

Chapter 1. Overall assessment and recommendations

This chapter presents the framework used in the report to analyse the extent to which policies in China are supportive of innovation and structural change, and how they affect access to and use of natural resources for productivity growth and sustainability. It also gives an overview of the findings of the review on a wide range of policies in China, and develops specific recommendations in each of these policy areas.

1.1. A framework to analyse policies for innovation, productivity and sustainability in the food and agriculture sector

Improvements in agriculture productivity growth are required to meet the growing demand for food, feed, fuel and fibre, and must be achieved sustainably through a more efficient use of natural and human resources and a reduction of pollution. A wide range of economy-wide policies affect the performance of the food and agriculture sector, and thus need to be considered alongside agriculture-specific policies. Recognising that innovation¹ is essential to improving productivity growth sustainably along the whole agri-food chain, this report devotes particular attention to the performance of agricultural innovation systems.

The framework used in this report to review policies in the People's Republic of China (hereafter "China") considers policy incentives and disincentives to innovation, structural change, and environmental sustainability of agriculture, which are key drivers of sustainable productivity growth (Figure 1.1).

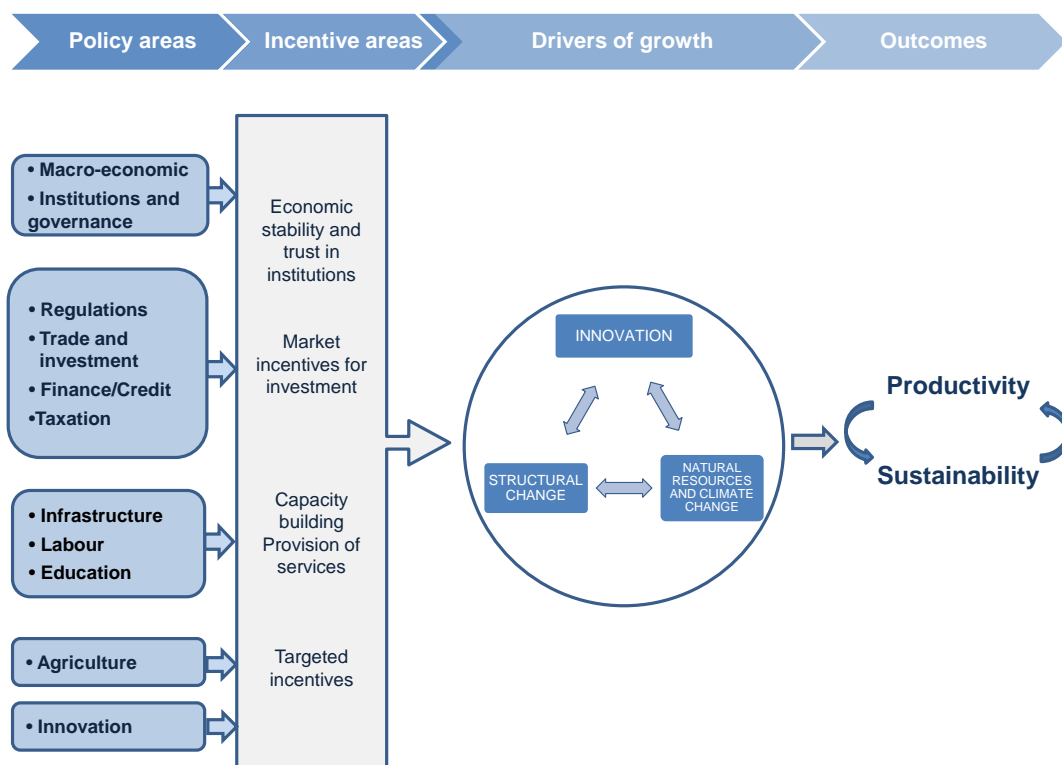
This review begins with an overview of the characteristics and performance of the food and agriculture sector and the challenges it will face in the future (Chapter 2). A wide range of policies is then considered according to the main channels or incentive areas through which they affect drivers of productivity growth and sustainable use of resources.

- Economic and institutional environment, both of which are essential to attract long-term investment (Chapter 3).
- Capacity building, including provision of essential public services (Chapter 4).
- Agricultural policy, domestic and trade-related (Chapter 5).
- The agricultural innovation system (Chapter 6).

This review draws on background information provided by the Development Research Center of the State Council and other experts, and on recent OECD agricultural, economic, rural, environmental and innovation policy reviews.

Throughout the report, the likely impacts of each policy area on innovation and sustainable productivity growth are discussed and recommendations are drawn from this review on a large range of policy areas.

Figure 1.1. Policy drivers of innovation, productivity and sustainability in the food and agriculture sector



Source: OECD (2015), “Analysing Policies to improve agricultural productivity growth, sustainably: Revised framework”, www.oecd.org/agriculture/policies/innovation.

1.2. Policy challenges for innovation, agricultural productivity growth and sustainability in China

The Chinese economy has shifted into a “new normal” situation in which lower but more sustainable economic growth rates are expected. Real GDP growth rates declined from more than 10% in the 2000s to 6.9% in 2014-16. *The economy is experiencing a number of significant structural changes that also have a deep impact on the food and agricultural sector.* The working age population in China started to decline in 2015 and the overall population is projected to peak in 2030. The population is expected to age rapidly over the coming decades. China’s remarkable economic growth in the last few decades has been sustained largely by an accumulation of capital, supported by large saving rates, rather than productivity growth (OECD, 2017a). However, increasing real wage rates since the early 2000s required China to transform its growth model from one that relied on an ample supply of low wage labour from rural areas. China is facing a challenge to shift growth based on the mobilisation of labour and capital resources to growth based on enhancing productivity through innovation and sustainable use of natural resources, including in the food and agricultural sector.

In China, agriculture still accounts for close to 30% of employment, but generates less than 10% of GDP, indicating that labour productivity is significantly lower than in the rest of the economy. However, the total *number of persons employed in agriculture is declining slowly*, and consequently the labour productivity gap between agriculture and other

industries is increasing. The growth rate of total factor productivity in primary agriculture in 2001-14 slowed down compared to the 1990s, while in other BRIICS countries the total factor productivity growth rate accelerated in 2001-14 compared with the 1990s, except for South Africa.

China's agriculture development has been achieved at the expense of sustainable use of natural resources. Agriculture uses most of the country's land and water resources. The expansion of the sector, especially for products with high self-sufficiency targets, has been aided partly by the intensive use of chemical inputs such as mineral fertilisers and pesticides. *Intensive use of chemical inputs* in the crop sectors have led to soil degradation, water pollution, and damaged bio-diversity. The dominance of small-scale farms also led to inefficient use of chemical inputs as small-scale farmers tend to have an inefficient knowledge of input use. They also have an incentive to substitute labour with chemical inputs in order to allocate more time to off-farm activities. *Water resources* reached the limit of sustainable use, particularly in areas where irrigation is intensive or water resources are scarce. The development of the livestock sector has created serious stress on China's grassland areas. The release of animal manure and wastewater from intensive livestock and aquaculture farms further pollutes the environment, especially water resources.

The rising cost of labour and the rapid aging of the rural population require agricultural production to concentrate on a smaller number of more productive farms. *Consolidating small and fragmented farm operations in large-scale units* is one of the most important pathways of productivity growth in China. It would also improve the sustainability of agriculture, as the small and fragmented farm structure is leading to an inefficient use of chemical inputs. Although small family farms still largely dominate the sector, "new-style" farms, such as large family farms, co-operatives, and farms run by agribusiness companies are increasing their importance. High labour costs also stimulate rapid farm mechanisation, allowing farmers to save labour input and expand farm size or engage in off-farm activities.

Dietary changes associated with income growth have been a major driver for the shift of domestic agricultural production towards livestock and fruits and vegetables. These sectors already dominate the agriculture sector in terms of production value. Due to the limited endowment of land and other natural resources, China does not have a comparative advantage in land-intensive grain production. Policies to promote grain production are hampering structural change towards more value-added production. Future growth opportunities of agriculture in China lie primarily in agricultural products that are intensive in capital and knowledge.

Growing environmental challenges have also become significant constraints to sustainable productivity growth of agriculture in China. Contamination and pollution of soil and water resources raises uncertainty about future productivity trends. *Climate change* is expected to impact agricultural production through rising temperatures, the spread of pests and disease, and more frequent and more severe droughts and floods. Growing competition from other users of land and water may also impact the future of the sector. The sustainable productivity growth of agriculture requires a policy strategy to curb and eventually reverse the current practice of intensive chemical inputs use. It should also increase the sector's resilience to resource-related risks.

1.3. Enhancing incentives for private investment in agriculture

Although the growth rate of GDP has slowed down, China has a favourable macroeconomic environment, considering its government's budget balance, gross national savings,

inflation, government debt, and the country's credit rating. However, the quality of governance is still lower than the OECD average, most notably in the protection of property rights, both physical and intellectual. Effective protection of property rights is key to attracting private investment, including in agriculture. The government should strengthen the enforcement of Intellectual Property Rights (IPRs) by raising awareness of laws and increasing penalties for infringements to ensure adequate protection for domestic and foreign innovators.

Reforms have significantly reduced *regulatory barriers to entrepreneurship*, but there is still large scope to reduce complexity and transaction costs related to compliance with regulations. Overall, China's regulations remain relatively complex and costly compared to OECD countries. China should continue its efforts to reduce administrative burdens and compliance costs for enterprises, and improve transparency and provision of public services. Specific areas where further efforts would be expected are the simplification of the licence and permit system and the reduction of administrative burdens for start-ups.

With markets playing an increasingly prominent role in resource allocation in China, the *competitive environment should be improved further*, including by strengthening the institutional capacity to ensure effective enforcement of Anti-Monopoly Law. While the importance of State Owned Enterprises (SOEs) in China has gradually declined, some areas of the service sector (e.g. financial services) are still dominated by SOEs. An earlier OECD study finds that SOEs are not very efficient producers and users of knowledge and have inefficient incentives to undertake risky investment in R&D (OECD, 2008). The government should continue opening up more sectors to private investment.

Developing *an efficient service sector and increasing its linkage to primary agriculture* is an important condition to promote more value addition to China's food and agriculture products, as the share of value added from domestic service sectors to food and agricultural production remains low. Both affordability and availability of financial services in China are limited compared to most OECD countries. While allowing farmers to collateralise land use rights and gradually liberalising the entry of new financial institutions to rural financing increases the accessibility of finance for farmers, diverse financial services should be made accessible for farmers, and in particular for emerging types of large farms operated by land co-operatives and enterprises.

The trade and investment environment facilitates knowledge flows embedded in agri-food trade and Foreign Direct Investment (FDI). China has been benefiting from opening up for trade, and has lower trade barriers as measured by the level of tariffs and by trade facilitation indicators compared to other BRIICS countries. While the recent FDI reform to move from an approval-based to a filing system will bring the FDI regime closer to internal levels of openness, China still maintains *barriers to FDI*. For example, in the food and agriculture sector, foreign companies are not allowed to conduct research on transgenic crop breeding in China. Non-transgenic plant breeding and seed production features as one of the "restricted" areas of FDI and requires foreign investors to establish a joint venture with Chinese companies.

Recommendations to improve incentives for private investment

- Strengthen the enforcement of IPR protection by raising awareness of laws, increasing penalties for infringements and systematically prosecuting violators to ensure adequate protection to domestic and foreign innovators and attract private investment.
- Continue efforts to reduce regulatory burdens and compliance costs for entrepreneurs, and improve transparency and provision of public services.
- Open up more sectors to private investment and strengthen an institutional capacity to ensure effective enforcement of Anti-Monopoly Law to develop a more competitive service sector.
- Improve the accessibility of financial services, in particular for emerging large-scale farms operated by land co-operatives and enterprises, through promoting more new entrants to rural finance.
- Continue simplifying the procedure for FDI and reduce restrictions to FDI in certain areas of agricultural R&D by foreign enterprises.

1.4. Improve the framework conditions for structural change and innovation at the farm level

China has developed *a competitive transport and electricity infrastructure network* which is comparable with most of the OECD countries. Economic activities benefit from a well-developed national transportation infrastructure network. On the other hand, the penetration of Information and Communication Technology (ICT) increased to one-third of the rural population but still lags significantly behind the urban population. Efforts to *increase the penetration of ICT in rural areas* should continue, including the promotion of ICT in agricultural production and marketing as stated in the 13th Five-Year Plan.

Institutional reform in the 1980s to allocate *land contract rights* to individual family farms contributed significantly to the productivity growth in agriculture during the early reform period. Since then, China has taken a number of steps to secure land contract rights and to activate the transaction of land operational rights between farms. However, the operational size of farms is small and the share of rented land is still lower than in many OECD countries. Local governments should play a proactive role in providing information on potential lenders of land and reduce the costs related to land transactions. Ensuring long-term stability of land contracts and operational rights is also important to provide incentives to commit to long-term investments in land. A proper registration system of operational rights of land also allows the government to target payment programmes to the cultivator. China should further promote the entry of diverse types of entities to agriculture including agri-business ventures and migrants from urban to rural areas, allowing them to obtain land operational rights.

China's policy approach to promote the *consolidation of farm operations through various organisational formats* (e.g. transaction of operational rights, establishment of land shareholding cooperatives and consolidation of farm operational by professional service provider) has the advantage of being adaptable to local conditions. Under a highly fragmented farm structure, the traditional approach to promote land consolidation through

transaction of land ownership and tenancy entails high transaction costs. China's adaptable approach to promoting consolidation of small and fragmented farm operations provides a policy lesson for other countries with a similar agricultural structure. The recent policy to establish geographical zoning for grains and other crop production to target government support, if it rationalises the geographical distribution of agricultural production based on natural and environmental conditions, facilitates structural change of agriculture and more sustainable agricultural production.

Saving labour inputs through *farm mechanisation* is another important pathway for agricultural productivity growth in China, considering rising costs of labour in rural areas. Mechanisation allows farmers to operate larger farms or to allocate more time to off-farm activities. The development of farm machine services in China contributed significantly to the rapid increase in the use of modern farm machines, including on small farms. Outsourcing major farming operations (e.g. ploughing, planting and harvesting) by small farms to farm service providers allows small farms to benefit from economies of scale in farm operations and reduce the cost of capital inputs. However, the fragmented land structure and lack of access roads to farms limits the efficient use of farm machinery.

China provides *a subsidy to purchase agricultural machinery*, which stimulated the replacement of inefficient smaller machines with more efficient larger ones. However, this subsidy should only have a transitory role in promoting the use of modern farm machinery. This programme should be scaled down, while increasing the role of a supporting credit to cover a wider range of farm capital investments such as a credit support programme for new types of professional farmers in 2015. Additionally, rural credit institutions should play a greater role in financing capital investment, including farm machinery. Public investment should focus more on land readjustment and developing farm access roads to promote efficient use of farm machinery. Recently announced plan to increase the investment in high standard farmland is in this policy direction.

China's *household registration (hukou) system* continue to restrict households registered in rural areas from accessing social security and education systems in urban areas, despite the introduction of a single national resident registration system in 2014. While China is improving medical insurance, pension and public education for rural residents, unequal access to social security systems remains between urban and rural residents. For example, it is difficult for the children of rural households living in cities to access the public school system in urban areas. On the other hand, only the members of rural collective economic organisations (villages) can receive an allocation of land contract rights. *Ensuring more equal access to social services* would facilitate the migration of rural residents to urban areas and allow aged farmers to transfer farm resources to more efficient and productive farmers. This would reduce an existing large income disparity between the urban and rural populations and improve productivity in agriculture.

Although most of the working age population obtains lower- and upper-secondary education, China currently has the lowest proportion of the adult population with tertiary level education among OECD and BRIICS countries. The education attainment of rural residents is largely limited to lower-secondary level. Increasing the level of attainment of *education and training in a broad skill set* would benefit rural regions, in particular, by improving the competence and capacity to adapt and innovate in the agriculture sector. Public support to vocational education in agriculture should be increased.

Recommendations to improve the framework conditions for structural change and innovation at the farm level

- Increase the policy effort to extend ICT to rural areas, including the promotion of ICT applications to agricultural production and marketing.
- Secure the long-term stability of contract and operational rights of land by increasing their duration, with contracts automatically renewable upon expiration, and implementing a registration system at the local level which provides certificates detailing operational rights.
- Reduce the cost of transferring operational rights of land through establishing transparent exchange platforms at the local level.
- Promote the consolidation of farm operations through diverse organisational formats such as land shareholding co-operatives and farm machine service providers, adapted to local conditions.
- Facilitate the entry of diverse types of entities to agriculture, including agri-business ventures and migrants from urban to rural areas, and allow them to obtain land operational rights.
- Scale down the subsidy to purchase farm machinery while increasing the role of the rural credit institutions in financing farm capital investment.
- Focus public investment more in land readjustment and farm access roads to promote an efficient use of farm machinery.
- Ensure more equal access to social services to facilitate the migration of rural residents to urban areas and allow aged farmers to transfer farm resources to more efficient and productive farmers.
- Ensure public support for education and knowledge institutions in rural areas to allow rural residents to obtain the equivalent level and quality of education as urban residents.
- Increase vocational training opportunities in the broad skills set needed to adapt and innovate in the agriculture sector and facilitate life-long learning and upgrading of skills in agriculture.

1.5. Improving the environmental performance of agriculture

Improving the *environmental performance of agriculture* has recently become one of the central objectives of China's agricultural policy. China has been increasing policy efforts through strengthening regulations as well as expanding the payments for resource conservation. The 2020 Zero-Growth Action Plan for Chemical Fertilizers and Pesticides restricts the annual growth of chemical fertiliser use to below 1% in 2015-19 and to zero by 2020 for major agricultural crops, compared to observed growth rates for nitrogen and phosphorus uses of 3.9% and 2.5% p.a. in 2000-13. However, existing agricultural policy instruments to promote grain production are not necessarily coherent such agri-environmental policy objectives. For example, the exemption of VAT on fertiliser sales

was removed in 2015, but implicit support to fertiliser producers exists in the form of a subsidy on rail transport.

Designing agri-environmental policies requires the definition of reference levels and environmental targets, as this plays a crucial role in choosing policy instruments. While a reference level is the minimum level of environmental quality that farmers are required to provide at their own expense, environmental targets establish a voluntary (desired) level of environmental quality. To establish a solid framework of agri-environmental policies, China should further clarify reference levels for environmental quality and provide environmental targets which adapting both to local ecological conditions.

China developed *a regulatory framework for environmental protection*, but its coverage and implementation can be improved. Regulations have been introduced in the agriculture sector: for instance, the Environment Protection Act and the regulation on livestock pollution prevention and control, which strengthened regulation at the production level and increased financial penalties for livestock breeders that mismanage waste. The regulation on pesticide use was also strengthened. However, regulations are often applied at the product level (e.g. maximum residue limits) rather than to production processes. Regulatory measures, as well as a monitoring system, should be applied more at the farm level, clarifying the minimum levels of environmental quality with which farmers have to comply.

The effective *enforcement of environmental regulations* remains a major challenge in China. Further monitoring and liability management will be necessary to make progress, but this is costly under China's small and fragmented agricultural structure. Compliance with environmental regulations can be enforced more effectively with complementary incentive measures. For example, making direct payments conditional on the recipient's compliance with environmental standards could increase the farmer's incentive to comply with environmental regulations and reduce the cost of monitoring at the farm level, considering the farm structure in China is dominated by small-scale producers. However, experience in OECD countries shows that such conditionality would not be effective unless it is adapted to the diversity of local farming practices and conditions.

In addition to strengthening the enforcement of environmental regulations to ensure compliance, the government could introduce policies to *encourage the adoption of environmentally friendly production practices*. Although China has introduced payments for long-term resource retirement and for environment restoration, payments linked to specific environmental actions by producers account for only 1.2% of total producer support and 4.2% of budgetary transfers to producers. In contrast, the majority of payments in the European Union and the United States are linked with improved environmental practices. In this light, voluntary targeted payments that reward better practices in key environmental areas could be employed to compensate farmers for the additional costs associated with improving environmental performance beyond the reference level. Such payments can be introduced by reorganising the existing area-based direct payments to make a portion of them conditional on additional action by farmers, such as the adoption of environmentally friendly production practices. Given China's small and fragmented farm structure, a community-based policy may also reduce the cost of monitoring small farms, e.g. a programme to support groups of farmers in localities to set up voluntary co-operative arrangements to collectively address common problems such as water pollution and soil erosion.

Sustainable agriculture productivity growth requires a sufficient and stable quantity of usable freshwater for crops and livestock, and minimised impacts of agricultural activities

on *water resources*. China has increased its efforts, investments and policies to address the multiple water challenges it faces. Recent policies, promoted in particular by the No. 1 Document of 2011 and reinforced by the No. 1 Document of 2017, have led to ambitious plans – with innovative pilot programmes – to increase conservation, water use efficiency and quality improvements. These plans include the establishment of a new agricultural water price mechanism by 2026: the mechanism aims to adjust the agricultural water price to cover the cost of operation and maintenance, control overall water use, establish new systems of accurate subsidies and water-saving rewards, as well as promote advanced water-saving technology. Given the scope and complexity of China’s water challenges, prioritising future policy efforts to regions where agriculture production faces the most water risks (a water risk “hotspot” approach) could help accelerate progress at a lower cost (OECD, 2017b). In particular, upscaling successful pilot agriculture water management initiatives, for instance those focusing on groundwater pricing in the North China Plain, could be an effective means to progress water policy reform. Examples from the past have also shown that implementation and enforcement remain the key challenges for water management improvements. The co-ordination of actions across multiple agencies and implementation levels will need to be closely monitored to see if progress can be achieved effectively. This is especially important as water resource scarcity is projected to remain a major constraint to productivity growth in Chinese agriculture.

Recommendations to improve the environmental performance of agriculture

- Review existing agricultural policy instruments to improve their coherence with agri-environment policy objectives including the removal of all the implicit support to fertilisers.
- Establish a framework of agri-environmental policies clarifying the reference level for environmental quality as well as environmental targets. Regulatory measures as well as a monitoring system should be applied more at the farm level, clarifying the minimum levels of environmental quality with which farmers have to comply.
- Strengthen the enforcement of environmental regulations through strengthening monitoring and liability management, and introduce complementary measures such as taxing polluting inputs and making agricultural payments conditional on the recipient’s compliance with environmental standards which are adapted to local conditions.
- Introduce targeted voluntary payments rewarding better practices in key environmental areas to compensate for the additional costs associated with improving environmental performance.
- Consider a community-based policy which supports groups of farmers in localities to set up voluntary co-operative arrangements to collectively address common environmental problems.
- Conduct a comprehensive review of water governance to better define responsibilities, remove conflicts and ensure effective and efficient policy implementation.
- Define and secure water rights for all users including in rural areas and implement the announced water pricing mechanism. Enforce the three “red

line” policies on water resource efficiency, conservation and water quality, especially in rural areas, with enhanced monitoring and evaluation. Further agriculture and water policy efforts could be prioritised to agricultural regions concentrating the most water risks. This may involve upscaling successful pilot water policy initiatives.

1.6. Rebalancing agricultural policy toward long-term productivity growth and sustainability

Over the last three decades, agricultural policy objectives in China evolved significantly, reflecting the different roles that agriculture plays at different stages of economic development. The policy objectives have been diversified from increasing the quantity of food production to ensuring food safety, increasing farmers’ income, enhancing competitiveness and improving environmental performance. To enhance innovation and productivity growth, China has been increasing public expenditure on general services support such as public investment in R&D and infrastructure, but the share of such expenditure is still much lower than the OECD average. In China, *the cost of public stockholding* has the largest expenditure share in general services support, accounting for more than one-third in recent years. China should further rebalance the *portfolio of agricultural support* to reflect its policy orientation towards long-term productivity growth and sustainability in agriculture.

China’s current domestic support and market price support systems strongly favour national food grain production (e.g. minimum support prices and intervention purchases). The major grain products tend to be intensive in using land resources and to rely on irrigation, especially in areas where the surface and underground water supply is already under stress. The continued pursuit of food grain self-sufficiency is becoming more costly in terms of both maintaining a large amount of public stock of grains and unsustainable use of land and water resources. Recently the emphasis on *food security policy* shifted to increasing use of international markets and preserving the domestic production capacity rather than boosting production itself. More integration with international markets and decoupling of support from production would optimise the domestic agricultural structure and reduce pressure on the environment and national resources. Consistent with this are recent reforms in soybean, corn and cotton policies to replace domestic price support with direct payments. The reform of the price support policy for rice and wheat, reducing or capping minimum purchase prices, is also already underway. In the future, China should consider shifting domestic price support for rice and wheat to a direct payment system.

China has developed area-based *direct payments* programmes such as direct payments for grain producers, agricultural input payments and an improved seed variety subsidy. The recent policy reform consolidated these payments into a single payment focusing on supporting the maintenance of grain production capacity rather than boosting production itself. It also focuses more on larger farms. However, the policy should not interfere with farm management decisions, including what to produce and what size of operation farmers choose. Moreover, the income support component of the direct payment should have only a transitory role in supporting farmers’ adjustment to a new policy and market environment. The payments should be further decoupled from commodity production and introduced as a transitional measure that is time-bound. Such payments would enhance production diversification to higher value crops and allow producers to set aside farmland while maintaining production capacity. Despite the policy objective to consolidate small farms

into large size ones, payments conditional on farm size could distort the farmer's decision on their operational scale.

The *subsidy for agricultural insurance premiums* launched in 2007 has become one of the key programmes to support producers. However, it is not a cost-efficient programme in increasing farm income as these instruments generate high transaction costs and rent-seeking behaviour by farmers and insurance companies. Insurance subsidies may lead to unsustainable choices of production and farm practices in the short term and to the adoption of maladaptive practices under a changing climate in the long term. They may also crowd out on-farm diversification strategies as well as the development of agricultural insurance markets. In general, insurance subsidies risk crowding out market-based solutions and own-farm risk management strategies, and may transfer to taxpayers a part of the risks that should be borne by farmers.

Recommendations to rebalance agricultural policy toward long-term productivity growth

- Further rebalance the portfolio of agricultural support from support to grain production and public stockholding to public investment in R&D and infrastructure oriented towards long-term productivity growth and sustainability.
- Further decouple the existing commodity-specific support from production to enhance reallocation of resources based on market demand and to allow producers to set aside farmland while maintaining production capacity.
- Following the reform to reduce or cap the minimum purchase prices for rice and wheat, consider in the future replacing the domestic price support policy with direct payments for rice and wheat, making domestic prices close to international prices.
- Evaluate the performance of the agricultural insurance premium subsidy to ensure it does not transfer risk that should be borne by farmers to taxpayers, and monitor if it is hindering the development of agricultural insurance markets.

1.7. Strengthening China's agricultural innovation system

China has developed the world's largest and most decentralised public agricultural R&D system (Chen, Flaherty and Zhang, 2012). Public investment in agricultural R&D accelerated in the 2000s, both in terms of expenditure and human resources. Agricultural R&D expenditure was almost four times greater in 2013 than in 2000 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 such expenditure is still lower than most OECD countries.

With a growing public investment in agricultural R&D, the *output from agricultural R&D systems* has improved significantly. China's share in global agri-food publications increased from 1% in 1996 to 9% in 2012. The number of applications for agricultural patents and new plant variety rights has also been rapidly increasing, 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 the agricultural R&D system 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 in 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, in China nearly three-quarters of R&D expenditure of agriculture public R&D institutions is directed to experimental development research. The dominance of **public R&D in a wide area of research is likely to be crowding out the private** agriculture R&D investment in China.

The good performance of the agricultural innovation system comes from strong investment over the long term, and tripartite collaborations between education, research and industry. Creating **public-private partnerships for agricultural innovation**, aimed at fostering long lasting co-operation in R&D and innovation between these actors, should be a priority to establish a high performing agricultural innovation system in China. While China has been encouraging collaboration between public R&D institutions and the private sector for the last decade, the roles of public and private agricultural R&D should be clarified to make them complementary. Public R&D institutions should concentrate more on areas of public interest, such as environment and resource conservation, and on areas where the private sector would under-invest, such as basic and pre-competitive applied areas of research, and commercially less viable commodities.

Although commercialisation of the agricultural research and extension system increased the capacity of China's agricultural innovation system to respond to farmers' needs, the system can be characterised as a top-down one, where scientists in the public sector create new technologies with little consideration of farmers' changing demands. Around the world, agricultural innovation is increasingly taking place in a network-based setting, in which a more inclusive, interactive, and participatory approach fosters greater innovation in response to emerging and pressing challenges facing food and agriculture systems. China's **agricultural innovation system should become more collaborative and demand-driven**. The linkage between public agricultural research institutions, higher education institutions, agri-food enterprises, and public and private extension service providers should be increased to reflect industry's changing demands to public agricultural R&D activities.

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 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 agricultural innovation system as a whole.

The reform to hand over part of the research funding authority to a third-party agency, such as the National Natural Science Foundation, and shift public funding in agricultural R&D

from administrative allocation to a more competitive system is a step forward. **Greater co-ordination of research institutions combined with strengthening of evaluation mechanisms** would improve the efficiency of public funding to agricultural R&D. Moreover, the public funding system should be driven more by changing industry's demand for technologies, as public funding has been biased towards frontier-technology projects (OECD, 2017a). One example in agriculture is R&D of transgenic crops. The breeding of transgenic crops is identified as a national strategic research area and has attracted continuous public investment since the 1980s. However, bio-safety regulation so strongly limits the commercialisation of transgenic crops that only papaya and cotton are in commercial production today.

China's public agricultural extension system has undergone a series of reforms to make it more responsive to farmers' demands. The commercialisation of extension activities reduced their capacity to provide a variety of technical advice. A more positive recent reform has been 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. Additionally, 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 small 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 from abroad. While IPR policies and regulations are largely in line with international rules and guidelines, China's protection of IPR still lags behind most OECD countries, particularly in the area of enforcement.

Recommendations to strengthen China's agricultural innovation system

- Public R&D institutions should focus more on areas of public interest, such as environment and resource conservation, and on areas where the private sector would under-invest, such as basic and pre-competitive applied areas of research and commercially less viable commodities.
- Strengthen the role of the private sector in agricultural R&D through more effective enforcement of IPR protection, more transparent biosafety regulations, fewer barriers to FDI in agriculture R&D, and by privatising public R&D institutions in commercially viable areas of research.
- Improve the governance structure of the Agricultural Innovation System, in particular co-ordination between government agencies and public research institutes at national and subnational levels, including the strengthening of the evaluation of research outcomes, to avoid the duplication of research efforts and investments.

- Increase the linkage between public agricultural R&D institutions, higher education institutions, agri-food enterprises, and public and private extension service providers to reflect industries' changing demands for public agricultural R&D activities.
- Redefine the role of public extension system to services which private organisations have less incentive to provide, such as promoting sustainable production practices, leaving a greater role for private technical service providers and intermediary organisations such as farmers' co-operatives and industry associations in transferring technologies, capital and information.

Note

¹ The Oslo Manual defines innovation as the implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organisational method in business practices, workplace organisation or external relations (OECD and Eurostat, 2005).

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