economic activity ("pricing externalities") and raise revenues. Specific taxes on energy, for

example, alter the relative prices of different forms of energy and thus alter patterns of energy use, with important economic and environmental consequences. They also affect net income and have important distributional implications.

163. Only a few countries have levied taxes and charges on farm inputs as a way of addressing environmental issues in agriculture. These have mostly been applied to environmentally-damaging chemicals, such as those associated with commercial fertiliser and pesticide use. This may at least partly reflect the practical problems of measurement – unlike other sectors where pollution can normally be monitored at "point", the pollution from agriculture is much more widely dispersed, as it tends to originate from many different farms and in varying intensities.

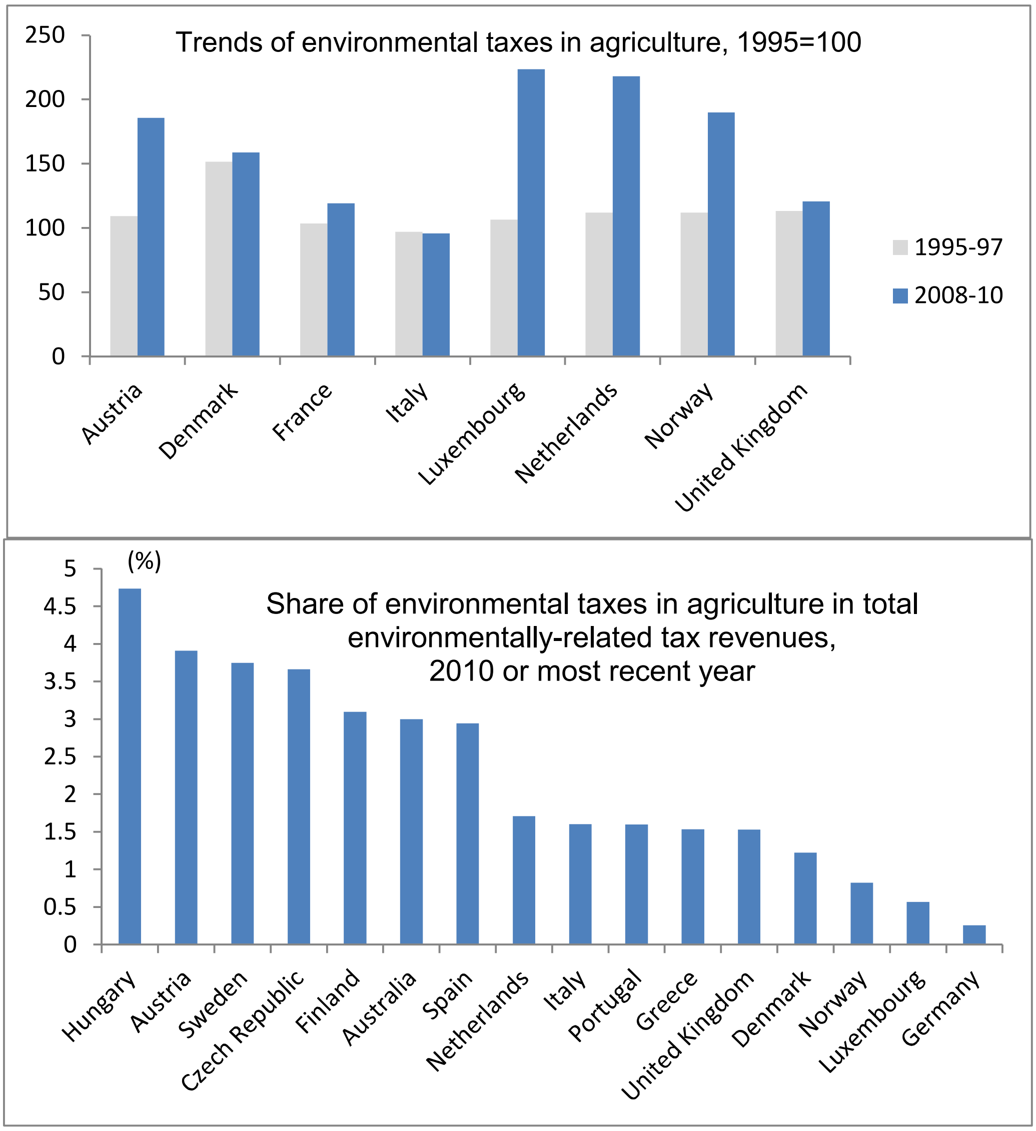
164. Although environmentally-related taxes in agriculture (including forestry) have increased in all countries for which data are available, their contribution to total environmentally-related tax revenues was lower than 5% in all countries reported (**Figure 5.3**). Looking at the contribution of the individual components, total energy and transport tax revenues were lower than 6% in all countries reported; while for pollution they were between 7 and 10% in two countries, and less than 1% in the remaining seven countries (**Annex Figure A.15**). Noteworthy, that while the agricultural sector in the OECD area, on average, pays around 6% of energy taxes, it accounts for 8% of net GHG emissions in the total economy.

165. Taxes on energy use are by far the single most important source of environmental tax revenue from agriculture. In 2010, energy taxes on agriculture accounted for more than 90% of environmental tax revenue from agriculture (e.g. Austria, Czech Republic, Italy and Spain). **Annex Figure A.16** sets out for each country (for the economy as a whole and for agriculture) the overall average effective tax rate, on a weighted basis on energy use (left panel) and on CO_2 emissions from energy use (right panel). Both at an economy-wide and agricultural sectoral level, there are significant differences in the overall level of energy taxation across the OECD area.

166. Overall, tax rates on energy use for the whole economy are much higher than those imposed on agriculture. One of the reasons for this is that fuel used in agriculture is often exempt from tax. Fuel tax exemptions provide no signal with respect to external costs, thereby encouraging over-use. In energy terms, the simple average rate on agriculture is almost half the rate on the whole economy (EUR 3.28 per GJ for the whole economy and (EUR 1.81 per GJ), while the differences are smaller in terms of weighted average rate (1.77 per GJ for the whole economy and 1.22 per GJ for agriculture). The range of country averages, however, is very wide – from EUR 8.91 per GJ in Ireland to zero in Australia, Chile, Mexico and the United States.

167. Similarly, there is a wide range of effective tax rates on carbon (as set out in the right panel of **Annex Figure A.16**). The simple average rate on agriculture is EUR 26.83 per tonne of CO_2, while the weighted average is EUR 20.85 per tonne of CO_2 **-** these rates are much lower than the corresponding rates for the whole economy. Again, there is a wide range around these averages: from zero in Chile and the United States to EUR 124.79 per tonne in Ireland. Overall, for agriculture the highest rates are observed in Ireland, Denmark, the Netherlands, the Slovak Republic and Norway.

Figure 5.3. Environmental taxes in agriculture



Notes: For United Kingdom data 1995-97 average equal to the 1997-99 average; for Denmark data 2008-10 average refer to 2008 data. Data include forestry; NAC REV2; Data for Denmark and Finland are for 2008.

Source: EUROSTAT; Australian Bureau of Statistics (ABS) (2013), *Towards the Australian Environmental-Economic Accounts*, Information Paper, Canberra.

Water pricing and cost recovery

168. Given the anticipated growth in demand for food and water and increasing pressures from climate change, agriculture will be a key target for policy makers, as it consumes about 70% of the world's total freshwater withdrawals (45% in OECD countries). OECD work shows that the level of charges for water supplied to farms has risen in OECD countries (OECD, 2010).

169. Frequently, however, farmers only pay the operational and maintenance costs for water supplied, and there is little or no recovery of agriculture's share of the capital costs of water infrastructure (**Table 5.2**). Where countries have raised water charges to farmers, available evidence indicates that it has

not led to reduced agricultural output. However, water charges rarely reflect scarcity and social values or environmental costs and benefits.

Table 5.2. Full supply cost recovery for surface water delivered on-farm in OECD countries, 2008

Supply cost recovery	Country
Full cost recovery of operation and maintenance, and capital costs	Austria, Denmark, Finland, New Zealand, Sweden, United Kingdom
Full cost recovery of operation and maintenance, but partial recovery of capital costs	Australia, Canada, France, Japan, United States
Partial cost recovery of operation and maintenance, and recovery of capital costs	Greece, Hungary, Ireland, Italy, Mexico, the Netherlands, Poland, Portugal, Spain, Switzerland, Turkey
Partial cost recovery of operation and maintenance, with capital costs fully supported	Korea

1. Full supply costs recovery for water deliveries to farms include: operation and maintenance costs (e.g. maintaining and repairing the irrigation infrastructure) and capital costs, both renewal capital costs (e.g. replacing irrigation canals) and new capital costs (e.g. constructing dams).

2. No information is available on the following OECD countries: Belgium; the Czech Republic; Germany; Iceland, Luxembourg, Norway, the Slovak Republic.

Monitoring economic opportunities

Policy context

170. The capacity of the agricultural sector to produce adequate supplies of food and feed in an environmentally sound manner is closely linked to the level of technological development and innovation. The strong growth in agricultural productivity experienced since the post-war period has been driven largely by technological advances and the rapid adoption and diffusion of new technologies.

171. Green growth can provide a new paradigm for agricultural research and innovation, placing the emphasis simultaneously on environmental and economic requirements, with the aim of enhancing productivity without compromising the natural resource capital. Technologies that can contribute to an economically efficient farm sector and provide financial viability for farmers, while at the same time improving environmental performance in a way that is acceptable to society, will provide "triple dividends" to green growth. The main challenges are to strengthen research, foster innovation and the use of new technologies in production, and encourage the creation of markets and the uptake of new technologies by consumers.

Monitoring progress

172. Monitoring progress towards green growth in agriculture can be assessed through proxy indicators on empowering people to innovate and on investing in green innovation. As shown in **Table 5.1**, in the sub-category empowering people to innovate, the proxy indicators proposed are: trends in expenditure on agricultural training and education; and the share of farm managers with basic or full education in agriculture attained. In addition, the age structure of farmers (share of young and elderly farmers in total); the enrolment rates of farmers in tertiary education; and trends in conservation technical assistance are proposed as supplementary indicators.

173. For the investing in green innovation sub-category, progress towards green growth can be assessed through proxy indicators of innovation. R&D expenditure (public and private) and patent applications of importance to green growth are the two most common indicators used (OECD, 2014).

174. Unfortunately, for agriculture, data on environmentally-related R&D expenditure across countries are not available, while data on patents of importance to green growth are limited. Consequently, the following proxy indicators are proposed:

- Share of farmers with agricultural training;
- Trends of payments on agricultural training and education;
- Trends in government R&D expenditure on agriculture; and
- Trends in patents in environmentally-related technologies. This entails patent applications in agriculture under Patent Co-operation Treaty (PCT) of waste management, renewable energy generation and of water management.
- Supplementary proxy indicators might include:
  - Government budget appropriations or outlays for R&D (GBAORD) on agriculture (share in total)
  - Business sector expenditure for R&D on agriculture (share in total)
  - Share of government R&D expenditure on agriculture in total support to agriculture.[15]

Interpretation

175. While interpretation of the proposed indicator on empowering people to innovate is rather straightforward, analysis of the trends of the indicators on investing in green innovation should be exercised with great caution. First, R&D expenditure is an input measure that indicates an economy's relative degree of investment in generating new knowledge and it does not reflect a green growth outcome. Second, cross-country comparisons should consider differences among countries in industrial structure and research capabilities; high R&D spending alone does not warrant a superior innovation performance (OECD, 1995).

176. Third, patent applications reflect inventive performance, but not all technologies or processes are the subject of patent applications, and not all enterprises wish to disclose their technological advances through patent applications. Also, patents may or may not lead to innovation. The development and adoption of new technologies with positive green growth implications may come from across all sectors of the economy. The patent indicators here thus do not measure the full extent of innovative activities and do not distinguish between high-quality and low-quality patents.

177. Finally, it should be noted that investigation of the influence of agricultural policies (and their reform) on productivity growth, and the generation and diffusion of technology in the agricultural sector, should be performed with caution since the relationship is complex and the existence of a correlation between productivity rates and policies does not imply causality (OECD, 1995).

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15. R&D expenditure can also be expressed as a percentage of agricultural GDP (research intensity ratios) to capture agricultural research efforts (see OECD, 1995).

Measurability

178. Data on agricultural training and education are published by EUROSTAT (Farm Structure Surveys) and by Agricultural Censuses of countries. The proposed indicator - share of farm managers with basic or full education in agriculture attained - provides information on the education level of farm managers within a region. This indicator covers managers of non-group holdings who have attained basic or full agricultural training.

179. The farm manager's agricultural training is defined by EUROSTAT as follows:

- *Only practical agricultural experience*: experience acquired through practical work on an agricultural holding.

- *Basic agricultural training*: any training courses completed at a general agricultural college and/or an *institution* specialising in certain subjects (including horticulture, viticulture, sylviculture, pisciculture, veterinary science, agricultural technology and associated subjects). A completed agricultural apprenticeship is regarded as basic training.

- *Full agricultural training*: any training course continuing for the equivalent of at least two years' full-time training after the end of compulsory education and completed at an agricultural college, university or other institute of higher education in agriculture, horticulture, viticulture, sylviculture, pisciculture, veterinary science, agricultural technology or an associated subject.

180. Data on government payments financing agricultural training and education are published by the OECD database on measuring agricultural support (PSE/CSE database). These data, which are part of the General Service Support Estimate expenditures, can underestimate government efforts to support education and training to farmers as they only include transfers to producers *collectively* (i.e. services that benefit agriculture but whose incidence is not at the level of individual farmers). On-farm advisory services and technical assistance are not included.[16]

181. The OECD PSE/CSE database on support to agriculture also publishes annual data on government R&D and extension expenditures on agriculture for OECD countries. The OECD database on *Science, Technology and Patent* contains data on R&D and patent applications. R&D expenditures include gross domestic expenditure on R&D by sector of performance (e.g. higher education, government, business and private non-profit), by field of science and socio-economic objective (e.g. environment, energy, etc.), as well government budget appropriations and outlays for R&D (GBAORD). Data on GBAORD are available for most OECD countries, but significant gaps exist concerning harmonised data on private-sector R&D expenditures, as well as harmonised micro-data.

182. Government budget appropriations or outlays for R&D (GBAORD) measure the funds committed by the federal/central government for R&D. This can be broken down by various socioeconomic objectives, including control and care for the environment. For more information, see the OECD Project on Environmental Policy and Corporate Behaviour (*www.oecd.org/env/cpe/firms*).

183. Determining whether an innovation is environmental or not is a question of degree and not of kind. The OECD publishes data on patent applications under the Patent Co-operation Treaty (PCT) which are of importance to green growth. More specifically, a search algorithm developed by the OECD Secretariat and the European Patent Office (EPO) was used to generate data on environmental technology

16. These data are included in the payments in the Producer Support Estimate (PSE).

patent applications. The data cover technologies for pollution abatement (air pollution control, water pollution control and wastewater treatment) and for waste management, recycling and prevention. For further details on classifications, see *www.oecd.org/environment/innovation/indicator.*

184. The link between patents and the scientific literature is based on an analysis of the "non-patent literature" (NPL) listed in patent documents. NPL includes peer-reviewed scientific papers, conference proceedings, databases and other literature.[17] The selection is based on the international patent classification code. For more information on patents data and methodology see OECD (2009) *Patent Statistics Manual*, www.oecd.org/science/inno/oecdpatentstatisticsmanual.htm

185. From these aggregate categories, the following items were identified for agriculture: fertilisers from waste; and energy generation from fuels of non-fossil origin (biofuels and fuel from waste, for example, methane) under the renewable energy generation. For technologies with climate change mitigation potential, the data are too aggregated and technologies relevant to agriculture cannot be identified.

186. Concerning data on green innovations related to water, new OECD work provides the first descriptive analysis of innovation in water-related adaptation technologies and of their international diffusion at the global level (Dechezleprêtre, Haščič and Johnstone, 2013). The analysis is based on a unique data set comprised of over 50 000 patents filed in 83 patent offices, between 1990 and 2010, and covers a wide range of technologies that may either increase the supply of water in drought conditions (e.g. rainwater collection, groundwater collection, water storage, desalination, etc., or decrease water consumption (e.g. water control in agriculture, drought-resistant crops, drip irrigation, water efficiency technologies in power production, domestic water recycling, efficient water distribution systems, etc.).

187. These three water-related technologies are defined as follows: *drought-resistant crops*: mutation or genetic engineering; DNA or RNA concerning genetic engineering, vectors (e.g. plasmids, or their isolation, preparation or purification for drought, cold, or salt resistance); *drip irrigation*: watering arrangements located above the soil which make use of perforated pipe-lines or pipe-lines with dispensing fittings; and *controlled watering*: watering arrangements making use of perforated pipe-lines located beneath soil level.

Trends

Training and education

188. Better educated and trained farm managers are more likely to make successful changes to farm-management practices and become more innovative (Labarth and Laurent, 2009). The results presented here only include European OECD member countries (i.e. the OECD member countries which are also members of the EU member countries, Iceland, Norway and Switzerland). As shown in **Table 5.3**, learning by doing is the main form of training for the majority of the farmers as the majority of the farm managers have acquired agricultural experience through practical work.

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17. The listed NPL gives journal title, author name(s), volume and page number, article title, but does not usually give the information needed for biblio-metric analysis (e.g. name and address of the author's organisation, names of authors other than the first listed). To fill in information gaps, NPL was matched with Scopus, the scientific literature database. This makes it possible to know if the NPL is a scientific article and to obtain bibliographical information not recorded in NPL. The matches were based on combinations of volume, page, year, journal name, author name, and article title. As a result, 1 612 green patents were retained out of the 48 249, and 2 803 NPL were scientific papers recorded in Scopus.

Table 5.3. Training and education in agriculture in selected OECD countries, 2005 and 2010 (%)

	Farm managers with agricultural training				Farm managers with practical experience only	
	Basic training		Full training			
	2005	2010	2005	2010	2005	2010
Austria	19.7	22.4	28.4	25.6	51.9	52.0
Belgium	23.8	21.4	23.9	26.4	52.3	52.2
Czech Republic	19.6	19.6	25.2	37.1	55.3	43.4
Denmark	39.4	43.6	5.0	5.0	55.5	51.5
Estonia	10.5	14.0	22.4	22.5	67.1	63.5
Finland	32.7	34.8	7.9	9.2	59.4	56.0
France	11.0	28.7	43.4	21.6	45.7	49.7
Germany	22.9	55.2	45.6	13.3	31.5	31.4
Greece	5.1	3.2	0.3	0.3	94.6	96.5
Hungary	4.9	11.3	8.5	3.3	86.6	85.4
Ireland	16.9	15.1	13.8	15.9	69.3	69.0
Italy	8.2	90.8	3.1	4.2	88.8	5.0
Luxembourg	13.9	14.5	42.0	45.9	44.1	39.5
Netherlands	66.6	64.6	4.9	6.6	28.5	28.8
Poland	22.2	21.3	16.3	24.6	61.5	54.1
Portugal	10.5	10.4	1.3	1.6	88.2	88.0
Slovenia	21.2	26.7	6.8	8.9	72.0	64.4
Slovak Republic	11.2	15.0	3.4	8.8	85.4	76.2
Spain	9.2	13.8	1.3	1.5	89.5	84.7
Sweden	15.6	12.1	17.9	18.8	66.4	69.1
United Kingdom	11.0	10.4	12.2	12.3	76.8	77.2
EU	*14.0*	*34.5*	*12.2*	*10.4*	*73.8*	*55.0*
Iceland	.	32.4	.	28.2	.	39.8
Norway	9.0	26.7	39.2	14.9	51.8	58.4
Switzerland	.	51.8	.	26.0	.	22.3

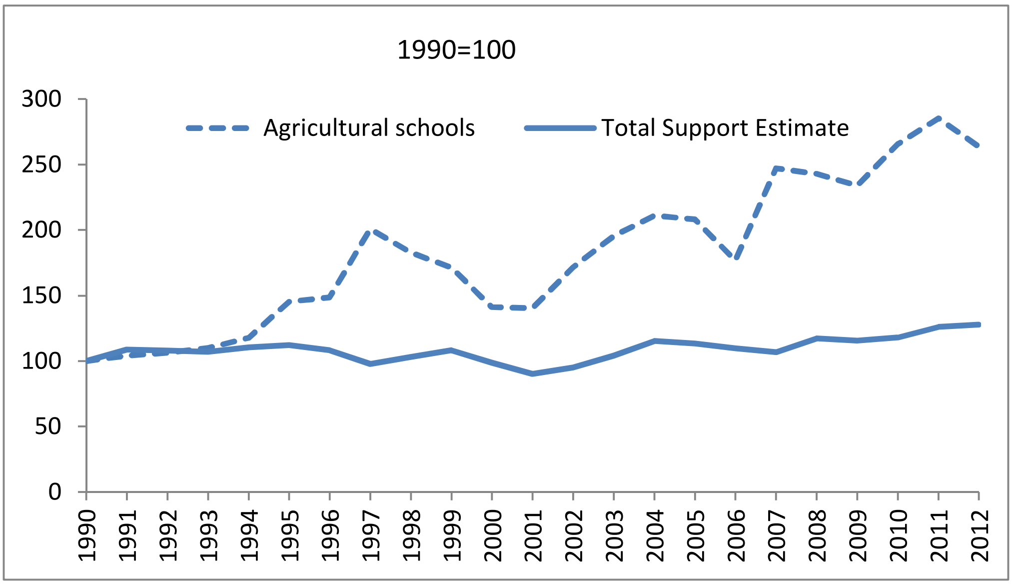
Note: EU includes only the EU member countries which are also OECD members.

Source: EUROSTAT, *Farm Structure Survey 2005* and *2007*.

189. In the EU, the majority of farmers have acquired their experience through practical work on an agricultural holding. A big part of agricultural training consists of basic training, as only 10% of farm managers completed full agricultural training in the EU. Greece (97%), Portugal (88%), Hungary (86%), Spain (85%) and Slovakia (76%) have the highest share of farmers without any type of agricultural training. On the other hand, in 2010 only two EU-OECD members (the Czech Republic and Luxembourg) registered the highest shares (of more than 30%) of farm managers who have followed a full cycle of agricultural training.

190. Concerning the provision of government support to education and training to farmers, on average, payments made to agricultural schools have increased at higher rates than total support to the sector in the OECD area (**Figure 5.4**). Nevertheless, such support constitutes very small percentage of the total support to the sector.

Figure 5.4 Evolution of payments on agricultural schools and total support to agriculture, OECD area, 1990-2012



Source: OECD, *PSE/CSE* database, 2013.

191. An important feature of structural change in agriculture in OECD countries is the general ageing of farming population. This ageing trend is caused by the combined effect of the low exit rate from farming of elderly farmers and of the low entrance rate of young farmers.

192. Across the EU, for example, overall numbers of young farmers are decreasing significantly, while numbers of older farmers are decreasing only slightly, thereby augmenting the share of elderly farmers in the workforce **(Annex Table A.1)**. These figures suggest that elderly farmers are not retiring and passing on their farms to the younger generation at a rate that would lower the average age of the agricultural workforce sufficiently to facilitate structural change and improve efficiency and innovation.

193. Generational renewal in agriculture is a precondition for maintaining viable food production and improving the competitiveness of the sector. New entrants are needed to take over from retiring farmers, to invest and to modernise their agricultural holdings. Young farmers are better trained and they perform better than older farmers in terms of economic potential, farm size, labour productivity and in adopting more environmentally friendly farm practices.

194. Young farmers are more likely to have received a full agricultural training than older ones. In the EU, while 17% of farmers under the age of 35 have had a full agricultural training, more than 80% of the farmers between 55 and 64 acquired their knowledge from practical experience. Attracting new entrants to a sector in a coherent and comprehensive manner is a major policy challenge.

Investing in green innovation

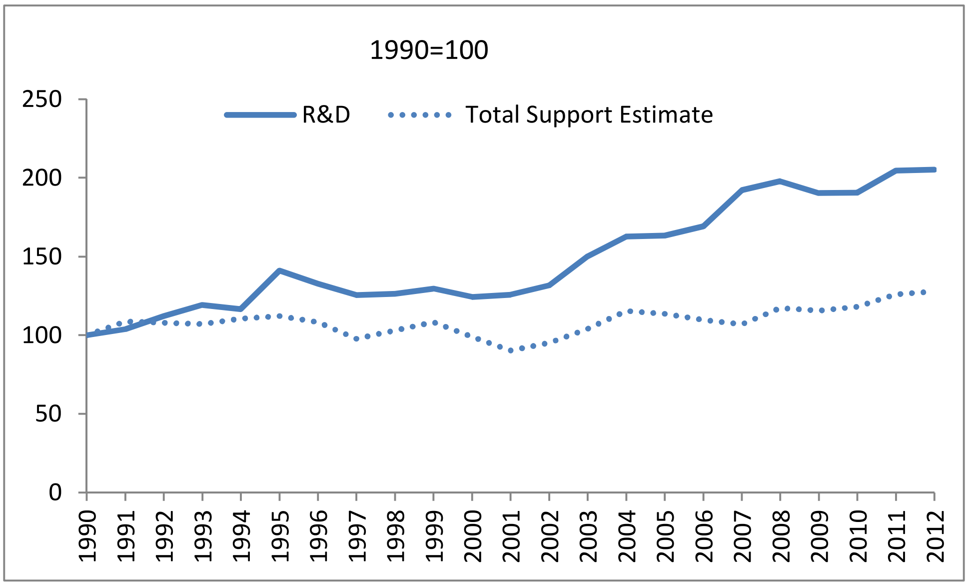
195. In most countries for which data are available, the public sector plays a major role in agricultural R&D. Expressing agricultural R&D expenditures as a percentage of total research expenditure provides an indication of the relative importance given to research on agriculture within the constraints imposed by overall public spending on research. **Annex Figure A.17** shows that that there is a wide disparity across countries in the amount of government R&D expenditure devoted to the agricultural sector. These percentages vary from about one-fifth in New Zealand to around 2% in Belgium. The empirical evidence

also suggests that share of the government R&D budget devoted to agriculture has remained relatively stable in the OECD area in the last two decades at around 3% of the total.

196. Business expenditures on agricultural R&D also account for a small share of total business R&D in most OECD countries for which data are available, with one exception: New Zealand has the largest share (7%), with the share of most of the remaining countries for which data are available being less than 2% (**Annex Figure A.18**). However, the share of the agricultural sector in public R&D is larger, and in several cases by a wide margin, than the sector's contribution to total GDP, implying that agricultural R&D expenditures are well maintained.

197. Nevertheless, juxtaposing public agricultural R&D expenditures against the support to the sector, as measured by the Total Support Estimate, suggests that agricultural R&D expenditures are modest compared to other types of expenditures (**Annex Figure A.19**). In absolute terms, however, R&D for the OECD area as a whole has recorded a steady increase, while the TSE has declined or slightly increased over 1990-2012 (**Figure 5.5**).

Figure 5.5. Evolution of agricultural R&D payments and total support to agriculture, OECD area, 1990-2012



Source: OECD, *PSE/CSE* database, 2013.

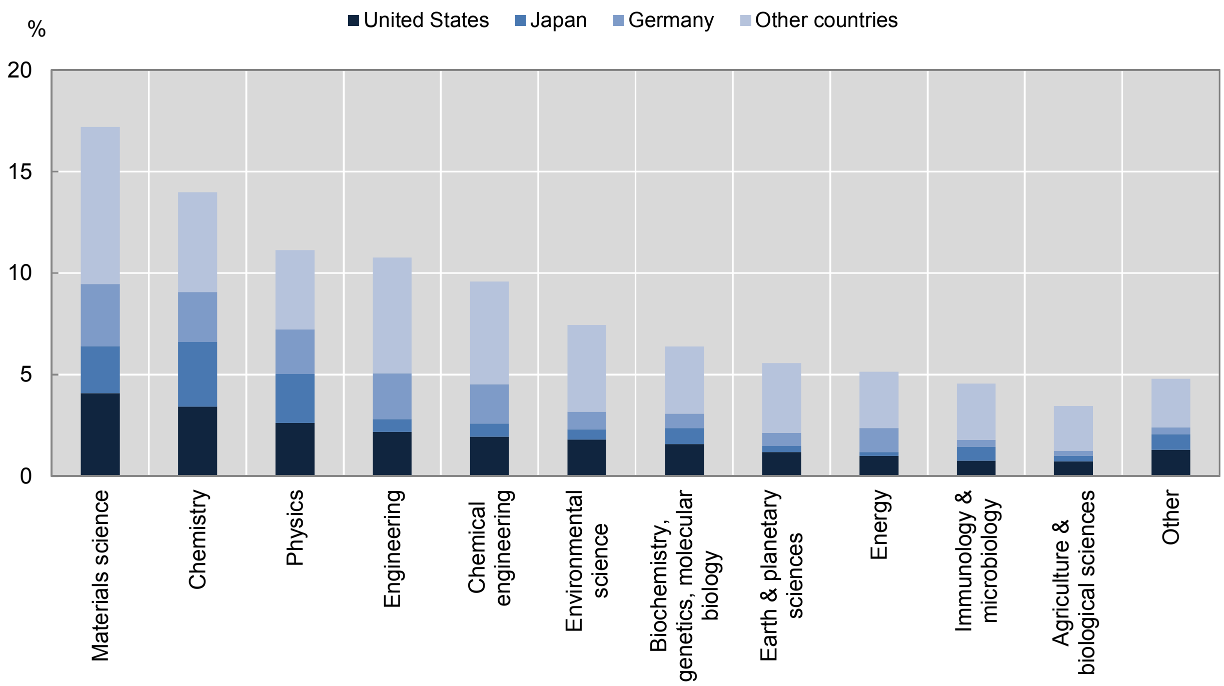
198. OECD work on green innovation indicates that green technology development is accelerating in all areas (OECD, 2013b). Since 1990, in most regions and countries, the share of green patents has been increasing, reaching 10% of total patents in 2010 (OECD, 2011). This is partly due to increased innovations related to technologies and optimisation processes that support cleaner energy generation and increased efficiency. Moreover, most of the technology development is concentrated in a relatively small number of countries. In general, the OECD countries with the highest all-purpose innovation are also among the most innovative in technologies relevant to green growth.

199. Public research has always been an important part of innovation systems and the source of significant scientific and technological breakthroughs. Effective linkages between public research institutions and industry are necessary to optimise the benefits from research. Environmental technologies draw on scientific knowledge that comes mainly from material science, from chemistry and engineering (**Figure 5.6**). Agricultural and biological sciences account, on average, for 3.7% of green technologies.

The link to publications for agricultural and biological sciences originate from US patents (0.7%), from Japanese patents (0.3%), from German patents (0.2%), and the remaining 2.5% from all other countries

Figure 5.6. Main scientific fields cited in "green" patents, by inventor country, 2000-07

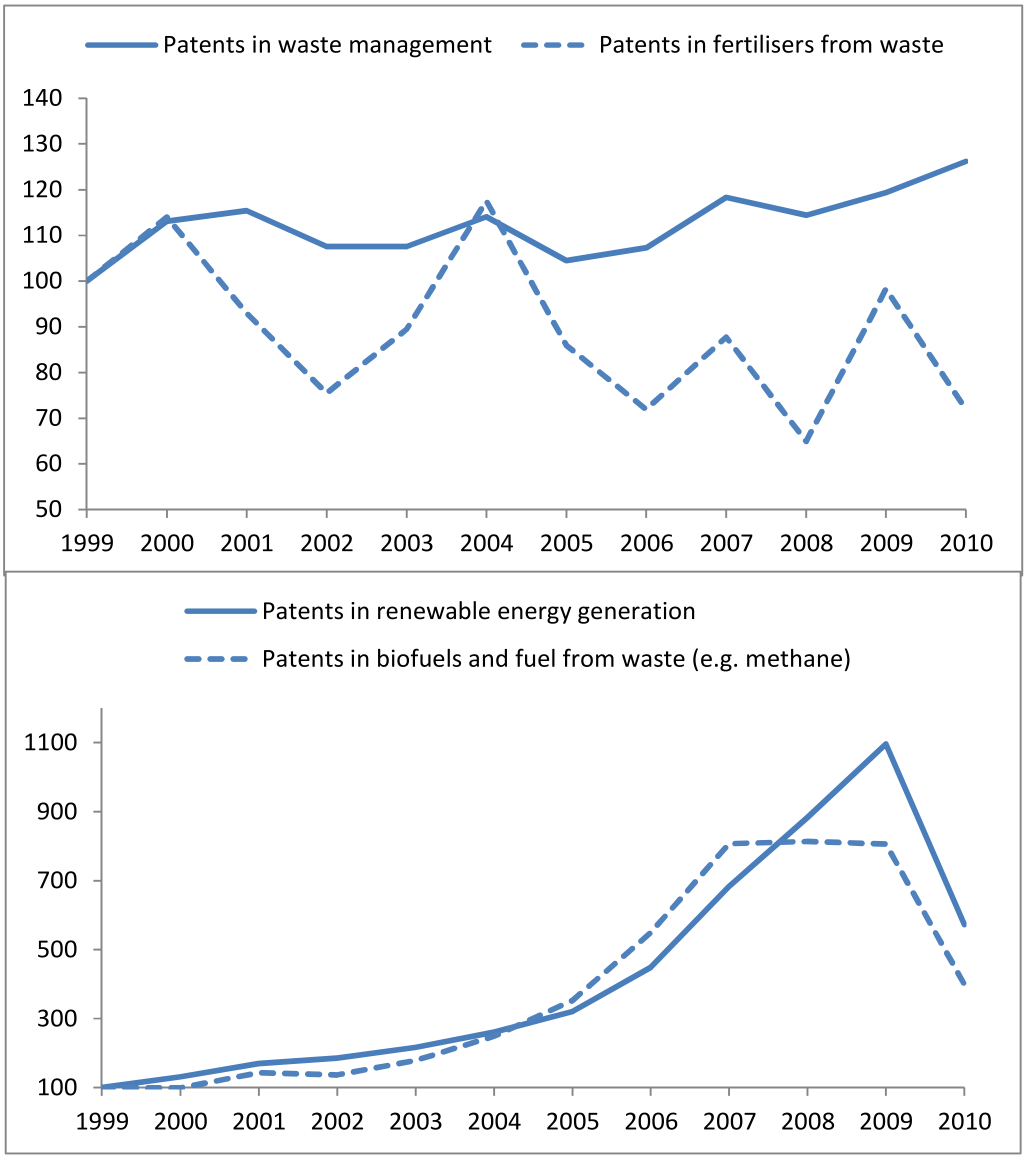
(As a percentage of all citations)



Source: OECD (2010), *Measuring Innovation – A new Perspective*, based on Scopus Custom Data, Elsevier, July 2009; OECD, Patent Database, January 2010; and EPO, Worldwide Patent Statistical Database, September 2009.

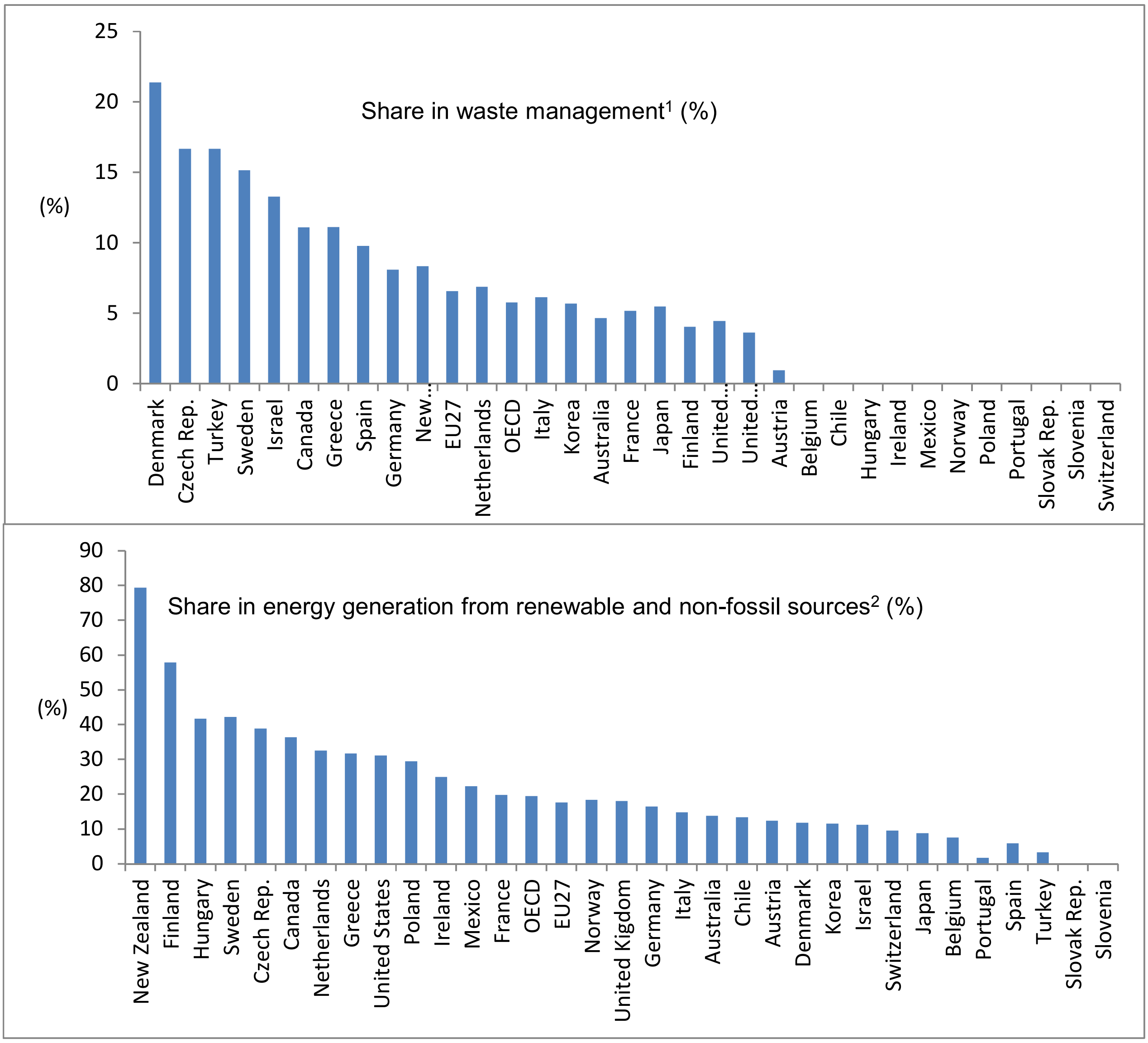
200. On waste management, while innovation for waste management has generally decreased over the last decade, patent levels in fertilisers for waste have decreased (**Figure 5.7**). On the other hand, patents for biofuels and fuel from waste have followed similar trends to those for renewable energy generation, with a steady increase over 1999-2009 and a subsequent decrease in 2010 (by 50%). Evidence at the plant level shows large differences in innovation efforts across countries (**Figure 5.8**).

Figure 5.7. Patents in environment-related technologies in agriculture, OECD, 1999-2010 (1999=100)



Source: OECD (2011), "Patents by Main Technology and by International Patent Classification (IPC)", OECD Patent Statistics (database). doi: 10.1787/data-00508-en, (accessed on 8 July 2013).

Figure 5.8. Patents in environmentally-related technologies in agriculture, 2008-10 (%)



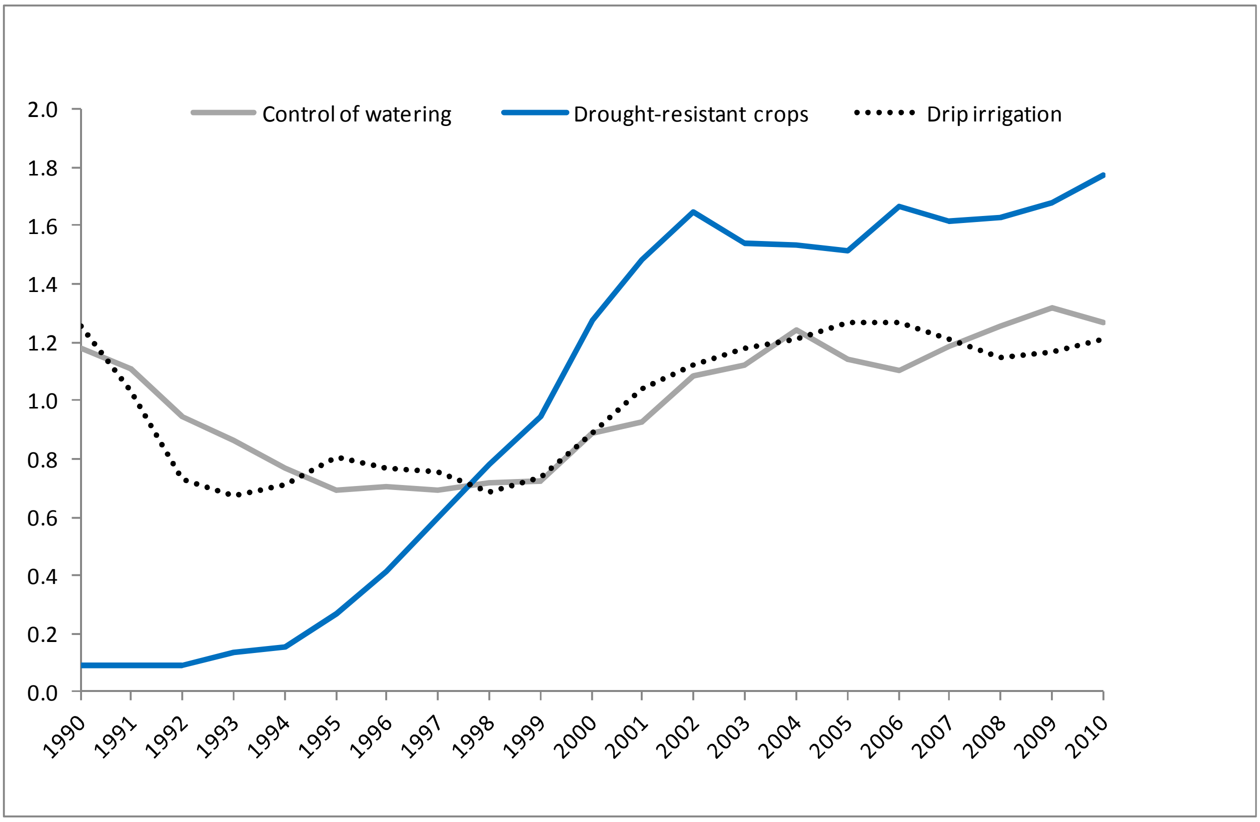
Note: 1. Refers to the share of fertilisers from waste; 2. Refers to the share of biofuels and fuel from waste (e.g. methane).

Source: OECD (2011), "Patents by Main Technology and by International Patent Classification (IPC)", OECD Patent Statistics (database). doi: 10.1787/data-00508-en, (accessed on 8 July 2013).

201. Concerning trends and patterns of innovation (as measured by patents) in water-related agricultural technologies, such as drip irrigation, drought-resistant crops and controlled watering these have grown steadily over the last decades (**Figure 5.9**). Drought-resistant crop technologies experienced the highest rate of growth, with very high growth at the end of the 1990s and the beginning of the 2000s, before flattening towards the end of the period. There was a peak in this field at the end of the 1990s, when inventions were filed in six different patent offices.

202. Innovation in water-related technologies appears to be concentrated in a handful of countries. World-wide, the United States is by far the frontrunner in innovations in agricultural water technologies, while certain countries have achieved strong positions in specific fields (OECD, 2013a).

Figure 5.9. Trends of water-related innovations in agriculture



Note: To make the series comparable they have been normalised by their own average.

Source: Dechezleprêtre, Haščič and Johnstone (2013).

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Chapter 6.
Conclusions and ways forward

A wide range of indicators related to economic and environmental performance of the agricultural sector as well as indicators describing the policy environment governing the sector can be constructed. Yet, capturing the dynamics of green growth in agriculture and presenting them in terms of quantifiable indicators that could be interpreted unambiguously and easily communicated to policy makers remains a challenging task.

203. For OECD countries, there are several indicators related to economic and environmental performance of the agricultural sector as well as indicators describing the policy environment governing the sector. Yet, capturing the dynamics of green growth in agriculture and presenting them in terms of quantifiable indicators that could be interpreted unambiguously and easily communicated to policy makers remains a challenging task. Tracking trends in decoupling of inputs to production from economic growth is an important focus for monitoring progress towards green growth.

204. Given its multidimensional nature, green growth cannot be adequately captured by a single indicator. To monitor progress towards achieving green growth in agriculture, in accordance with the OECD *Green Growth Framework*, a small set of indicators able to track the central elements of green growth issues associated with the agricultural sector across OECD member countries has been proposed and applied to selected OECD countries in this paper. The list of the proposed indicators constitutes work in progress and will be further elaborated over time as data become available and as concepts evolve.

205. **Table 6.1** provides a synopsis of the proposed indicators, while the full list is provided by group in each relevant chapter. The proposed set of indicators comprises approximately twenty-five indicators, not all of which are, as yet, measurable. At this stage, only three indicators fulfil all the criteria: the indicators related to carbon and energy productivity, and the indicator related to the potentially most environmentally harmful producer support.

206. There are important caveats concerning the proposed list of indicators. First, the set of indicators is limited in number. It represents a first selection made on the basis of the Secretariat's existing work and experience and member countries' experiences with green growth in agriculture.

207. The second caveat is that not all of the proposed indicators are relevant across all countries. Emphasis will vary, depending on the overall development status and priorities/particularities of a given country. National circumstances such as socio-economic structure, geography and climate will also influence the relevance, selection and interpretation of specific indicators. Not all indicators are relevant for the agricultural situation in all countries, but others are highly relevant in certain cases (for example, indicators on water quality).

208. Third, the proposed indicators related to policy tools refer only to market-based instruments and do not include indicators for regulatory instruments. Construction of indicators for regulations is complicated due to the fact that the information is often of a qualitative nature and it is not easy to compare across countries. Thought will be given to how indicators on economic instruments can be complemented by indicators on environmental regulation so as to balance the picture of international comparisons of policy responses.

209. Finally, gaps exist and some of the selected indicators are not currently measurable and merit further development. Work continues on refining and elaborating the indicator set as new data become available and as concepts evolve. Among the areas identified as having the largest gaps was that of indicators for green innovation and investments in agriculture, indicators on natural asset base and indicators on environmental quality of life.

Table 6.1. Synopsis of the proposed list of indicators

Topic or issue	Criteria			
	Capturing the nexus between the environment and the economy	Ease of communication to different users and audiences	Refecting key global environmental issues	Measurable and comparable across countries
Environmental efficiency				
Carbon productivity	***	***	***	***
Nutrient balance intensities	***	***	***	*
Resource efficiency				
Energy productivity	***	***	***	***
Renewable energy	***	***	***	*
Water productivity	***	***	***	*
Material (biomass) productivity	Indicators to be developed			
Environmentally adjusted mutlti-factor productivity	***	**	***	*
Natural asset base				
Changes in agricultural land use and cover	***	***	***	**
Environmental quality of life	No indicator is proposed			
Economic opportunities and policy responses				
Potentially most environmentally harmful producer support	***	***	***	***
Environmentally related taxes	***	***	***	**
Water pricing	***	***	**	*
Empowering people to innovate in agriculture	***	***	n.a.	**
Environment-related innovation in agriculture	***	**	***	*
Regulatory instruments	Indicators to be developed			

*** = high; ** = medium; * = low; n.a. = not applicable.

210. Constructing indicators to monitor technology and innovation relevant to green growth in agriculture is not a straightforward issue, due to the difficulty in providing an unequivocal definition for "green" innovation or technology both at the sectoral and economy-wide level. Conventional indicators capture only part of the innovation process. For example, input indicators measure investment in innovation, such as R&D expenditures and the number of staff. Output measures include the number of publications and quotations cited in academic journals, or the number of patents registered. However, patents are an indicator of invention rather than innovation since not all patents are commercialised and some types of innovation in the agricultural sector are not patentable. The limits of bibliographic indicators are obvious.

211. Moreover, data on the level of technology and innovation in agriculture, as measured by conventional indicators (such as expenditure on green technologies) and the number of patents are not available for most countries. In general, aspects related to green innovation and investments in agriculture are inadequately captured by the currently available indicators and merit further development.

212. Further improvements in monitoring the progress of green growth in agriculture will largely depend on the follow-up work which is currently underway or planned in the context of the OECD *Green Growth Measurement* agenda, on the finalisation and implementation of the SEEA, as well on other

relevant work, such as the World Bank's WAVES (Wealth Accounting and Valuation of Ecosystem Services) project (www.wavespartnership.org/waves/).

213. The OECD, UNEP, the World Bank and the Global Green Growth Institute (GGGI) are working together through the Green Growth Knowledge Platform (GGKP), to help countries advance on the measurement, design and implementation of green growth policies. Where possible and meaningful, the indicators proposed by the various international agencies are being harmonised. A first step towards a common internationally agreed approach on green growth indicators was made in April 2013 with the publication of a scoping paper *Moving towards a Common Approach on Green Growth Indicators*, prepared jointly by the GGKP member organisations (GGKP, 2013). This common approach is based the OECD Green Growth measurement framework.

214. The SEEA is a crucial ingredient of the measurement agenda as it provides an overarching, consistent statistical framework for compiling and presenting economic and environmental data (UN 2014). It constitutes an accounting framework that will ensure consistent basic data for environmental and economic variables. Furthermore, it provides an integrated framework for the compilation of statistics on the various aspects of wider concepts. Its implementation is expected to maximise international comparability and consistency, and it will become the primary framework from which green growth indicators will be derived. The OECD is working in collaboration with the UN in the development of the SEEA.

215. In particular, specific priority areas for follow-up work to address important methodological and data gaps include the following areas:

- Extension of the traditional growth accounting to include natural assets, thereby deriving new measures of multi-factor productivity growth.
- Development of indicators for regulatory instruments. The construction of such indicators is more complicated than that of indicators on economic instruments (e.g. government transfers and taxes) and careful thought should be given to how indicators on policy responses can be complemented by indicators on environmental regulations, which are very important for the agricultural sector in most OECD countries.
- Improvement of the data on water pricing and cost recovery.
- Further improvement on green-related R&D and innovation data in agriculture.

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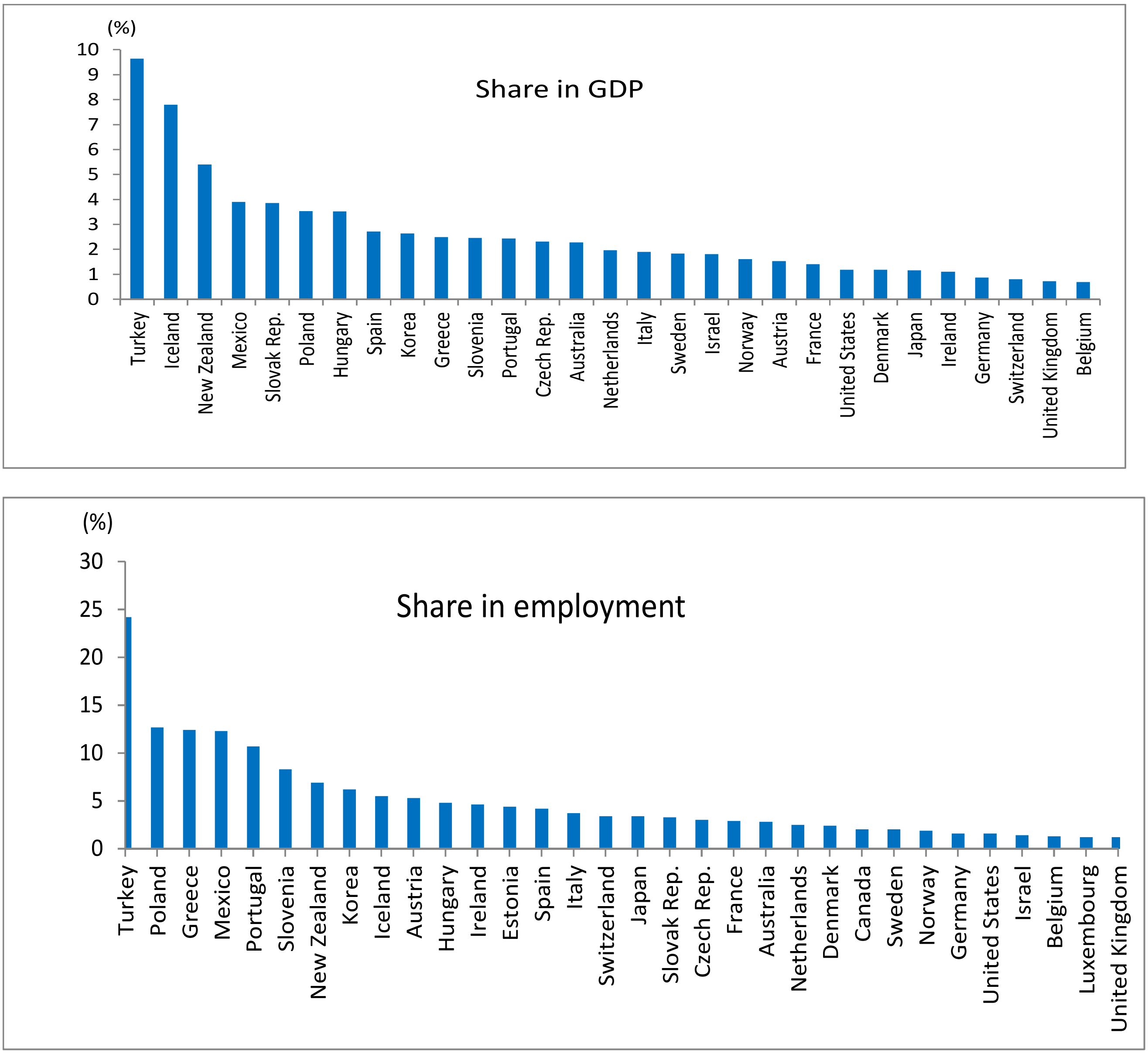
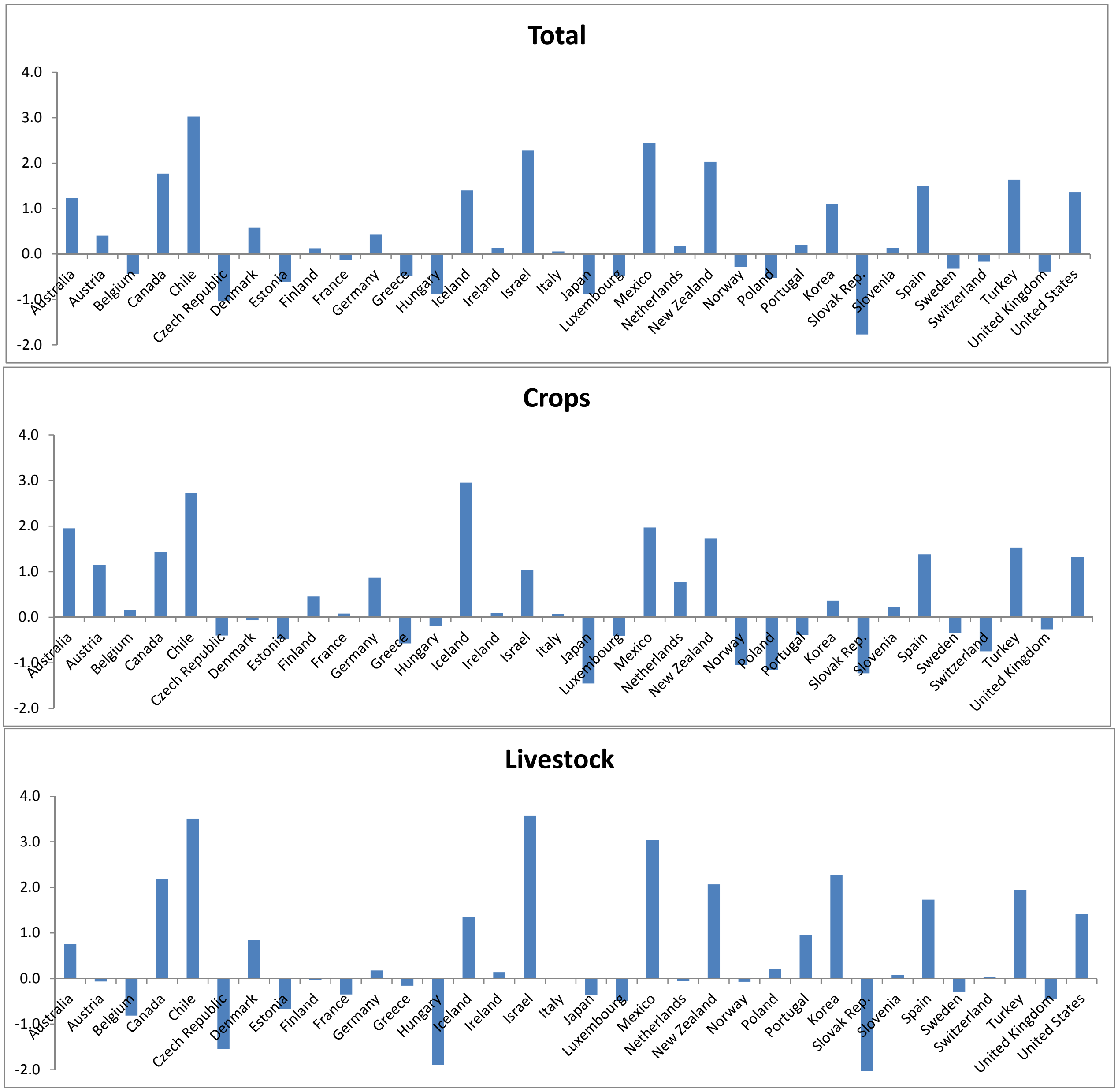
ANNEX FIGURES AND TABLES

Annex Figure A.1. Agriculture's contribution to the economy, 2010 or latest, OECD countries



Source: World Bank, *World Development Indicators*; EUROSTAT.

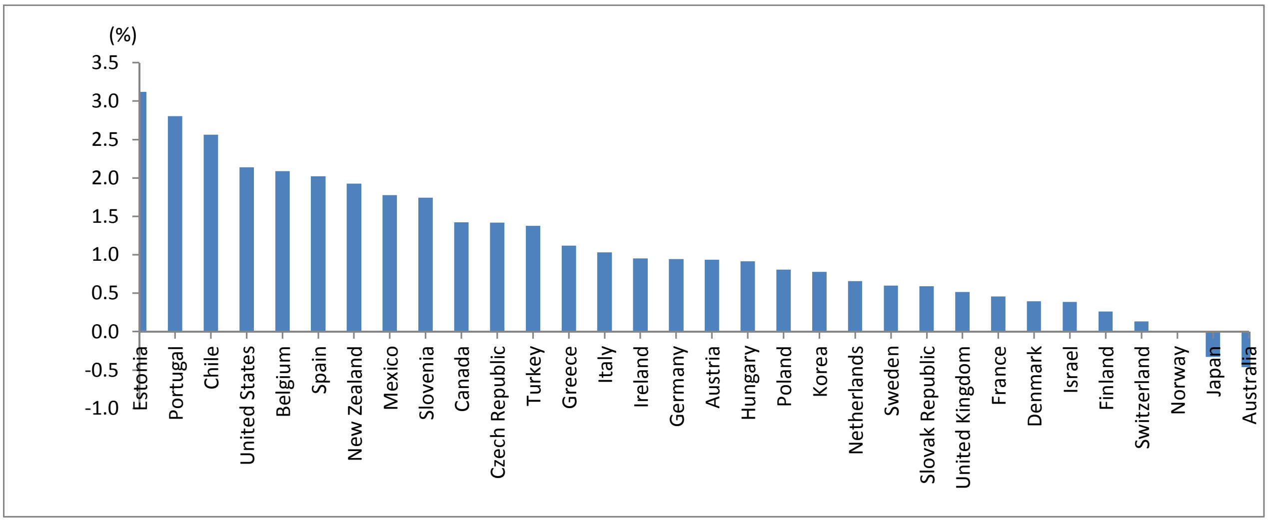
Annex Figure A.2. Average annual growth in agricultural production volume, 1990-2011 (%)



Note: The least-squares growth rate, r, is estimated by fitting a linear regression trend line to the logarithmic annual values of the variable in the relevant period, as follows: Ln(xt) = a + r * t and is calculated as [exp (r) – 1].

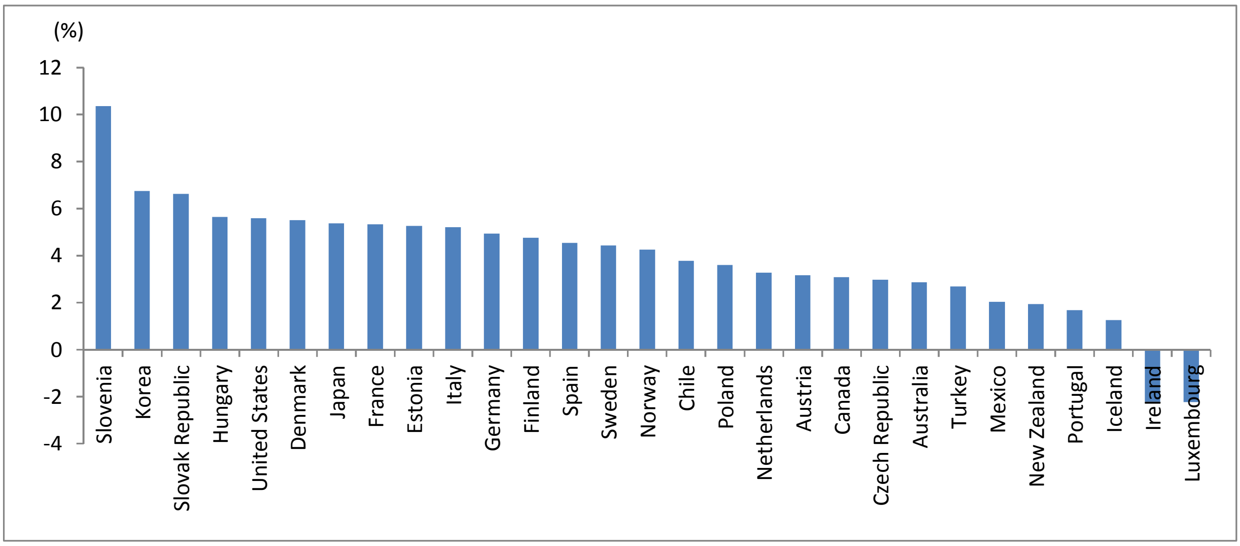
Source: FAO, *FAOSTAT* database.

Annex Figure A.3. Cereal yield growth rates, 1990-2011 (%)



Source: FAO, *FAOSTAT* database.

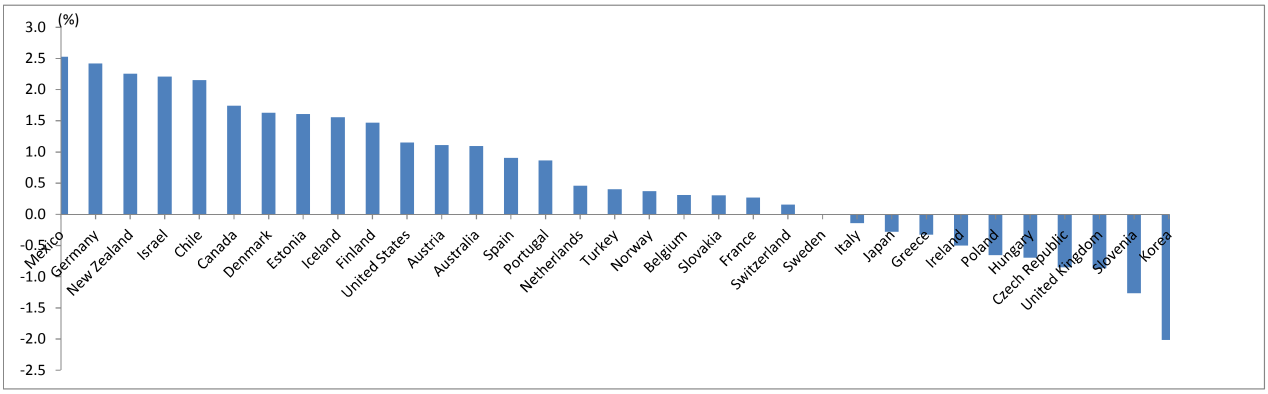
Annex Figure A.4. Agricultural labour productivity growth rates, 1990-2010 (%)



Note: Agricultural labour productivity is defined as agriculture value added per worker (constant USD 2000).

Source: World Bank, *World Development Indicators*.

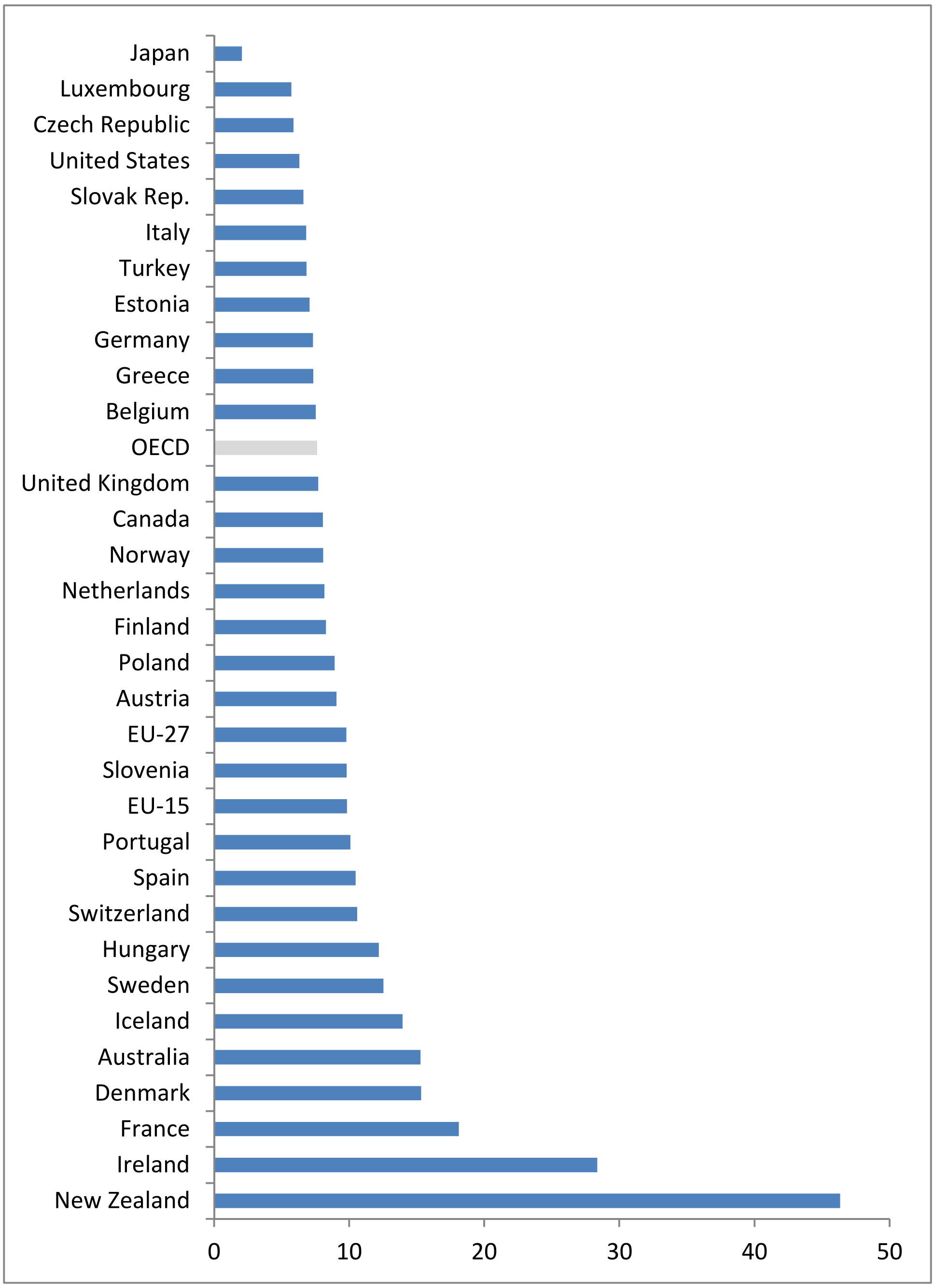
Annex Figure A.5. Agricultural investment productivity growth, 1990-2007 (1990=100)



Note: Investment productivity is defined as agricultural production at constant 2004-06 prices (mill. USD) divided by net capital stock in agriculture at constant 2005 prices (mill. USD).

Source: FAO, *FAOSTAT* database.

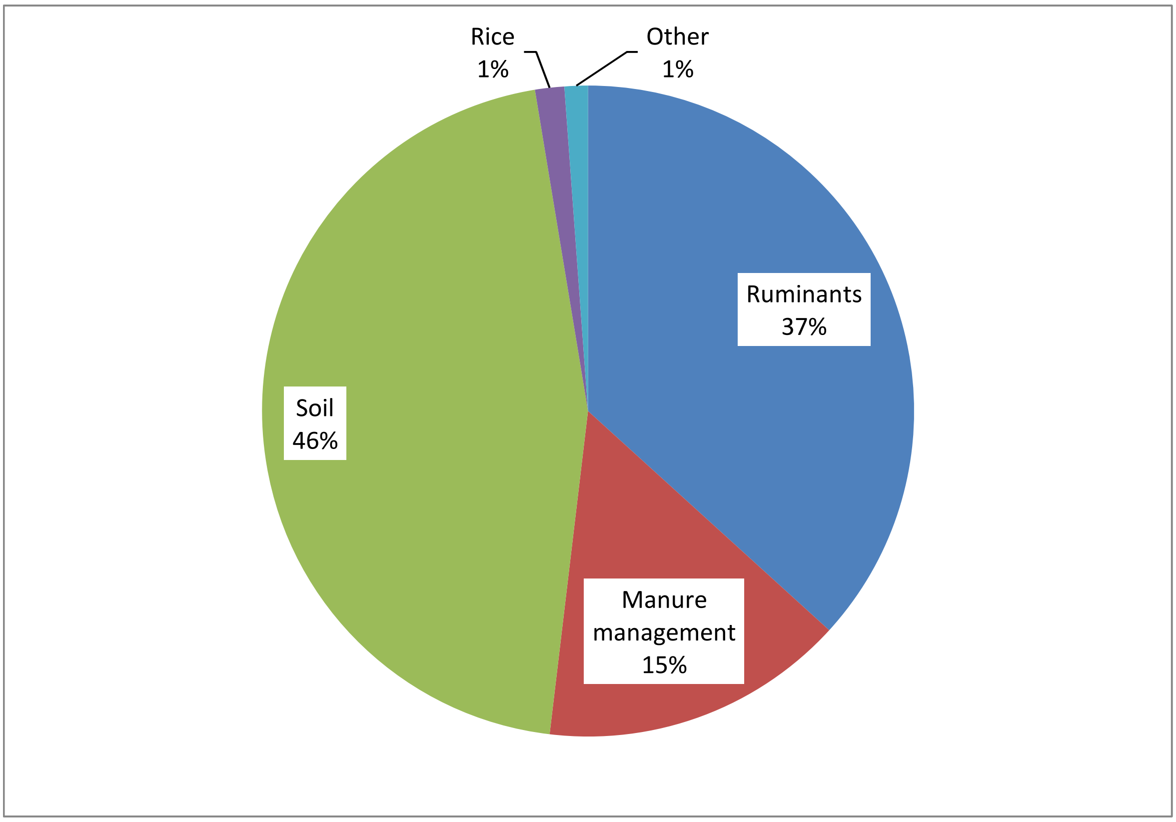
Annex Figure A.6. Share of agriculture in total GHG emissions, 2008-10 (%)



Note: Excluding LULUCF (land use, land use-change and forestry).

Source: UNFCCC *Greenhouse Gas Inventory Data*.

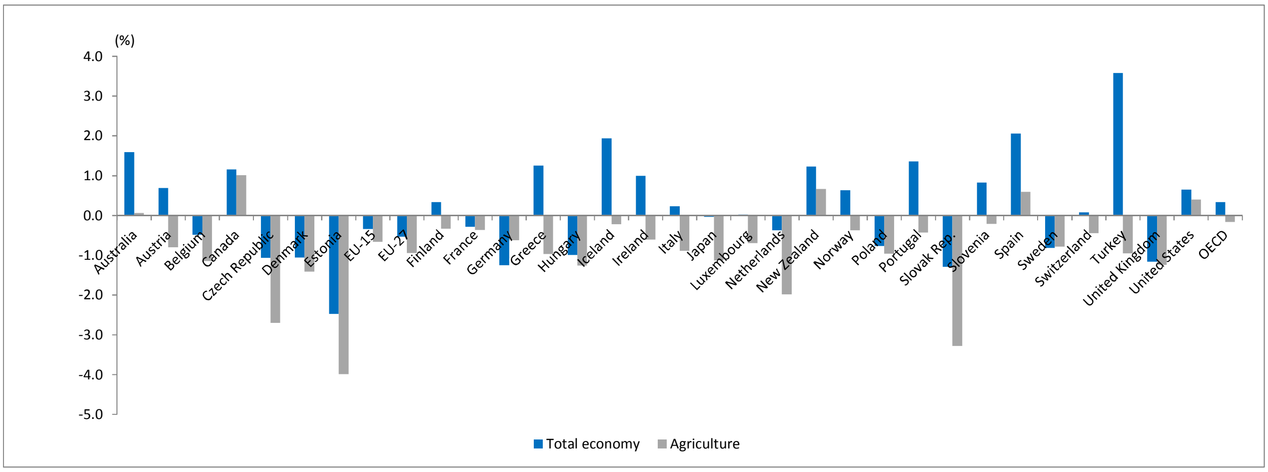
Annex Figure A.7. GHG emission from agriculture in the OECD area, by source, 2008-10 (%)



Note: Excluding LULUCF (land use, land use-change and forestry).

Source: UNFCCC *Greenhouse Gas Inventory Data*.

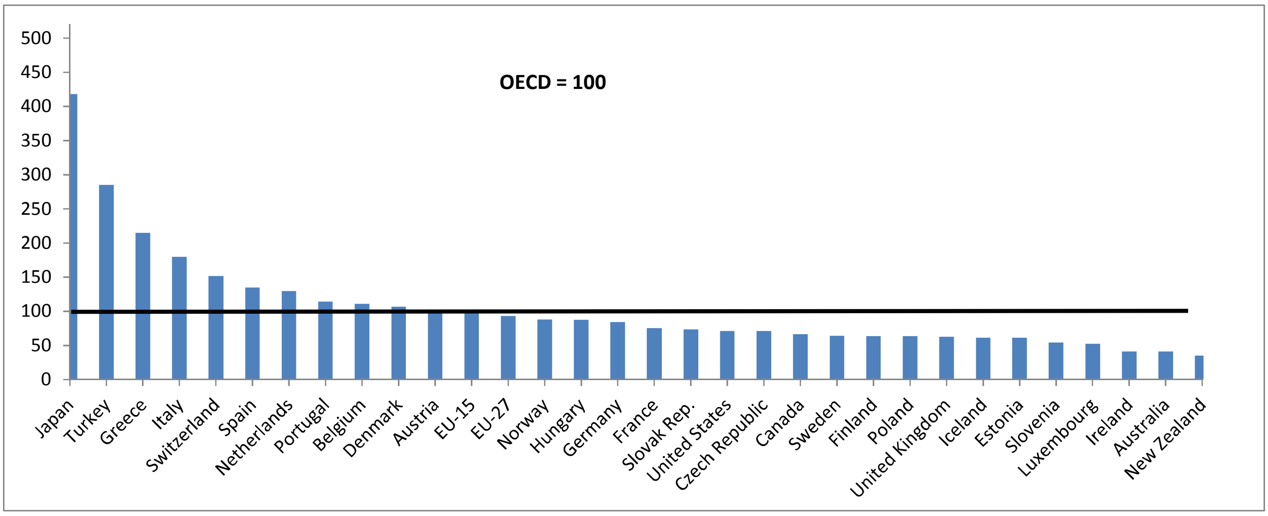
Annex Figure A.8. Growth rate of total economy and agricultural net GHG emissions (Gg CO2 equivalent)



Note: Excluding LULUCF (land use, land use-change and forestry).

Source: UNFCCC *Greenhouse Gas Inventory Data*.

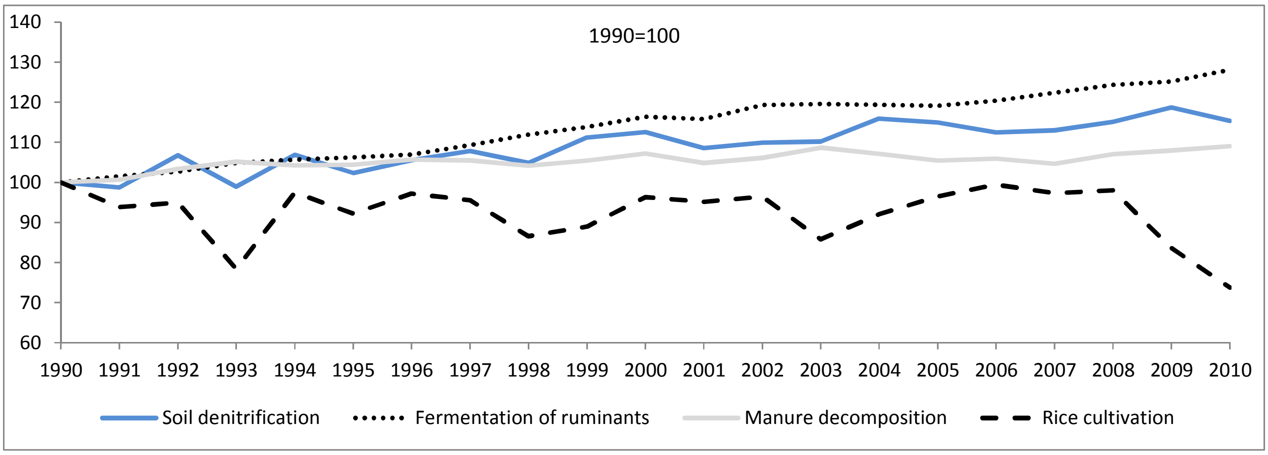
Annex Figure A.9. Agricultural GHG emissions productivity, by country, 2008-10



Note: Excluding LULUCF (land use, land use-change and forestry).

Source: UNFCCC *Greenhouse Gas Inventory Data;* FAO, *FAOSTAT* database.

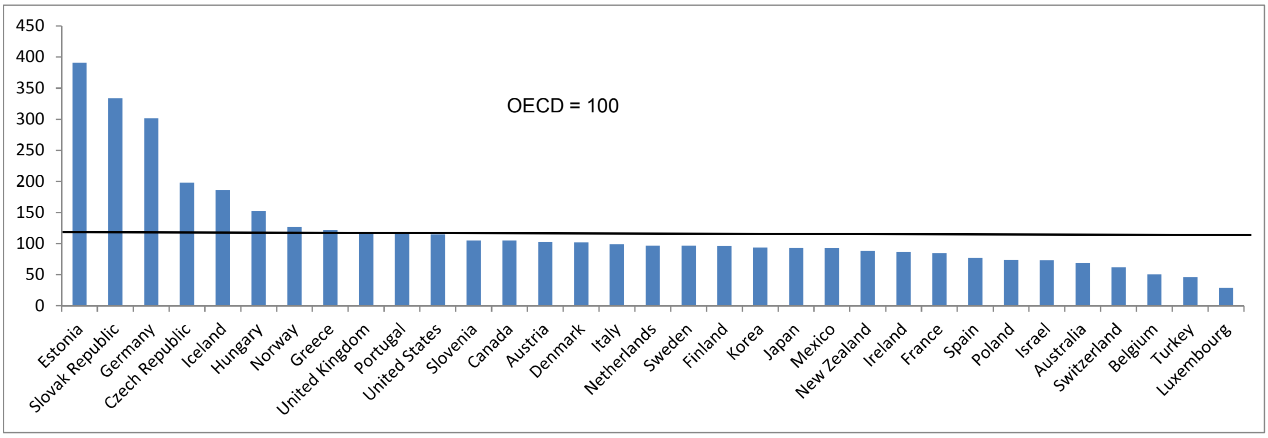
Annex Figure A.10. Agriculture GHG emissions productivity by source in the OECD area, 1990-2010



Note: Excluding LULUCF (land use, land use-change and forestry).

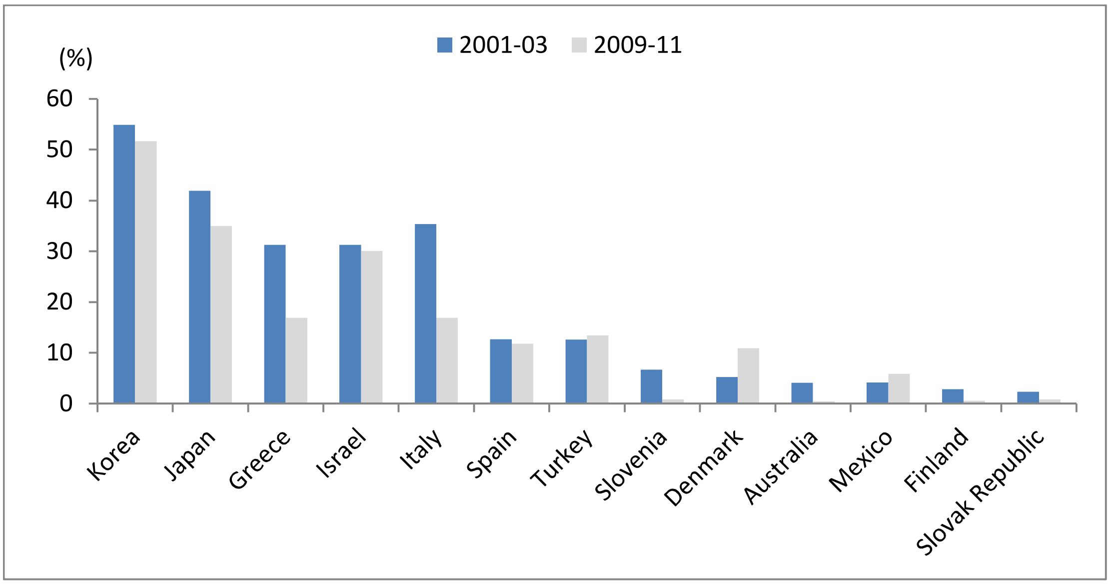
Source: UNFCCC *Greenhouse Gas Inventory Data*; FAO, *FAOSTAT* database.

Annex Figure A.11. Direct on-farm energy productivity, OECD countries 2009-10



Source: OECD, *Agri-environmental Indicators* database; FAO, *FAOSTAT* database.

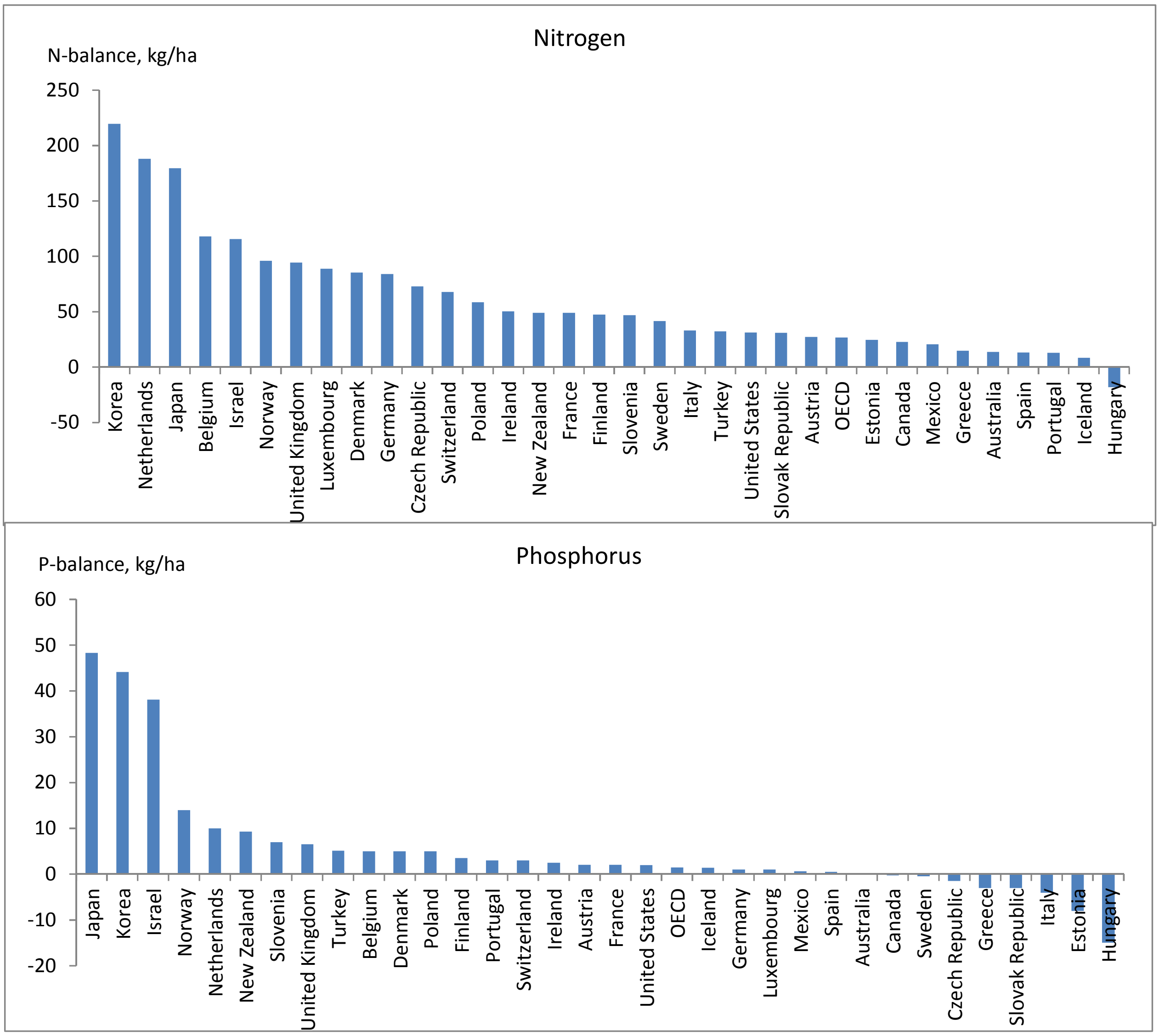
Annex Figure A.12. Irrigated area, OECD countries: 1990-2010



Note: Korea 2007 instead of 2009-11.

Source: World Bank, *World Development Indicators*.

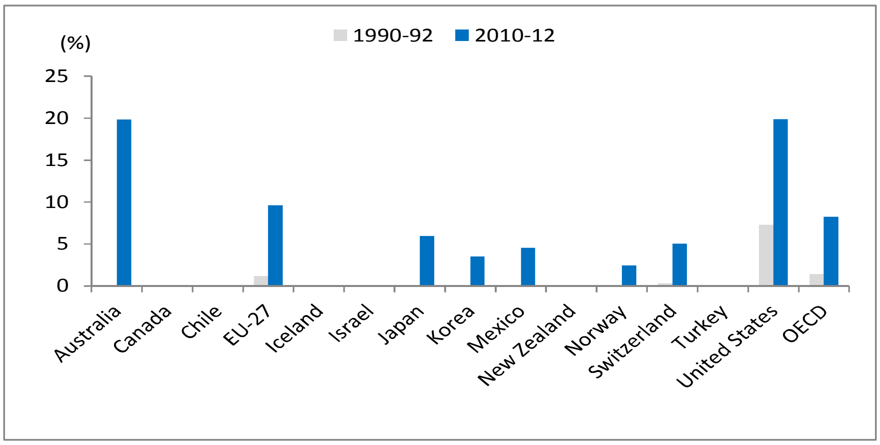
Annex Figure A.13. Nutrients intensities per area of agricultural land, OECD countries, 2008-09 (kg/ha)



Source: OECD, *Agri-environmental Indicators* database.

Annex Figure A.14. Potentially most environmentally beneficial producer support in OECD countries

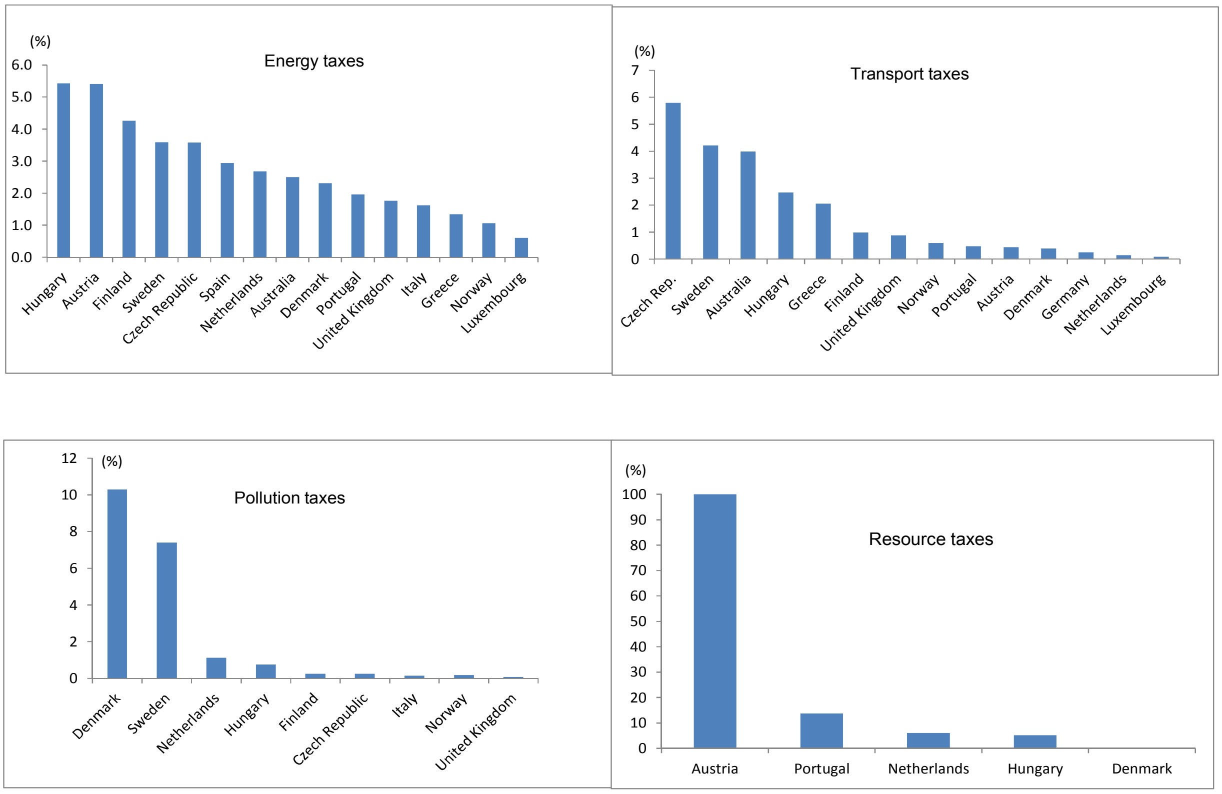
Share in total producer support (%)



Note: 1995-97 for Israel.

Source: OECD, *PSE/CSE* database, 2013.

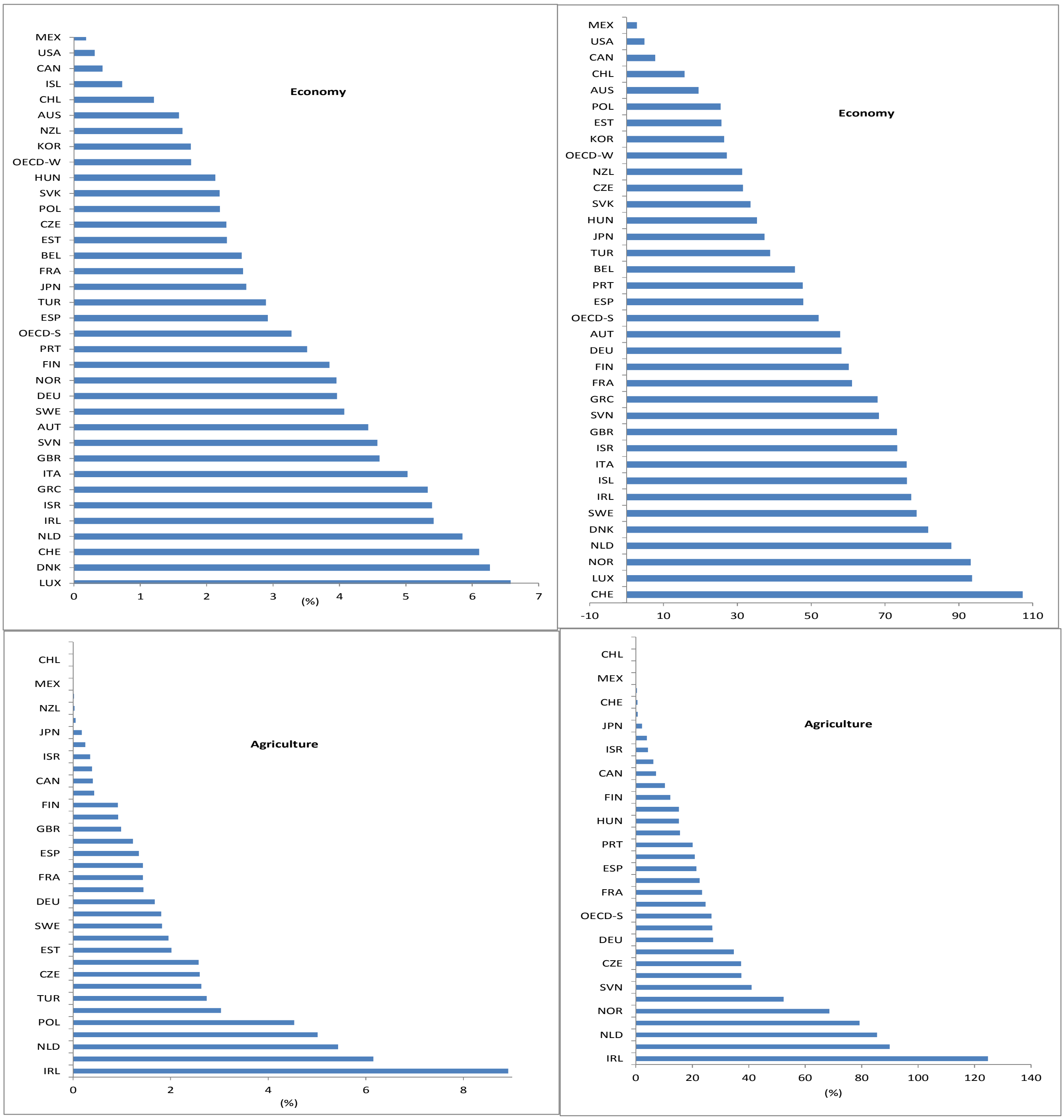
Annex Figure A.15 Environmental taxes in agriculture by type - share in total (%), 2010 or more recent year



Note: includes forestry; NAC REV2.

Source: EUROSTAT; Australian Bureau of Statistics (ABS) (2013), Towards the Australian Environmental-Economic Accounts, Information Paper, Canberra.

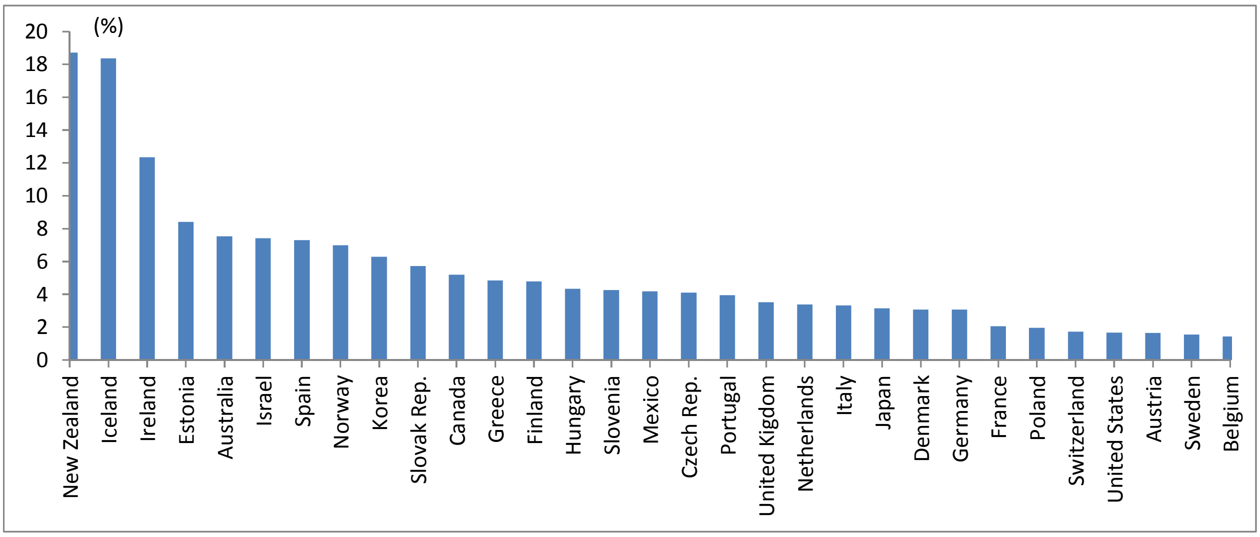
Annex Figure A.16. Average effective tax rates on energy (left) and CO2 from energy (right) in OECD countries



Note: Tax rates are as of 1 April 2013. Further details on the methodology can be found in the OECD (2013), *Taxing Energy Use*.

Source: OECD (2013), *Taxing Energy Use*.

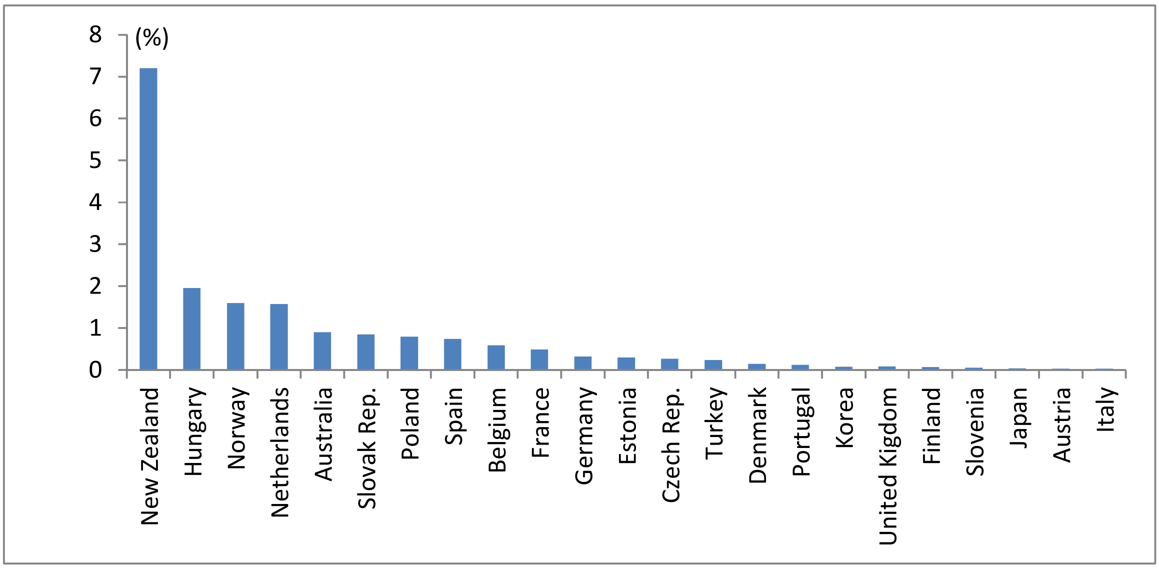
Annex Figure A.17. Government budget appropriations or outlays for R&D (GBAORD): share of agriculture, 2010-12 (%)



Note: GBAORD by socio economic objective.

Source: OECD, *Science, Technology and Patents* database.

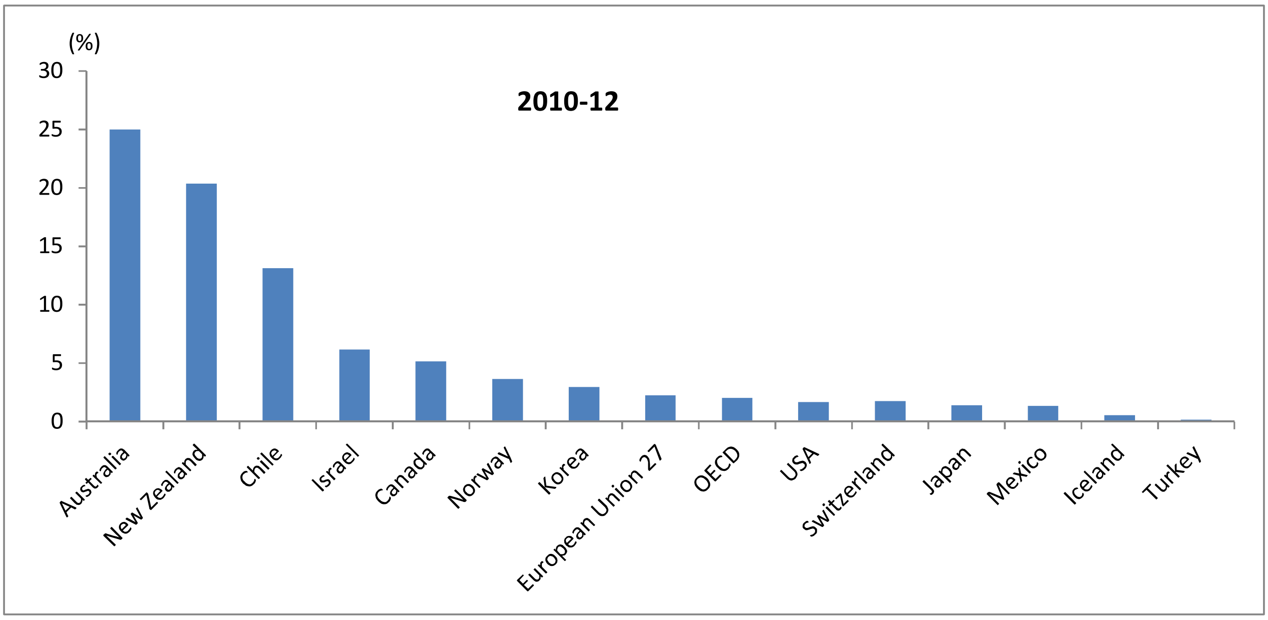
Annex Figure A.18. Business enterprises R&D expenditure: share of agriculture in total, 2010 or more recent year



Note: ISIC REV.4.

Source: OECD, *Science, Technology and Patents* database.

Annex Figure A.19. Share of agricultural R&D payments in total support to agriculture, 2010-12 (%)



Source: OECD, *PSE/CSE* database, 2012.

Annex Table A.1. Share of young and elderly farmers in some EU member states, 1990, 2007 and 2010 (%)

	<35					≥65				
	1990	2000	2005	2007	2010	1990	2000	2005	2007	2010
Austria		16	12	10	11			10		8
Belgium		11	7	6	5			20		20
Czech Republic			10	10	12			17		13
Denmark	11	10	7	6	5	20		18	20	19
Estonia			7	6	7			28		28
Finland		11	9	9	9			6		10
France	13	10	9	8	9	14		14	13	12
Germany		17	9	8	7			7		5
Greece	9	9	7	7	7	25		36	36	33
Hungary			8	8	7			27		29
Ireland		13	11	7	7			21		25
Italy	5	5	3	3	5	31		41	43	37
Luxembourg	13	11	8	5	7	14		14	14	14
Netherlands	11	7	5	4	4	14		17	18	18
Poland			13	12	15			17		8
Portugal	7	4	2	2	3	28		46	47	46
Slovenia			4	4	4			34		30
Slovak Republic			4	4	7			29		23
Spain	8	9	6	4	5	21		31	31	30
Sweden		7	6	5	5			20		26
United Kingdom		5	4	3	4			27		28
EU-15		8		5	6					

Source: EUROSTAT, *Farm Structure Survey*, 1990, 2007, 2010.