CHAPTER 1

Agricultural Markets and Risk Management

1.1 INTRODUCTION

Agriculture has always been a core human activity, and over the past century it has made enormous progress in increasing the production of food and agricultural raw materials. Much of the growth is due to specialisation, verticalisation, expansion in land use and water resources, the improvements in farming techniques and risk management. At the same time, food production has become globalised, is dominated by a few producing countries, and has managed to keep pace with population growth and increasing demand.

The large growth in production, verticalisation and industrialisation has led to increased stress on natural resources and a higher vulnerability to unexpected shocks, including natural disasters and epidemic diseases that impact local and global markets. Climate change, including more extreme weather events, and future economic developments are major factors that drive supply and demand for agricultural products and food security. Risk management, including risk transfer, has been an integral part of advancing agricultural production in coping, mitigating and transferring production risks. The (re)insurance industry and capital markets have been developing products to satisfy the growing need of farmers, agribusinesses and governments to transfer risks.

This chapter provides a brief introduction of the main trends that drives demand and supply in agriculture, while trends in the individual sectors are discussed in subsequent chapters. Key risks and risk management options are discussed for producers, agribusinesses and governments.

1.2 TRENDS AND CHALLENGES IN THE AGRICULTURAL SECTOR

At the change of the millennium, there was a reasonably high level of confidence that projected food demand could be met by improved crop production. In more recent years, the consensus is that future food production will struggle to keep up with growing demand. Part of the change in viewing future global food security is that (i) grain prices were initially assumed to decrease in future decades, (ii) rates of economic development in the most populated countries have exceeded initial projections, (iii) the demand for grain, energy and livestock products has increased more rapidly through higher than anticipated increases in purchasing power, (iv) increases in grain yields have been slowing, and (v) climate change is perceived to have larger impacts on most agricultural activities. The global 2017 World Economic Forum (WEF) risk survey revealed that (i) extreme weather events ranked as the likeliest of the 10 most likely risks and ranked as number 2 of the 10 risks with the largest impact and (ii) food security was ranked seventh among the 10 risks with the largest impact.[1]

Generally, a more sustainable approach to agriculture is needed to use land, water and input supplies more efficiently (conservation agriculture) and to increase farm incomes and food security while adapting to climate change through mixed crop–livestock systems and sustainable livestock production (climate-smart agriculture).[2] Producing more with fewer resources, reducing greenhouse gas (GHG) emissions (global warming) and enhancing the livelihoods of smallholders in low- and middle-income countries remain key challenges for the agricultural sector. Increasing investments that are backed by safety nets of more specialised and verticalised agriculture (risk transfer) is essential to increasing production.

RISING DEMAND

Recent projections on demand and supply conclude that the agricultural sector will need to produce almost 50% more food, feed and biofuel by 2050 compared with 2012.[3] This means global markets will need to produce on average one third more, while sub-Saharan Africa and South Asia will need to double production. There is a consensus that the additional food will need to come predominately from yield increases since expansion of arable land is challenging as it is not readily available due to a lack of infrastructure in remote locations and a concentration of available land in only a few countries.

A key driver of demand is a growing human population that is likely to reach 9.73 billion in 2050 and 11.2 billion in 2100. Demand is undergoing structural changes in that increasingly affluent middle classes in low- and middle-income countries can afford to change their dietary pattern towards more resource-intensive dairy and meat products. As the global demand for livestock products is projected to increase by 70% by 2050 relative to 2010, production of feed from grains and cereals has to increase substantially to satisfy demand for meat and dairy products.[4] Additionally, the demand for biofuels, which use the same grains and oilseeds as livestock feed, is projected to

[1] WEF, 2017: The Global Risks Report 2017. 12th edition, World Economic Forum Insight Report, Geneva, 78p.
[2] FAO, 2016: Managing Climate Risk Using Climate-Smart Agriculture. FAO Publication, Rome, 22p.
[3] FAO, 2017: The Future of Food and Agriculture – Trends and Challenges. FAO Publication, Rome, 180p.
[4] FAO, 2012: World Agriculture Towards 2030/2050: The 2012 Revision. ESA Working Paper 12-03, Rome, 154p.

continue growing and has increased the competition between food and non-food uses of biomass and created an interlinkage between food, feed and energy markets.

After peaks in 2008 and 2011, food prices have stabilised, but price volatility seems to have increased since 2000. Future food price levels are difficult to estimate and depend on how production systems will respond to resource constraints and climate change. On average, imports are 0–20% of domestic food supply, with some large agricultural economies exporting 50% of their domestic production while many African and Asian countries are among net food importers.

CHALLENGED SUPPLIES

While productivity in all agricultural sectors and key markets has significantly improved over the past 50 years, intensification and industrialisation put increased stress on natural resources, while the industry is going through structural changes. In a number of countries, faulty and distortionary government policy incentives led agriculture production to be highly inflexible to market demand. Global free trade and stringent domestic agricultural policies have added to the vulnerability of individual agricultural sectors and producers. A growing number of interrelated and longer-term trends that are likely to include more frequent natural disasters (climate change), rural transformation, stresses on natural resources and financial shocks in the global economy are difficult to estimate, but all have the potential to severely impact all agricultural sectors.

Structural Changes

The agricultural sector has undergone large structural changes, particularly in high-income countries where farming's share of gross domestic product (GDP) has decreased and where the industrial and service sectors have become multiple times larger. Under such changes, agriculture has become more efficient, specialised and verticalised, as well as more capital-intensive and better integrated into the wider economy. Consolidation of smaller farms into large operations has gained efficiency while entire supply chains have been developed and integrated. Although evidence is still limited, the same transformational processes seem to appear in agricultural sectors of low- and middle-income countries. As agricultural production bears large risks and low productivity, agriculture results in low income, most of any young rural population preferring to work in other sectors in cities, which leads to a lack of resources in agriculture, aging of farmers and rural–urban migration.

Productivity

The production of most main crop types has increased by more than 300% (1961–2016) as a function of greater arable land, higher yields and advanced production technology (Section 6.2). However, production of main crop types is concentrated in a few countries that dominate global markets, and while yields of key staple crops have doubled in the past 50 years, they have been stagnating since the 1990s at annual growth rates of 1%. While the area equipped for irrigation has increased at annual rates of 1.6% (1961–2009), it is projected to grow at 0.1% in future decades due to competition for water from other sectors.

Industrial-scale livestock production led the doubling of the global livestock population in 2016 compared with 1961. As grain and oilseeds are important components in livestock feed, a larger part in the increase of crop production is explained by the needs of the livestock industry. Increased livestock mobility, global trading and large differences in biosecurity plans of high- and low-income countries have resulted in a higher overall vulnerability to large-scale outbreaks of epidemic diseases (Section 7.2). Future increases in livestock production are thought to come from larger herds rather than from higher per-animal productivity, which in turn requires larger quantities of grains and oilseeds for feed.

Between 1960 and 2016, the production of aquatic animals increased 50 times based on the adaptation of new production methods and the expansion of aquaculture areas (Section 8.2). Aquaculture provided only 7% of fish for human consumption in 1974, which grew to 44% in 2014. However, intensified production has led to overuse of antibiotics in fish feed, polluted waste waters and environmental degradation. Growth rates in aquaculture production are expected to slow due to constraints in water availability and accessibility of high-quality broodstock.

Driven mainly by commercial agriculture in tropical environments, global forest land decreased by 3% between 1990 and 2015, while over the same time, forest plantations increased in size (Section 9.2). With strong demand for forest conversions from population growth and crop production, the global forest area is likely to continue to decrease.

Availability of Natural Resources and Investments

Agriculture production is highly water intensive and accounts for 70% of global water withdrawals. While the efficiency of irrigation has increased, water allocations to agriculture are shifting towards other industries and growing urban centres. Adaptation of production techniques is necessary to increase the efficiency of water usage, such as drop irrigation and alternate wetting and drying, which can reduce water use in rice cultivation by 25% without affecting yields. Today, over 33% of the global arable land is moderately to highly degraded, with particularly high levels in dryland production systems.

Investments in agriculture have increased over the past 15 years and low- and middle-income countries now invest, with US$190 billion annually, about the same as high-income countries. Government-driven investments into research and development rapidly reduced after the *green revolution* in the 1970s but are now growing, particularly in low- and middle-income countries. Agricultural trades closely follow global economic trends, with rapid increases since 2000 and a drop during the 2008–2009 financial crisis and a recovery thereafter, agriculture being one of the most protected sectors through import tariffs.[5] The use of biotechnology, including genetically modified organisms, which is thought to support production increases through higher-yielding crop species, remains controversial in Europe and Asia.

Supply Chains

Inefficient supply chains in harvesting, storing, transporting, processing, packaging and marketing agricultural products and changing consumer attitudes have led to

[5] FAO, 2015: The State of Agricultural Commodity Markets – Trade and Food Security. FAO Publication, Rome, 89p.

food waste in the range of 33%, which is a particularly severe problem in low- and middle-income countries. Improving supply chain efficiency and linking local food production systems to growing cities are thought to be key measures to reduce food losses and wastage.

Conflicts and Poverty

Civil conflicts have increased since the 2000s and are the cause of large-scale migration, which undermines agricultural development and can lead to humanitarian crises. Countries with the highest levels of undernourishment tend to have experienced conflicts, and the prevalence of hunger rises exponentially with the degree of fragility.[6] Poverty is closely linked to agricultural productivity as both are highly concentrated in rural areas. Population increases, growing income inequalities, resource stress and impacts of climate change are likely to aggravate poverty and food security in the next decades.

Climate Change

The agricultural sector contributes 21% of total global GHG emissions and if energy usage is included (e.g. fuel for tractors) the share of agriculture activities increases to 26%. With intensification of production, agriculture-related GHG emissions have nearly doubled in the past 50 years and projections foresee a further increase. Climate change is seen as a significant hunger-risk multiplier and projections anticipate that by 2050, an additional 120 million people, particularly in sub-Saharan Africa, will be at risk of undernourishment.

Climatological Disasters

Global warming is likely to change the frequency and severity of climatological and meteorological disasters with potentially more frequent and intensive events. Climate change through increasing temperatures can lead to an intensification of certain plant pests and diseases and these spreading to larger areas. This will make agricultural production more volatile and requires adaptation strategies in the most affected regions and an increase in humanitarian assistance. Through increasingly globalised markets, production shocks from severe weather events in major producing markets are immediately reflected in commodity prices, which can rapidly develop into food security crises such as the events of 2007–2008 and 2011. Many low- and middle-income countries are likely to continue to rely on grain imports for food security and are at the mercy of international markets and export bans in the case of low domestic supply of a key production country. For example, following a severe drought in 2010, the Russian government ordered a ban on grain exports, which increased global wheat prices significantly and caused grain shortages for large net importers such as Egypt.

Impacts on Crop Production

The latest Intergovernmental Panel on Climate Change (IPCC) report states that (i) crop production in low-latitude countries will be negatively affected by climate change with high confidence while impacts in northern latitudes are more uncertain,

[6] http://fundforpeace.org/fsi (accessed November 2017).

(ii) climate change will increase the inter-annual variability of crop yields in many regions with medium confidence, and (iii) agronomic adaptation can improve yields by 15–18% with moderate confidence. Rainfed smallholder production systems in highland areas and the tropics, which produce 60% of global agricultural output on 80% of the global arable land, will be most severely impacted through more volatile rainfall and temperature patterns.[7] Most studies of climate change impacts on crop yields show that crop yield variability will generally increase in the future (2030); however, this varies per crop type and by geography.[8] Potentially more frequent and severe extreme weather events increase yield variability and the volatility of staple food prices.[9] Past climate trends display yield volatilities of 20–24% and could increase to 43–53% in 2020–2040.[10]

Impacts on Livestock, Aquaculture and Forestry
Depending on the region, climate change has large impacts on livestock production through lower quantity and quality of feed, increased heat stress and limited water availability, potentially more frequent and extreme climate events (e.g. severe winters in Mongolia, El Niño-associated flooding in east Africa and droughts in southern Africa) and faster spread of certain livestock diseases. Poor livestock households in Africa and South Asia, and pastoralists in drylands in Africa and the Middle East, are most severely impacted by climate change due to limited water and forage availability, with a potential for political conflicts. Temperature increases in low-latitude regions are likely to cause local extinction of some fish species, while rising sea levels will threaten coastal aquaculture systems in river deltas and estuaries. Warming temperatures could prolong the wildfire season through heatwaves and fewer snowcaps in winter.

1.3 RISK MANAGEMENT IN AGRICULTURE

Risk management has been an integral part of agricultural industrialisation, which has led to significant production growth that is necessary to satisfy growing demand for food and agricultural raw materials. Sources of risk in agriculture are numerous and diverse and the sector is exposed to random (idiosyncratic) and highly systemic (co-variate) risks, which can impact an individual producer, a larger region, the wider supply chain, an entire country or global commodity markets. Production and market risk are some of the largest risks in the agricultural sector and are addressed through constantly evolving risk management approaches.

[7] FAO, 2011: The State of the World's Land and Water Resources for Food and Agriculture. FAO Publication, Rome, 308p.
[8] McCarl, B.A. et al., 2008: Climate change and future analysis: Is stationarity dying? *Amer. J. Agr. Econ*., 90(5), 1241–7.
[9] Tadesse, G. et al., 2014: Drivers and triggers of international food price spikes and volatility. *Food Policy*, 47, 117–28.
[10] Diffenbaugh, N.S. et al., 2012: Response of corn markets to climate volatility under alternative energy futures. *Nat. Clim. Chang*., 2, 514–18.

RISK MANAGEMENT STRATEGIES

Risks in agriculture are diverse and often interconnected and require different strategies to cope with the risk, mitigate the risk or transfer the risk, depending on its magnitude. Considering the risk and the impact on the economy and the wider society, government agencies and the private sector collaborate to develop adequate risk strategies. Holistic risk management approaches include a set of complex relations between the original sources of risk, the available strategies and interrelated tools from governments and markets.[11] The holistic framework supports a system where public policy enables market solutions and risk is managed at different levels, including (i) frequent and limited losses are part of the normal business environment and are managed at farm level, (ii) larger and infrequent risks that are beyond farm-based risk management are addressed by market mechanisms (e.g. financial and insurance products), and (iii) very large and rare risks that can lead to market failure require government intervention.[12]

Risk Strategies

Agricultural risk management strategies can be divided into (i) mitigation to limit the adverse impact of a disaster, including production diversification (e.g. growing different crop types), income diversification and management measures (e.g. soil drainage, mulching, optimal planting schedules, weather forecasts), (ii) transfer of the financial consequences to a third party through informal, formal and/or semi-formal approaches, (iii) coping to manage financial consequences in, for example, complementing farm income by other activities, contract farming, and (iv) prevention, through irrigation, flood water management, drainage and crop protection.

Risk strategies can further be distinguished as (i) informal approaches, which are ex-ante strategies and include diversification of income sources, risk-adopted agricultural production strategies (e.g. buffer stock accumulation, irrigation) and risk avoidance, (ii) formal approaches provided by governments (e.g. infrastructure development, establishment of social schemes and/or cash transfer schemes) or markets (e.g. financial products and insurance), and (iii) semi-formal approaches, including informal risk sharing and mutualisation. Risk strategies largely depend on the type of risk, the impact in terms of area affected and the available response measures and risk mitigation and transfer mechanisms that are in place (see Figure 1.1).

Risks are often classified according to severity on three levels, including (i) micro-level risks, where random (idiosyncratic) risks affect individual producers, (ii) meso-level risks, where systemic (covariate) risks affect larger communities and the agricultural supply chain, and (iii) macro-level risks, where systemic and highly systemic risks impact an entire country and can have global consequences (see Figure 1.1).

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[11] OECD, 2010: Risk Management in Agriculture – A Holistic Conceptual Framework. OECD Publishing, Paris, 59p.

[12] Tangermann, S., 2011: Risk Management in Agriculture and the Future of the EU's Common Agricultural Policy. ICTSD, Issue Paper 34, Geneva, 50p.

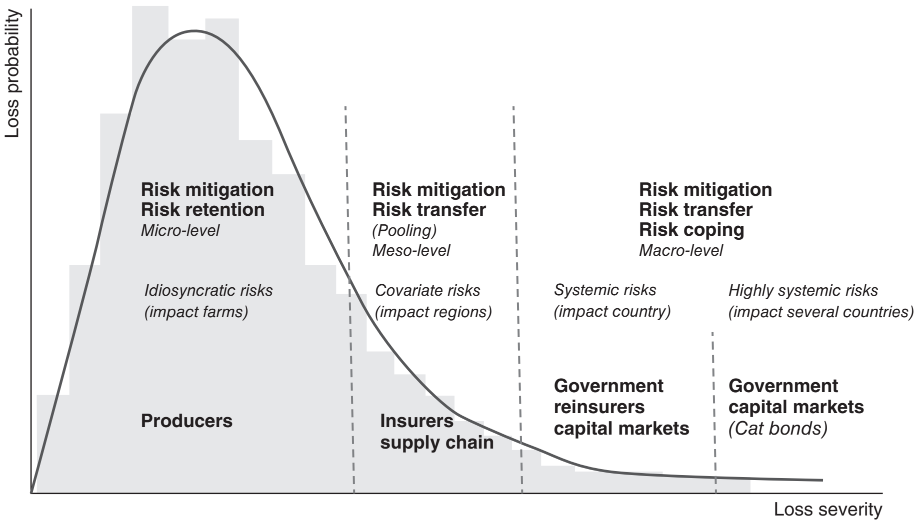

FIGURE 1.1 Layering of risks in function of loss probability/severity with typical risk management approaches.
Source: Adapted from World Bank (2016) and OECD (2009).

Risk Layering
Risk layering is a core analytical concept to develop a risk financing strategy to protect against events of different frequencies and severities; it includes different mechanisms to address needs for funds before or after a disaster. Risk layering assigns monetary levels at which risks can be retained, pooled or transferred through different levels of the agricultural sector while assuring that financial resources are optimised. Optimal risk layering contains probabilistic analyses where frequent low-consequence events and rare catastrophe-type events are assessed in terms of loss potential to develop disaster risk management strategies for each layer, which is particularly important in the wake of climate change.[13]

Risk Transfer

Risk transfer is one of the key risk strategies in agriculture and shifts identified risks or responsibilities from their source to a third party through mechanisms such as (re) insurance, capital market instruments and legislation. In a narrower sense, risk transfer instruments include financial derivatives, insurance and insurance-linked securities.[14]

Financial derivatives derive a value from one or more underlying assets, securities, prices or indices and differ according to (i) the type of the underlying value (e.g. equity, interest rate, exchange rate, commodity or credit), (ii) the structure of the derivative contract, (e.g. forward, swap, option), and (iii) the market in which they are offered.

[13] Linnerooth-Bayer, J. and Hochrainer-Stigler, S., 2015: Financial instruments for disaster risk management and climate change adaptation. *Clim. Change*, 133(1), 85–100.
[14] Anderson, P.R.D., 2014: Market Risk Transfer. Background Paper for the World Development Report 2014 on Opportunity and Risk. World Bank Report, Washington DC, 7p.

Insurance transactions are financial agreements that transfer losses against a cost (premium) and where insurers pool risks over different lines of businesses and geographical areas to absorb risks while maximising revenue from premiums and minimising the risk of payouts. While financial derivatives focus on transfer of market risk, insurance instruments cover production risks and some elements of market risks. Insurance-linked securities present an alternative to reinsurance with transfer of insurance risk to capital markets.

MARKET RISK MANAGEMENT

High price volatility is one of the main causes of volatile farm revenues and delayed or defaulted loan reimbursements and payments of input supplies. For low-income countries with large agricultural sectors and exports of a few leading commodities, commodity price volatilities have a large impact on export earnings, fiscal revenues and creditworthiness.

The international community and governments have tried to manage commodity price risks by stabilising price volatility through market interventions, including compensatory mechanisms (e.g. stabilisation funds, stockpiles, buffer stock), international commodity agreements and marketing boards. As set prices were often based on political bargains, market fundamentals were not accurately reflected and led to a failure of most stabilisation schemes and to the development of market-based commodity risk management mechanisms.[15] The main price risk management approaches for agriculture include financial instruments and contract farming.

Commodity Price Management Instruments

The main price hedging instruments include forward contracts, futures, options and swaps, which are available through standardised exchanges or are bilaterally negotiated between two parties. As price risks are spatially correlated, futures and options are efficient mechanisms to manage price risks as long as the basis risk is acceptable in that the volatility of price risks for a given area relates reasonably well to prices at a commodity exchange.

Forward Contracts

Forward contracts are private agreements (over the counter) for the seller (e.g. farmer) to deliver a specified quantity of a commodity to the buyer (e.g. a processor) at some time in the future for a specified price, with fix-priced contracts being the most common form.[16] Forward contracts are used to acquire physical delivery of the underlying commodity. While forward contracts buffer against negative price developments for the seller, the seller does not benefit from upsides when prices increase. Forward contracts contain (i) credit risk when the buyer fails to pay at maturity of the contract, and

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[15] Varangis, P. et al., 2002: Agricultural Markets and Risks. World Bank Working Paper 2793, Washington DC, 34p.

[16] Other forms of forward contracts that allow for more flexibility in how prices at delivery are derived include price-to-be-fixed contracts, deferred pricing contracts, deferred payment contracts, minimum price contracts, reference price forward contracts, basis contracts and hedge-to-arrive contracts.

(ii) default risk when the seller is not able to deliver the commodity, in which case the seller is obliged to purchase the shortfall from another source.

Futures Contracts
Futures contracts are standardised contracts that trade forward through commodity exchanges and are mainly used to hedge price risk rather than acquiring physical delivery of the underlying commodity. Futures contracts allow producers who own a commodity to protect themselves from declining commodity prices by selling a futures contract. As futures are settled between the seller and the buyer through the clearing house of the exchange, there is no credit and default risk. Futures are based on approximate prices, with the effective costs varying with market conditions. In case a futures position is not closed before expiry, the position could either be physically delivered or settled for cash. Futures only exist for the most common and main agricultural commodities.

Call and Put Options
Options are used to provide the seller with a guarantee of obtaining a minimum selling price and the buyer to obtain a maximum price with downside protection while retaining some upside potential. The buyer of the option pays the seller a non-refundable cost (option premium). A put option (call option) gives the buyer of the put option (call option) the right to sell (buy) the underlying commodity at a specified price, while the seller of the put (call) has an obligation to buy the commodity on the exercise of the option. Farmers without an existing physical contract (e.g. contract farming) typically buy a put option for protection against declining prices. Producers with physical delivery contracts can gain a financial upside above the pre-agreed delivery price of the physical contract through call options.

While exchange-traded options are standardised, privately arranged options provide more flexibility but contain credit risk. Options are settled in (i) offsetting the trade by taking the opposite position where the buyer or seller sells the option, (ii) exercising the option by the buyer when the underlying commodity is physically bought or sold through the exchange, or (iii) letting the option expire. European-type options can be exercised at expiry only, while American-type options can be exercised at any time.

Swaps
A commodity swap contract obligates the hedger (e.g. a farmer) to pay a fixed price and receive a floating price for a predefined volume of a commodity over a certain time from the hedge provider (e.g. a processor). For agricultural commodities, the existence of liquid and well-established futures markets limits the need for swaps.

Contract Farming

For a producer, prices can be pre-agreed through a contract farming agreement with a processor that can take the form of (i) a marketing contract, which defines the price of the commodity to be delivered before harvest, or (ii) a production contract that specifies production input supplies, quality and quantity of the commodity to be delivered as well as the price. An out-grower scheme involves contract farming by small-scale farmers with a processor, which in turn supports production planning, provides input supply and technical expertise as well as transportation, and therefore assures guaranteed market access. Some cooperatives, associations and farmer groups operate under collective marketing plans to manage price risk through higher bargaining power with domestic and international markets.

PRODUCTION RISK MANAGEMENT

Production risks derive from adverse weather conditions, pests and diseases, and technological changes that impact production quantity and/or quality and, depending on the severity, can impact large areas and lead to temporary failure of markets. Forest fires and epidemic disease outbreaks are production risks that can impact a sector long-term until reestablishment has occurred and productivity is back to normal levels. Production risks are mostly managed through risk transfer to (re)insurance markets, while some efforts have been undertaken to develop financial instruments to hedge against crop yield volatility.

Financial Instruments

As financial instruments are widely used to manage commodity price risks, in some markets efforts were undertaken to develop financial solutions to manage crop yield volatility. In 1995, the Chicago Board of Trade (CBOT) introduced futures and options for crop yield to hedge against yield volatility in using state-based yield estimates by the United States Department of Agriculture (USDA) during the growing and harvest season for commodities such as corn, soybeans, rice and winter wheat.[17] A yield futures contract allows a producer to lock in a crop yield several months into the future and hedge the revenue through a combination of yield and price futures. Put and call options were available on the corn yield futures. Theoretical models were developed to simultaneously hedge price and yield risk through financial instruments.[18] However, limited interest from producers led to the CBOT yield futures and options being discontinued in 2000, which was probably related to the emergence of large-scale, government-subsidised area-yield index insurance.

Insurance

Agricultural insurance remains the main approach to managing production risks and mainly covers physical damage to an agricultural asset. Over time, specific products have been developed, including indemnity- and index-based covers that provide payouts for production volatility from physical damage, reduced revenue from production and price volatility, and low farm income from different commodities (Chapter 5). Compared with price management instruments, insurance products are more tailor-made and often benefit from government support through premium subsidies. As agricultural insurance covers systemic risks, insurers rely on government and private-sector reinsurance to prevent market failures.

[17] Vukina, T. et al., 1996: Crop yield futures: A mean–variance analysis. *Amer. J. Agr. Econ.*, 78, 1015–25.
[18] Nayak, G.N. and Turvey, C.G., 2000: The simultaneous hedging of price risk, crop yield risk and currency risk. *Can. J. Agric. Econ.*, 48(2), 123–40.

FARM RISK MANAGEMENT

Producers are exposed to a variety of constraints which depend on a farm's location, the agriculture production system, the climatic conditions and the market environment. Farm risk management is mostly a combination of formal and informal approaches, depending on available products and key constraints within an agricultural production system. Constraints are typically highest in low-income countries with limited financial services, underdeveloped infrastructure and a lack of regulation and market access.

Commonly, risks that affect agriculture production include (i) production risks driven by weather conditions, pests, diseases and technological changes, (ii) ecological risks, including climate change and management of natural resources such as water, (iii) market risks through volatility of output and input prices, relationships with the food chain with respect to quality and risks associated with the introduction of new products, and (iv) institutional risks from changes in agriculture policies, food safety and environmental regulations (see Table 1.1).[19] Often, personal risks, financial risks and human resources risks are added as risks for producers.

Farmers in high-income countries benefit from the greatest diversity of risk management options, while smallholders in low-income countries are limited in their ability to manage risk and often rely on government support in the case of disasters or are left alone to cope with various risks.

SUPPLY CHAIN RISK MANAGEMENT

Agricultural supply chains are networks that support the flow of (i) physical products (e.g. from input suppliers to producers, processors and consumers), (ii) finances from credit to lending, payment schedules and repayments, savings and insurance, and (iii) information related to products and finances.

Modern risk management theory states that risk reduction can add to a firm's value by (i) reducing the likelihood of raising expensive external capital, (ii) reducing expected tax liabilities due to different marginal tax rates at different income levels or general differences in taxation, or (iii) lowering the likelihood of financial distress. Enterprise risk management (ERM) aims at the holistic identification of risk exposures to increase the understanding of events that can prevent the firm from achieving its strategic objectives. Further, stock exchange rules and credit rating agencies increasingly require corporations to integrate ERM, with analysts and shareholders becoming more sensitive to deviations of earnings compared with projections.

Major risks for agribusinesses include weather and natural disasters, biological and environmental risks, market risks, logistical/infrastructural risks, managerial and operational risks, policy and institutional risks as well as political risks (see Table 1.1).[20] Further risks include product contamination and recall, loss of access to sites/people/suppliers, reduced capacity, contractual obligations, dual sourcing and general market forces.

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[19] Hardaker, J.B. et al., 2015: Coping with Risk in Agriculture: Applied Decision Analysis. 3rd edition. CABI Publishing, Wallingford, 296p.

[20] Jaffee, S. et al., 2010: Rapid Agricultural Supply Chain Risk Assessment: A Conceptual Framework. World Bank Discussion Paper 47, Washington DC, 64p.

TABLE 1.1 Overview of the main risk types for an individual crop farmer and a grain processor with informal and formal risk management options.

	INDIVIDUAL OPERATOR (CROP FARMER)		AGRIBUSINESS (GRAIN PROCESSOR)	
Risk	**Parameter**	**Risk Management (Non-Exhaustive)**	**Parameter**	**Risk Management (Non-Exhaustive)**
Production risks	▪ Physical damage to crops leading to lower yield, unharvested areas ▪ Physical damage to farm infrastructure	*Informal*: ▪ Diversification of production by crop types and geography ▪ Vertical integration ▪ Use of irrigation, crop protection ▪ Early warning systems *Formal*: ▪ Government social/cash transfer and disaster compensation schemes ▪ Leasing agreements to manage production cycles ▪ Insurance for production, revenue or income volatility ▪ Weather derivatives	▪ Physical damage to regional/national crop production leading to lower production available for processing ▪ Physical damage to infrastructure, e.g. grain elevators and storage facilities ▪ Deteriorating grain quality in storage facilities/warehouses ▪ Physical damage during road and sea transport ▪ Non-delivery of grain by contractors due to production constraints	*Informal*: ▪ Diversification of sources of production ▪ Permanent monitoring/sampling of grain in storage ▪ Acquisition of processor in markets that are not exposed to the same perils at the same time *Formal*: ▪ Property and transport insurance ▪ Insurance (or weather derivative) for grain production volatility ▪ General liability insurance
Ecological/ environmental risks	▪ Uncertainties of production environment, e.g. management of natural resources (water grants) ▪ Impacts of climate change	*Informal*: ▪ Acquisition of water rights ▪ Climate change adaptation measures	▪ Uncertainties of production environment ▪ Impacts of climate change	*Informal*: ▪ Special storage facilities to reduce environmental risks ▪ ISO certifications *Formal*: ▪ Environmental liability insurance

(*Continued*)

TABLE 1.1 *(Continued)*

	INDIVIDUAL OPERATOR (CROP FARMER)		AGRIBUSINESS (GRAIN PROCESSOR)	
Risk	**Parameter**	**Risk Management (Non-Exhaustive)**	**Parameter**	**Risk Management (Non-Exhaustive)**
Market risks	▪ Volatility of input and output prices ▪ Foreign exchange rates ▪ Interest rates ▪ Risks in dealing with the food value chain (food quality, food safety)	*Informal*: ▪ Diversification and vertical integration *Formal*: ▪ Government minimum support prices ▪ Forward contracts, options and futures ▪ Contract farming, collective marketing plans ▪ Revenue or income insurance	▪ Volatility of commodity prices ▪ Volatility of freight costs ▪ Competitor behaviour (e.g. mergers and acquisitions) ▪ Restricted access to capital	*Informal*: ▪ Diversification and vertical integration *Formal*: ▪ Forward contracts, options and futures ▪ Contract farming with key producers ▪ Corporate revenue or income insurance
Institutional risks	▪ Changes in government actions/rules, e.g. pesticide usage, environmental/farm practices, tax provisions ▪ Restricted access to markets (e.g. closing of ports, export ban)	*Informal*: ▪ Lobby groups to obtain first-hand information	▪ Changes in fiscal and tax policies ▪ Changes in trade and market policy (e.g. foreign government subsidies, trade barriers) ▪ Strikes in harbours ▪ Political instability, corruption, nationalisation of assets	*Informal*: ▪ Lobby groups to obtain first-hand information on changing government rules *Formal*: ▪ Political risk insurance

Financial/ infrastructure risks	▪ Inability to pay interest rates for credit and loans, farmworkers' wages and leased machinery/ equipment	*Informal*: ▪ Cash flow management/ planning ▪ Off-farm work to complement farm income *Formal*: ▪ Increase borrowing levels ▪ Leasing of machinery/ equipment	▪ Volatility in foreign currency exchange rates ▪ Volatility in interest rates ▪ Counter-party credit risk ▪ Inability to pay debts and interest ▪ Deteriorating transport infrastructure	*Informal*: ▪ Cash flow management/ planning *Formal*: ▪ Refinancing of debt ▪ Liquidating assets ▪ Interest rate swaps ▪ Counter-party–credit risk derivatives
Operational risks	▪ Machinery breakdown ▪ Uncertain life events (e.g. death, disability) ▪ Unavailable employees	*Informal*: ▪ Regular health checks and inspection of machinery ▪ Access to temporary employees *Formal*: ▪ Life and disability insurance	▪ Poor management decisions ▪ Retention of key personnel ▪ Pension and employment benefits schemes ▪ Health and safety risks for employees ▪ Contamination of produced grain (food safety) ▪ Changes in reputation/ perception of supply chain and products	*Informal*: ▪ Performance-based retention plan of key personnel ▪ External evaluation of pension schemes and contributions ▪ Audits of safety and health procedures ▪ Tracking of input supplies and grain delivery to comply with food safety standards for domestic and export markets (e.g. HACCP and ISO 9000) *Formal*: ▪ Directors & officers insurance ▪ Workers' compensation insurance ▪ Product liability insurance

Source: Adapted from OECD (2000) and various grain processors' annual reports.

Recently, green mandates oblige the supply chain to follow environmentally-friendly production processes, which bears additional risks.[21]

Most agribusinesses are well versed in the use of financial instruments to manage commodity prices and freight costs, interest and foreign exchange rates, and purchase insurance programmes to cover risks including general and product liability, environmental liability (where available), workers' compensation and transportation. Increasingly, production volatility risks related to natural perils and lower-than-expected volumes of agricultural commodities have become insurable and support agribusiness to manage fix costs and earnings volatility (Section 6.8).

GOVERNMENT RISK MANAGEMENT

Governments have different options for coping with the financial impact of natural disasters, depending on the severity of the disaster, geographical scope, and population directly and indirectly affected. Governments play a key role in providing agricultural assistance, including public food grain reserves, disaster assistance programmes, social protection schemes and disaster risk financing, most of which are anchored in the national disaster risk management strategy.

Depending on the scale and intensity of a natural disaster, a government has budgetary outflows for relief operations, recovery operations and reconstruction and therefore needs liquidity over several months, if not years. While for some low-loss events that occur frequently risk-reduction measures are appropriate, for low-probability but high-severity disasters, ex-ante and ex-post disaster financing strategies are necessary.

Disaster Assistance Programmes

Disaster assistance programmes include disaster risk management and/or disaster risk reduction programmes that aim to reduce the risk (e.g. early-warning systems, environmental protection) and mitigate impacts on livelihoods through response, recovery and reconstruction.

Disaster Risk Financing Programmes

Disaster risk financing aims to deal with the financial impact of disasters and includes (i) ex-post measures such as tax increases, reallocating funds from other budget items, and access to domestic and international credit and borrowing from multilateral finance institutions, and (ii) ex-ante measures including the building of financial reserves, contingent debt agreements and risk transfer to the (re)insurance industry or capital markets, typically through parametric products.

Ex-post Disaster Financing Instruments

Governments have several ex-post financing instruments available, which include both short-term and longer-term measures. Allocation of funds to cope with disasters from other priority development projects takes considerable time and often needs

[21] Enyinda, C.I. and Mbah, C.H., 2017: Quantifying sources of risk in global food operations and supply chain. *Thunderbird Int. Business Rev.*, 59(6), 653–61.

parliamentary approval. Equally, rising debt and obtaining credits from domestic and international sources after the occurrence of disaster are longer-term approaches. While appropriate to finance reconstruction efforts, debts and credits do typically not provide the required liquidity to finance immediate post-disaster needs and depending on the damage extent, post-disaster borrowing costs can be significantly higher compared with pre-disaster time and depend on a country's level of indebtedness and ability to service the debt. Obtaining assistance from international donor countries and multilateral financing institutions in the aftermath of a disaster is a common approach adopted by many low-income countries. However, donor funding largely depends on the level of visibility of a disaster in the international media and it can take time until funds are available. Increasing taxes over time to support reconstruction following a disaster are often used ex-post financing instruments; however, tax increases can discourage new private investments that are essential to redeveloping the economy after disaster impact.

Ex-ante Disaster Financing Instruments

Ex-ante instruments are considered more proactive risk financing strategies that provide faster funding than ex-post approaches. IPCC states that insurance and other financial instruments can play an important role in managing natural disaster risks in the framework of climate change adaptation.[22]

A reserve fund can be developed through borrowing or accumulating tax revenues to finance immediate post-disaster needs. Reserve funds are well established in high-income countries to smooth out peak financing requirements, but they are generally rare in low-income countries. Contingent debt provides immediate capital after disaster occurrence with interest rate and loan maturity defined on a pre-loss basis. For disbursement, contingent debt contracts can contain hard triggers (debt is disbursed only according to physical criteria of the intensity of the disaster) or soft triggers (debt is disbursed in the case of an emergency declaration being issued by the government).

Risks can be transferred to (re)insurance markets that provide adequate coverage for natural disasters. In high-income countries, compulsory insurance against natural disasters has proved effective for property assets, despite some political resistance. In low-income countries, insurance markets tend to be underdeveloped and inefficient without or with only limited coverage for natural perils, which leaves governments only with the option to transfer risks through indices directly to reinsurance and capital markets. Unlike contingent credit agreements, parametric risk transfer products are based on hard triggers where payouts are based on a disaster of a predefined intensity which is commonly defined through outputs of catastrophe risk models. As based on indices and model results, these products inherently contain basis risk and might not cover all types of natural disasters.

[22] IPCC, 2012: Summary for policymakers. In Fields, C.B. (ed): Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation. Cambridge University Press, 1–19.

Change of Paradigms

In the face of the rising frequency and intensity of losses in low- and middle-income countries, the old model of post-disaster financing and reliance on the donor community is increasingly inefficient. Ex-ante financial schemes that are based on optimal risk layering and an efficient disaster risk management framework can provide efficient solutions around immediate liquidity and reconstruction for low-income countries. International financing institutions and the donor community have been promoting proactive disaster risk management systems, including catastrophe risk financing models to reduce external assistance based on (i) assessing a government's contingent liability to natural disasters, (ii) enabling risk transfer to competitive (re)insurance markets, and (iii) financing sovereign risk.

In high-income countries, losses from natural disasters are typically funded through private risk financing agreements and an efficient public revenue system that relies on taxes. For low-income countries, which typically have low tax ratios and ongoing financial pressures, post-disaster funding comes mainly from international donors through multilaterally sourced infrastructure loans and relief aid. In low-income countries, the catastrophe insurance and risk transfer markets are clearly underdeveloped, which is demonstrated by the fact that while over 40% of the direct losses from natural disasters are insured in high-income countries, less than 10% of these losses are covered by insurance programmes in middle-income countries and less than 5% in low-income countries.[23] Post-disaster development lending from multilateral financing agencies is important for middle-income countries, while support from bilateral donors is typically more dominant in low-income countries.

Risk Layering

Optimal risk layering contains probabilistic analyses where frequent–low-consequence events and rare catastrophe-type events are assessed in terms of loss potential to develop disaster risk management strategies for each layer, which is particularly important in the wake of climate change (see Figure 1.1).[24] The optimal strategy to finance post-disaster liquidity for a government that has restrictions with budget reallocation and reserve funds is likely to include risk retention through reserving to cover small losses and contingent credit as well as risk transfer through reinsurance and/or capital markets to cover large losses.[25] While frequently used by governments or a group of governments to transfer risk to the (re)insurance industry and capital markets, such solutions in the form of insurance or financial instruments (derivatives) are becoming increasingly available for agricultural assets.

Government Risk Transfer for Agricultural Risks in Beijing, China

In 2007, the Beijing Municipal Government (BMG) implemented a new agricultural insurance policy to subsidise crop and livestock insurance premiums by up to 80%,

[23] Cummins, J.D. and Mahul, O., 2009: Catastrophe Risk Financing in Developing Countries: Principles for Public Intervention. World Bank Publication, Washington DC, 299p.

[24] Linnerooth-Bayer, J. and Hochrainer-Stigler, S., 2015: Financial instruments for disaster risk management and climate change adaptation. *Clim. Change*, 133(1), 85–100.

[25] Clarke, D. and Mahul, O., 2011: Disaster Risk Financing and Contingent Debt – A Dynamic Analysis. World Bank Policy Research Paper 5693, Washington DC, 31p.

with additional support for 10% of the administrative costs. The insurance programme covers field and horticultural crops against natural perils, livestock against diseases (including epidemics) and greenhouses for physical damage to contents and structures. In the first year, insured values of US$1.2 billion were covered through three insurers, which increased to US$1.6 billion in insured liabilities in 2017 with seven insurers.

Natural Disaster Fund

BMG established a protection fund for natural disaster losses to the underlying agricultural insurance portfolios of each insurer. The new agriculture policy framework works at three different levels that are based on combined loss ratios (CLRs) as (i) CLR is below 100% where insurers assume all losses with surpluses in good years to be put into the protection fund, (ii) CLR of 100–160% where insurers compensate losses from the protection fund and arrange for adequate reinsurance, and (iii) CLR above 160% when BMG assumes all losses. The 160% CLR has been established based on the advice of agricultural insurance experts and quantitative analyses of past calamity data by main peril and losses from previous agricultural insurance programmes in the province of Beijing.

A quantitative analysis that uses historical insurance experience through nonparametric information diffusion modelling shows that the probability of a loss over a CLR of 160% is 70%.[26] However, it has to be noted that past insurance claims stem from relatively small portfolios and different insurance terms and did not benefit from government premium support.

Sovereign Risk Transfer

In 2009, BMG decided to enter into an ex-ante sovereign risk transfer to proactively manage its liabilities above a CLR of 160%. Under the stop-loss reinsurance structure, the risks that are pooled by BMG are transferred to the national reinsurer and international markets for CLRs between 160% and 300%. The insurance regulator approved the risk transfer agreement and estimated the loss frequency at a CLR of 300% at a 50-year event. BMG has bought stop-loss reinsurance continuously since 2009, and in 2017, the stop-loss structure provided cover for US$125 million and incurred a payout in 2012 (excessive rainfall) and 2016 (rainstorm).

In China, province governments are becoming increasingly aware of potential financial liabilities from natural disasters in the agricultural sector and liabilities arising from the National Agricultural Insurance Program (Section 5.2). In 2016, the Heilongjiang government followed the example of Beijing and bought parametric reinsurance to cover income volatility of poor rural households from flood, excessive rainfall, drought and low temperature based on weather- and satellite-derived indices.

[26] Xing, L. and Lu, K., 2010: The importance of public–private partnerships in agricultural insurance in China: based on analysis for Beijing. *Agric. Agric. Sci. Procedia*, 1, 241–50.

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