Chapter 11

CLIMATE INSURANCE: OPPORTUNITIES FOR IMPROVING AGRICULTURAL RISK MANAGEMENT IN KENYA

Berber Kramer

Climate change represents a major challenge to food systems. It is associated not only with rising average temperatures but also with less predictable weather and changes in humidity, with severe consequences for agricultural production, input markets, aggregation, processing, distribution, and consumption. Negative impacts on food production can raise consumer prices, potentially leading to social unrest and conflict; increased temperatures and changes in humidity require stronger cold chains and improved storage facilities to avoid postharvest damage (de Brauw and Pacillo 2022).

This chapter highlights several innovations in climate insurance that were developed and tested in Kenya with the aim of improving smallholder farmers' ability to manage the production risks associated with climate change.

In Kenya, farmers and herders are facing increasingly unpredictable and unreliable rainfall patterns, resulting in agricultural losses from drought and excess rain, as well as pests and disease. Climate change will continue to negatively affect crop and livestock production and food security (Kogo, Kumar, and Koech 2021). Increased incidence of droughts and other natural hazards reduces agricultural productivity in two ways. The most visible channel is that, when these shocks occur, they limit crop growth and the amount of food and water available for livestock, with a negative impact on production and food security. But even in the absence of such a shock, the mere possibility of a natural hazard occurring will discourage risk-averse farmers and herders from investing in agriculture (Vargas Hill et al. 2019), and lenders from financing these investments (Carter, Cheng, and Sarris 2016). Thus, an increase in agricultural production risks as a result of climate change lowers agricultural productivity both ex post, when a shock occurs, and ex ante, when the farmer merely anticipates the risk of a shock occurring; and these ex ante impacts are estimated to be twice as large as the impacts of shocks themselves (Elbers, Gunning, and Kinsey 2007).

In this context, adapting to climate change is important to meet growing food demand and to improve vulnerable smallholder farmers' livelihoods. Farmers and herders can adopt new technologies or practices to reduce their exposure to climate-induced risks, and adapt to climate change, but this requires investments in rural and agricultural development—particularly in resilience technologies such as drought-tolerant cultivars, irrigation and soil and water conservation, or improved methods to store and preserve livestock feed (Bryan et al. 2013). Unfortunately, adoption of these solutions remains slow, in part because they require upfront investments while not providing full protection from all types of climate risk. For instance, a farmer purchasing drought-tolerant cultivars will spend more on seeds than will farmers growing more common varieties, and although the drought-tolerant cultivars offer protection from moderate droughts, they do not offer as much protection from more extreme droughts and other natural hazards. As a result, farmers may still lose their crops or livestock. The risk of being unable to recuperate investments in risk-reducing technologies will discourage farmers from investing in these technologies.

Climate insurance can help reduce these risks that farmers cannot manage through better practices and technologies. Providing farmers with insurance for more severe droughts and other natural hazards will help protect their investments, and potentially increase investments in adaptive measures (Kramer and Ceballos 2018). There are, however, several challenges in the provision of climate insurance (Carter et al. 2017; Kramer et al. 2019).

On the one hand, there are indemnity-based insurance products that aim to settle claims based on actual losses experienced by a farmer. Such insurance is typically unavailable to smallholder farmers; if it is available, it will be unaffordable. Indemnity-based products carry high transaction costs because the value that a smallholder farmer seeks to insure is small relative to the cost of in-person visits required to verify that damage has indeed occurred in case of a claim. Such products are also known to be expensive because of asymmetric information between insurers and the insured. Providing compensation for a farmer's actual loss can induce moral hazard: it lowers the farmer's incentives to minimize damage, as payouts are made only when crops are damaged regardless of someone's effort, and efforts to minimize risk reduce the chances of a farmer receiving an insurance payout. It can also induce adverse selection: at a given premium, only farmers with relatively higher risk exposure will enroll in insurance, which will drive up expected insurance payouts, and insurers will reflect such selection by raising their premiums (Just, Calvin, and Quiggin 1999; Gunnsteinsson 2020; Ceballos and Kramer 2021).

On the other hand, index-based insurance settles claims based on objective measurements of an index, which has been designed to proxy for agricultural losses, for instance rainfall. The advantage of index insurance products is that, in principle, they can be implemented at a relatively low cost, since no in-person visits are required to verify damage. In addition, the perfect observability of the index helps overcome any information asymmetries, eliminating concerns around moral hazard or adverse selection driving up insurance premiums. Index-based insurance therefore helps address some of the key challenges associated with the provision of indemnity-based insurance (Barnett and Mahul 2007). However, these products often suffer basis risk, meaning that the index and thus insurance payouts do not correlate adequately with the actual losses that a farmer or herder experiences. Too often, insurance beneficiaries experience damage for which the index does not trigger a payout, given that the index is a proxy only for agricultural losses. Such basis risk, combined with limited understanding of how index insurance works, also results in poor trust and low take-up of insurance products (Clarke 2016).

Another major challenge in the provision of agricultural insurance, regardless of whether a scheme provides indemnity- or index-based insurance, is that limited market intelligence goes into the design of these insurance schemes. Programs often fail to differentiate across different types of farmers, who require different solutions (Hansen et al. 2019; Kramer et al. 2022). For instance, more commercially oriented farmers have more risk-absorbing capacity because of their greater wealth levels and will hence be less risk-averse (Clarke 2016; Vargas Hill, Hoddinott, and Kumar 2013). Because of the risk-absorbing capacity and the lower vulnerability levels of this type of farmer, partial insurance—covering, for instance, only their inputs—will likely be sufficient, and they will not have to insure the full value of production or income over a season. Subsistence-oriented farmers are more vulnerable, with lower risk-absorbing capacity. This is why they will benefit from more complete insurance, covering not only investments in inputs but also the forgone profits from selling crops in the case of a bad harvest. Nonetheless, insurance policies offered to smallholder farmers are typically designed to cover only a portion of their investments in inputs, for instance only seeds. Existing solutions rarely protect households from the full loss in consumption or income that they experience in a bad season.

Finally, insurance providers are challenged by farmers' ability to pay and liquidity constraints, the sharing of risks across value chain actors, and the broad nature of risks experienced. More subsistence-oriented farmers may be able to purchase insurance for a small portion of their investments but they will not be able to afford an unsubsidized commercial insurance premium for their

full value of production, or the full loss that they may experience in a bad year, even though this would provide them with the type of social protection that would enable increased investments in their farms (Kramer et al. 2022). More commercially oriented farmers may be able to afford insurance premiums, but only at the time of harvest, when they have cash on hand. For them, overcoming liquidity constraints to premium payment will be critical to create demand. Collecting the full insurance premium from vulnerable smallholder farmers can also be difficult when the risk is shared across value chains. A weather shock that lowers productivity will affect not only farmers but also their lenders, input providers, aggregators, and laborers. Farmers' decision to take up insurance can hence benefit these other actors, and innovative mechanisms are required to share the costs of insurance premiums across them. It is, however, important to recognize that insurance cannot cover all risks, including reduced market prices for farmers' produce and other postharvest risks, which can, in some cases, affect farmers' incomes more than production risks (Ceballos, Kannan, and Kramer 2021).

The remainder of this chapter describes examples of innovations that have been tested in Kenya, along with the shortcomings and implications for Kenya's national agricultural insurance scheme. Given that insurance design often neglects the role of gender and social inclusion, the chapter includes a separate section discussing how to advance gender and social equity through climate insurance. The chapter focuses on Kenya; for reviews of innovations in climate insurance from a more global perspective, see Carter and colleagues (2017), Kramer and colleagues (2019), and Kramer and colleagues (2022).

Innovations in climate insurance with a focus on solutions tested in Kenya

This section discusses potential solutions to the challenges introduced above. The discussion focuses on technological innovations as well as those in the institutional space, including, for instance, bundling insurance with other vital services for smallholder farmers, providing macro-level insurance coverage, and integration in social safety nets. This is not a comprehensive overview of solutions in the agricultural insurance sector, since the section focuses on innovations developed and tested in the context of Kenyan agriculture. However, many solutions have been either developed or tested in Kenya, and the innovations provided below are therefore a valuable starting point.

On the technological side, remote sensing has been used to make low-cost index-based livestock insurance (IBLI) available for Kenyan pastoralists. IBLI

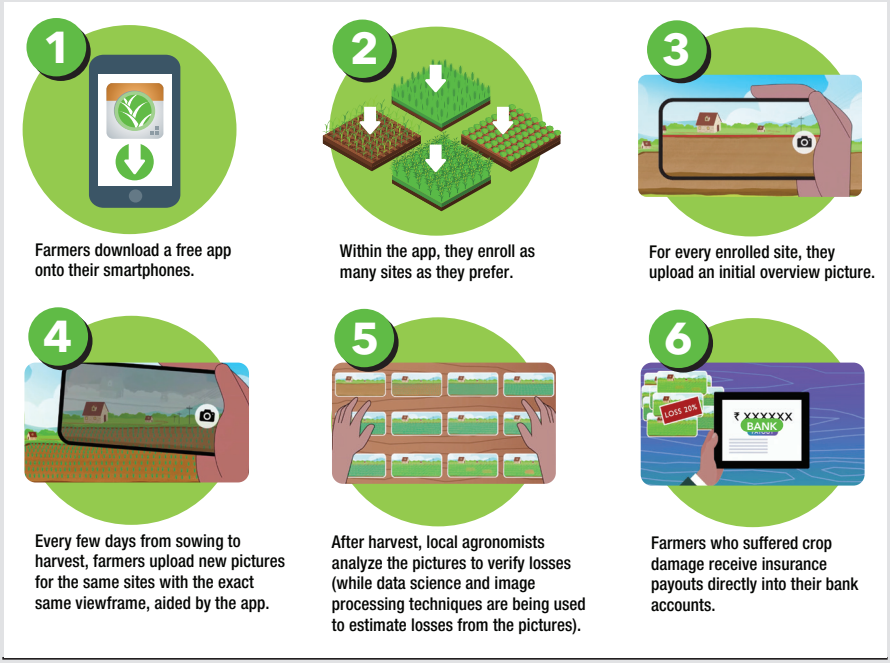
was designed by linking semi-annual seasons of longitudinal household data on livestock mortality with remote sensing data to construct a vegetation index-based proxy for livestock mortality. The Kenya Livestock Insurance Program (KLIP) provides fully subsidized IBLI coverage for up to five tropical livestock units for eligible pastoralists, and more commercially oriented herders can purchase additional unsubsidized coverage.[1] IBLI was predicted to have positive welfare effects (Chantarat et al. 2013). Empirical impact evaluations indeed show that, for many households, it substantially reduces exposure to covariate risk, or risks that affect households in a wider region at the same time (Jensen, Barrett, and Mude 2016). Also, among households experiencing drought, it reduces reliance on costly coping strategies such as selling assets to smooth consumption or reducing consumption to protect assets (Janzen and Carter 2019). Yet, basis risk remains a challenge: IBLI policyholders are left to manage on average 69 percent of their original risk because of idiosyncratic livestock mortality (Jensen, Barrett, and Mude 2016).

In the area of crop insurance, remote sensing has been used to improve farmers' options to manage risk as well. ACRE Africa is a private company headquartered in Kenya that offers solutions for smallholder farmers to manage climate risks. It designed an index insurance product that uses remote sensing-based data on soil moisture to proxy for crop health. ACRE Africa and its partners state that the product has been successfully piloted and scaled out to thousands of farmers but there are no peer-reviewed publications to validate product quality or the welfare impacts of this insurance scheme. While remote sensing-based crop insurance products may achieve substantial reductions in spatial basis risk compared with weather index-based insurance products that use weather stations to proxy for crop losses, they may still face considerable design basis risk, where indexes derived from satellite spectral bands are a limited proxy for individual crop damage. In addition, remote sensing products suffer from limited visibility of ground conditions owing to cloud cover, and decreasing signal-to-noise ratios as spatial resolution increases. They also require considerable processing power and storage capacity at very high resolutions (IFAD 2017), with providers such as PlanetLabs now offering a global 3–5 meter resolution of daily red-green-blue images. To address such basis risk, ACRE Africa has started introducing picture-based insurance into its index insurance solutions (Ceballos, Kramer, and Robles 2019, see Box 11.1).

1 Tropical livestock units are livestock numbers converted to a common unit, whereby larger animals are converted into a larger number and smaller animals into a smaller number. As a result, two cows, for instance, will result in a greater measure of tropical livestock units than will one cow and one sheep.

BOX 11.1 Picture-based insurance

Picture-based insurance (PBI) is a new way of delivering affordable multi-peril crop insurance. By relying on smartphone pictures taken from a farmer's field, PBI settles claims based on plot-level damage, resembling indemnity insurance without having insurance agents visit fields to verify losses. Sending in pictures can also make the insurance process more engaging, comprehensible, and accessible to small farmers. Here is how it works:



Source: https://www.ifpri.org/project/PBInsurance

IFPRI tested this approach in Kenya with ACRE Africa, Kenya Agricultural and Livestock Research Organization (KALRO), and Wageningen University, first offering it as a free trial and later at commercial insurance premiums. An initial proof of concept (Ceballos, Kramer, and Robles 2019) shows PBI to be feasible and sustainable: insurance experts can quickly and accurately process claims for sites where farmers report crop damage remotely; the research team has been able to use machine learning to partially automate image processing and damage classification for claims settlement (Hufkens et al. 2019); and limited smartphone ownership has been overcome by relying on village-based agents to send in pictures on behalf of insured farmers in their villages.

Given that PBI revolutionizes the insurance–client relationship, enabling insurers to directly observe the farm, PBI could be implemented as indemnity-based insurance, whereby costly in-person visits by insurance agents are replaced by inspections of images of the damaged crop. In addition, the wealth of information in field pictures and the direct communication channel with farmers enabled by a smartphone app could be further capitalized to design more comprehensive risk management solutions for smallholder farming.

An institutional innovation that has been piloted in the context of insurance programs in Kenya is bundling insurance with other vital services for smallholder farmers. First, insurance has been offered in combination with seeds. In fact, this is how ACRE Africa—the organization mentioned above—started. Its originator, the Kilimo Salama project, launched by the Syngenta Foundation for Sustainable Agriculture and the Global Index Insurance Facility, provided weather index-based insurance to farmers purchasing certified maize seeds, which they could activate at the time of planting using a scratch card found in the seed bag, using the same methods as in topping up airtime. In case of drought or excess rainfall, Kilimo Salama would send an insurance payout to the mobile money account linked to the phone number that was used to activate insurance coverage. In its inception, the program subsidized the premiums of these so-called replanting guarantees, with the idea that, over time, seed companies would start paying the premiums directly as they would see the value of providing farmers with insurance (as it would increase farmers' loyalty and thus demand for their products).

The program shows that uptake of Kilimo Salama was positively and significantly associated with the use of chemical fertilizer and improved seeds, and also with crop yield (Sibiko and Qaim 2020). A key challenge, however, lay in understandings of product benefits. Many farmers were not aware that the seeds they were purchasing came with insurance coverage, or they did not know how to activate the coverage. Farmers were also unaware of how rainfall measurements and thresholds were linked to insurance payouts, suggesting a need for more transparency (Sibiko, Veetill, and Qaim 2018). Moreover, removing subsidies for seed companies to bundle their products with insurance appears to have crowded out their interest in insurance. Companies do not have the marketing budgets to include insurance free of charge and they fear that adding insurance premiums to the costs of seeds will reduce their competitiveness.

Bundling seeds with insurance could, however, have positive impacts. Bulte and colleagues (2020) use a randomized trial in Kenya to show that farmers increase effort—increasing total investments and taking more land in production—when receiving a free hybrid crop insurance product conditional on purchasing certified seeds. In addition to adopting more certified seeds, they invest more in complementary inputs such as fertilizer and hired-in farm machinery and nonfarm labor. They also find that being provided with insurance free of charge increases ex post willingness to pay for the insurance product. This suggests that learning about the benefits of (subsidized) insurance outweighs any anchoring effects on the zero price during the pilot study. A study in Mozambique and Tanzania finds favorable resilience impacts of

bundling insurance with drought-tolerant maize: the drought-tolerant maize protects farmers from moderate droughts while insurance provides payouts in case of a severe drought (Boucher et al. 2021). Bundling with seeds offers a natural entry point for increasing insurance coverage. A policy recommendation, then, is to explore instruments that encourage seed companies to bundle their seeds with insurance.

Second, there have been successful initiatives bundling insurance with contract farming. Casaburi and Willis (2018) tested this strategy through a randomized controlled trial in Kenya. They find that such bundling can increase the demand for insurance because the buyer of crops can deduct the insurance premium from farmer revenues at harvest time (just like the cost of any other inputs). This offers a mechanism for farmers to pay insurance premiums in the future, which can help overcome challenges around limited trust, present bias, and liquidity constraints. The One Acre Fund, a large-scale program that provides agricultural service packages including inputs such as seeds and fertilizers, often on credit, and typically along with extension, offers crop insurance as part of its standard agricultural service package to farmers in five African countries, including Kenya. This allows the One Acre Fund to reimburse farmers for a portion of their upfront investments in seeds and fertilizer when weather harms their crops, easing the immediate financial pressure of a poor harvest. Insurance has also been bundled with credit alone; see more on this in Chapter 12 on risk-contingent credit.

The third set of successful insurance programs has been operating at the macro level, with governments funding insurance coverage out of their social protection, disaster relief, or agriculture budgets. One example of macro insurance provided in the African continent is African Risk Capacity (ARC), which was launched in 2012 to provide African Union member states with parametric insurance to finance disaster risk management operations, facilitating faster delivery of assistance to beneficiary households (Kramer, Rusconi, and Glauber 2020). Kenya was part of ARC's first two risk pools (2014–2015 and 2015–2016) but has opted out since then, after having developed a national disaster risk management plan—which Kenya perceived as the main benefit in joining ARC. However, the KLIP has been integrated with Kenya's major social safety net, the Hunger Safety Net Program (HSNP). Jensen, Ikegami, and Mude (2017) find that this integration of insurance into a cash transfer program improves cost-effectiveness, as it protects the vulnerable non-poor from falling into poverty and requiring permanent cash transfers. The Alliance to Feed the Earth in Disasters (ALLFED) is developing bonds or insurance products that trigger financing when there is a risk of a locust outbreak in the Horn of

Africa; the funding, when a payout is triggered, is used to finance locust control operations for the Food and Agriculture Organization of the United Nations (FAO), so that FAO together with in-country partners can intervene through a coordinated response and prevent locust outbreaks from causing major damage (ALLFED 2021).

Gender and social equity: How to make climate insurance more equitable?

Given public investments in climate insurance, an important question relates to the extent to which insurance programs achieve gender and social equity. Most studies on gender and agricultural insurance focus on gender inclusivity by analyzing gender gaps in insurance *reach*, for instance by comparing the number of men and women enrolled, and by studying how to increase uptake among women. Altamirano and Beers (2018), for instance, discuss the inclusiveness of the Kilimo Salama program that was bundling insurance with seeds. In the short term, the use of mobile technology and remote sensing was likely not inclusive, given limited access to and understanding of this phone-based system, and particularly control over mobile money accounts, among the most vulnerable. The authors argue that the inclusiveness of this innovation may increase in the longer term. However, gender inclusiveness is not enough to create equity; to *benefit* or *empower* socially excluded groups, more attention needs to be paid to the distribution of insurance outcomes—that is, the extent to which insurance benefits and empowers women as much as men (Timu and Kramer 2021).

In theory, insurance programs can promote gender equity in *benefits* from insurance by addressing both demand- and supply-side constraints to uptake. This also involves providing quality insurance products that are beneficial to both men and women; targeting not only primarily male-controlled livestock and crops but also crops that are more commonly produced and commercialized by women; focusing on those risks that are difficult to manage for women, such as covariate risks that reduce the capacity of women's informal risk-sharing networks, including rotating savings and credit associations, to provide a safety net; and working through gender-inclusive distribution channels. Unfortunately, to date, there is limited research on how to create more gender-equitable insurance schemes. IFPRI's insurance research in Kenya is working to address these evidence gaps. This includes, for instance, using rigorous randomized controlled trials to analyze whether agricultural insurance has equally large impacts on technology adoption, agricultural productivity, and dietary diversity for women as for men. It also includes looking at which agricultural risk

management bundles—insurance alone, insurance offered in combination with seeds of stress-tolerant varieties, or insurance combined with remote advisory services—have the greatest impacts for women vis-à-vis men.

Other examples of IFPRI research, focused primarily on supporting women's *empowerment* through climate insurance, include efforts to ensure that contracts purchased by women are registered under their names and that payouts are subsequently paid to their accounts; initiatives that bundle insurance with empowerment tools such as behavioral change communication and "edutainment" around gender roles; and working through local champion farmers, who preserve and connect with informal mutual assistance group activities, to promote insurance. To track the extent to which insurance benefits empower men and women alike, it is important to collect gender-disaggregated data. Given that many women are members of male-headed households, this type of research needs to move beyond a comparison of impacts for the primary decision-maker in male- and female-headed households. Rather, impact evaluations should track outcomes measured for different types of male and female household members, to shed light on the distribution of insurance outcomes within a household.

An important area in which careful consideration of gender and social equity is necessary is the digitization of insurance. The rapid expansion of mobile phones and cellular coverage in rural Africa has led to increased interest in digital financial instruments for the agriculture sector. This includes a large push to improve agricultural finance and insurance for smallholder farmers through digital innovations. At the same time, mobile technologies are not yet revolutionizing agriculture in Kenya, and there is still a long way to go to reap the full benefits from digitization. Parlasca, Johnen, and Qaim (2021), for instance, find that more than 80 percent of farmers use mobile money but only 15 percent use this innovation for agriculture-related payments; less than 1 percent of farmers use mobile loans for agricultural investments. Indicative of a digital divide, ownership and use of digital agricultural services are lowest among the most vulnerable. Koo and colleagues (2022) note that rural areas, especially in sub-Saharan Africa, are underserved when it comes to digital infrastructure, with limited access to digital services especially among women. Bridging this digital divide will require policy incentives and public–private partnerships to accelerate investments in digital infrastructure, and investments in agricultural service providers' capabilities to strengthen their digital services in a socially equitable way.

Shortcomings and implications for Kenya's national agricultural insurance scheme

The innovations discussed above, while promising, also come with a few key challenges. This section discusses these, and how the public sector can address them by creating a more enabling environment for insurance schemes.

A first challenge is the lack of historical data to design and underwrite insurance products. Designing high-quality index insurance products that are correlated with agricultural losses and do not suffer major basis risk requires access to sound historical data on both the proposed index and agricultural losses. Such data are hard to come by. This is a key reason why agricultural insurance often faces basis risk, even when high-resolution satellite imagery is limiting basis risk in the spatial domain. Further, absence of such data makes it difficult for insurers and reinsurers to determine expected payouts from a product, which inflates premiums.

To address this challenge, it is important for the public sector to increase data availability. The government could, for instance, improve access to geo-referenced yield data, which are collected already through multiple initiatives. These include the World Bank-funded One Million Farmer Platform, led by KALRO, other KALRO initiatives, and Kenya's national agricultural insurance scheme. Moreover, initiatives can create incentives for the private sector to share data. For instance, the Lacuna Fund awarded ACRE Africa a grant to publish its labeled smartphone images of targeted crops, collected as part of its picture-based insurance operations (see Box 11.1), and make the data publicly available. This could, in fact, be made a requirement for start-up companies accepting grant money. Overall, the problem is not so much that the data are not there, but that the infrastructure, capacity, and incentives for sharing these data are not in place. Infrastructure is needed to access data and associated satellite imagery in an ethically sound way, whereby exact GPS coordinates—because they are personal identifiers—are kept confidential.

A second challenge requiring government intervention in the context of agricultural insurance is in the regulatory space. Regulators should play an important role in quality control and consumer protection. Capacity development is required to enable regulators to assess insurance products and to ensure they are of high quality, with limited basis risk and reasonable insurance premiums. The United States Agency for International Development's Innovation Lab for Markets, Risk, and Resilience has developed a tool that allows regulators to calculate the expected welfare impacts of an insurance product and to assess the extent to which the product meets basic quality standards, prior to approving its commercial sale.

Moreover, if bundled with other services, insurance premiums should not be hidden in the total price of the product bundle. For instance, when insurance is bundled with loans, farmers should be made aware of the fact that the loan comes with insurance, how to file a claim under that policy, and by how much the bundling with insurance is increasing their interest rate. Too often, bundling insurance with other services and inputs helps programs increase uptake but customers are not aware of their coverage, limiting the impacts on resilience. Regulators could monitor whether adequate consumer education is in place.

At the same time, regulation in an early stage of piloting new products could discourage innovation. Innovation in product design and delivery will therefore require regulatory sandboxes, making it possible to pilot new products without having to go through the longer regulatory approval processes that would be desirable for more mature products offered at a larger scale (Jenik and Lauer 2017).

A third challenge facing insurance markets is the existence, and increasing incidence, of systemic catastrophic risks that are too expensive to insure through micro or meso insurance. For instance, an individual farmer will most likely not be able to access affordable micro insurance against the risk of a locust outbreak or a large-scale drought that causes food insecurity throughout the country. These types of scenarios, which can affect millions of farmers at once, are well suited to be insured through macro insurance schemes, for instance the above-mentioned ARC (Kramer, Rusconi, and Glauber 2020) and the ALLFED initiative to insure response operations for locust outbreaks (ALLFED 2021). An important question for a next generation of insurance research to address is what impacts the public sector can have on micro and meso insurance markets by insuring these catastrophic risks. It is likely that a transfer of catastrophic risks out of the country, to international insurance markets, will create a more favorable environment to offer insurance for the more moderate risks. These complementarities between different levels of insurance coverage have, however, not been studied sufficiently; additional research in this area is crucial to better assess the costs and benefits of innovations in catastrophic disaster risk management.

A fourth challenge is low demand for new products that farmers and other value chains actors will not have seen at work yet. On the one hand, for more commercially oriented farmers, who should in principle be able to afford unsubsidized insurance, the government can help increase demand by providing smart subsidies, mainly to stimulate adoption in the short run. These smart subsidies enable insurers to provide products at a discount (or even free of

charge) on a promotional basis, giving potential clients the product experience that is a prerequisite for creating demand (Vargas Hill et al. 2014; Hazell and Varangis 2020). For commercially oriented farmers, a program would want to clearly communicate that the policies are being sold at a discount, to encourage early adoption but prevent farmers from using the discounted premium as an anchor for what future premiums should be. These subsidies would need to be phased out over time. On the other hand, for more subsistence-oriented farmers, subsidies may be required in the long run, given that these farmers likely cannot afford unsubsidized insurance premiums. Moreover, subsistence-oriented farmers will require higher levels of insurance coverage, given their lower absorptive capacity. For these types of farmers, one would want to look at protecting their full income loss in a bad year, not only investments. In addition, insurance should not be tied to the purchase of inputs, given that farmers may not be able to plant or invest in more expensive inputs when the rains fail.

The HSNP, the KLIP, and IBLI schemes provide an interesting example of how Kenya has integrated social safety nets, targeting different types of subsidies and solutions toward different types of herders. Some (the relatively poorest, including laborers who do not have their own land or livestock) are eligible to receive regular cash transfers through the HSNP. Others (the vulnerable non-poor, but subsistence-oriented) receive subsidized livestock insurance through the KLIP for up to a given number of tropical livestock units. More commercially oriented herders have the option to buy additional insurance for their larger herds. In the context of crop insurance, a similar system could be applied. The poorest would be eligible for cash transfers; the vulnerable non-poor engaged in subsistence farming would be able to obtain subsidized crop insurance with a sufficiently large amount covered to protect not only investments but also their incomes from extreme weather shocks; and, finally, more commercially oriented farmers seeking higher coverage levels could purchase additional unsubsidized insurance, facilitated through value chain actors such as input providers, aggregators, and contract farming schemes. Such a layered approach is also essential to create social equity; adequate targeting of insurance subsidies will help ensure the benefits accrue not only to commercial farmers who can afford unsubsidized premiums but also to the most vulnerable, who will not have the financial means to pay insurance premiums.

The solutions provided above illustrate how a government can invest in an enabling environment for scale-up of agricultural insurance. This will, however, require public investments. It is therefore important to expand the evidence base on what impacts insurance programs have on the resilience and welfare of beneficiary communities, what costs and benefits public investments in

these programs will have, and how these costs and benefits compare with the cost-benefit ratios of other types of social protection, for instance cash transfer programs. Demand for an insurance product, or levels of insurance payouts, should not be seen as an indicator of impact; to study impacts of an insurance program, and get at true costs and benefits, factors such as agricultural incomes, investments, and gender and social equity need to be considered and quantified. It is important to build in these impact evaluations and cost-benefit analyses, including metrics of gender equity and social inclusion, from the onset of an insurance program. Monitoring and evaluation plans would ideally move beyond a comparison of impacts for male- and female-headed households to investigate how the program interacts with gender norms, and how an insurance program affects different members *within* a household, considering that the vast majority of women reside in male-headed households and are overlooked in a comparison based on the gender of a household head (Timu and Kramer 2021).

Finally, a challenge with designing and implementing agricultural insurance programs is that smallholder farmers face a multitude of risks, including not only droughts but also other weather-related hazards, biotic stressors such as pests and disease, and price fluctuations. By design, an index-based insurance program cannot insure farmers from all these risks at once. Moreover, insurance is not the appropriate instrument for every type of risk; it is the right instrument to manage more severe and extreme risks but not to manage more moderate risks, for instance a moderate drought that affects only a small portion of the harvest or herd. Farmers can manage those moderate risks at a lower cost using other financial instruments such as savings and credit, as well as risk-reducing technologies and practices such as crop diversification, stress-tolerant cultivars, or better food and water storage facilities. Insurance should complement these other risk management instruments, rather than crowd out their use. This also involves designing insurance subsidies such that they do not discourage farmers and herders from adopting unsustainable practices. Heavy premium subsidies can result in environmentally risky production behaviors such as growing high-risk crops on unsuitable land (for example, growing maize in an area where rainfall has become generally inadequate to grow maize), increasing pesticide and fertilizer use beyond socially optimal levels (Weber, Key, and O'Donoghue 2016; Möhring et al. 2020; Dougherty, Gallenstein, and Mishra 2021), rapid livestock accumulation disrupting natural pasture recovery dynamics (John et al. 2019), or disincentivizing climate change adaptation in agriculture (Wang, Rejesus, and Aglasan 2021). Insurance programs need to be carefully designed to avoid such distortionary effects.

Conclusion

In conclusion, climate insurance is an important financial instrument that can help improve agricultural risk management for smallholder farmers, herders, and other value chain actors. In the face of the present climate crisis, it will be crucial for Kenya to improve agricultural risk management, and in particular smallholder farmers' capacity to adapt to increasing incidence of weather extremes. At the same time, prioritizing investments by the public sector to create a more enabling insurance environment can come at the expense of investing in other agricultural development programs or social safety nets. Before prioritizing investments that aim to roll out agricultural insurance programs at scale, policymakers will need evidence in the form of rigorous impact assessments and cost-benefit analyses, and a comparison of the cost-effectiveness of insurance programs versus other social protection instruments.

It is therefore important to differentiate between different types of farmers and herders, distinguishing at the very least between the poorest farmers, typically landless laborers; the vulnerable non-poor, typically subsistence-oriented farmers; and more commercially oriented smallholder farmers. Each of these groups will require different insurance or social protection solutions (Kramer et al. 2021). This will also involve putting social and gender equity at the forefront of impact assessments, to ascertain that, among the most vulnerable segments of the population, insurance programs reach, benefit, and empower women and men alike.

Agricultural insurance is also not a stand-alone solution but, if treated that way, a program will have limited impacts on technology adoption, market participation, and other indicators of structural transformation. If not carefully designed, insurance could even induce the adoption of environmentally unsustainable practices and technologies. A more holistic approach to insurance program design acknowledges that farmers and herders have their existing informal insurance solutions, such as saving for a rainy day or sharing risks within their social networks; and that this, along with financial instruments as well as adaptive technologies and practices, can help them manage relatively moderate risks. Insurance is then designed to provide financial protection from more severe and extreme risks, and could even be offered to existing risk-sharing groups. As shown by an experiment in Ethiopia, this could help crowd in demand for formal insurance (Dercon et al. 2014). In this light, insurance programs, including premium subsidies, need to be "climate-smart," and encourage farmers and herders to use complementary risk management instruments along with insurance.

Finally, digitalization offers great potential to improve the cost-effectiveness of agricultural insurance. Remote sensing and the use of smartphone photos and other sensors increase the amount of data available on smallholder farming systems, which will allow insurers to better monitor smallholder farms, reduce basis risk, and lower the cost of insurance products. Groundbreaking work is being done in this area in Kenya, with several pilots underway that can shed light on how to better embed agricultural insurance into adaptation and disaster risk management plans. At the same time, most solutions are still in a pilot phase, and the hard digital infrastructure and softer capabilities to use digital technologies are not yet sufficiently developed to transform the insurance sector at scale. Efforts to digitize agricultural insurance will not be socially inclusive and will potentially widen gender gaps if nothing is done to bridge the digital divide. Investments will be required in digital infrastructure to enhance phone ownership and use, mobile coverage, and internet access among the most vulnerable smallholder farmers and herders in Kenya.

Summarizing, there are exciting areas of innovation in climate insurance, with great promise to improve smallholder farmers' ability to manage climate change-related production risks. However, investments to scale these innovations will need to undergo rigorous cost-benefit analysis, positioning in a broader risk management strategy, and, when involving digitalization, complementary efforts to address digital divides. This will take time, and thus climate insurance will not provide a short-term solution that can be widely and successfully adopted by farmers at scale.

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