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Is Agricultural Insurance Fulfilling Its Promise for the Developing World? A Review of Recent Evidence

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Abstract

Innovations in agricultural index insurance have raised expectations that the private sector can overcome shortcomings associated with more traditional indemnity-based products like multiperil crop insurance and strengthen agricultural risk management at scale across developing countries. This article updates previous reviews on agricultural insurance but differs in that it goes beyond the prognosis that recent innovations can help make insurance more commercially viable. As such, it addresses two important challenges that have received limited attention. First, it distinguishes different types of farm households and recognizes that many are excluded from the insurance market, describing additional innovations that can help make insurance more accessible to these excluded groups. Second, it acknowledges that insurance for catastrophic risks is unaffordable for most farmers and summarizes new developments in disaster assistance and safety net programs that can provide broader protection against these risks. The review concludes that cost-benefit analyses of subsidized insurance programs will be crucial for guiding public spending decisions.

1. INTRODUCTION

Agricultural insurance has attracted considerable interest in recent years, and innovations in index-based insurance have raised expectations that they might yet overcome many problems that plague more traditional indemnity-based insurance programs like multiperil crop insurance. This could help make insurance accessible to many more farmers around the developing world. Agricultural insurance (hereinafter shortened to insurance) has also grown substantially in recent years. A survey found that in 2020, about 265 million insurance policies were sold around the developing world (Hazell et al. 2021), enough to provide about half of all farms with some level of insurance. Moreover, 80% of the surveyed programs were index based, demonstrating that this relatively new form of insurance has achieved considerable scale.

Despite these favorable developments, challenges remain. Although the number of insurance policies sold in developing countries has grown, these policies provide low coverage levels, often just sufficient to buy new seeds or repay loans, contributing little to smoothing household incomes or consumption. Moreover, sales are heavily concentrated in just a few large countries where most of the world's small farmers live; about 95% of insured farms are in China and India (where 60% of all farmers live), while elsewhere in the developing world less than 10% of farms had any agricultural insurance in 2020. The main reason for this concentration is that insurance in China and India is heavily subsidized—approximately 80% of the premium on average in both countries—and compulsory for some farmers (Hazell et al. 2021). Many programs in other countries are also subsidized but typically at more modest levels and targeted to specific groups of farmers. Without strong government support, in most developing countries insurance does not seem to scale up.

There has been a sequence of review papers over the past 15 years taking the pulse of the latest insurance innovations (e.g., Banerjee & Duflo 2011, Binswanger-Mkhize 2012, Carter et al. 2017, Clarke & Dercon 2009, Greatrex et al. 2015, Hazell & Hess 2017, Hazell et al. 2010, ISF 2018, Robles 2021, Skees et al. 2008). Yet despite describing numerous experiences facing low take-up, these reviews have often taken the view that it is just a matter of finding the right technological, institutional, or policy innovations to achieve major breakthroughs. Many researchers and practitioners continue to search for light at the end of the tunnel, taking advantage of new opportunities offered by advances in remotely sensed data systems, digital technologies, smartphones, e-banking, social networking, and the like.

This review provides another update but differs from most previous reviews in that it goes beyond the prognosis that such innovations will make insurance more commercially viable in developing countries. We also address two important challenges that have received limited attention in the published literature. First, we distinguish between different types of farm households and recognize that many poorer smallholders and women farmers are excluded from the insurance market even where it is well developed. This begs the question: What additional innovations are needed to help make insurance more accessible to these excluded groups? Second, we recognize that insurance for catastrophic risks is typically unaffordable for most farmers and increasingly so with climate change. This leaves many farmers dependent on disaster assistance in catastrophic years. The development of macroinsurance provides opportunities to strengthen disaster assistance programs (DAPs) and safety net programs (SNPs), with insurance against catastrophic risks helping farmers improve their ex ante risk management and reduce their dependence on disaster assistance. Many of these innovations require subsidies, though, and the review finds far too few cost-benefit analyses of subsidized insurance programs to guide public spending decisions.

2. A CONCEPTUAL FRAMEWORK

Agriculture is inherently risky, but farmers differ in their exposure to different kinds and levels of risk, in their options for managing and coping with them, in their preferred risk management

strategies, and in their ability to access and pay for insurance. Recognizing this diversity of situations is crucial for segmenting the insurance market and for designing and targeting insurance that meets different types of farmers' needs.

2.1. Segmenting Risks

From an insurer's perspective, risks can be ordered according to the size of a possible loss and the probability of occurrence. Assuming a typical hump-backed distribution of outcomes, all outcomes below the mean represent losses, or downside risks, which are of concern to risk-averse decision makers. These downside risks can be segmented into three risk layers as proposed by Sandmark et al. (2013):

- First-layer or idiosyncratic risks consist of frequent but typically low-impact and mostly idiosyncratic losses, such as modest yield and production losses due to local pest and weather problems, or livestock disease. Since losses tend to be modest and independent, most households manage these risks on their own or through informal risk sharing.
- Second-layer or intermediate risks comprise risks involving less-frequent but larger losses that may be correlated within groups of households, such as frost, hail, or flood damage, or disruptions to local markets. Many of these risks are insurable at affordable premiums.
- Third-layer risks or catastrophic risks are tail-end risks that are infrequent but have high, systemic impacts, such as a severe flood or drought, affecting many households within a region through widespread losses of crops, livestock, and other assets. Some of these risks are insurable, but at premiums that are unaffordable for most farm households. Many governments choose to provide ex post disaster assistance against these shocks, though such assistance is often delayed.

2.2. Segmenting Households and Their Insurance Needs

There have been several recent attempts to create typologies that capture the diversity of farm households to improve the targeting of smallholder assistance programs (e.g., AGRA 2017, chapter 1; Hazell & Rahman 2014), which can be adapted for insurance purposes as follows.

Group 1: Chronically poor agricultural households comprise near-landless agricultural workers and small-scale subsistence farmers. Many are marginalized for a variety of reasons that are hard to change, such as being located in remote areas with limited agricultural potential. Many of the same factors prevent them from accessing productive nonfarm jobs and diversifying their livelihoods. This group is generally the most vulnerable to risk because of limited asset ownership and other options for coping with losses and the least able to afford any insurance. They are a major target group for social protection, including SNPs and DAPs.

Group 2: Nonpoor, subsistence-oriented farm households are weakly linked to markets, if at all, but have sufficient resources to avoid chronic poverty. While many may be better positioned than the chronically poor to manage risk, they likely depend on DAPs for coping with catastrophic losses, and repeated intermediate income shocks and asset losses can conspire to pull them into poverty and trap them there (Carter & Barrett 2006). Insurance can prevent these households from falling into poverty and requiring assistance from SNPs and DAPs. It may even enable them to invest more in their farms and transition to commercial farming. But any insurance offered to this group would need to be heavily subsidized.

Group 3: Commercially oriented small farms are those who are already linked to value chains. This group is more exposed to market and production risks than subsistence-oriented farmers, but they may have savings to cope with bad years and have better access to credit. Many of these households have nonfarm sources of income, protecting their income from agriculturally related

Table 1 Types of insurance listed by risk layer and type of farm household

Risk layer	Type of farm household			
	Group 1: chronically poor	Group 2: nonpoor, subsistence-oriented farms	Group 3: commercially oriented small farms	Group 4: medium and large commercial farms
First layer	Regular social protection transfers	Informal risk sharing and savings	Informal risk sharing and savings, personal and asset insurance	Personal and asset insurance
Second layer	Regular social protection transfers	Agricultural insurance (largely subsidized)	Agricultural insurance (partially subsidized)	Agricultural insurance
Third layer	Additional social protection payments or disaster assistance	Disaster assistance and/or heavily subsidized catastrophe insurance	Disaster assistance and/or subsidized catastrophe insurance	Catastrophe insurance, disaster assistance

losses and reducing their need for insurance (Mukherjee et al. 2021). Because of their links to value chains, they may have access to insurance through a range of financial service providers and agribusinesses, where insurance policies may be bundled with services such as credit and modern inputs.

Group 4: Medium and large commercial farms face high levels of production and market risk but also have the most options for managing risk, which can reduce their need for formal insurance. This group is generally well served by private insurance companies both directly and indirectly through a range of financial service providers and agribusinesses. They may also be able to afford insurance against catastrophic risks.

Table 1 provides an overview of how—at least in theory—the different risk layers can be managed by different types of farm households. It also shows situations where insurance may intersect with social safety nets and DAPs.

Conceptually, commercially oriented insurance is most appropriate for intermediate risks and groups 3 and 4 (commercially oriented small, medium, and large farms). It is only likely to be offered to group 2 (nonpoor, subsistence-oriented farms) if it is financially supported, and it is generally irrelevant for group 1 (the chronically poor) who are better served by SNPs. If the private sector offers insurance against catastrophic risks, it is likely to be expensive and only affordable by group 4 and some households in group 3. Many governments prefer to use DAPs to help rural households cope with such major tail-end risks, though macrolevel insurance could be used to finance DAPs and unlock a more rapid response (Clarke & Hill 2013), and subsidizing individual insurance may sometimes be an option.

Our discussion of recent insurance developments is structured around this framework. In the next section we focus on innovations that are helping make insurance more sustainable, which, if left to the private sector alone, will mostly benefit groups 3 and 4 against second-layer risks. We then consider innovations that are helping make insurance more inclusive against second-layer risks for households in group 2. Next, we consider two types of innovations that are helping make insurance more relevant for managing third-layer risks for all household types: the use of indices in macroinsurance contracts to improve the effectiveness of DAPs and the possibility of DAPs to offer subsidized insurance against catastrophic risks so that farm households can improve their ex ante risk management and reduce dependence on disaster assistance.

3. INNOVATIONS FOR SUSTAINABLE AGRICULTURAL INSURANCE

Large-scale commercial farmers often have access to a range of insurance products, such as single- or multiperil indemnity insurance from private insurance companies, standard weather

index-based derivatives offered at commodity markets (Taušer & Čajka 2016), or over-the-counter contracts from private companies tailored to cover specific weather occurrences (Keucheyan 2018). However, the high premiums associated with these commercial products and their limited distribution channels make them inaccessible for most small- and medium-sized commercial farmers. Unlocking this insurance market segment has long been a focus of governments and the international development community, as evidenced by the public multiperil crop insurance programs of the 1970s and 1980s, and current public insurance programs in India and China. These interventions, however, have had limited success and mostly at huge cost to national exchequers.

The challenge for most developing countries is to find innovations that aid in the design of sustainable insurance products, that is, products through which the private insurance sector can insure small- and medium-sized commercial farmers on a commercially viable basis without depending on sustained public funding. This section provides reasons for why the private insurance sector has not been more interested in this market segment.

3.1. The Supply Problem

Several technical, data, and regulatory obstacles hinder the development of a broad and inclusive supply of index insurance products (Jensen & Barrett 2017). First, sparse and poor-quality weather and yield data limit the design of products that align well with historical farmer losses and the accurate pricing of insurance contracts. This is exacerbated by uncertainties around climate change. Second, offering insurance to multiple small, spatially dispersed farms, often in remote areas, requires a capillary distribution or agent network to enable prospective customers to learn about insurance and access it. Such networks are normally rudimentary in developing countries and can be costly to establish and administer. Third, because countries' regulatory frameworks generally predate the concept of index insurance, insurers face numerous hurdles when attempting to obtain approval for new index products. A lack of an enabling environment for development and innovation often contributes to this problem. Finally, because weather events can be systemic, smaller private insurers may not have the financial capacity to bear the burden of covariate agricultural claims and require costly reinsurance.

Despite these challenges, examples abound of private sector initiatives overcoming them across a range of contexts. The growth of agent networks to serve mobile money development in Kenya and Bangladesh shows how distribution networks for insurance can be set up (Frydrych & Aschim 2014, Jack et al. 2013). By temporarily bypassing cumbersome requirements, regulatory sandboxes can provide an environment to test novel insurance products, simultaneously helping to inform insurers about the quality of and demand for an insurance product and regulators about financial soundness and customer protection aspects (Jenik & Lauer 2017, Wechsler et al. 2018). Other technological innovations such as digitization of enrollment and claims processes, mobile money, blockchain and smart contracts, or the Internet of Things, while still in a nascent stage of development, can help insurers expand distribution channels, improve contract design, speed up claim payments, reduce administration costs, and increase transparency and trust (Grima et al. 2020, Hazell et al. 2021).

Many of these innovations are also facilitating arrangements for bundling insurance with other agricultural services, for instance, by sharing digitized information about farmers between insurers, lenders, and other service suppliers. Index insurance products have been distributed alongside agricultural inputs such as seeds, fertilizer, or pesticides (Kilimo Salama/ACRE Africa, One Acre Fund) or agricultural credit [the Pradhan Mantri Fasal Bima Yojana (PMFBY), India's national insurance scheme (Giné & Yang 2009, Meyer et al. 2017)], and risk-contingent credit in Kenya (Ndegwa et al. 2020, Shee et al. 2019). Some of these programs have achieved considerable scale,

with ACRE Africa having sold more than 1.7 million contracts in Kenya, Rwanda, and Tanzania from 2009 to 2018 (Hazell et al. 2021). These examples indicate that tapping into preexisting agricultural distribution networks can give programs a considerable head start. However, a limitation of bundling is that insurance coverage is generally limited to the cost of the bundled product, such as input costs or the principal of the loan, limiting the benefits of insurance for farmers, because in the event of an insured loss they may still be subject to large income losses.

3.2. The Demand Problem

Beyond supply-side constraints, insufficient farmer demand for insurance is an important deterrent to the development of insurance markets, as evidenced by the many failed attempts at scaling nonsubsidized insurance to date. But why does smallholder demand for new agricultural risk management products fail to materialize? As a starting point, we focus on the different barriers to demand identified by the literature on index insurance in the early 2000s (Cole et al. 2013, Giné et al. 2008) and subsequently revisited by many others (e.g., Carter et al. 2015, Matul et al. 2013).

3.2.1. Reducing basis risk. Basis risk, or the risk that the incidence of an insurance payout does not adequately match the incidence of an actual loss, is arguably the largest barrier to index insurance. Basis risk is a direct consequence of relying on a proxy for determining individual farmers' compensation. If insurance is to work as an income smoothing instrument for a given individual or household, not being able to precisely identify the bad states of the world makes it more akin to a lottery ticket. Clarke et al. (2012), for example, report an astoundingly weak correlation between India's Weather Based Crop Insurance Scheme (WBCIS) payouts and average yield losses across Indian subdistricts.

As a result, recent work has focused on reducing basis risk. A first approach relies on increasing flexibility. Ceballos & Robles (2020) offer simplified, independent insurance products or units, individually covering against specific risks in different calendar months, which can be combined to form tailored insurance portfolios that better match farmers' risk profiles. Testing this approach with horticultural farmers in Uruguay, the authors find substantial heterogeneity in farmer risk profiles but observe limited impacts on overall demand, even when subsidies are provided.

A second approach comes in the form of gap insurance or audits, where either individual farmers or a larger insurance unit (e.g., farmer group) can appeal to the insurance company for the index not triggering by presenting some evidence of substantial on-the-ground damage (Flatnes et al. 2018, Berhane et al. 2015). While this can help reduce downside basis risk, such features still do not push farmers' willingness to purchase the product above commercially viable rates.

Another opportunity is offered by the increasing spatial and temporal resolution in remote sensing products, providing data to predict losses at a relatively low variable cost (Black et al. 2016, Enenkel et al. 2018).[1] Although such products may achieve substantial reductions in spatial basis risk, they still face considerable design basis risk, where indices derived from satellite spectral bands are a limited proxy for individual crop damage or free-ranging livestock losses. In addition, remote sensing products suffer from limited visibility of ground conditions due to cloud cover (particularly important when attempting to insure against excess rainfall or floods) and decreasing

[1] In the extreme, microsatellite products provide coverage of most of the Earth several times a week at 3- to 5-m resolution though usually entail a high cost, as they are privately owned. Alternatively, remote sensing imagery from unmanned aerial vehicles (UAVs) can identify highly localized losses, but UAVs only achieve small geographic coverage in a single flight and are generally subject to local flight regulation constraints such as the need for the UAV to be within line of sight of its operator, increasing operational costs.

signal-to-noise ratios as spatial resolution increases, and require considerable processing power and storage capacity at very high resolutions (IFAD 2017).

In parallel, technological advances have unlocked the potential for reduced-cost indemnity insurance, circumventing basis risk altogether. For instance, using radio frequency identification (RFID) in a livestock insurance product in India significantly improved smallholder livestock insurance take-up and reduced information asymmetry and insurance fraud (Samad et al. 2010). Research on picture-based insurance (PBI), an approach that uses smartphone pictures of insured crops for claims settlement, has shown that one can detect severe crop losses remotely and at a relatively low cost from a stream of ground images provided throughout the growing season (Ceballos et al. 2019). Further, PBI does not necessarily reintroduce moral hazard and adverse selection (Ceballos & Kramer 2019), and the stream of pictures can help deliver personalized risk-reducing advice (Ceballos et al. 2018) and strengthen phenological monitoring that, together with crop modelling, can improve yield prediction at the individual plot level (Afshar et al. 2021, Hufkens et al. 2019). Although still at an early stage of development, this is a promising avenue to provide farmers with affordable field-level insurance.

3.2.2. Lowering costs and addressing liquidity constraints. Even when products do not suffer basis risk, demand may remain low. The pricing of insurance is a key determinant of market demand, especially among relatively poorer segments of the farm population, such as group 2 in **Table 1**. Studies varying premium subsidy levels have found moderate price elasticities of −0.33 to −0.65 (Bageant & Barrett 2017; Hill et al. 2016, 2019; Mobarak & Rosenzweig 2012). Cost-reducing technologies such as mobile premium collection or payout distribution, simplified know-your-customer rules, blockchain, and even peer-to-peer insurance can help reduce premiums, but they only act on the administrative margin of insurance premiums, as the actuarially fair portion of premiums is directly related to expected payouts based on historical data. Many studies find meager farmer demand even at actuarially fair rates (e.g., Ceballos & Kramer 2019, Hill et al. 2016, Mobarak & Rosenzweig 2012), indicating that generating farmer take-up at scale may require large subsidies or alternative approaches to increase demand.

Small-scale farmers may not have the liquidity to purchase insurance at the start of the agricultural season, as they need to invest in seeds, inputs, labor, and machinery. Deferring the payment of insurance premiums for a given agricultural season until after harvest, when resources are more readily available, can thus ease liquidity constraints. Studies have found that such premium deferral increases take-up, with estimates of increased demand ranging from 8 to 72 percentage points (Belissa et al. 2019, Casaburi & Willis 2018, Liu et al. 2020). Promising as this design may seem, it is akin to providing the farmer with a loan equivalent to the insurance premium for the duration of the season. This brings the possibility of farmer default and requires strong institutions through which farmers can be held accountable at the end of the season, such as contract farming or strong ties with farmer associations. It is an open question whether this kind of design can be extended to other settings where such an enforcement mechanism is absent.[2]

3.2.3. Overcoming a lack of trust and poor understanding. Deferring the payment of insurance premiums until after harvest could help address not only liquidity constraints but also a lack of trust in the insurer and the accompanying uncertainty around whether an eligible payout would be actually made. As an alternative solution to improve trust, Cole et al. (2013) randomize whether the insurance agent is recommended to the household by a trusted local source. This endorsement

[2]For instance, Belissa et al. (2019) report substantial default rates in their study in Ethiopia.

increases demand by 10 percentage points. Giné et al. (2008) find that preexisting customers of the insurance company marketing a new weather index product in India are almost 7 percentage points more likely to purchase the product. In a choice experiment in Bangladesh, Akter et al. (2016) find that receiving insurance information from government agents significantly increases insurance take-up among women. Additional evidence of the importance of trust in a new financial product is provided by studies that analyze repeat insurance purchase behavior, where households who have directly received an insurance payout in a previous season or have witnessed a payout to someone else in their village show a significantly higher propensity to purchase the product ahead of the next season (Cole et al. 2014, Hill et al. 2016, Stein 2018). In this case, the quantitative effects on take-up are significant, ranging from 9 to 50 percentage points (Cole et al. 2014), even though they may combine other effects beyond trust alone.

Farmer understanding is another potential cause of low demand, considering the sophisticated nature of index insurance products and the generally low financial literacy of target populations. Hill et al. (2016) report a 5-percentage-point increase in demand by Indian households receiving an intensive training module, though with no sustained effects over the following season. By contrast, Takahashi et al. (2016) find that while training kits improve knowledge, this does not lead to increased demand for livestock insurance in Ethiopia. Cai & Song (2017), Janzen et al. (2021), and Jensen et al. (2018) also find moderate effects on demand from exposing farmers to insurance education games. Even if they worked, the scalability of such education modules to larger populations remains a challenge.

To summarize, programs aiming to provide high-quality affordable insurance for smallholder farmers face various supply- and demand-side barriers. Supply-side challenges are related to the regulatory environment, poor data availability, and distribution costs. Demand-side constraints include basis risk, liquidity constraints, and a lack of trust and understanding. Compared to commercially oriented farmers, many of these constraints are worse for subsistence-oriented farmers. The next section focuses on innovations to increase these farmers' access to agricultural insurance.

4. INNOVATIONS FOR INCLUSIVE AGRICULTURAL INSURANCE

The most challenging types of insurance to design and deliver are those targeted at subsistence-oriented farms that are vulnerable but not sufficiently poor to qualify for regular benefits from SNPs (group 2 in **Table 1**). For-profit insurers have virtually no incentive to serve this group on a commercial basis, and it typically takes a government, donor, or nongovernmental organization (NGO) project to initiate and financially support insurance for this group. Adding to the challenge, any useful insurance for this group needs to provide a reasonable level of protection against household income or consumption shortfalls; it may not be sufficient to insure specific crops, assets, purchased inputs, or the principal of a loan. There is a large gray literature documenting the experience with numerous insurance projects targeted to this group (for a recent review, see Hazell et al. 2021), but academic literature often glances over the important differences in insurance needs among small subsistence-oriented versus commercially oriented farms. Moreover, women and vulnerable minorities often fall within this group, owing to barriers in accessing credit and formal markets, but the insurance literature pays little attention to inequities based on factors such as gender (for a review, see Timu & Kramer 2021).

One promising way of targeting insurance to subsistence-oriented farmers is by linking formal insurance to informal risk-sharing groups, such as social funds or village savings and loan associations. While these groups can be effective in managing idiosyncratic risks that affect only a few members at a time, they cannot cope well with larger and more systemic losses, and this is where formal insurance can help out (Clarke & Dercon 2009); evidence shows that this can increase

informal risk sharing and crowd-in demand for index insurance at the same time (Dercon et al. 2014). This is also a strategy to make insurance more gender inclusive. As women farmers tend to be more active in these social networks than men, working through informal groups can also improve inclusivity of insurance program design (IFAD 2020).

Another approach is for SNPs to reach out and make transfers in catastrophic years to many of the nonpoor but vulnerable households who do not normally qualify for regular SNP payments. This is in effect a form of insurance against catastrophic risks that is fully funded by government. An example is the Hunger Safety Net Programme (HSNP) in Kenya, which targets households based on wealth (FAO 2021). Since 2015, the HSNP has been empowered to scale out its payments in drought years in the arid and semiarid pastoral lands (Gardner et al. 2017). The payments are determined by local drought indices in the same manner as an index-based product. One advantage of using SNPs in this way is that they usually have good databases of the rural households that can be used to target their payments.

In the absence of targeting data, one could use similar targeting mechanisms as those used by SNPs, such as employment guarantee schemes, to screen out the vulnerable nonpoor. Beneficiaries of the R4 Rural Resilience Initiative in Ethiopia can pay for their insurance premiums through public works programs that create risk-reducing assets for their communities, including, for instance, improved watersheds. Because more commercial farmers, likely having a higher opportunity cost of time, will opt to pay premiums in cash, this can improve targeting. These public works programs have the added benefit of improving communities' ability to manage moderate weather risks (first-layer), typically not covered under insurance. However, the work-for-insurance scheme needs to be funded, and although quasi-experimental evaluations show positive impacts (Madajewicz et al. 2013), evidence on the costs and benefits of this approach is lacking to date.

Regardless of whether households pay for premiums using cash or labor, insurance targeted toward nonpoor, subsistence-oriented farms is invariably subsidized. This is to be expected during an initial phase, but subsidies typically become entrenched for the long term. No studies have tested whether subsidies could be phased out if insurance, by encouraging farmers to acquire modern farm inputs and technologies, increases farm productivity and incomes and allows farmers to graduate into commercial farming. Nor is there much evidence that private insurers have been able to develop commercially sustainable insurance programs without subsidies for subsistence-oriented households. Sustained insurance subsidies for these households may have to be seen as an alternative to a fully funded SNP. The cost can be reduced if the subsidies are designed and targeted in smart ways for achieving their goals (Hazell & Varangis 2020, Hill et al. 2014). This is easier to achieve when the insurance is channeled through an intermediary like an NGO or a SNP with adequate databases of beneficiaries, requiring better integration of insurance and SNPs.

5. INNOVATIONS FOR INSURING CATASTROPHIC RISKS

Developing sustainable and inclusive insurance against catastrophic (third-layer) risks is especially challenging given their systemic nature and the high losses that are often incurred. As a result, DAPs to relieve the effects of catastrophic losses must be provided and fully funded by governments, bilateral donors, United Nations (UN) agencies, or NGOs. DAPs are designed to save lives, rebuild assets and livelihoods, and target the population at large in affected areas, not just farm households, and they do not try to recoup any costs from beneficiaries, unlike most agricultural insurance programs that are offered at the micro or meso level. However, to be effective such assistance requires (*a*) flexible financing, (*b*) flexible, rules-based identification of needs, and (*c*) flexible and swift program implementation, often based on a preplanned strategy (Alderman & Haque 2006).

Recent developments using indexed instruments for macroinsurance, which provides coverage at a country or regional level, can help improve the effectiveness of DAPs in two ways. First, indexed instruments can provide an automatic triggered source of funding for a DAP's relief efforts. Second, once a DAP has obtained macroinsurance, it can underwrite contracts for individual farm households to improve their ex ante risk management and reduce dependence on future disaster assistance.

5.1. Macroinsurance for Financing Disaster Assistance Programs

A DAP's ability to respond quickly to disasters hinges on having adequate funds when a catastrophe occurs. Traditional sources of financing, such as government contingency funds held in reserve, or contingent credit arrangements held with development partners or financial institutions, are often slow to activate, and they do not assist a country to transfer risk from its own budget to the international market. The use of catastrophe (or CAT) bonds does transfer some of the risks to investors, but these add to a country's debt burden and bear relatively high interest rates. Donor assistance is frequently a last resort option for financing disaster assistance and can lead to significant delays. One study estimated that the average time from the onset of a crisis to a first disbursement is 398 days, at a significant cost; for instance, in Ethiopia, the cost of a drought to poor households increased from $0 to $50 for a 4-month delay versus $1,300 for a 6-to-9-month delay (Clarke & Hill 2013).

Macroinsurance for DAPs not only automatically funds disaster assistance but can, with the aid of reinsurance, move some of the tail-end risk out of the country and into either a regional sovereign risk pool or international reinsurance markets. Unlike microinsurance for individual farmers, macroinsurance can be based on weather indices defined at aggregate regional levels, which are easier and less expensive to design and monitor and less susceptible to basis risk. The Fund for Natural Disasters (FONDEN) in Mexico offers an example of this approach. FONDEN used government funding to purchase insurance and CAT bonds for excessive rainfall-related damage to infrastructure. Using a regression discontinuity, del Valle et al. (2020) estimate substantial impacts on economic activity in municipalities with excessive rainfall compared to those just below the rainfall threshold. Although this result dissipated after 1 or 2 years, they speculate that impacts on human capital investments might be longer lasting. FONDEN was dismantled in late 2020, in part to address COVID-19 concerns, but the CAT bond funding remains in place.

Another way in which indexed instruments can help finance disaster assistance is through sovereign risk pools. For example, the Caribbean Catastrophe Risk Insurance Facility (CRRIF), established in 2007, pools risk using parametric policies. It is capitalized by a multidonor trust fund and by membership fees of its 20 Caribbean and Central American partners. It offers five different products, ranging from risks due to earthquakes to those from excess rainfall and hurricanes, and has considered covering drought. A similar trust funded the Pacific Catastrophe Risk Insurance Company (PCRIC). In the same vein, the African Union inaugurated the African Risk Capacity (ARC) in 2014, which not only provides countries with insurance for humanitarian disasters but also develops the capacity to build contingency plans that specify how insurance payouts will be used in the event of a disaster. Of the three country pools, the CRRIF has the longest experience and has delivered over $200 million in payouts.

In practice, both the ARC and PCRIC have had issues with basis risk (Clarke & Dercon 2019, Johnson 2021, Kramer et al. 2020, Martinez-Diaz et al. 2019), contributing to limited take-up. In the years between the ARC's founding in 2013 and 2019, only eight countries purchased policies, and five of these failed to continue coverage, although 11 countries joined the risk pool for 2019–2020. In response to member concerns over basis risk, the CRRIF added a secondary trigger and a

small payout if the trigger was not met, but modeling losses reached half of the attachment point, essentially the equivalent of a deductible (Martinez-Diaz et al. 2019). One response to limited take-up in the ARC has been the Africa Risk Replica, which allows UN agencies and NGOs to match ARC countries' insurance policies to provide humanitarian assistance within established contingency plans. However, the ARC has likely not reaped the full benefits from this process, as payouts were mostly used to scale traditional food aid, instead of using payouts in areas where real gains were projected: the financing of (state-contingent) SNPs, DAPs, or microinsurance schemes (Kramer et al. 2020).

Another instance of indexed instruments funding disaster assistance is through payouts from policies that donors purchase directly. This was piloted in 2006 by the World Food Programme (WFP) and AXA insurance company, with the plan of using payouts triggered by a drought index to augment Ethiopia's Productive Safety Net program (Hellmuth et al. 2009). While such direct donor support would seldom cover the entirety of the needs generated by a major disaster, it could bridge a funding gap and facilitate early intervention prior to the mobilization of additional funds. Implementation was however discontinued after a few years, without payouts triggered (Clarke & Dercon 2016), perhaps because donors fund ex ante development assistance using different criteria and sometimes different budget lines than ex post humanitarian relief, clouding the potential for financing response operations through macroinsurance.

5.2. Macro- and Microinsurance Linkages

Once a DAP has access to macroinsurance, it can provide index insurance against catastrophic risks to the individual households that would normally benefit from its disaster payments (Hess et al. 2010). Mobile banking can then send these beneficiaries timely indemnity payments or cash transfers once an index is triggered. This can generate benefits beyond disaster protection. For example, by providing households with advance notice of their insurance coverage under the DAP—e.g., through use of early recovery vouchers (Hess et al. 2010)—they might be able to make investments in livestock feed or new seeds that help minimize losses ex post. Reducing their risk exposure could encourage productivity-enhancing investments ex ante. Payouts might be conditioned on households undertaking risk-preventative actions at individual or community levels, which may also help overcome concerns around moral hazard. Further, insuring some of the worst catastrophic risks facing farmers may make it easier for private insurers to offer affordable insurance against many of the remaining risks.

Kenya provides an example of how these macro- and microinsurance linkages can work in practice. Kenya's disaster risk planning for the arid north involves a public-private partnership that is largely based on the interplay of three programs spanning the range of risk layering: Low-income households receive targeted monthly cash transfers under the HSNP, targeting group 1 in **Table 1**; pastoralists meeting certain conditions can obtain fully subsidized livestock insurance for up to five tropical livestock units under the Kenya Livestock Insurance Program (KLIP), to include additional beneficiaries in the event of a serious drought and prevent previously nonpoor households (group 2) from falling into a poverty trap; and herders can purchase more unsubsidized coverage through commercial index-based livestock insurance (IBLI), primarily targeting group 3. Payments are made rapidly using mobile money transfers.

Although HSNP, KLIP, and IBLI are operated separately, there are some interesting interactions between them. Jensen et al. (2017b) found that regular cash transfers had a significant and positive impact on the purchase of IBLI. Similarly, using data from a pilot phase of HSNP, Jensen et al. (2017a) find that HSNP is complementary with insurance in the sense that the integration of the programs reduces poverty to a greater degree than cash transfers would do alone. Janzen

et al. (2021) generalize on this possibility by indicating the reasonable assumptions under which targeted subsidies for producer insurance can reduce the need for outlay on social protection.

The CADENA (Componente de Atención a Desastres Naturales) program in Mexico is another case where macroinsurance is linked to microinsurance for farmers. Individual farmers are not insured directly in this program; rather, state governments pay premiums, receive payments, and distribute them to farmers. The insurance is provided by both public and private insurers (FAO 2021). Livestock insurance is triggered based on a crop cover normalized difference vegetation index purchased from an international reinsurer. Drought insurance is triggered through rainfall data while yields are also insured based on municipality data. Although most payments are passed from the states to farmers who own fewer than 20 hectares of land or 60 units of livestock (FAO 2021), generally registered in advance, payments can also be used to fund infrastructure. De Janvry et al. (2016) contend that CADENA may prevent households from resorting to costly coping mechanisms.

Another form of a macromicro interface outside of agriculture serves to insure common property resources. A pilot project initiated by a Central American NGO, the Mesoamerican Reef Fund (MAR Fund; **https://marfund.org/en/mar-rescue-initiative/**), and supported by the German development bank KfW, which was subsequently supported by the Nature Conservancy and contracted with Swiss Re, insured a section of coral reef against hurricane damage. In 2020, the insurance paid the state of Quintana Roo in Mexico for initial reef restoration. This provided timely reseeding of coral for reef rehabilitation (Einhorn & Flavelle 2020). The approach can also provide immediate employment for individuals who depend on the reef for their livelihood.

6. PUBLIC POLICY OPTIONS FOR PROMOTING AGRICULTURAL INSURANCE

Although technological and institutional innovations are helping to make insurance more commercially viable, the available evidence (e.g., Hazell et al. 2021) shows that the advances so far are insufficient to make insurance affordable and accessible to many smallholders in developing countries without substantial government support. In this section we review evidence on the effectiveness of three key areas for public sector intervention: providing an enabling legal and regulatory environment, improving data availability and government extension services, and providing insurance subsidies.

6.1. Providing an Enabling Legal and Regulatory Environment

A favorable regulatory and business environment encourages private investors, creates competition, lowers insurance premiums, enables other complementary services like bundling insurance with agricultural credit, and encourages the take-up of emerging innovations like mobile-based, blockchain, and drone-based insurance designs. Additionally, laws and regulations for insurance need to be consistent with international standards to improve the chances of national insurers gaining access to global markets for risk transfer. Current regulations that restrict agricultural insurance to be offered only to farmers, e.g., by tying insurance to operating land, growing specific crops, or purchasing farm inputs like bags of seed, impede the provision of insurance to other value chain actors such as agricultural laborers, agribusinesses, and local shopkeepers, whose incomes also suffer when there is a systemic shock to local agricultural production.

Beyond an enabling regulatory environment, governments can create an enabling legal framework that supports product development. New insurance products can be replicated relatively easily, discouraging private insurers from investing in new product development, unless they can protect their intellectual property rights. This also justifies a certain level of government and/or

donor support for research and development around innovations in new insurance products. These investments should be targeted at feasibility studies and pilot tests of new products with the involvement of local private-sector partners to facilitate future scaling efforts, as is done, for instance, by the Mahalanobis National Crop Forecast Centre in India. This government agency supports India's national crop insurance scheme in research and development by overseeing a wide range of private-sector pilot projects using new technologies for yield measurement (Gov. India 2017). The public sector can also promote the exchange of expertise among insurance companies and access to international best practice through training courses, operations manuals, and other means (Mahul & Stutley 2010).

6.2. Improving Data Availability and Government Extension Services

Obtaining reliable data on key risk variables at relevant spatial scales has long been a problem for insurance. Governments can help by providing accurate weather information, satellite imagery, and yield data, including expanding networks of weather stations, and investing in public data centers and information systems that consolidate, analyze, and disseminate intelligence to all interested parties (FAO 2021). It is not necessary that governments themselves collect and provide all these data—they can contract private firms and research organizations, potentially with cost-sharing arrangements—but the government can play a central role in coordinating all actors and ensuring that these public goods are delivered. These data are useful not only for improving insurance product quality and reducing basis risk, which can come at significant benefits (Ceballos et al. 2019; de Oto et al. 2019; Fava & Vrieling 2021; Jensen et al. 2019; Hill et al. 2016, 2019; Mobarak & Rosenzweig 2012), but also for applications outside of insurance, such as weather forecasting or operationalizing DAPs, helping to justify their cost.

Agricultural extension systems can also be used to support insurance by educating farmers about the value of insurance. One approach is developing and funding extension networks of individuals from local communities who are trained in insurance. The private insurance sector can also be encouraged to leverage the public extension system in its own outreach efforts. This not only can reduce the cost of delivery (Carter 2013, FAO 2021, Greatrex et al. 2015, Hess & Hazell 2016) but may also improve trust and public confidence in the insurance products. In Kenya, ACRE Africa works with village extension service providers, basically community-based champion farmers, to provide insurance education and enroll farmers in insurance (Gumucio et al. 2021). An impact evaluation of an ACRE Africa program employing this approach found that being targeted by champion farmers increased farm investment, promoted the use of complementary risk mitigation strategies (e.g., crop diversification as opposed to a monoculture of maize), and increased the share of cultivated land (Cecchi et al. 2021).

6.3. Subsidizing Agricultural Insurance

Many governments have also resorted to subsidizing insurance as a policy instrument to promote agricultural risk management. A 2020 survey found that about 80% of the surveyed insurance programs were subsidized to some extent (Hazell et al. 2021). Sometimes subsidies are used on a temporary basis to help overcome initial market failures and help kick-start private insurance initiatives, which is justified when farmers are initially uncertain or distrustful about insurance because they have insufficient knowledge to assess its real risks and benefits, particularly for farmers with limited numeracy skills and financial knowledge. Temporary subsidies can also be useful when an insurer initially charges a high-risk loading for a new line of insurance because it has inadequate data to properly assess the actuarial risks, and the risk loading is expected to fall once the insurer has acquired additional data over time (Carter 2013). As an example, by experimenting with

subsidized picture-based insurance, HDFC ERGO General Insurance, a private insurer in India, acquired data on the feasibility of this new insurance approach and decided to lower premium rates.

Most insurance subsidies are more permanent, and while objectives can vary, a common goal is to increase farmers' demand for insurance, especially among smallholders (Hazell & Varangis 2020). Although the aggregate demand for insurance is typically quite inelastic (see Section 3), empirical research shows that the provision of premium subsidies can significantly increase insurance demand among smallholders (Bageant & Barrett 2017; Cole et al. 2013, 2017; Hill et al. 2019; Jensen et al. 2017a; Karlan et al. 2014; Tafere et al. 2019; Takahashi et al. 2016). Subsidies can offer several private and social benefits.

- For farmers themselves, insurance payouts help avoid costly and less-efficient ex post disaster coping strategies (Janzen & Carter 2019, Matsuda et al. 2019, Noritomo & Takahashi 2020, Taye et al. 2019). They can increase productivity ex ante by derisking investments in improved farming technologies (J. Cai 2016, H. Cai et al. 2015, Karlan et al. 2014) and better animal husbandry practices (Jensen et al. 2017a). This is especially beneficial for households who cannot afford insurance and would otherwise be excluded (group 2 in **Table 1**).
- Resulting increases in food production and outward shifts of aggregate supply curves may lower domestic food prices and food insecurity, enhance agricultural exports, and generate a potential net increase in social welfare over the cost of the subsidy (Siamwalla & Valdés 1986); and increased demand for inputs, including hired labor, can generate positive benefits for casual wage laborers and other actors in the value chain (Emerick et al. 2016).
- Increased product demand can also encourage private insurers to engage in the agricultural sector, for example, with many private insurers in the KLIP now offering IBLI on an unsubsidized basis to herders who want additional insurance beyond their subsidized KLIP coverage. Private sector participation may sometimes be contested, though, as is the case of the PMFBY, India's main crop insurance scheme (Mishra 2020).
- Finally, subsidies can reduce dependence on safety nets and disaster assistance, which may be less effective in encouraging farmers to improve their ex ante risk management, and protect farm assets because of delays in their response compared to insurance-based payments (see Section 5). Empirical evidence from northern Kenya suggests that reallocating a small portion of cash transfers to insurance subsidies reduces poverty more than cash transfers alone, as reduced risk exposure among insured households increases investments, and thereby productivity and incomes, compared to conventional cash transfers (Jensen et al. 2017a).

Subsidies can also come at major costs, though. Inelastic aggregate demand for insurance means that premium subsidies need to be set at high levels to attract a significant customer base. For governments that aim to insure most of their farmers, this can lead to very high subsidy bills. Beyond these direct costs, subsidies can generate additional economic, social, and environmental costs. They cover up problems in the design, delivery, and administration of public insurance schemes and introduce unfair competition that could crowd out private insurance alternatives (Hazell & Varangis 2020), allowing, for instance, highly inefficient claims settlement procedures in India's PMFBY to continue. If not well targeted, subsidies also lead to undesired distributional outcomes and skew benefits toward farmers who buy more insurance who are in most cases less likely to be poor (Glauber 2012). The KLIP therefore subsidizes insurance for up to five livestock units per household. By contrast, the PMFBY requires farmers to provide proof of land ownership at the time of enrollment, which directs subsidies toward relatively wealthier farmers who own their land. Heavy subsidies further introduce distortions and can induce farmers to adopt environmentally risky production behaviors such as growing high-risk crops on unsuitable land, increasing pesticide and fertilizer use beyond socially optimal levels (Dougherty et al. 2021, Möhring et al. 2020,

Weber et al. 2016), rapidly accumulating livestock that disrupt natural pasture recovery dynamics (John et al. 2019), or disincentivizing climate change adaptation in agriculture (Wang et al. 2021).

Given these costs, the question is whether insurance subsidies are worthwhile. Although, as noted above, a growing body of experimental studies show that subsidized insurance can help immediate beneficiaries, these gains have not been valued and compared to the costs of the subsidy, nor have they been tested and evaluated at scale. Ideally, subsidies should be justified in terms of their cost-benefit versus alternative uses of public funds, considering the total benefits generated by the subsidy together with other indirect economic, social, and environmental costs. Unfortunately, there have only been a few quantitative studies of the net social returns to insurance subsidies (e.g., Bassoco et al. 1986, Tsujii 1986), which are very dated and do not reflect the significant improvements that have been made in the design and implementation of insurance programs. Given the large amounts of public money spent on insurance subsidies in the developing world, additional and more comprehensive cost-benefit analyses of subsidized insurance programs will be crucial for guiding public spending decisions.

7. CONCLUSIONS

We have reviewed evidence on innovations in three areas: innovations for sustainable, commercially viable insurance, for inclusive insurance, and for insuring catastrophic risks. The previous section highlights that the public sector can support innovations in each of these three areas by providing an enabling legal and regulatory environment, improving data availability and government extension services, and introducing carefully designed subsidies for insurance. At the same time, there are certain aspects that are specific to each of these areas, which warrants discussion of them separately.

7.1. Sustainable Insurance

The pace of technological and institutional innovations has accelerated in recent years and may finally be moving us toward commercially viable insurance for many more smallholders without hefty subsidies. Our review highlighted two promising developments that could help transform insurance markets: (*a*) increased availability of data for designing contracts and reducing basis risk through advances in remote sensing and on-the-ground crop monitoring through smartphone pictures and (*b*) bundling of insurance with various other value-adding services like drought-tolerant seeds, credit, or extension.

We remain cautiously optimistic, though; just how far insurance can scale is still not known, and expecting full coverage seems unwarranted given the large protection gaps in much better-developed industries such as property and casualty or life insurance (Holzheu et al. 2015, Howard 2018). In addition, it is easy to overestimate individual farmer demand, as farmers must also manage other risks that cannot reasonably be insured. This calls for additional research on holistic risk management strategies that include coverage against other agricultural and even some nonagricultural risks and on quantifying the added value of insurance compared to other financial instruments that (especially more commercially oriented) farmers can use to partially manage their risks. Technological progress creates new opportunities to strengthen the quality of insurance, credit products, and forward contracts.

As we have argued, scaling up insurance also requires public sector involvement, in both creating an enabling environment and, in some cases, providing temporary subsidies. Subsidies should be justified based on cost-benefit analysis, but so far, as discussed in the previous section, such evidence is scarce. Conducting additional and more comprehensive cost-benefit analyses of subsidized insurance programs will be crucial for guiding public spending decisions.

7.2. Inclusive Insurance

On its own, the development of sustainable commercial insurance markets does not enable subsistence-oriented households to access insurance. Additional interventions are required, often through an intermediary like an NGO or SNP that can address the complex targeting problems in designing and delivering insurance for different types of farmers in these groups. Permanent subsidies may be necessary and justified on equity grounds. However, a limitation of most past research on insurance is that it does not distinguish between commercial and subsistence farmers, and there is an urgent need for randomized trials to estimate costs and benefits of insurance programs that are designed to reach and benefit excluded groups.

7.3. Catastrophe Risk

Many tail-end risks are too expensive for farmers to insure, and the public sector needs to help finance their removal from the agricultural sector. Subsidies are inevitable, and the real question is whether heavily subsidized insurance for farmers would improve on other forms of disaster assistance or safety net transfers in terms of encouraging better ex ante risk management, improving the speed at which disaster assistance is delivered, reducing future dependence on disaster assistance, and crowding-in insurance for remaining risks. Very limited evidence exists in this area, highlighting insurance-based financing of disaster assistance as a key priority for future research.

This brings us to a final observation. One commonality observed across all three areas of innovation is a lack of cases of scaling of insurance led by the private sector alone, without public sector intervention. Governments, donor agencies, or NGOs usually appear as the first mover, with the private sector, be it insurers, financial institutions, or agrodealers, seemingly reluctant to take on that role. For agricultural insurance to fulfill its promise for the developing world, public sector intervention will have to keep playing this role, but cost-benefit analyses will be crucial for guiding public spending decisions.

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