Chapter 6. The agricultural innovation system in China

This chapter describes the Agricultural Innovation System in China and outlines the recent changes it has undergone. It first provides an overview of the general innovation system; presents agricultural innovation actors and their roles in the system; outlines changes in roles and themes of R&D; and presents the main policy instruments and monitoring efforts. It also reviews the main trends in public and private investments in R&D, the funding mechanism and the means used to foster knowledge markets and networks. This is followed by an overview of policy incentives for the adoption of agriculture innovation, with an emphasis on the role of training and advisory services at farm level.

6.1. General innovation profile

Innovation is regarded as the most important engine to promote the sustainable growth of agricultural productivity in the People's Republic of China (hereafter "China"). Agricultural innovation includes technological advances which enable agricultural development to be decoupled from material inputs. It also includes innovation in business operation systems and management which enable the creation of a modern agricultural business sector based on household operations, interconnected via co-operation and alliances, and supported by services from other sectors in the economy. China's innovation-driven development strategy also defines innovation as a broad concept including scientific and technological innovation, management innovation, institutional innovation, business model innovation, organisational innovation, and cultural innovation.

The fundamental objective of agricultural innovation in China has been the enhancement of the supply capability of major agricultural products like grains to ensure food security. Recent policy documents in China such as the 2016 No. 1 Document of the State Council establish innovation as one of the most important policy agendas in agriculture. Its primary goals are the fostering of engines for healthy and sustainable agricultural growth and the promotion of sustainable agricultural development which is innovative, coordinated, green, open and shared.

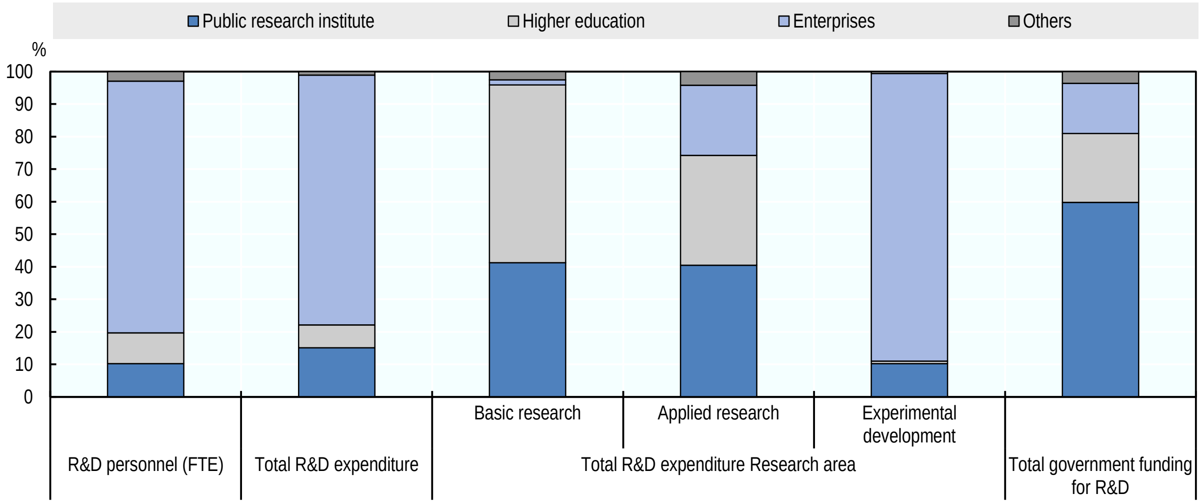
The No. 1 Document of 2017 emphasised strengthening basic research in agricultural R&D and enhancing innovation capacity through constructing national agricultural high-technology development zones and promoting public and private partnerships. It also strengthens the extension system of agricultural R&D, stressing the importance of public support to allow diverse actors to participate in extending agricultural science and technology. The Document urged improvement in the incentive mechanism for innovation in agricultural science and technology through: allowing researchers in public research institutions to work in the private sector; introducing an outcome-based compensation system; enhancing public support to basic research; establishing a differentiated technology evaluation system; and strengthening agricultural intellectual property rights.

Innovation in agriculture depends on innovation in the broader economy, for example through developments in ICT, biotechnology and nanotechnology, but also through marketing and non-sector-specific innovations. A thriving innovation system will ensure that general knowledge and specific knowledge in other fields (which are needed to develop and implement agriculture innovations) are available, and that economic actors and society in general share an innovation culture (OECD, 2015).

Gross expenditures in research and development (GERD) as a percentage of GDP are slightly lower in China than the OECD average. According to OECD statistics, China spent about 2.1% of GDP on overall research and development (R&D) in 2015, which is close to the EU15 average, and slightly lower than OECD average of 2.4%. The gap with the OECD average has been narrowing compared to the early 2000s, when the GDP share of gross R&D expenditure was less than half of the OECD average. In China, the government financed 21% of GERD, which is lower than the OECD average of 26% in 2015. The private sector has become the largest R&D performer in China, accounting for 74% of total R&D personnel and expenditure in 2015 (Figure 6.1).

The private sector in China contributed R&D outlays equivalent to 1.5% of GDP in 2015, exceeding the level as the OECD average. The intensity of private R&D investment increased more than three times since 2000, indicating the increasing role of the private sector in R&D in China Self-financing accounts for more than 90% of R&D expenditure in the private sector. By contrast, the share of the government funds in R&D expenditure in government research institutions and higher education was 84% and 64% in 2015, respectively.

Figure 6.1. Share of R&D by performers in China, 2015



Source: National Bureau of Statistics and Ministry of Science and Technology (2016), China Statistical Yearbook on Science and Technology 2016.

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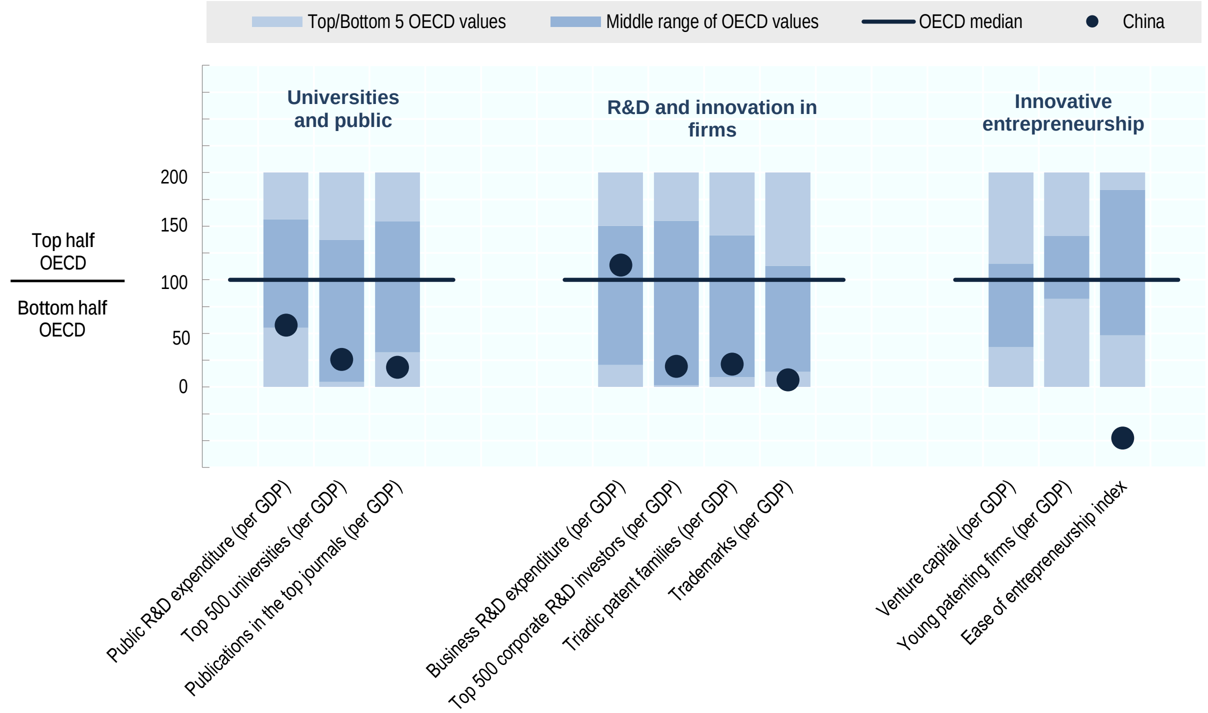
Overall, 5% of total R&D expenditure goes to basic research, while applied research and experimental development account for 84% and 11% of total R&D expenditure in 2015, respectively. The share of basic research is considerably lower than in most OECD countries spending more than 10% of GERD on basic research (e.g. 17% in the United States and 12% in Japan in 2015). Among the performers of R&D, nearly all the private R&D expenditure is experimental development, accounting for 88% of China's R&D on experimental development in 2015.[1] On the other hand, higher education concentrates more on basic research, accounting for the majority of China's R&D expenditure for basic research. Public research institutes account for approximately 41% of basic and applied research, but they allocate 57% of total R&D expenditure for experimental development.

While the financial input to China's innovation system is now comparable to most OECD countries, the system's output still lags OECD countries (Figure 6.2). China has fewer top 500 University and top 500 corporate R&D investors than expected, considering the size of its GDP. Similarly, publications in the top journals, triadic patent families (a set of patents registered in various countries) and trademarks are increasing in China, but remain below OECD medians if compared on a per GDP basis.

Figure 6.2. Science and innovation in China, 2016



Notes: Normalised index of performance relative to the median values in the OECD area (Index median = 100). The OECD aggregates do not include Lithuania.

Source: OECD (2017a), "China", in *OECD Science, Technology and Innovation Outlook 2016*, OECD Publishing, Paris, http://dx.doi.org/10.1787/sti_in_outlook-2016-58-en.

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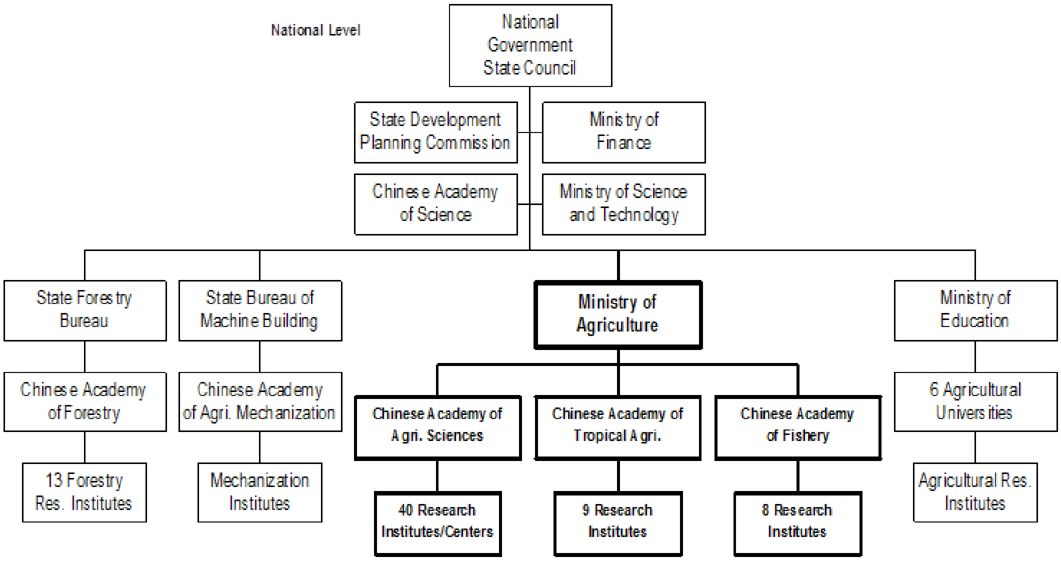
6.2. Actors, institutions and their roles in agricultural innovation system

The agricultural innovation system (AIS) in China functions as a part of the overall national science, technology and innovation system. The AIS is composed of a broad range of actors who enable, guide, fund, perform, implement, inform and facilitate innovation. The key players include government, public research institutions, industry, academia and other organisations (OECD, 2015). The main actors in AIS in China also include government, public research institutes, colleges and universities, enterprises and intermediate organisations. Family farms, farmer co-operatives, agricultural enterprises and other agribusinesses are important actors in the AIS (Table 6.1).

Both central and local governments are responsible for formulating, implementing and managing the policies related to agricultural innovation, developing the institutions and infrastructure to support agricultural innovation, and making investments. These governments are also directly involved in R&D and extension activities. For example, they fund agricultural R&D; provide education and training to human resources engaging in AIS; and are involved in extension and application of agricultural innovations through public and private agricultural extension services.

The government structure at the provincial and municipal level resembles that of the central government. The local governments are important actors in the innovation governance structure. Provincial counterparts exist for all the central government ministries and agencies. Science and Technology Commissions are established in each province, minority autonomous region and municipality. Provincial governments play a major role in policy making, implementation and financing R&D and innovation. However, OECD (2008) finds that the lack of a co-ordination mechanism between the central and provincial governments may reduce the efficiency of China's innovation system as a whole and delay the creation of a truly national system of innovation which makes optimal use of regional R&D and innovation resources and strengths.

Figure 6.3. China's public agricultural R&D system



Source: Huang, Hu and Rozelle, 2003.

Higher education institutions including colleges and universities undertake more basic areas of agricultural R&D and develop human resources for the AIS. Additionally, enterprises in the same industry or industry chain often form associations or alliances to implement joint R&D programmes and to learn from each other, complementing the resources available to each enterprise. Intermediary agents such as industry associations and farmers' co-operatives function as a bridge between farmers and other actors of AIS, including public research institutions, colleges and universities, and enterprises. Given the nature of China's agricultural structure, these intermediate agents play an important role in promoting the flow of knowledge, capital, information and talents, and matching the supply and demand of agricultural innovation.

Table 6.1. Major actors in the agricultural innovation system in China

Type	Participant	Role
Government	Central government Provincial government Municipal and county government	Designing rules and measures for supervising and stimulating innovation; providing basic knowledge, industrial generic technologies and infrastructure for technology innovation; providing capital and necessary conditions for innovation.
Public research institutions	Research institutes	Playing a leading role in basic research, applicable research and strategic technical development; undertaking high-risk research.
Colleges and universities	Universities Independent colleges	Incubators of talents and knowledge; central pillar bridging industry and scientific basic research
Enterprises	Trans-national corporations Large- and medium-sized enterprises Small-sized enterprises	Sponsoring and innovating new technologies and products; promoting the commercialization of science and technology achievements by applying their results.
Intermediary organisations	Industrial alliances Industrial associations Farmers' co-operatives	Functioning as a bridge between farmers, industries, R&D institutions to promote technology innovation.

AIS governance and coordination mechanisms

The governance of the AIS should ensure that national priorities are coordinated and communicated clearly, that progress is monitored, and policy outcomes and impacts are evaluated against the defined objectives. The integration of the AIS into the overall governance of the innovation system ensures a better use of public funds and increased efficiency through the pooling of different types of expertise.

In China, the leading group of science and technology education of the State Council oversees the innovation system and plays a key role in the decision-making for major innovation plans, including coordinating related ministries and agencies at the national level. The Ministry of Science and Technology (MOST) and the State Intellectual Property Office develop R & D innovation policy, including for agriculture. The Ministry of Agriculture (MOA), Ministry of Water Resources (MWR) and the State Forestry Administration then implement the agricultural R&D policy, together with the attached public R&D institutions. The National Development and Reform Commission (NDRC) and the Ministry of Finance (MOF) allocate public funding for innovation and the technological upgrading of various economic sectors, while the National Natural Science Foundation of China plays an important role in allocating resources for scientific research (OECD, 2008).[2]

China defines different responsibilities for the actors in AIS, including public agricultural R&D institutions at national, provincial and municipality level, experimental stations and enterprises' technology research and development centres (Table 6.2). The national agricultural R&D institutions perform research on key technologies, high- and new technologies with strategic significance, basic and applied agricultural research, as well as general basic scientific and technological work. Regional agricultural research centres are responsible for developing key technologies that have a broad application for regional industrial development. These centres also engage in applied basic and frontier research where China boasts strengths and specialty. They are also involved in integrating and transferring key technologies.

Agricultural science and technology experimental stations apply achievements of research in typical agricultural areas and agricultural ecological areas of different types, integrate such achievements, demonstrate experiments and spread technologies. The agricultural R&D divisions of enterprises conduct, on a commercial basis, independent research or combine production, learning and research to promote R&D and process improvement of agricultural inputs, and major agricultural and forestry processed products.

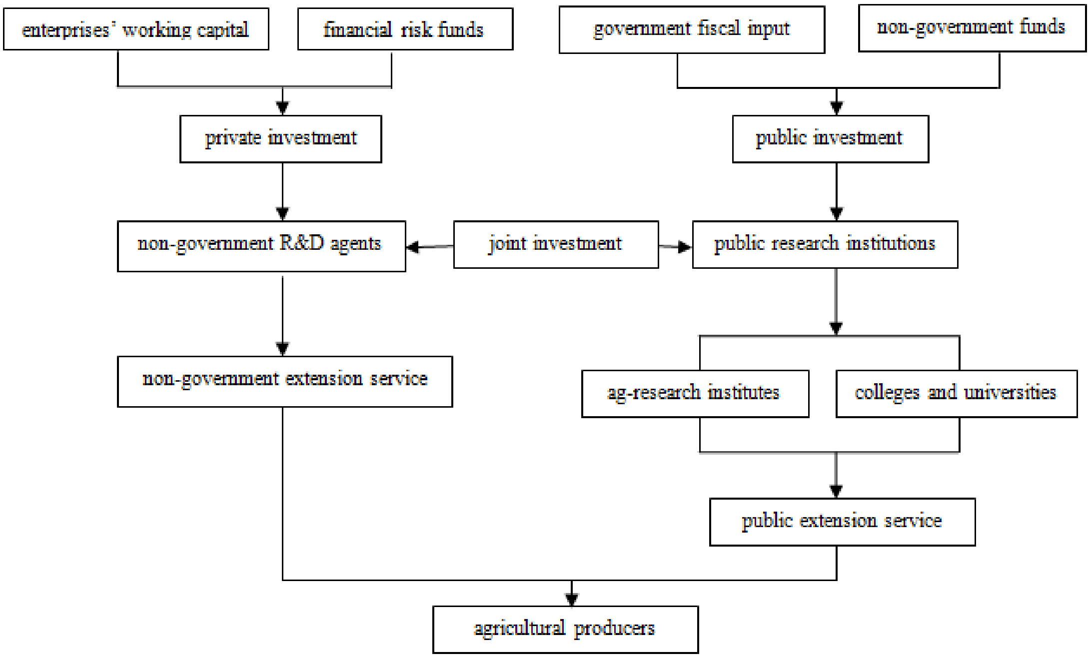
Table 6.2. Responsibilities of major participants in agricultural innovation system

	Basic research	Applied research	Experiment and development	Extension and application of results
Government	√	√	√	√
Public research institutions	√	√	√	√
Colleges and universities	√	√	√	√
Enterprises		√	√	√
Intermediary organisations				√
Agribusinesses				√

The government often plays a major role in investing in agricultural innovation, as certain agricultural knowledge and technologies have a public goods nature and it often takes time to get returns from the investment. The benefits of R&D often have a spill-over effect to other firms and consumers, justifying government investment in R&D. The market failure argument was originally formulated to bolster public support for basic research, but a recent economic study finds that large gaps in the social and private rate of returns apply for a wide range of industries, including agriculture (Pardey, Alston and Ruttan, 2010). However, the public sector could crowd out private investment in agricultural R&D if it competes with private investors in the development of new technologies. This is not the case if public sector focuses on the areas where a large gap between social and private returns on investment exist (OECD, 2016).

In China, there are two sources of public investment in agricultural R&D. The first is investment from government departments, which have different focuses at different administrative levels (i.e. national, provincial and municipal level), or are sourced from different projects, such as from the National Natural Science Foundation, the Major National Science and Technology Projects, the National Key Research and Development Plans, the Guiding Projects for Technology Innovation, or the Innovation Base Projects and Talent Projects (State Council, 2014). The second form, not as common in China, is non-government funds coming from various donors, which is more likely to finance basic and non-profit agricultural research (Figure 6.4).

Figure 6.4. Investment in Agricultural R&D and innovation



In China, private investment in agriculture R&D takes the form of investment by enterprises, financial institutions and venture capital. The private sector mainly invests in agricultural R&D activities that have a high market return on investment. They tend to concentrate on applied and development research and on areas that protect their returns through the protection of their intellectual property rights. For example, private investors favour sectors such as food processing, agricultural chemical inputs, farming machinery, hybrid seeds and genetically modified crops breeding (Zhao, Liu and Yang, 2015). In general, good performance of the agricultural innovation system hinges on strong investment over the long term, and tripartite collaboration between education, research and industry to explore complementarities.

Several forms of joint investment in agriculture R&D between public and private funds exist in China. Private enterprises compete for public agricultural R&D projects. Alternatively, the government sometimes funds private R&D activity directly. The private sector may also participate in application of new technologies developed by government research institutions. Collaboration in R&D activities between public agricultural R&D institutions and the private sector is a common format of public-private partnership in agricultural R&D (Box 6.1). Agricultural producers and other agribusinesses adopt technologies based on scientific results and communicate their needs to agricultural R&D institutions and extension staffs. This encourages problem-oriented decision making for public R&D activity.

Box 6.1. Collaboration between public agricultural R&D institutions and private sector

In China, public R&D institutions have been collaborating with the private sector for the last decade to complement research funding and to apply R&D outcomes in practice. This allows public R&D institutions to share risk, deepen cooperation, and share research and development responsibility.

In general, five categories of collaboration exist. First, research staff in public R&D institutions engages in R&D activity in private enterprise on a part-time basis. This is one of the most simple and feasible modes of cooperation. Second, joint development of new technology has become a common model of cooperation: public R&D institutions, higher educational institutions and enterprises work together to develop new materials, new products, new technology, new equipment. The third model involves indirect cooperation between public R&D institutions and the private sector through intermediaries such as brokers, consulting firms, industry associations, federations and government agencies and departments. These intermediary institutions play a major role in bridging, monitoring and coordinating the cooperation. Fourth, public R&D institutions and the private sector sometimes establish a joint research institution. This model of cooperation can clarify the direction of R&D and reduce waste of resources, thus shortening the research cycle. It also can share the responsibility between researchers and the private sector, thus shortening the industrialisation cycle of R&D outcomes. Finally, public R&D institutions and the private sector could set up an enterprise. In the current legal framework, three types of companies are the most practical: a limited liability company; a joint stock limited company; a cooperative organisation.

The key objectives and priorities in overall science and technology development in China are set by the National Plan for Long- and Medium-Term Scientific and Technological Development (2006-2020) (State Council, 2006). The Plan aims to make innovation the driver of future economic growth and to build up an indigenous innovation capability in China. Based on this objective, the Plan has set the specific goal that science and technology development should contribute to 60% of economic growth and the intensity of R&D investment increase to 2.5% of GDP by 2020.[3] The National Plan for Science and Technology Talent Development (2010-20) addresses the business sector's need for innovative human resources through supporting the mobility of highly skilled personnel and investing in innovation platforms and key national laboratories to foster talented and leading R&D personnel.

The most recent 13th Five-Year Plan (2016-2020) called for an innovation-driven development strategy. Based on the Outline of the National Innovation-Driven Development Strategy published in May 2016, the State Council issued its 13th Five-Year Plan for National Science and Technology Innovation in August 2016. This Plan set the basic principles of science and technology innovation and announced 12 major targets; these targets included raising the national innovation capacity ranking to the top 15 in the world, and increasing the GDP share of the knowledge-intensive service industry to 20%. Additionally, development of productive, safe and ecological modern agricultural technology is included as one of the top ten strategic research areas. Following the 13th Five-Year Plan for National Science and Technology Innovation, the MOA issued the 13th Five-Year Plan for Agricultural Science and Technology Development in February 2017. This Plan lays out the objectives and targets of agricultural R&D up to 2020 (Box 6.2).

Box 6.2. 13th Five-Year Plan for Agricultural Science and Technology Development

The Plan announced three stages in the long-term objective of agricultural science and technology development: catching up to advanced country level in agricultural science and technology innovation capacity by 2020, becoming one of the leading countries by 2030, and being the leader of world agricultural science and technology innovation by 2050. The plan set three basic principles of agricultural R&D: 1) demand and problem-solution orientation; 2) following the basic principles of public, basic, socially-oriented and market mechanisms; and 3) independence and originality of innovation.

Based on the overall objectives and basic principles, the Plan identifies specific targets and indicators of outcomes for its reference period in 11 fields. For example, in the area of seed modernisation, the Plan aims to achieve 97% self-sufficiency of main crops and a contribution of more than 50% of grain yield growth from new variety through a breakthrough in the identification of genetic resources and developing high quality and more efficient seeds more suitable to farm mechanisation. The area of efficient use of agricultural resource sets a target of reducing agricultural non-point source pollution of nitrogen and phosphorus emissions by more than 30% through developing non-point source pollution control technology.

To achieve the targets, an action plan covering all the stages of agricultural innovation system includes: 1) development of agricultural science technology; 2) extension of technology; 3) human resource development; and 4) institutional innovation. In the area of science and technology development, priority is put on comprehensive solutions for regional agricultural problems, reducing chemical fertiliser and pesticide, farmland conservation, improvement of water use efficiency, livestock breeding, comprehensive mechanisation, waste recycling, safety and quality, and management of agricultural non-point source pollution.

The plan also proposes institutional reform to strengthen co-ordination between AIS actors, such as the establishment of an inter-ministerial coordination mechanism, improving the linkage between ministries and provincial government, and strengthening public and private collaboration. The reform of the organisation and management of innovation includes the establishment of a network model of science and technology innovation, a national innovation platform, comprehensive human resource development, and an effective monitoring and evaluation mechanism.

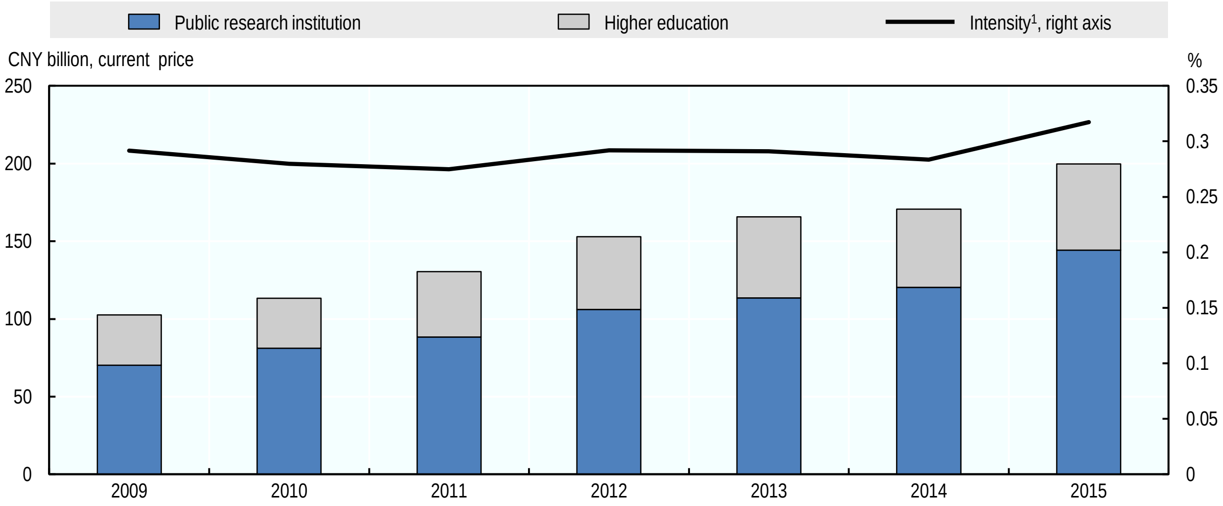
6.3. Investments in agriculture R&D

Trends in public agricultural R&D spending

In China, the majority of agricultural R&D spending is made by the government. Although information on private R&D expenditure in agriculture is not available in China’s official statistics, Chen (2009) estimates that it accounts for only 10-20% of the overall investment in agricultural R&D. Public research institutions are the main performers of agricultural R&D activities, which account for 60-70% of the total public agricultural R&D expenditure in China. The public agricultural R&D spending by public research institutions and higher education account for around 0.3% of value added in agriculture, forestry and fisheries in recent years (Figure 6.5).

Public agricultural R&D expenditures in China more than doubled between 2002 and 2010, when measured in purchasing-power-parity (PPP) dollars (Figure 6.6). By contrast, public expenditure in the United States declined by 10% in the same period, overtaken by investment by the private sector. The rapid increase in the size of public expenditure for agricultural R&D in China in the last decade made China one of the largest investors in public agricultural research in the world.

Figure 6.5. Expenditures for public agricultural R&D in China, 2009 to 2015



Notes: R&D expenditure in public agricultural R&D institutions is defined as intramural expenditure on R&D in agriculture, forestry, animal husbandry, fishery and related service activities. Intramural expenditure on R&D in agriculture, forestry, livestock and fishery in higher education is estimated based on the share of expenditure for these disciplines.

1. Share in agriculture, forestry and fisheries value added.

Source: NBSC and MOST (2016), China Statistical Yearbook on Science and Technology 2016.

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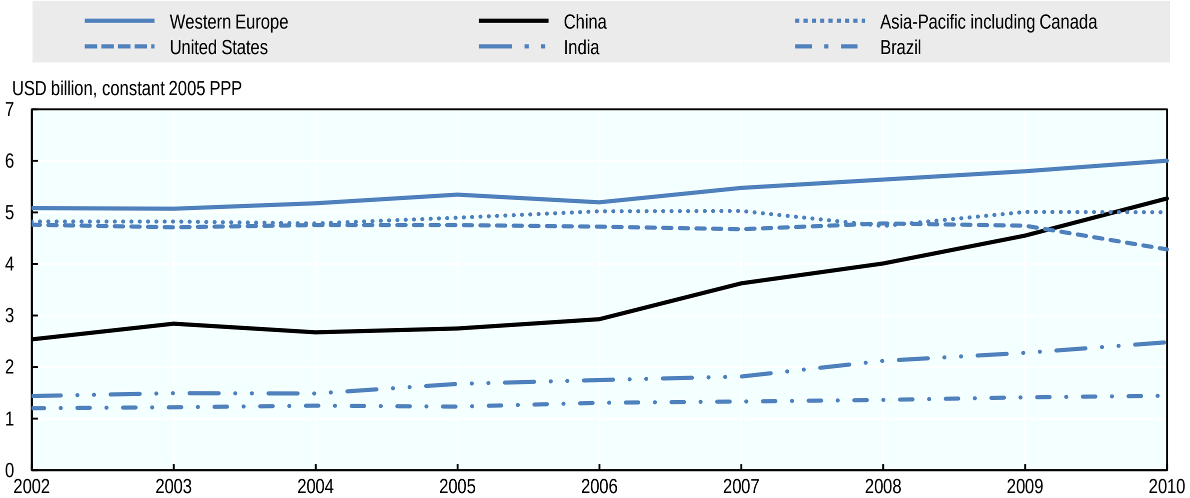
Figure 6.6. Expenditures for public agricultural research by China and selected countries and regions, 2002 to 2010



Source: Agricultural Science and Technology Indicators (2015) (ASTI), OECD and USDA (2015) Economic Research Service.

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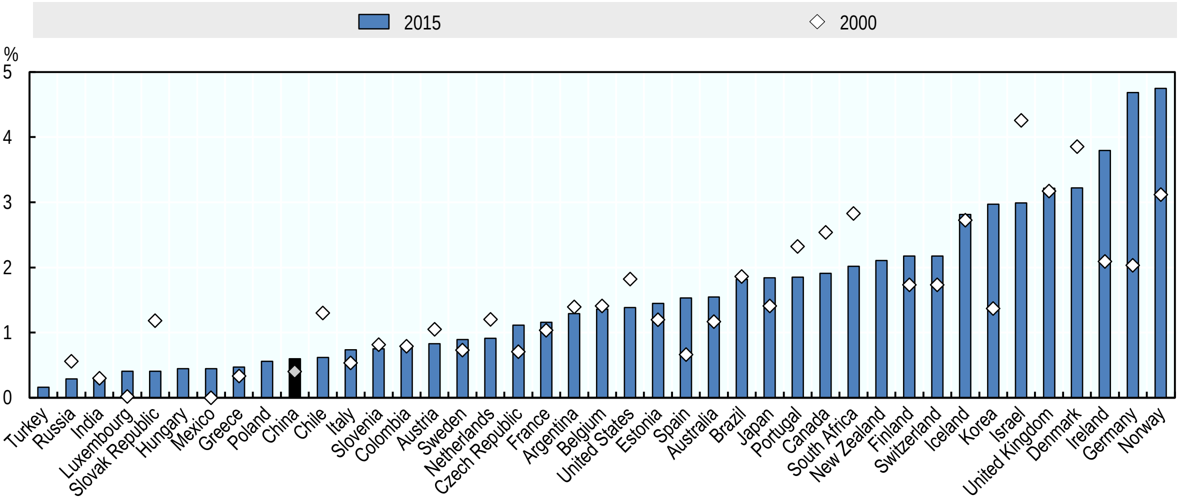
Despite an increase in public agricultural R&D expenditure, the intensity of agriculture R&D spending in China remains lower than most OECD countries and Brazil.[4] China's intensity in agricultural R&D is lower than the average intensity of 1% around the globe and 2% in developed countries (Figure 6.7).

Figure 6.7. Share of agriculture R&D spending as a percentage of agricultural gross value added, 2015 and 2000*



Notes: * or closest available year.

Total agricultural R&D spending (excluding private for-profit sector) includes salaries, operating and programme costs, as well as capital investments for all government, non-profit, and higher education agencies involved in agricultural research in the country.

Source: OECD (2017b), [Research and Development Statistics, National Accounts]; ASTI (2017) for Argentina, Brazil, Chile, China, Colombia and South Africa (accessed in June 2017).

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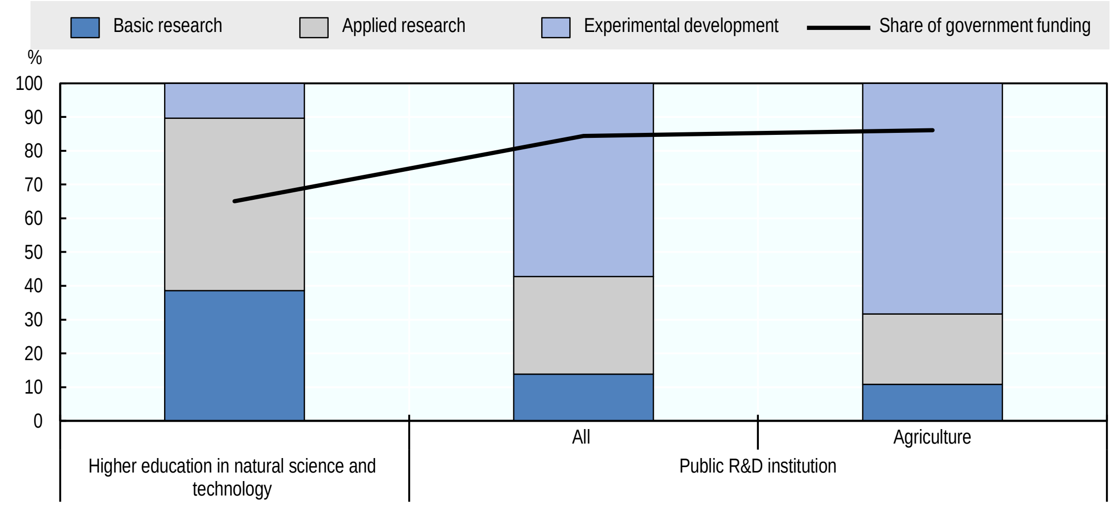
The public agricultural R&D institutions financed 86% of R&D expenditure with government funding in 2015, which is higher than the public R&D institutions in other research areas (Figure 6.8). By contrast, R&D expenditure in higher education is financed more by non-government funds, which accounted for 35% of R&D expenditure in natural science and technology in 2015. Although China is trying to establish a system of diversified channels of investment for public agricultural R&D, considerable room still exists for a greater involvement of the private sector. The role of the public R&D system in China needs to be redefined, increasing the agricultural R&D capacity in the private sector.

In the area of research, 68% of the expenditure of agricultural R&D in public agriculture R&D institutions in 2015 was directed to experimental development, and basic research accounted for 11%. By contrast, higher education institutions focus more on basic research, which accounted for 38% of their R&D expenditure. Public R&D investment should concentrate more on areas of public interest and on those in which the private sector would under-invest, such as basic and pre-competitive applied research.

The distribution of R&D expenditure in public R&D institutions and higher education in China shows a strong focus on the crop sector (Figure 6.9). In 2015, investment in the crop sector accounted for 56% both in public research institutions. While the share of livestock products in agricultural production has increased, public R&D investment still favours the crop sector, reflecting the self-sufficiency objective in grain production (Box 6.3).

Figure 6.8. R&D expenditure by research area and funding source in China, 2015



Source: NBSC and MOST (2016), China Statistical Yearbook on Science and Technology 2016; MOA (2016), National Statistics of Agricultural Science and Technology 2016.

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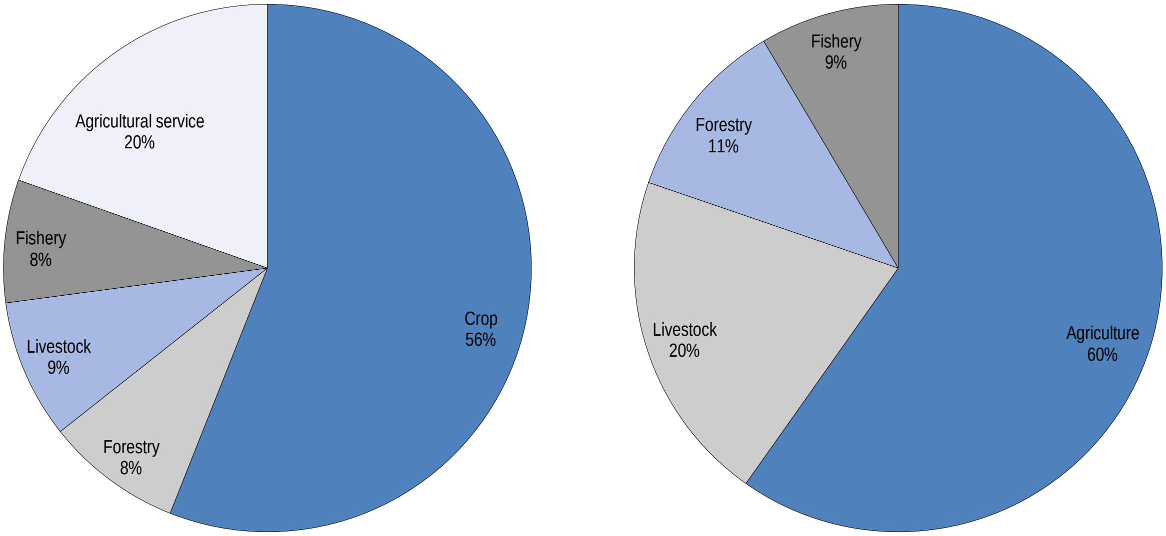
Figure 6.9. Distribution of agricultural R&D expenditure by area in China, 2015

A. Public research institution

B. Higher education



1. Area of research is classified by industry area and discipline in public research institution and higher education, respectively.
2. Numbers may not add up to 100 due to rounding.
Source: NBSC and MOST (2016), China Statistical Yearbook on Science and Technology 2016; MOA (2016), National Statistics of Agricultural Science and Technology 2016.

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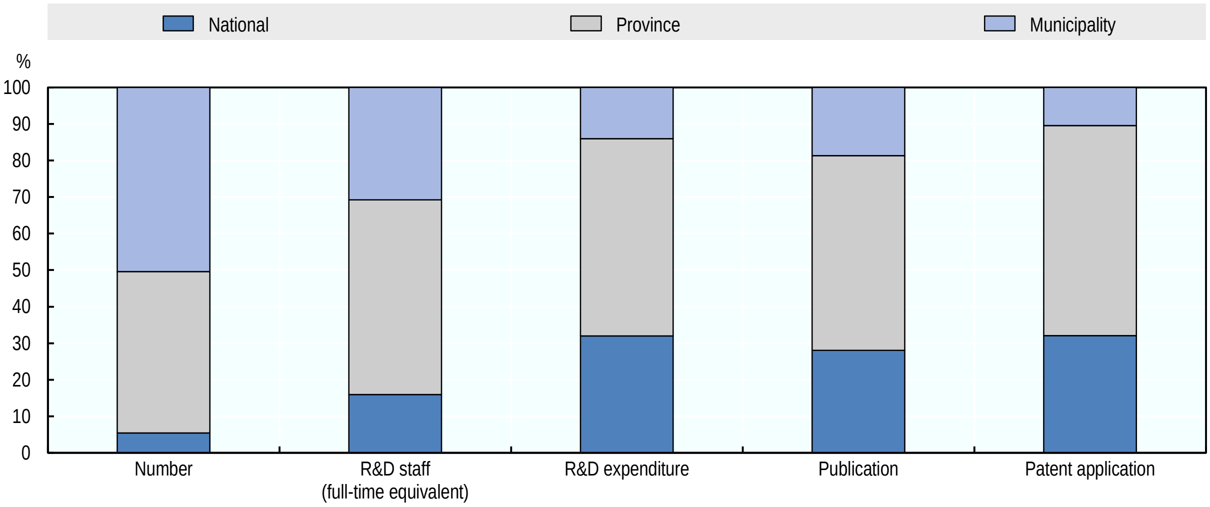
Public agricultural research institutions exist at national, provincial and municipality levels. The majority of R&D staff in public agricultural research institution is at the provincial level institutions, which account for more than half of the R&D expenditure (Figure 6.10).

The national level institutions, which belong to the MOA, account for 16% of overall R&D staff in public research institutions, but their share in R&D expenditure is around 32% in 2015. They also spent a higher share of R&D expenditure for basic research (21%) than those at provincial level (7%) and municipality level (2%). R&D on experimental development accounts for nearly 90% of R&D expenditure for the public research institutions at the municipality level.

Figure 6.10. Public agricultural R&D institutions at national and sub-national level in China, 2015



Source: MOA (2016), National Statistics of Agricultural Science and Technology 2016.

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Box 6.3. R&D of farm machines and seeds in China

Over the past 10 years, China has achieved remarkable results in developing large agricultural machinery for the plains of north and northeast China, but there is a lack of suitable machinery for the mountainous southwestern regions. In the future, mechanisation is expected to expand from grains to cotton, rapeseed, sugar cane, potato and forage as well as livestock production. The scope of mechanised tasks is also expected to expand from planting and harvesting to deep ploughing, deep loosening, prevention of plant diseases and insect pests, as well as marketing activities such as processing, packaging, warehousing, and transportation of agricultural products.

To encourage R&D in agricultural machinery technology, the Chinese government promulgated the Law on Promotion of Agricultural Mechanization in 2004, with articles providing support of capital, projects and policies for R&D, extension and social services of agricultural machinery. Since then, a series of documents have been issued emphasising support for agricultural mechanisation, such as the Opinions of the State Council on Promoting Fast and Sound Development of Agricultural Mechanization and Agricultural Machinery Industry, the Development Plan of Agricultural Machinery Industry (2011-2015), China’s 12th Five-Year Plan of Agricultural Mechanization Technology Development (2011-2015), and China’s 13th Five-Year Plan of Agricultural Mechanization Technology Development (2016-2020).

Over four decades after the opening-up reform, China has made significant achievements in agricultural biotechnology and other high-tech fields, like breakthroughs in core technology including hybrid rice, transgenic insect-resistant cotton, dwarf male-sterile wheat, and genetically engineered vaccines for major animal diseases. China has built a system for space-breeding technology to cultivate new varieties and strains of rice, wheat, cotton, green pepper and tomato; it has successfully applied, in a wide range, the technologies of livestock embryo transfer and splitting, gender determination and in vitro fertilisation, and produced test-tube sheep and cattle, clone sheep and cattle, and genetically-modified cattle. China has also fostered new high-quality aquatic species with nuclear transplantation and transgenic technology. In addition, China has selected core and micro-core germplasm of rice, wheat, and soybeans, and cloned a number of important genes. At the same time, further efforts are needed to strengthen survey, collection, protection, evaluation and use of germplasm resources, advance the reform concerning the rights and interests of R&D achievements in the seed sector, and speed up the cultivation of modern seed enterprises which are internationally competitive.

6.4. Fostering knowledge flow: Intellectual property protection

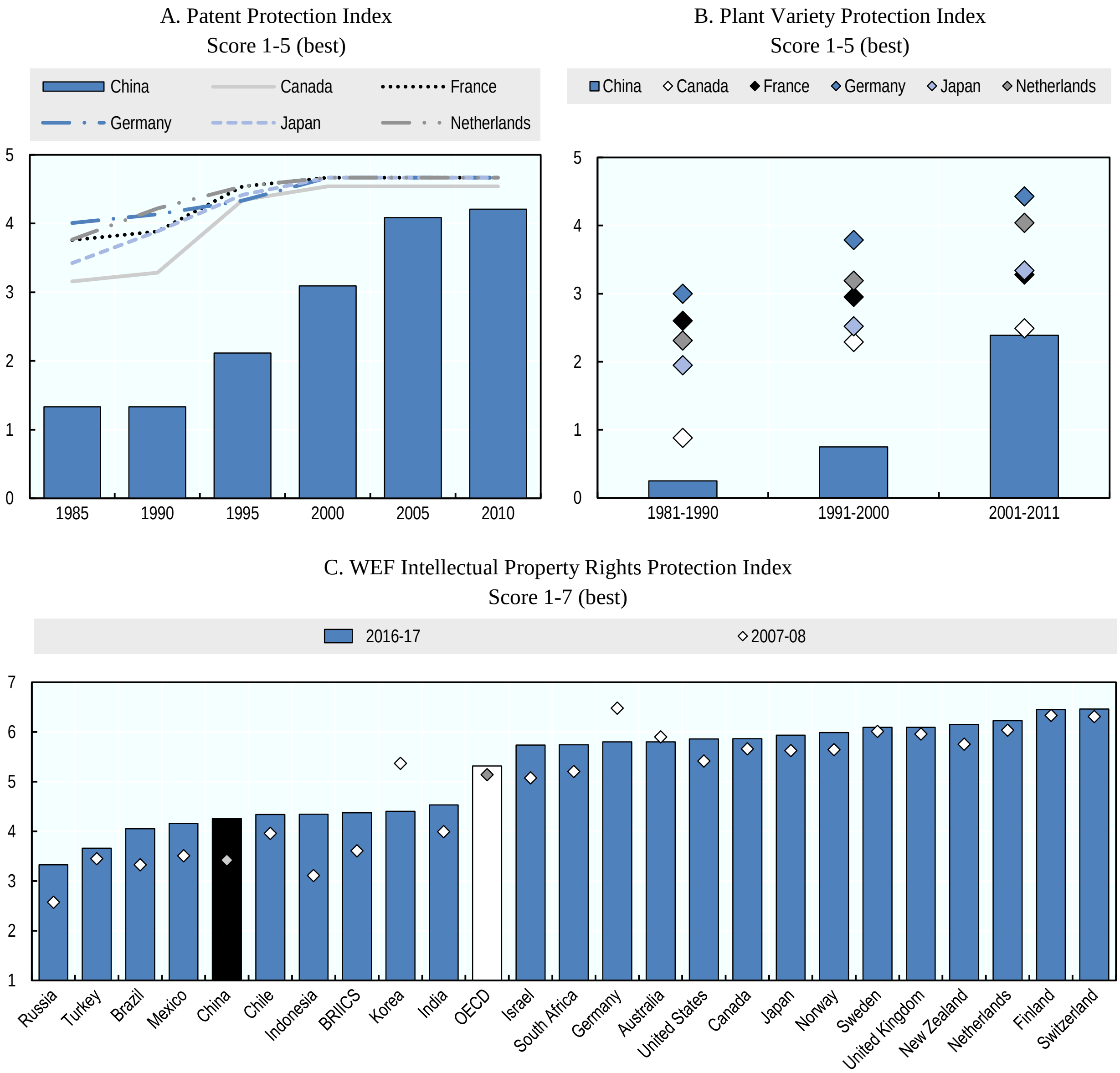
The fragmented structure of agricultural production (relatively small firms producing multiple homogeneous products) makes few farms willing to invest in private R&D activities. Meanwhile, the biologically self-replicating nature of improved crop seed and animal breeds complicates the ability of innovators to protect intellectual property (OECD, 2016). Private firms would not have an incentive to invest in agriculture R&D unless they can recover the cost of doing so. To foster private R&D, China should allow private firms to maintain exclusive control over their discoveries by protecting intellectual property rights (IPR).

Although a system granting inventors' certificates and exclusive patent rights has existed since the 1950s, the modern IPR protection system in China was established after the late 1970s, when the country initiated its opening-up reform policies. Since the 1980s, China has developed a number of laws and regulations covering the main areas of IPR protection and has continued strengthening them.[5] For example, the Patent Law first enacted in 1985 was amended three times (1992, 2000 and 2009). China has also issued a series of relevant rules for the implementation of these laws and regulations, and their legal interpretations.[6]

China is increasingly participating in the international rules of IPR protection. For instance, China joined the *Madrid Agreement Concerning the International Registration of Marks* in 1989, the *Universal Copyright Convention* in 1992, and the *Patent Co-operation Treaty* (PCT) in 1994. China also made comprehensive revisions to its laws and regulations regarding IPR protection and their legal interpretation prior to its participation to the WTO in 2001, to comply with the WTO's *Agreement on Trade-related Aspects of Intellectual Property Rights*. China joined the International Convention for the Protection of New Varieties of Plants and World Intellectual Property Organization Copyright Treaty in 1999 and 2007, respectively.

Several cross-country indicators confirm the improvement of IPR protection in China in recent years. For example, the patent protection index developed by Park (2008), which accounts for patent duration, enforcement, loss of rights, membership and coverage, improved significantly between 1990 and 2005 (Panel A in Figure 6.11). Similarly, the Plant Variety Protection Index, developed by Campi and Nuvolari (2013) shows an improvement, particularly during the 2000s (Panel B in Figure 6.11).

Figure 6.11. Intellectual property protection, selected years



Note: Indices for BRIICS and OECD are the simple average of member-country indices. The OECD aggregates do not include Lithuania.

Source: Unpublished update to the series from Park, W. G. (2008), "International Patent Protection: 1960-2005", Research Policy, No. 37, pp. 761-766 (panel A); Campi, M. and Nuvolari, A. (2013): Intellectual property protection in plan varieties: A new worldwide index (1961-2011), LEM Working Paper Series, No. 2013/09 http://hdl.handle.net/10419/89567 (panel B); World Economic Forum (2016), The Global Competitiveness Report 2016-2017: Full data Edition, Geneva 2016. www.weforum.org/reports/the-global-competitiveness-report-2016-2017-1 (panel C).

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Despite improvements, these indices show that China's IPR protection is still weaker than in most OECD countries. According to the World Economic Forum, IPR protection in China is still weaker than OECD and BRIICS averages (Panel C in Figure 6.11). The literature finds that the enforcement of IPR laws and regulations remains an issue (e.g.

Yueh, 2009). In China, enforcement can occur through the judicial system or the administrative system, but both judicial and administrative decisions are difficult to enforce owing to the lack of appropriate infrastructure and mechanisms as well as of manpower (OECD, 2008). Effective enforcement is often restricted by local government (Shi, Pray and Zhang, 2012). China should improve the enforcement of the laws, especially at the local level, to attract more private R&D investment in agriculture.

6.5. Facilitating knowledge flows and linkages within AIS

Reinforced linkages across participants in agricultural innovation can help match the supply of research to demand, facilitate technology transfer and increase the impact of public and private investments. Many agricultural technologies tend to be geographically specific, meaning that they do not transfer directly to other locations with different soil types, weather patterns, or topography. These features imply that unique policies to foster innovation in agriculture are required (OECD, 2016).

Traditionally, public agricultural extension services facilitate knowledge flows from public research institutes to producers. With the introduction of the household responsibility system in the late 1970s, China started to establish a public agricultural extension system (PAES), and had built extension service centres in all rural counties and municipalities by the mid-1980s. In 1985, to reduce public expenditure for the PAES, the central government started to encourage PAES to earn income through commercial activities such as selling farm inputs. However, some studies find that the conflict of interest that resulted from allowing public extension agents to pursue commercial activities resulted in weakening the public function of the extension system (Hu, Huang and Li, 2004; Qia, Zhang and Hu, 1999; Sun, 1993; Hu and Huang, 2001). In 2000, the government started to enhance the non-commercial function of PAES.

A MOA survey indicates that the government financed 80% of funding of the local extension organisations in 2011 (Zhong, 2014). PAES centres provide a range of services: introducing modern input factors to rural areas, including new technology, information, human resource management and capital. They also help to develop new businesses and to build agricultural technology parks and industrialisation bases. At present, they cover 90% of counties and municipalities. By the end of 2015, there were 16 000 technical service centres, housing 729 000 extension officers who provided technical services to 12.5 million farming households, equivalent to a total of 60 million farmers (MOST, 2016). Agricultural extension officers have three ranks according to experience and qualification, which is a part of the national vocational qualification system.

China also started an initiative to build agricultural technology parks to demonstrate new technologies and facilitate the collaboration between agriculture and other industries. National Agricultural Science and Technology Parks (NASTPs) are intended to create innovation hubs and an entrepreneurial chain to strengthen the transformation and incubation function of agricultural science and technology achievements. In 2001, MOST, MOA and six other Ministries jointly launched a pilot project to construct 65 NASTPs nationwide. By the end of 2015, 246 NASTPs had been established by both public and private funds. This system also combines non-profit and profit services, special and comprehensive services (MOST, 2016). Each park is composed of a core area, a demonstration area and an extended zone. The principle of the operation is defined as "government guidance, enterprise operation, intermediary participation, farmers benefit". The most recent 2017 No. 1 Document also promoted the development of NASTPs to demonstrate innovative technologies, apply R&D outputs, train human resources and support new business plans.

The Chinese government has also established a system for training and extension of agricultural machinery technology, including trials, demonstration and on-farm technical advice. Local governments and non-government organisations set up agricultural machinery leasing centres, harvesting machinery service centres and agricultural mechanisation associations; these provide comprehensive services related to the use of various agricultural machines, compensating for gaps in government services.

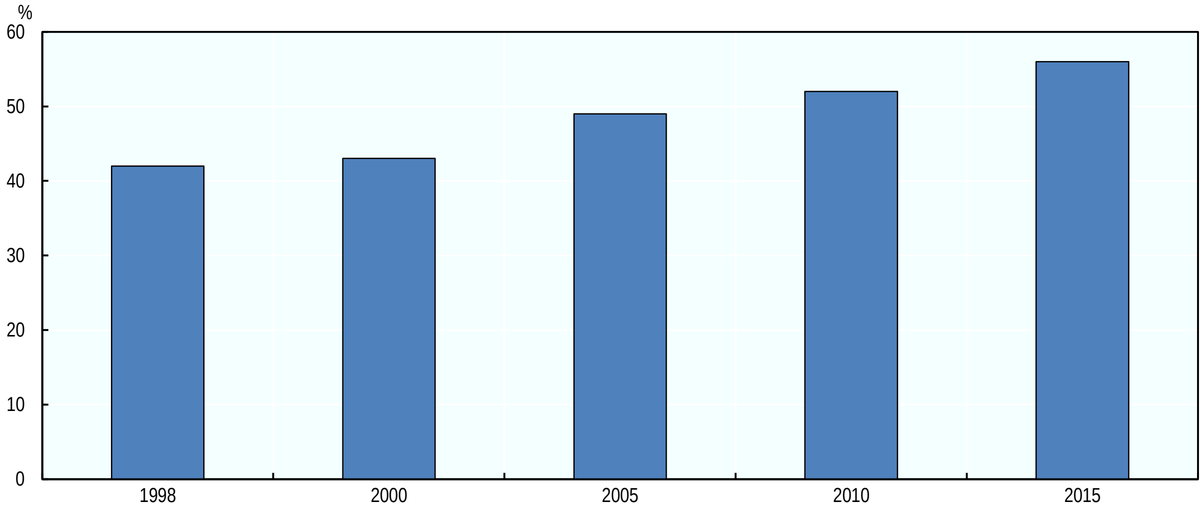
The government recently increased public support to training of farmers and agriculture co-operatives as a part of an initiative to foster the new professional farmer. For example, the central government allocated CNY 1.1 billion (USD 175.1 million) in 2015 to carry out training programmes for large specialised farmers, operators of family farms, leaders of agricultural co-operatives, personnel from agribusinesses and agricultural service providers, as well as returning migrated workers. This programme covers 4 provinces, 20 municipalities and 500 demonstration counties. Other programmes include training programmes for rural practical talents and for rural leaders with university degrees, the “million vocational school students” plan to increase the annual enrolment to vocational school to more than 70 000, and the National Top Ten farmers’ funded projects.

Several forms of education and training of the new professional farmer exist in China. First, farmers’ cooperatives offer training courses, which often meet the practical needs of farmers to understand technical issues such as rice cultivation technology. Second, some communities offer farming schools, which are normally designed for farmers who have lost land to find new employment in intensive agricultural production operations. Third, evening school is organised in many rural areas in China developing a “one village one product” initiative to produce a village speciality product. Training classes are organised at night to learn production and processing technologies such as planting tobacco and hybrid rice cultivation, off-season vegetable production technology and rice flour processing technology.

The government needs to ensure that outcomes and impacts of agricultural innovation policies are evaluated against their policy objectives. Monitoring progress in innovation across time and across countries can be useful in evaluating and adjusting R&D policy. Overall progress to create and adopt relevant innovations can be monitored by proxy measures, such as the number of patents and of bibliographic citations, which is available from international databases (OECD, 2015).

As a result of its increasing public investment in agricultural R&D, China achieved significant improvements in breeding technology for major grains. Along with subsidy polices for quality seeds and a public extension system to ensure 96% of crop seeds are of high quality, development of new breeding technology strongly supported the stable yield growth of major agricultural products. Per-ha yield of rice, wheat and corn increased by 9.9 %, 44.2% and 28.1% in 2000-15, respectively, achieving one of the highest yield levels in the world. But this has been achieved at the cost of increasing environmental pressure due to the intensive input use.

Figure 6.12. Contribution of Agricultural Science and Technology Progress to agricultural output in China, selected years



Source: Song Hongyuan (2000) and Han Changfu (2015a).

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Despite strong growth of output and productivity, China still lags OECD countries in creating new knowledge and technology in agriculture and food science. Although the number of patents is not a comprehensive indicator of R&D outcomes as not all innovations are patented, it can be considered as a proxy for the output of the R&D system.

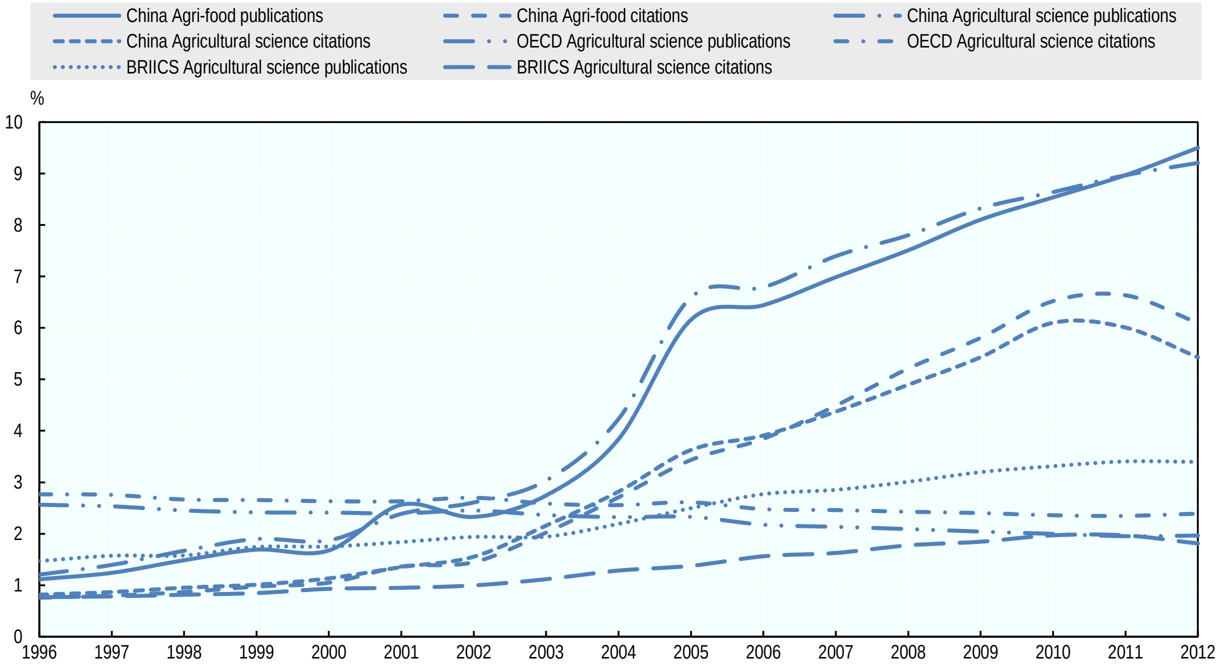
According to the agricultural patent application filed under the Patent Co-operation Treaty (PCT), which protects inventions in all signatory countries, China has become a significant contributor to total world agri-food patents (Table 6.3). China's share in patents is higher than OECD and BRIICS averages, but still lags that in the United States, the EU28 and Japan. Data on agricultural publications and citations also shows that China's contribution to world innovation increased rapidly from the early 2000s. China's share in global agri-food publication increased from 1% to 9% between 1996 and 2012, while the average contribution in OECD countries declined over time (Figure 6.13).

The number of applications for agricultural patents and new plant variety rights has been increasing in China; from 2007 to 2012, it grew by an annual average of 26%. According to the China Center for Intellectual Property in Agriculture, the number of applications and of those granted increased by 12.0% and 13.1%, respectively in 2013-14. However, there is still a large gap in the intensity of patent application between China and some OECD countries (Table 6.3).

Bibliometrics on agriculture and food sciences provide an additional measure of R&D outcomes. The number of China's agricultural science publications has been increasing rapidly since 2000, to the point that their share in the global total began to exceed that of the OECD. China's share in the world's agricultural science publications increased from 1.9% to 9.2% in 2000-12. Moreover, the number of China's agricultural science citations rose dramatically, from less than 2% to 6.1% of the world total between 2003 and 2010, outnumbering that of OECD (Figure 6.13).

Figure 6.13. Evolution of scientific output and impact in agricultural sciences, 1996 to 2012

Percentage of world output



Note: The OECD aggregates do not include Latvia and Lithuania.
Source: SCImago (2014), SJR — SCImago Journal & Country Rank, http://www.scimagojr.com (accessed March 2014).

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Table 6.3. Agriculture and food science R&D outcomes, 2007-12

	China	United States	EU28	Japan	Brazil	Russia	BRIICS average	OECD average
Agro-food specialisation: Agro-food science outputs as a share of country’s total (%)								
Patents	2.8	6.8	5.7	3.5	11.0	5.4	3.8	5.6
Publications	5.1	6.7	8.4	6.8	19.4	5.2	12.3	9.4
Citations	6.8	6.3	10.7	6.9	15.5	5.2	12.0	11.9
Country’s contribution to world agro-food science output (%)								
Patents	1.0	10.8	9.5	3.7	0.2	0.2	0.3	0.7
Publications	8.3	18.3	30.8	4.3	4.7	1.0	3.1	2.0
Citations	6.7	27.2	36.6	4.2	1.2	0.8	1.8	2.4

Note: Patent data refer to 2006-11.
Source: OECD Patent Database, January 2014; SCImago (2007), SJR - SCImago Journal and Country Rank, retrieved March 19, 2014, from http://www.scimagojr.com.

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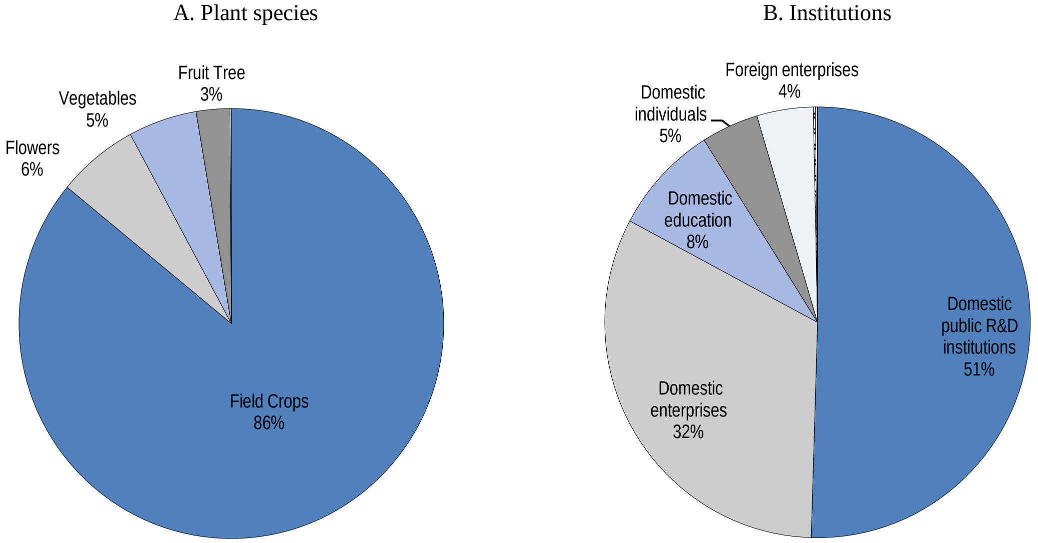
China applied for a total of 15 552 new plant varieties, 6 258 of which were granted for patent protection between 1999 and 2015. Field crops account for 86% of the new plant variety granted, followed by flowers, vegetables and fruit trees (Figure 6.14). In China, public R&D institutions received a majority of new plant variety rights, and foreign enterprises and institutions account for less than 4% of patents granted in 1999-2015.

During the 12th Five-Year Plan Period (2011-2015), China applied for the protection of 1 450 new varieties annually, a number that increased by 52% from the previous five-year period. Notably, in 2015, the number of applications of new varieties reached 2 000, reaching the second largest in the world (MOA, 2015a).

Figure 6.14. Share of new plant variety rights granted in China, 1999-2015



Note: Numbers may not add up to 100 due to rounding.
Source: NBSC and MOST (2016), China Statistical Yearbook on Science and Technology 2016.

StatLink http://dx.doi.org/10.1787/888933829664

Box 6.4. R&D and production of transgenic crops

The Chinese government identifies biotechnology as a strategic industry. China's agricultural biotechnology research started in the early 1970s. In the late 1970s, China began R&D on genetic engineering technology. The sustained funding for biotechnology started under the National High Technology Development (“863”) Program issued in Mach 1986. Transgenic crops in China were developed in the mid-1980s and virus-resistant tobacco was the first commercialised crop in early 1990. Although China has commercialised six genetically modified plants since 1997 (cotton, tomato, sweet pepper, petunia, poplar, and papaya), only papaya and cotton are in production today due to difficulties in bringing the products to commercialisation (GAIN-CH16065). Although the MOA approved the bio-security certificates of Bt rice and phytase maize, none has yet been approved for commercialisation. An important reason is public concern about the commercialisation of genetically modified crops. The government is also concerned that China's food biotechnology will be controlled by multinational companies, thus affecting the country's food security (Cai et al., 2017).

While China established a biosafety regulatory system in the mid-1990s and strengthened it in the early 2000s, the discovery of unapproved transgenic crops or unlabelled derived products implies that enforcement of the biosafety regulatory system could be improved (Karplus and Deng, 2006). The National Biosafety Committee developed a guideline for biosafety assessment (environmental and food safety) to streamline the processes. The Committee consists of 44 experts with diverse backgrounds from different Chinese ministries, research institutions, and universities (GAIN-CH13033).

In 2014, China was the 6th largest producer of transgenic crops worldwide. This ranking is primarily driven by 3.9 million hectares of insect-resistant Bt cotton produced by 7.1 million farmers (GAIN-CH15032). Since the approval of Bt cotton for commercial production in 1997, adoption has risen to approximately 80% of total cotton production. While there have been regional differences, empirical evidence suggests that farmers have achieved higher yields and net income gains from the use of Bt cotton compared to non-Bt traditional varieties (e.g. Smale et al., 2009; Qiao et al., 2016). In addition to increasing productivity, Bt cotton has also reduced environmental pressure and input costs through a reduced demand for pesticides. In the Hebei province, for instance, Bt cotton is associated with a 55% decrease in pesticide use (Pray et al., 2011). Interestingly, pesticide use has also declined on non-Bt cotton fields since 1999, suggesting that the spread of Bt cotton has reduced bollworm infestation on neighbouring crops (Pray et al., 2011).

Since 2004, China's imports of genetically modified food have increased rapidly. In particular, the annual import of genetically modified soybeans jumped from less than 20.17 million tonnes in 2004 to more than 81 million tonnes in 2015, almost seven times the total domestic production of soybeans in China. In addition to soybeans, China imports a large quantity of transgenic maize and rapeseed each year.

Accelerating the breeding of Genetically Modified Organisms (GMO) is listed as one of the strategically important R&D topics in the most recent 13th Five-Year Plan for National Science and Technology Innovation of 2016. The Plan promotes the commercialisation of key products, including the new generation Bt cotton, Bt corn, and herbicide-tolerant soybeans and pledges to establish the technical system for biosafety evaluation to guarantee safety of genetically engineered products (GAIN-CH16065). In 2016, China also revised the biosafety regulation on transgenic organisms. The amendments remove timelines for approvals, extend the National Biosafety Committee’s term from three to five years, and emphasise that entities engaging in GMO research and experiments are accountable for safety management (GAIN-CH16065).

The lack of a clear path to commercialise major biotechnology crop varieties (other than cotton) has limited incentives for local seed companies to invest in biotechnology. It has also encouraged public labs to focus on basic research rather than develop commercially viable seeds. Inconsistent protection of intellectual property and the fragmented nature of China’s seed industry further discourage private sector investment in biotechnology (GAIN-CH16065).

6.6. International co-operation on agricultural innovation

International co-operation in agriculture R&D offers universal benefits. The benefits of international co-operation for national innovation systems stem from the specialisation it allows and from international spill-overs. International co-operation in agricultural R&D is particularly important where global challenges (as in the case of responding to climate change) or trans-boundary issues (related to water use or pest and disease control) are confronted, and when initial investments are exceptionally high.

China’s key policies and documents have been focusing on promoting open development of agriculture, strengthening international exchanges and co-operation in agricultural science and technology, introducing and adapting foreign agricultural technology, and science and technology playing a better role in agricultural development. According to the plans of MOA and MOST, the key fields of international co-operation in agricultural science and technology include crop breeding and germplasm resources, animal and veterinary sciences, plant protection, agricultural applied microbiology, agricultural resources and environmental science, agricultural product processing and food safety, agricultural mechanisation and agricultural engineering, digital agriculture and agricultural information, agricultural economy and development as well as fishery and aquaculture.

China has undertaken both bilateral and multilateral co-operation efforts, but most of its agreements have been concluded on a bilateral basis. According to existing but incomplete statistics, China has established long-term bilateral co-operation agreements in agriculture with more than 140 countries, signed 189 agricultural co-operation and substantive agreements, and established 64 agricultural committees and working groups since 2011. Partners include both developed and developing countries. For example, the EU-China Cooperation Plan on Agriculture and Rural Development includes the FAB Flagship Initiative, which focuses on the areas of food security, sustainable agriculture and marine and inland water research and the bio-economy.

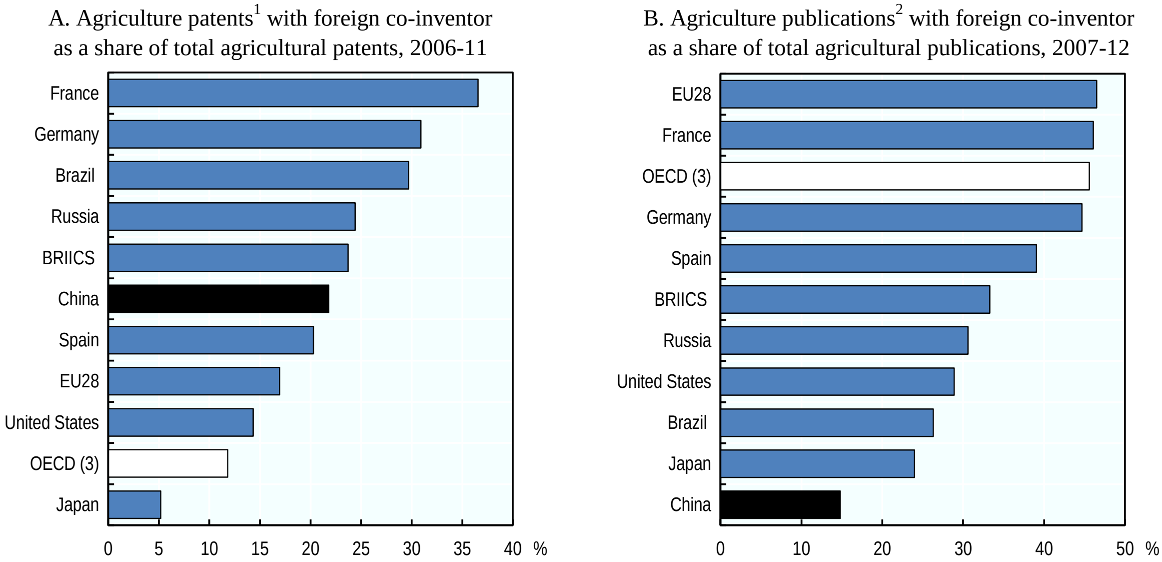
Multilateral co-operation includes partnerships with international organisations such as the FAO, UNDP, EU, ASEAN, CGIAR, CABI, PPIC, IAEA, IFS and the WWF. In addition, China has participated in regional agricultural co-operation efforts such as the co-operation between ASEAN, China, Japan and Korea (ASEAN+3), agricultural co-operation in the Shanghai Co-operation Organization, the China-FAO South-South Co-operation within the framework of the "Special Program for Food Security", and agricultural co-operation forums between China, central and eastern European countries.

China established a mechanism for introducing, training and stimulating talents to engage in international co-operation in science and technology, implement training plans of innovative talents and outstanding agricultural scientific research personnel, and speed up cultivating leading talents and innovation groups for international co-operation in agricultural science and technology.

By the end of 2014, China had arranged over 14 000 overseas visits and study-abroad programmes for Chinese scholars, students and short-term training staff, and invited more than 30 000 foreign experts to China. Over more than a decade, under the ASEAN+2 and ASEAN+3 frameworks, China has initiated over 150 agricultural exchange and co-operation projects, and trained more than 1 000 technical and managerial staff in ASEAN countries through courses in agricultural technology. Since 2004, China had trained more than 4 000 agricultural technical and managerial staff from Africa.

Internationally co-authored patents and publications reflect the degree of international collaboration. China's co-authored patents represented 22% of its all agri-food patents; a similar share for the OECD area was 12%, and 17% for the European Union. Around 10% of the country's co-authored patents was in the areas of agriculture and food processing, which is below OECD and BRIICS averages. (Figure 6.15 and Annex Figure 6.A.5). Between 2007 and 2012, Chinese authors produced a relatively small number of joint publications with foreign co-authors in agri-food sciences. In an international comparison, this constituted one of the lowest shares of total agricultural science publications in a country. Less than 15% of agriculture science publications by Chinese scholars had foreign co-authors, while almost every second publication in both the OECD area and in the European Union, and one-third in BRIICS had at least one (Figure 6.15 and Annex Figure 6.A.5). These indicators suggest that while China has been active in the integration of international collaboration frameworks in the agri-food area, it has yet to advance substantially in exploiting the potential of these frameworks.

Figure 6.15. International co-operation in agri-food R&D


A. Agriculture patents[1] with foreign co-inventor as a share of total agricultural patents, 2006-11

B. Agriculture publications[2] with foreign co-inventor as a share of total agricultural publications, 2007-12

1. Agriculture patents include IPC classes A01, A21, A22, A23, A24, B21H 7/00, B21K 19/00, B62C, B65B 25/02, B66C 23/44, C08b, C11, C12, C13, C09K 101/00, E02B 11/00, E04H 5/08, E04H 7/22, G06Q 50/02. Patent counts are based on the priority date (first filing of the patent worldwide), the inventors' country of residence, using simple counts.

2. Agricultural science publications include the following Scopus journal classifications: agronomy and crop science, animal science and zoology, aquatic science, ecology/evolution/behaviour systematics, forestry, horticulture, insect science, plant science and soil science, and miscellaneous agriculture/biological sciences.

3. The OECD aggregates do not include Latvia and Lithuania.

Source: OECD (2014b), Patent Database, http://www.oecd.org/sti/inno/oecdpatentdatabases.htm (panel A); SCImago (2014), SJR - SCImago Journal and Country Rank, http://www.scimagojr.com (accessed March 2014) (panel B).

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6.7. Summary

China has developed the world's largest and most decentralised public agricultural R&D system (Chen, Flaherty and Zang, 2012). Public investment in agricultural R&D accelerated in the 2000s both in expenditure and R&D personnel. The expenditure for agricultural R&D increased nearly four times between 2000 and 2013 in real terms (Stads, 2015). Although the size of expenditure for public agricultural R&D in China already exceeded that of the United States, making China the largest investor in public agricultural research, the intensity of public agricultural R&D expenditure is still lower than in most OECD countries.

In addition to technological progress and extension, institutional innovation is a core part of China's agricultural innovation system. The first stage was the introduction of the household responsibility system, which dissolved the collective farming system and provided households with individual land contract rights. The second stage removed agricultural taxes and fees, implemented a direct payment system and strengthened rural public services. The third stage includes a reform of the rural land system, introduction of new types of agribusinesses and building of new agricultural operation system such as Famer Professional Co-operatives and Specialized Custom Plowers, Planters and Harvesters (Han Changfu, 2015b).

With growing public investment in agricultural R&D, the output from agricultural R&D systems has improved significantly. China's share in global agri-food publication increased from 1% in 1996 to 9% in 2012. The number of applications for agricultural patents and new plant variety rights has been rapidly increasing in China, with an annual average growth rate of 26% between 2006 and 2011. However, China's global share in agri-food patents, publications and citations remains far below those in the United States and the EU28. The output of agricultural R&D systems indicates scope to improve the productivity of R&D expenditure in China.

In China, agriculture R&D activities are dominated by public agricultural R&D institutions, and private agriculture R&D expenditure is estimated to account for only 10-20% of overall agriculture R&D. The role of private agriculture R&D is lower than most OECD countries. In the United States, the private sector funded 76% of food and agriculture research and performed 72% of research activities in 2013. In particular, the private sector performs the majority of commercially viable areas of research such as food and feed manufacturing, farm machinery, and plant system and crop protection (OECD, 2016). By contrast, nearly three-quarters of the R&D expenditure of public agricultural R&D institutions in China is directed to experimental development research. The dominance of public R&D institutions is likely to be crowding out private investment in agriculture R&D in China.

Public agricultural R&D institutions in China are composed of numerous research institutes administered by multiple ministries and agencies both at national and sub-national levels. While the current governance structure provides local governments and research institutions with the freedom to take initiatives and to adapt and implement policies at the national level, this complex structure limits their co-ordination and has led to funding inefficiencies and duplication of research efforts and investment (OECD, 2008; Huang and Rozelle, 2014). The lack of a co-ordination mechanism between the central and provincial governments may reduce the efficiency of China's innovation system as a whole and delay the creation of a coherent system of agricultural innovation.

China's public agricultural extension system has undergone a series of reforms to make it more responsive to farmers' needs. The commercialisation of extension activities reduced their capacity to provide a variety of technical advice. More recent reforms to improve the quality of service to farmers by separating commercial activity from extension services and introducing a more inclusive approach at the local level are more favourable. At the same time, private organisations are increasingly playing a major role in facilitating knowledge flows in China. For example, farmers' co-operatives often function as intermediate agents to facilitate the adoption of technology and reduce transaction costs, allowing smallholder farms to overcome systematic constraints in adopting technology, integrating them in supply chains and increasing their operational size. The public extension system should evolve so that it can provide advisory services which private organisations have less incentive to provide, such as promoting agricultural production technologies to conserve resources and protect the environment. A greater use of ICT would also improve the performance of advisory services.

Protection of intellectual property rights (IPRs) is an important factor influencing the performance of agricultural innovation systems. Adequate protection of IPR enhances private R&D investment in agriculture, including those from abroad. While IPR policies and regulations are largely in line with international rules and guidelines, China's protection of IPR still lags most OECD countries, particularly in terms of enforcement.

Notes

[1] As defined in the Frascati Manual (OECD, 2002), basic research refers to experimental or theoretical research aiming to obtain new knowledge about the fundamental principles of phenomena and observable facts (for example, revealing the nature of objects and the rules of their operations, acquiring new discoveries, and establishing new theories). Applied research refers to creative research carried out in order to acquire new knowledge, mainly aimed at a certain purpose or objective. Experimental development refers to systematic work carried out for the production of new products, materials and devices and the establishment of new manufacturing techniques, systems and services, and the fundamental improvement of such items on the basis of application of knowledge available from basic research, applied research and practical experience.

[2] The National Centre for Science and Technology Evaluation (NCSTE) is in charge of evaluating government-sponsored R&D projects. The NCSTE aims at “providing an objective and impartial basis for government departments, enterprises and investment organisations to make better decisions, to offer consulting service in a wide range of sectors, and to promote dialogue between government, industries and academies”. The NCSTE was created in 1997 based on a research team active in evaluation as early as 1994 (Fang, 2013).

[3] A process of mid-term evaluation of the Medium and Long-term Plan for Science and Technology Development was launched in 2014. The management of the main science and technology development programmes have been revised to simplify the application process; scientists applying for project funding run by MOST do not have to conduct the questions and answers session in person, as most of the application and evaluation procedures can be done through the Internet; additionally, the budget management system was improved by building a project library and science and technology programme information system (OECD, 2014a).

[4] ASTI’s national agricultural research expenditure data is categorised as salary-related expenses, operating and programme costs, and capital investments by government, non-profit, and higher education agencies. Data on spending by private entities are excluded, due to lack of availability. OECD’s GERD data captures all performing sectors for agricultural science. However, it is difficult to obtain a comprehensive estimate of GERD in the ago-food sector which would cover multiple fields of science beyond agricultural science.

[5] In addition to General Principles of the Civil Law that has specific articles concerning intellectual property rules, the Civil Law and the Criminal Law also include articles on IPR, and other related laws and regulations have been promulgated like the Patent Law, the Copyright Law, the Trademark Law, the Foreign Trade Law, the Anti-Unfair Competition Law, the Regulations on the Protection of New Varieties of Plants, the Seed Law, and the Regulations on the Customs Protection of Intellectual Property Rights.

[6] They include, for example, the Detailed Rules for the Implementation of Regulations on the Protection of New Varieties of Plants, and Several Provisions of the Supreme People’s Court on Applying Specific Laws in Cases of Infringement of New Plant Varieties.

References

Agricultural Science and Technology Indicators (ASTI), International Food Policy Research Institute, Washington, DC, http://asti.cgiar.org/.

Cai, Jinyang, Ruifa Hu, Jikun Huang and Xiaobing Wang, (2017) “Innovations in genetically modified agricultural technologies in China’s public sector: Successes and challenges”, *China Agricultural Economic Review*, Vol. 9 Issue: 2, pp.317-330, https://doi.org/10.1108/CAER-10-2016-0170.

Campi, M. and A. Nuvolari (2013), “Intellectual property protection in plan varieties: A new worldwide index (1961-2011)”, *LEM Working Paper Series*, No. 2013/09. http://hdl.handle.net/10419/89567.

Chen, C. (2009), “Study on Investment Efficiency of Agricultural Science and Technology in China”, Journal of Agricultural Science and Technology, February, pp 9-10 (in Chinese).

Chen, K. Z., K. Flaherty and Y. Zang (2012), *China: Recent Developments in Agricultural Research*, ASTI Country Note, International Food Policy Research Institute, Washington, DC.

Fang Zheng (2013), “Analysis of the Role of Government in China’s Agricultural Science and Technology Innovation” [J], *Journal of Changchun University of Science and Technology (Social Science)*, Issue 12.

GAIN-CH13033 (2013), “China – Peoples Republic of: China, Agricultural Biotechnology Annual”, USDA FAS, 15 July.

GAIN-CH 15032 (2015), “China – Peoples Republic of: China Agricultural Biotechnology Annual, Considering Major Revisions to Biotechnology Regulations”, USDA FAS, 21 December.

GAIN-CH16065 (2016), “China – Peoples Republic of: China Agricultural Biotechnology Annual Moving Towards Commercialization of Its Own Biotechnology Crops”, USDA FAS, 16 December.

Han Changfu (2015a), “Achievements in Agriculture and Rural Areas during the 12th Five-Year Plan Period”, [J], *Rural Work Letters*, Issue 21, (in Chinese).

Han Changfu (2015b), “Separating land ownership, contracting right and management right is another major innovation in China’s rural reform”, *Guangming Daily*, 26 January (in Chinese).

Hu, R. and J. Huang (2001), *Agricultural technology extension investment and its impact in China. Strategy and Management*, 3, 25−31.

Hu, Ruifa, Jikun Huang and Liqiu Li (2004), “China’s Agricultural Extension System: Status, Problems, and Solutions”, *Management World*, Vol. 5, pp. 50-57.

Huang, J. and S. Rozelle (2014), “Agricultural R&D and extension”, in Fan, S., Kanbur, R., Wei, S. and Zhang, X. (eds.), *Oxford Companion to the Economics of China*, Oxford University Press, London, pp. 315-319.

Huang, J., R. Hu and S. Rozelle (2003), “Agricultural Research Investment in China: Challenges and Prospects”, Chinese Financial and Economic Press.

Karplus, V.J. and Deng, X.W. (2006), “Agricultural Biotechnology in China: Past, Present and Future”, in X. Zhihong, L. Jiayang, X. Yongbiao, W. Yang (eds) *Biotechnology and Sustainable Agriculture 2006 and Beyond*, Springer.

MOA (2016), *National Statistics of Agricultural Science and Technology 2016*, China Statistics Press, Beijing (in Chinese).

MOA (2015a), *Opinions on Deepening the Reform of Agricultural Technology Mechanism and Accelerating the Implementation of Innovation-Driven Growth Strategy* (in Chinese).

MOST (2016), *Technical Specification of Evaluation for Agricultural Science and Technology Achievements*, GB/T 32225-2015 (in Chinese).

NBSC and MOST (2016), *China Statistical Yearbook on Science and Technology 2016*, China Statistics Press.

OECD (2017a), “China”, in *OECD Science, Technology and Innovation Outlook 2016*, OECD Publishing, Paris, http://dx.doi.org/10.1787/sti_in_outlook-2016-58-en.

OECD (2017b), OECD statistics, Research and Development, OECD National Accounts, http://stats.oecd.org/ (accessed in June 2017).

OECD (2016), *Innovation, Agricultural Productivity and Sustainability in the United States*, OECD Publishing, Paris, http://dx.doi.org/10.1787/9789264264120-en.

OECD (2015), "Analysing Policies to improve agricultural productivity growth, sustainably: Revised framework", http://www.oecd.org/tad/agricultural-policies/Analysing-policies-improve-agricultural-productivity-growth-sustainably-december-2014.pdf.

OECD (2014a), "China", in *OECD Science, Technology and Industry Outlook 2014*, OECD Publishing, Paris, http://dx.doi.org/10.1787/sti_outlook-2014-en.

OECD (2014b), *OECD Patent databases*, OECD Publishing, Paris, http://dx.doi.org/10.1787/patent-data-en.

OECD (2008), *OECD Reviews of Innovation Policy: China 2008*, OECD Publishing, Paris, http://dx.doi.org/10.1787/9789264039827-en.

OECD (2002), *Benchmarking Industry-Science Relationships*, OECD Publishing, Paris, http://dx.doi.org/10.1787/9789264175105-en.

Pardey, P., J. Alston and V.W. Ruttan (2010), "The economics of innovation and technical change in agriculture", in *Handbook of the Economics of Innovation*, Volume 2 (B. Hall and N. Rosenberg, eds.), Elsevier, Amsterdam, pp. 939-984.

Park, W. G. (2008), "International Patent Protection: 1960-2005", *Research Policy*, No. 37, pp. 761-766.

Pray, C. E. et al. (2011), "The impact of Bt cotton and the potential impact of biotechnology on other crops in China and India", in Genetically Modified Food and Global Welfare, *Frontiers of Economics and Globalization*, Vol. 10, Emerald Group Publishing.

Qiao F, Huang J, Zhang C. (2016), "Sustainability of the farm-level impact of bt cotton in China", *Journal of Agricultural Economics*, 67, 602–618.

SCImago (2014), SJR - SCImago Journal and Country Rank, retrieved March 19, 2014, http://www.scimagojr.comSource.

Shi G., C. Pray and W. Zhang (2012), "Effectiveness of Intellectual Property Protection: Survey Evidence from China", *Agricultural and Resource Economics Review*, Vol. 41, Issue 3, pp.286–297.

Smale, M. et al. (2009), "Measuring the Economic Impacts of Transgenic Crops in Developing Agriculture during the First Decade: Approaches, Findings and Future Directions", *Food Policy Review 10*, International Food Policy Research Institute, Washington DC.

Song Hongyuan (2000), *Evolution of China's Agricultural and Rural Economic Policies Since Reform and Opening-Up*, [M], China Economic Publishing House (in Chinese).

Stads, Gert-Jan (2015), "A Snapshot of Agricultural Research Investment and Capacity in Asia", Resource Paper for the Asia Pacific Association of Agricultural Research Institutions' High Level Policy Dialogue, Bangkok, December 2015.

State Council (2014), "Opinions on Improving and Strengthening Management of Scientific Research Projects and Funds Supported by Central Finance", Guofa No. 11 (in Chinese).

State Council (2010), "Opinions on Promoting Fast and Sound Development of Agricultural Industrialization and Machinery Industry", Guofa No. 22 (in Chinese).

State Council (2006), "National Plan for Long- and Medium-Term Scientific and Technological Development (2006-2020)", (in Chinese).

Sun, Zhenyu (ed.) (1993), *A Study on Science and Technology Extension*, China Agricultural Science and Technology Press, Beijing (in Chinese).

USDA-Economic Research Service. *Agricultural Research Funding in the Public and Private Sectors*, On-line Data Product. US Department of Agriculture, Washington, DC.

World Economic Forum (2016), *The Global Competitiveness Report 2016-2017: Full data Edition*, Geneva 2016, www.weforum.org/reports/the-global-competitiveness-report-2016-2017-1.

Yueh, L. (2009), "Patent Laws and Innovation in China", *International Review of Law and Economics*, Vol. 29, No. 4, pp. 304-313.

Zhao Huijuan, Liu Niya, Yang Weikun (2015), "Enterprises as the Main Players in Agricultural Technology Innovation System: US Experience and Inspirations" [J], *World Agriculture*, Issue 7.

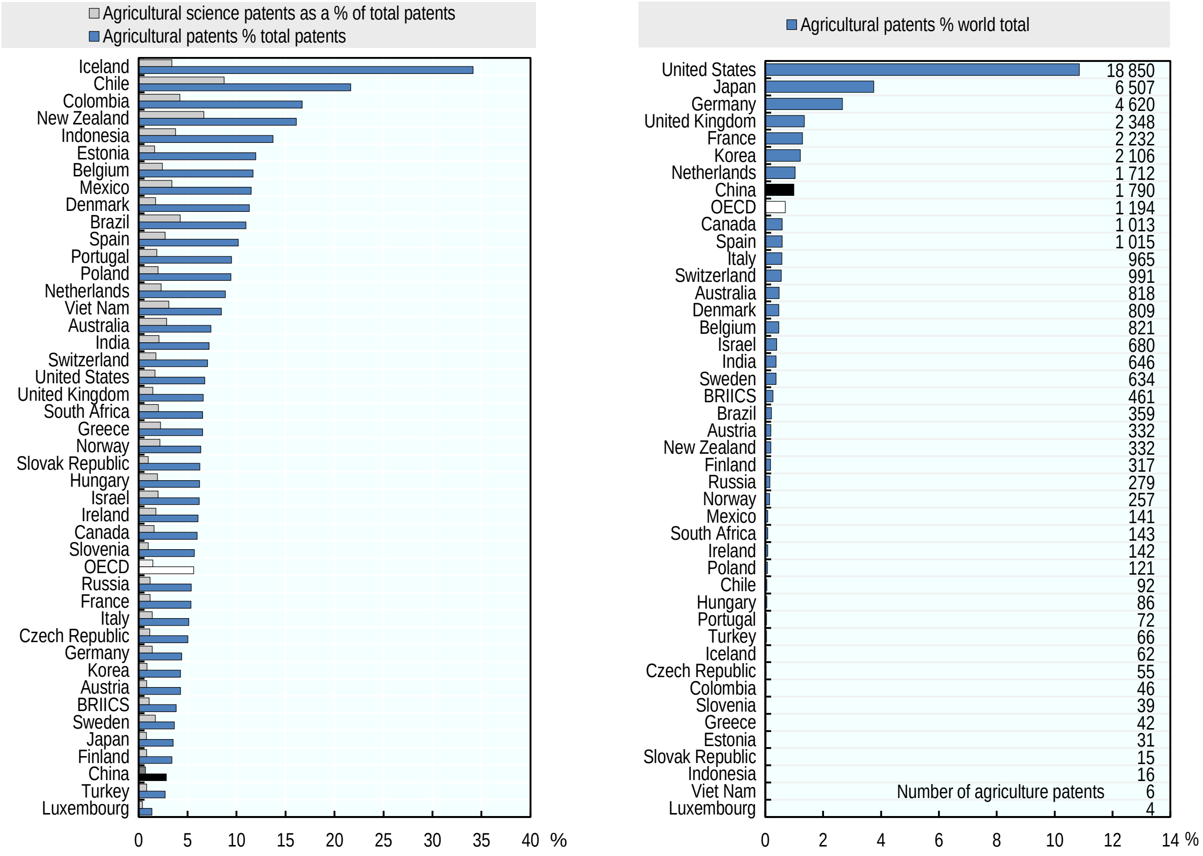
Zhong, Z. (2014), "China Agricultural Extension: History, Current Status and Supply-Demand Characteristics", *FFTC Agricultural Policy Articles 2014-02-10*, FFTC Agricultural Policy Platform, http://ap.fftc.agnet.org/ap_db.php?id=194.

Annex 6.A. Background indicators of R&D outcomes

Annex Figure 6.A.1. Agricultural patent applications filed under the Patent Co-operation Treaty (PCT) in agriculture, 2006-11

A. Agricultural specialisation (using fractional counts, country receives partial count for co-inventions)

B. Share of countries in total agriculture patents, 2006-11



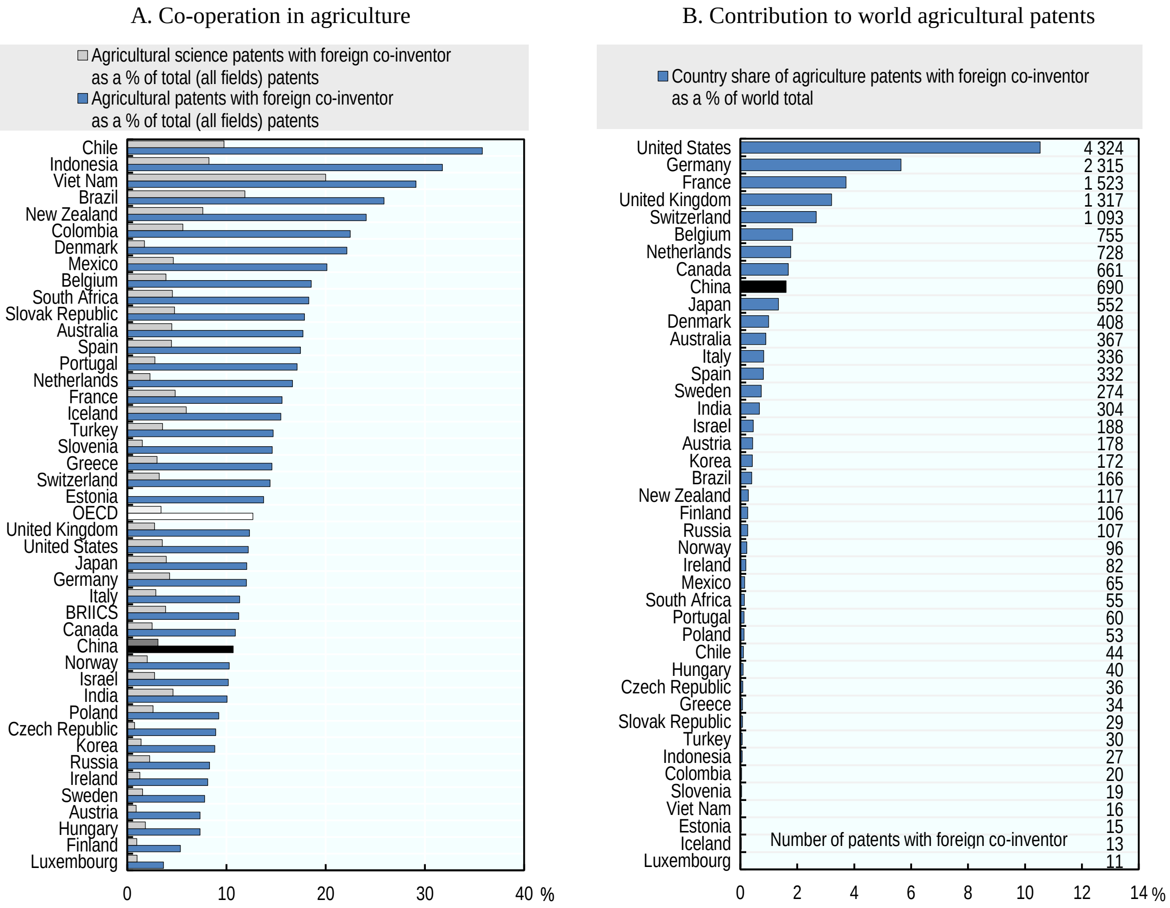
1. Agriculture includes patents from IPC classes A01, A21, A22, A23, A24, B21H 7/00, B21K 19/00, B62C, B65B 25/02, B66C 23/44, C08b, C11, C12, C13, C09K 101/00, E02B 11/00, E04H 5/08, E04H 7/22, G06Q 50/02.

2. The OECD aggregates do not include Latvia and Lithuania.

Source: OECD (2014b), OECD Patent Database (accessed January 2014).

StatLink http://dx.doi.org/10.1787/888933829702

Annex Figure 6.A.2. Agriculture patents with a foreign co-inventor filed under the Patent Co-operation Treaty (PCT), 2006-11



A. Co-operation in agriculture

B. Contribution to world agricultural patents

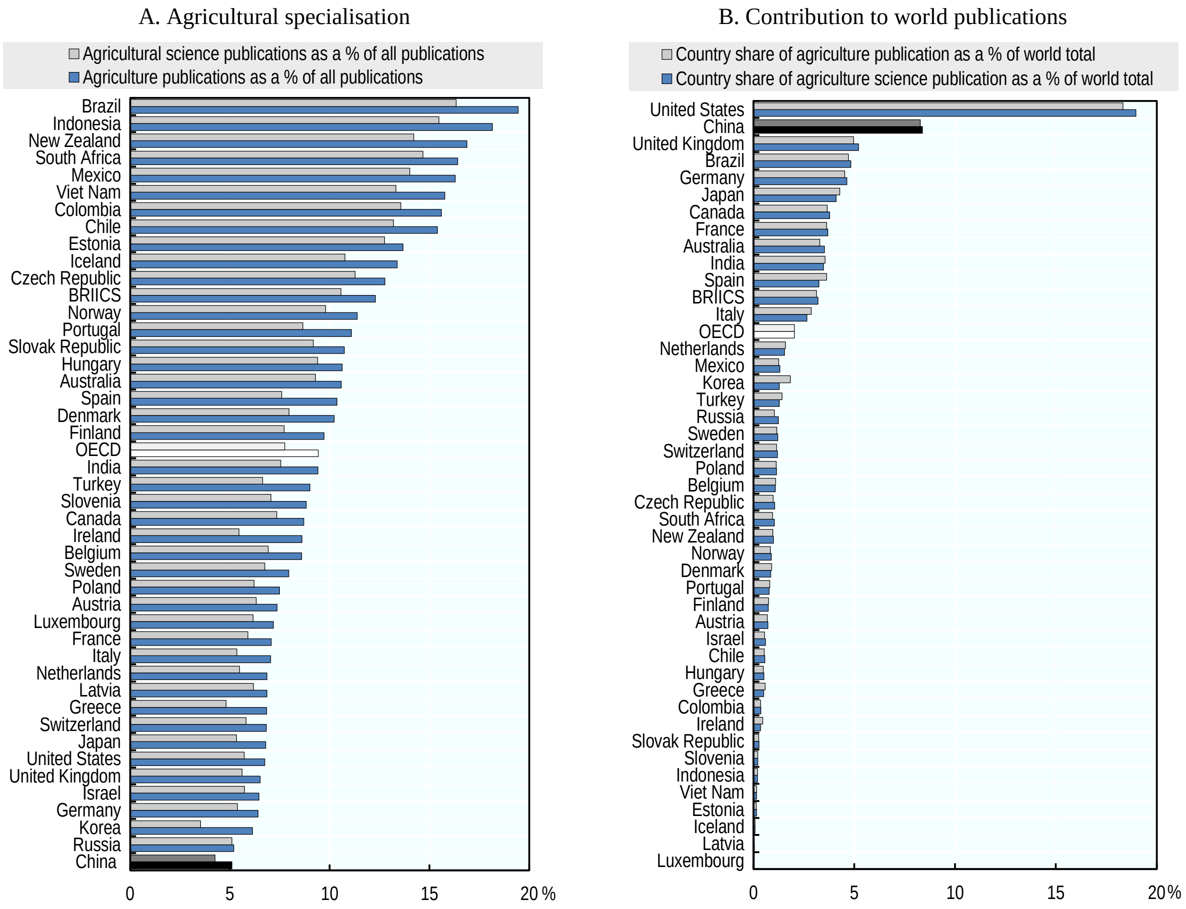
1. Agriculture includes patents from IPC classes A01, A21, A22, A23, A24, B21H 7/00, B21K 19/00, B62C, B65B 25/02, B66C 23/44, C08b, C11, C12, C13, C09K 101/00, E02B 11/00, E04H 5/08, E04H 7/22, G06Q 50/02.

2. The OECD aggregates do not include Latvia and Lithuania.

Source: OECD (2014b), *OECD Patent Database* (accessed January 2014).

StatLink http://dx.doi.org/10.1787/888933829721

Annex Figure 6.A.3. Agriculture publications, 2007-12



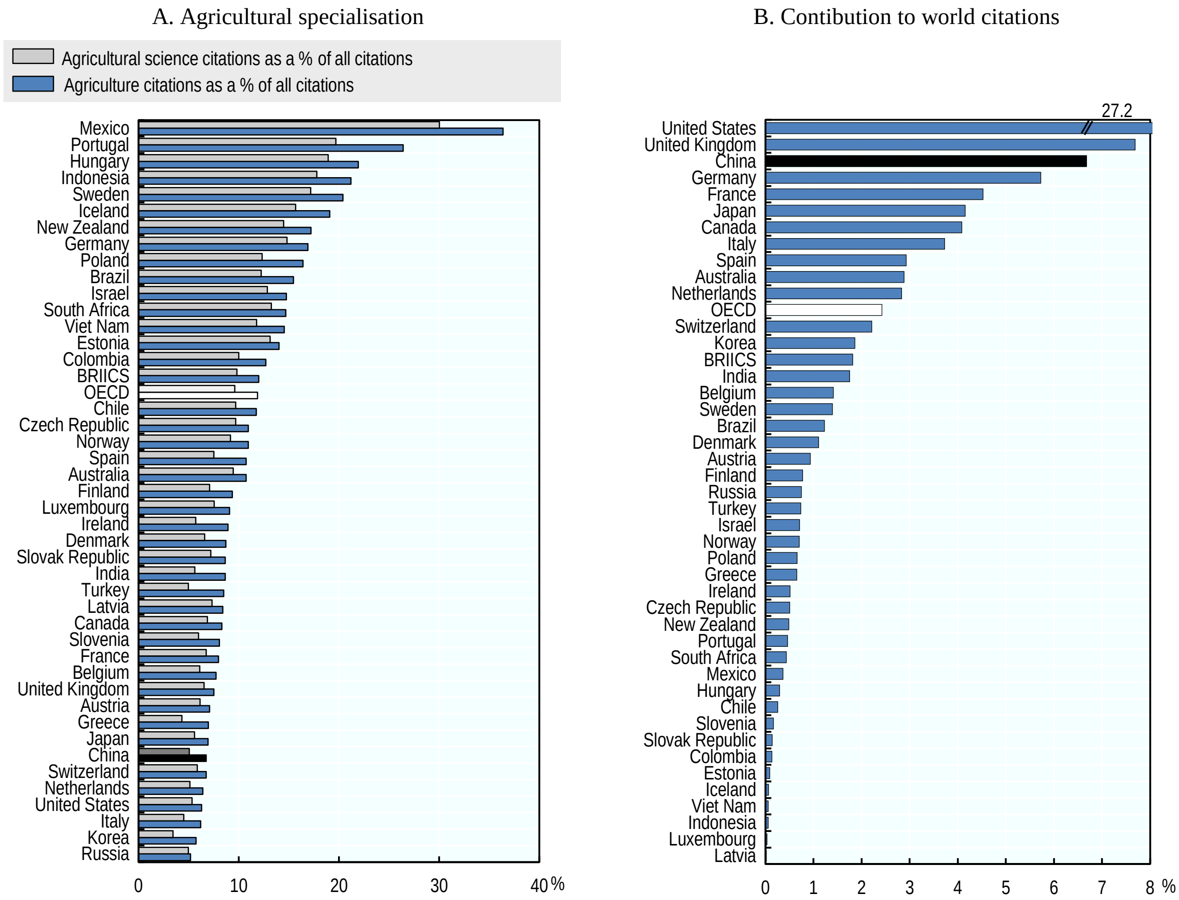
1. Agricultural science include Scopus journal classifications: agronomy and crop science, animal science and zoology, aquatic science, ecology/evolution/behavior systematics, forestry, horticulture, insect science, plant science and soil science, and miscellaneous agriculture/biological sciences.

2. The OECD aggregates do not include Latvia and Lithuania.

Source: SCImago (2014), SJR — SCImago Journal & Country Rank, http://www.scimagojr.com (accessed March 2014).

StatLink http://dx.doi.org/10.1787/888933829740

Annex Figure 6.A.4. Agriculture citations, 2007-12



1. Agricultural science include Scopus journal classifications: agronomy and crop science, animal science and zoology, aquatic science, ecology/evolution/behavior systematics, forestry, horticulture, insect science, plant science and soil science, and miscellaneous agriculture/biological sciences.

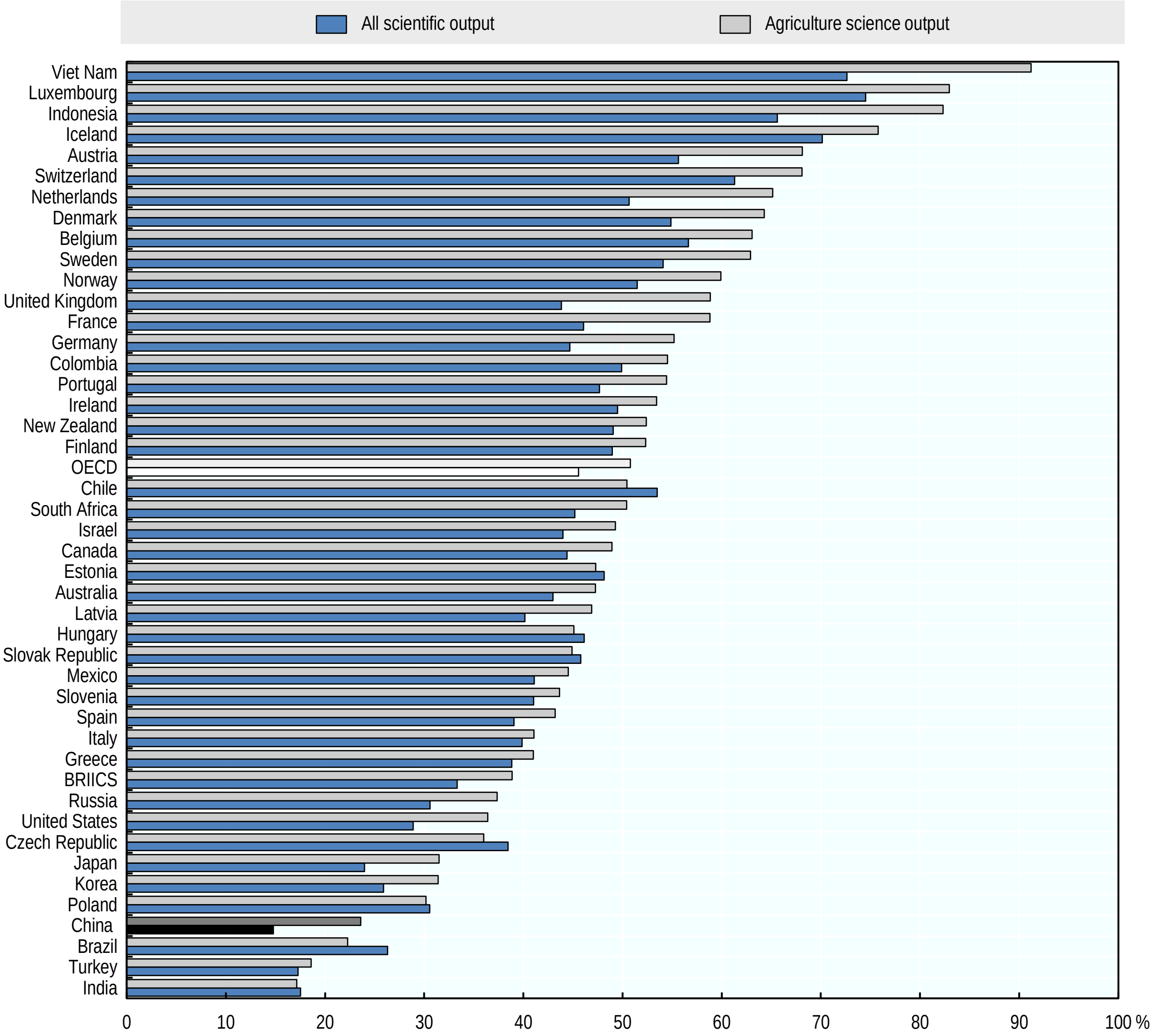
2. The OECD aggregates do not include Latvia and Lithuania.

Source: SCImago (2014), SJR — SCImago Journal & Country Rank, http://www.scimagojr.com (accessed March 2014).

StatLink http://dx.doi.org/10.1787/888933829759

Annex Figure 6.A.5. International collaboration, 2007-12

Percentage of documents with collaborating authors in foreign country

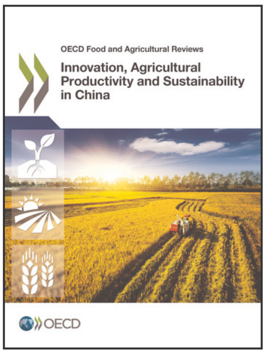


Notes: Agricultural science include Scopus journal classifications: agronomy and crop science, animal science and zoology, aquatic science, ecology/evolution/behavior systematics, forestry, horticulture, insect science, plant science and soil science, and miscellaneous agriculture/biological sciences.

The OECD aggregates do not include Latvia and Lithuania.

Source: SCImago (2014), SJR — SCImago Journal & Country Rank, http://www.scimagojr.com (accessed March 2014).

StatLink http://dx.doi.org/10.1787/888933829778



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