ANNUAL REVIEWS

Annual Review of Resource Economics

Recent Advances in the Analyses of Demand for Agricultural Insurance in Developing and Emerging Countries

Williams Ali,[1] Awudu Abdulai,[1] and Ashok K. Mishra[2]

[1]Department of Food Economics and Consumption Studies, University of Kiel, 24118 Kiel, Germany; email: aabdula@food-econ.uni-kiel.de

[2]Morrison School of Agribusiness, W.P. Carey School of Business, Arizona State University, Tempe, Arizona 85212, USA

Annu. Rev. Resour. Econ. 2020. 12:411–30

The *Annual Review of Resource Economics* is online at resource.annualreviews.org

https://doi.org/10.1146/annurev-resource-110119-025306

JEL codes: D52, G22, O13

Keywords

risk and uncertainty, agricultural insurance, trust, developing and emerging countries

Abstract

Despite the significant risks and uncertainties that farmers in developing and emerging countries face in their production process, efforts at encouraging them to adopt agricultural insurance to mitigate their production risks have mainly yielded little success. This article reviews the recent literature on the demand for agricultural insurance in developing and emerging countries, by presenting the state of uptake, drivers of the demand for it, and the potential welfare gains from it. Our review reveals that while risk aversion is necessary for the demand for agricultural insurance, liquidity constraints, rates of time preference, basis risk, and trust are equally relevant in explaining the demand for insurance in poor countries. An interesting observation is the increasing number of studies that employ randomized control trials to analyze farmers' uptake of agricultural insurance in developing and emerging countries. Our comprehensive review finds some information gaps in the literature, and we propose some avenues for further research.

1. INTRODUCTION

Perhaps the most highly exposed countries to natural and climatic shocks are those in developing and emerging countries (DEMCs), and yet these countries are among the least prepared in effectively managing these risks. A recent Munich RE (Löw 2019) report shows that storms and floods together made up about 88% of the global natural and climatic disaster events in 2018. More than 50% of these natural disasters struck DEMCs in the Asia-Pacific region and Africa, negatively impacting agriculture. These extremely volatile weather and climatic conditions are projected to increase in both intensity and frequency (Bates et al. 2008, FAO 2013), which has called for intense efforts by policy makers and researchers to find innovative means of mitigating their impacts. The high incidence of pests and diseases and highly volatile input and output prices, among other factors, further exacerbate the significant risks agricultural producers face in DEMCs. The welfare consequences of farmers' exposure to these risks without effective mitigation measures are well documented in the economic and policy literature (Rosenzweig & Binswanger 1993, Barnett & Barrett 2008). Dercon (2004), for example, documents how farmers' exposure to rainfall shocks can substantially impact welfare that persists beyond the period the shock was experienced. The continuous exposure to risks, without relevant mitigation measures, has been found to limit farmers' decision making, thereby trapping them perpetually in poverty (Vargas & Angelino 2012).

Farmers in DEMCs have traditionally used several measures to mitigate or cope with risks, including the cultivation of low-yielding but resistant varieties, diversifying their production practices, and mutually sharing risks. Most of these measures may only offer partial reprieve mainly when the risk involved is of high frequency in occurrence but low severity in nature. However, in low-frequency but high-severity conditions with broader coverage, the measures poor farmers use to mitigate risks are often inefficient. When farmers resort to cultivating low-yielding but resistant varieties because of the high-risk exposure, they tend to be less productive, thereby failing to generate enough income to spur them out of poverty and food insecurity. Insights from an extensive literature review by Alderman & Paxson (1994) illustrate that these informal strategies are likely to have varying impacts on household consumption smoothing. For these reasons, among others, policy makers and researchers have been looking for innovative means of addressing the inherent challenges present in the traditional methods of mitigating and coping with risks. Despite being an important risk-mitigating measure in most developed economies since the eighteenth century (Mahul & Stutley 2010), agricultural insurance was only introduced, sometimes on a pilot basis, in most DEMCs two to three decades ago. Agricultural insurance is a financial mechanism by which risks of losses are transferred from one entity, for example, a farmer, to another entity (insurer), in exchange for a premium or small quantifiable losses to prevent a larger one (Iturrioz 2009).

Despite their increasing significance in the face of extreme weather conditions, agricultural insurance markets remain underdeveloped in most DEMCs owing to known problems of moral hazard and adverse selection. Moral hazard occurs when farmers can influence losses because the insurer cannot accurately monitor their practices. Adverse selection, on the other hand, occurs when farmers with high probabilities of losses tend to be more likely to adopt the insurance program because of the higher expected returns of participating, compared to their counterparts with lower probabilities. An alternative is index-based insurance, where payouts depend on an index that correlates with individual farmers' losses and which farmers have no influence on, which has the potential to confront the challenges associated with the traditional indemnity-based insurance (Miranda & Farrin 2012, Karlan et al. 2014). Given its inherent advantages, index-based insurance has received increased attention from researchers and policy makers over the past two decades. However, several pilot and implemented index insurance programs have either completely failed,

or uptake has been far below expectations, even with massive government subsidies (Giné et al. 2008, Cole et al. 2013). Giné et al. (2008), for example, report that only 5% of farmers in India's state of Andhra Pradesh purchased insurance in their experimental study.

Despite the overwhelming evidence of farmers in DEMCs being averse to risks (Dercon & Christiaensen 2011, de Brauw & Eozenou 2014), the low agricultural insurance uptake continues to baffle researchers. Therefore, a growing body of both theoretical and empirical literature seeks to improve our understanding of the reasons for the low demand and the potential welfare gains from its adoption. As argued by some authors (e.g., Giné et al. 2008), farmers' perception of the perceived distribution of benefits from agricultural insurance may be highly uncertain, making the decision of whether or not to purchase insurance similar to the decision to adopt a new technology.

A clear observation on the methodological front is an increasing number of studies using randomized control trials to examine the impact of interventions on farmers' uptake of agricultural insurance in DEMCs. This shift is aimed at ensuring reduced bias and more precise estimates of program counterfactuals (Cai et al. 2015, Hill et al. 2019). In particular, there has been a shift from the use of stated preferences approach in assessing the key determinants of insurance purchasing decisions of farmers (Hill et al. 2013, Tadesse et al. 2017) to exogenously introduced interventions that seek to examine the impact of specific programs on insurance uptake, as well as effects of uptake on farm performance and welfare (Karlan et al. 2014, Cai et al. 2015, Belissa et al. 2019, Hill et al. 2019).

This article aims to comprehensively review the literature on the demand for agricultural insurance and how participation in the insurance programs affect farmers' welfare in DEMCs. We showcase the recent advances in analyzing the uptake of agricultural insurance products in these countries. The rest of the review proceeds as follows: Section 2 presents the concept and general overview of the agricultural insurance markets. Section 3 outlines theoretical models employed in explaining the demand for agricultural insurance. Section 4 reviews some empirical evidence of the drivers of insurance demand, while section 5 presents evidence of the impacts of insurance. Section 6 presents the concluding remarks and suggests avenues for further research.

2. CONCEPT AND OVERVIEW OF AGRICULTURAL INSURANCE MARKETS

2.1. The Concept of Agricultural Insurance

Agriculture is an extremely risky business, with farmers often exposed to a number of market and production risks. Exposure to these risks result in highly volatile incomes that may affect farmers' consumption if the farmer lacks relevant mitigating measures. The sources of agricultural risks include yield losses from adverse weather conditions, including droughts, incidence of pests and diseases, unexpected low output prices, or even unexpected high input prices. Of course, these risks are not unique to DEMCs but also persist in some developed countries. The difference arises from the existence of better mechanisms to address these risks and uncertainties. Some of these measures include efficient irrigation facilities, resistant varieties, and the use of futures markets to hedge against risks and uncertainties. Thus, farmers in developed countries are able to better manage these risks and uncertainties. These mechanisms for managing risks and uncertainties are often nonexistent, or even if they are, they are often beyond the financial capabilities of farmers in DEMCs. Notwithstanding their financial constraints, farmers in these countries have devised measures to address these risks and uncertainties. However, these measures frequently prove to be inadequate if the risks affect a large number of people within the same geographic enclave at the same time.

Agricultural insurance is one mechanism to manage risks in agriculture by safeguarding farmers' income losses under adverse conditions beyond their control. It provides the financial mechanism for a farmer to either transfer the whole or part of their losses to an entity (insurance firm) through the payment of a small quantifiable amount in exchange for a larger potential loss (Iturrioz 2009). Based on the level at which damages are assessed and insured, insurance can be broadly classified as indemnity based or index based. While claim payments are determined based on actual losses the policyholder incurs in indemnity-based agricultural insurance, the index-based agricultural insurance is based on an index—a measure highly correlated with losses that cannot be influenced by the policyholder. Although there still exist some indemnity-based agricultural insurance programs in some DEMCs, most of the insurance programs implemented for the past few decades have mainly focused on index-based schemes, because of reasons of reduced administrative costs, moral hazard, and adverse selection challenges. In the next section, we discuss indemnity-based insurance.

2.1.1. Indemnity-based insurance. This type of insurance is a financial mechanism that exists between a farmer and an insurance firm, such that the policy covers farmers' actual or potential losses at the farm level, with payouts accordingly made at the level of losses incurred. Indemnity-based insurance can be either single peril or multi-peril, depending on the number of losses the policy covers. Single or named-peril indemnity covers damages for an individual or specifically named perils such as fire, hail, pests, and diseases. When such losses occur, the insurer assesses the extent of the damage at the insured unit, and payments are made according to the terms of the policy. Multi-peril, on the other hand, provides insurance coverage for losses caused by virtually any peril other than that specifically excluded from the policy. Indemnity-based insurance is characteristically expensive to operate because of the high operational costs in assessing losses at the individual farm levels. They are, therefore, much more prevalent in regions with robust welfare systems and more mature agricultural markets.[1] A typical example is the government-subsidized multi-peril crop insurance program in China, in which the state (including province and county) subsidizes up to 80% of the insurance premium (Krychevska et al. 2017).

A related issue with operating indemnity insurance is the insurer's inability to accurately monitor the production activities of the insured to reduce opportunistic behavior. When the insurer is unable to accurately monitor the activities of the farmer, the farmer may be incentivized to alter her production activities to influence losses. A more significant challenge is the tendency for farmers with a higher probability of incurring losses participating in the program, in which case, the insurer increases the cost of the product because the company has no accurate information to price discriminate between high-risk and low-risk farmers. This, in turn, crowds out farmers with lower probability of incurring losses, making the insurance unsustainable. These operational challenges increase the need for an alternative insurance product, index-based insurance.

2.1.2. Index-based insurance. In index-based insurance, on the other hand, payment of liability and amount payable are based on the measured value of an objective and independent index. The liability is not based on proof of a specified loss or the assessment of the actual losses, hence making them less costly to administer. The main advantage of index insurance resides in its ability to substantially reduce the incidence of moral hazards, recognized in the insurance literature as one of the major causes of underdevelopment of the insurance market. Weather and area-yield index insurance constitute the two main index insurance types currently on the insurance market.

[1] Indemnity-based insurance makes up about 62% of all agricultural insurance underwritten in Latin America and about 70% in Eastern Europe and Central Asia. It only constitutes about 24% in Africa.

However, there have been significant increase in experimental index-based livestock insurance (IBLI) across some parts of Africa. While measures of weather parameters, such as the amount of rainfall within a specified period, are used as indices for weather index insurance, a percentage of average yield in a specified geographic area is used for an area yield. Satellite measures of the normalized difference vegetation index (NDVI) also serve an essential role as an index for both crop and livestock index insurance. These measures of indices continue to evolve with better indices under development to improve risk measurements (Flatnes & Carter 2015, Guan et al. 2016).

Despite its appeal in addressing some of the pertinent challenges associated with an indemnity-based insurance, the index-based program may be fraught with challenges. Indices that form the basis for indemnifying losses for the index-based programs are often more appropriate for homogeneous settings. In reality, however, it is often either too expensive to collect data to design a product for such homogeneous settings or it may be totally infeasible to undertake particularly in developing countries' context (Smith & Watts 2019). For these reasons, among others, there may be a weak correlation between these indices and farm-level losses. Smith & Watts (2019), for example, document studies that report as low as a 27% correlation between rainfall and weather station yields in the Sahel regions of Africa. This may result in farmers incurring losses but the index failing to trigger payments to indemnify these losses. Under this condition, termed downside basis risk, farmers are much worse off, because in addition to losses incurred on their farms without receiving indemnities, costs are incurred on premium payments. On the other hand, given the potential disparity between indemnity-activating indices and farm-level losses, the index may trigger payment even though farmers may not have incurred losses; this is termed upside basis risk. Of course, farmers are better off under this condition, but the insurer experiences high loss ratios and may undergo financial distress, putting the sustainability of the insurance program into question.

2.2. The Agricultural Insurance Market Overview

The global agricultural insurance markets have increased considerably over the past decades, mainly because of the exponential growth in premium contributions from some DEMCs, particularly from China and India. For example, the agricultural premium for China grew by 342% from US$1.84 billion in 2006 to US$6.3 billion in 2016, compared to the global growth of 191% over the same period (excluding China). With this strong growth, China's share of the global agricultural insurance premium increased from 1% to 23% over the same period. This trajectory, as shown in **Figure 1**, is projected to continue, as the value of agricultural products in China and other DEMCs continues to grow (Swiss Re Inst. 2013, Krychevska et al. 2017).

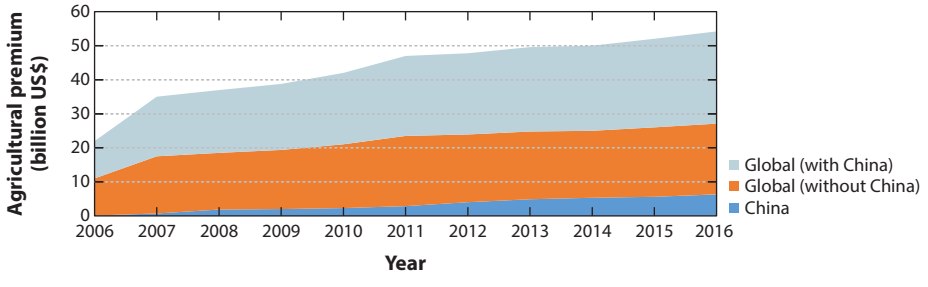

Figure 1

Relative contribution of China to the global insurance premium. Growth of the Chinese agricultural insurance market in relation to the global agricultural insurance premium growth. Data from Mahul & Stutley (2010), Swiss Re Inst. (2013), Löw (2019), and Krychevska et al. (2017).

There have been rapid developments in the agricultural insurance markets in Latin America and the Caribbean. For the past two decades, agricultural insurance premiums have doubled every five years, reaching $1.6 billion in 2015 (Swiss Re Inst. 2016). This exponential growth has been primarily driven by Brazil, Mexico, and Argentina. In terms of volume, about 61% of the insurance premiums were written in Brazil, while Mexico and Argentina contributed about 30%. The rest were written in countries such as Peru, Guatemala, and Cuba (Swiss Re Inst. 2016). The insurance market operations span complete government control through private-public partnerships to commercial operation. In the Caribbean, for example, agricultural insurance has featured prominently in the government and development partners' agenda in mitigating the impacts of climate in the region. Climate Risk Adaptation and Insurance in the Caribbean is an innovative two-phase project implemented in several regional countries to mitigate climate-induced disasters in the region (World Bank 2010, Swiss Re Inst. 2016).

With the exception of South Africa, where agricultural insurance has been in existence since the 1970s, most countries on the African continent have only been introduced to the program, mostly at pilot levels, only within the last two decades (Hess & Hazell 2016, Miranda & Mulangu 2016). Between 2011 and 2016 for example, Sahel Crop Insurance, a weather-based insurance, was piloted across a number of West African countries in the Sahel region owing to the worsening incidence of droughts. The World Bank and other international development agencies spearheaded these pilot projects across countries such as Senegal, Mali, and Burkina-Faso. These programs have primarily focused on corn, as a food security crop, and cotton and peanuts as commercial crops. In addition to instituting and piloting index insurance for crops, that for livestock has also been piloted in these regions (Miranda & Mulangu 2016). In particular, the IBLI was piloted in northern Kenya in 2010 and then subsequently extended to Ethiopia. A year after introducing the IBLI, uptake fell considerably by about 70% from 1,979 subscribers in 2010 to 599 subscribers in 2011 (Miranda & Mulangu 2016). Despite the initial disappointing results, researchers and policy makers expect improved uptake through the continuous efforts to improve program designs and other policy interventions (Miranda & Mulangu 2016).

2.3. Emerging Trends in Agricultural Insurance: Information and Communication Technologies

With recent advances in information and communication technology (ICT), there has been an increased application of ICT to address some of the challenges inherent in the agricultural insurance market. In particular, delivering insurance to sparsely populated areas of farming households in developing countries significantly increases the operational costs. Hence, there is an emerging trend to apply ICT to decrease these costs. Although the African continent continues to be a beneficiary of these modern technologies in the agricultural insurance markets, most of the revolutions are taking place in Asia. We briefly itemize some of the critical trends of the implementation of ICTs in agricultural insurance.

- Ceballos et al. (2019) document the feasibility of incorporating smartphone pictures into index-based insurance to reduce the incidence of basis risk in India. Leveraging the increasing number of smartphone users among farmers, the authors show that farmers could take pictures of their farms at various stages of maturity for onward assessment. The authors find a significant reduction in downside basis risk for picture-based insurance compared to weather index-based insurance and area-yield insurance.
- Although the field of machine learning is nascent in the area of agricultural insurance, there are emerging trends for the application of deep learning and artificial intelligence to better predict weather risks and to inform better agricultural insurance administration.

- Regarding the application of ICT in the livestock insurance sector, researchers are piloting the possibility of using artificial intelligence to identify farm animals to improve performance of the livestock insurance market (Kumar et al. 2016).

3. THEORETICAL MODELS

Although the expected utility theory (EUT) formally developed by von Neumann & Morgenstern (1944) continues to be the standard for explaining decisions under uncertainties, there have been new developments, apparently because of some fundamental inconsistencies in the assumptions underlying the EUT to explain agricultural insurance demand. Researchers have for some time resorted to using behavioral models to explain some of these apparent inconsistencies in the observed demand for agricultural insurance. We review these evolving theories on agricultural insurance literature in this section. We begin with the two dominant theories by first summarizing the literature on the expected utility and then the prospect theory. Other behavioral models are also presented.

The EUT postulates that people maximize their expected utility in their decisions to purchase or not purchase insurance. This decision is driven by the curvature of their utility function, which in turn is determined by the level of risk aversion. Basically, if consuming more of a good results in correspondingly lower additional utility relative to the previously consumed good, then the marginal utility is said to decrease, resulting in a concave utility function. Individuals who exhibit this kind of utility function are said to be risk averse. On the other hand, when marginal utility increases over wealth, a convex utility function is obtained, and individuals displaying his utility function are described as risk seekers. However, when the marginal utility from an additional unit consumed remains constant, the utility exhibits a linear function, and such persons are said to be risk neutral. Due to the concavity of the utility function, the risk-averse individuals always prefer outcomes that are certainly known to uncertain outcomes. Thus, such risk-averse individuals are willing to pay a positive price to avoid such risks. In fact, this willingness-to-pay behavior is the underlying reason for the development of the insurance market. A brief description of this theory is presented in **Figure 2*a*,*b***.

To illustrate how risk aversion affects insurance demand, let us assume a farmer has two plots of land, A and B, on which to farm. Plot A is less fertile but without incidence of locust pest attacks. Plot B is more fertile but susceptible to locust pest attacks. When the farmer cultivates plot A, she is certain to obtain 20 tonnes, and with a price of $10 per tonne, this implies the farmer receives $200. Cultivating Plot B, in a different location, yields 40 tonnes in the absence of locusts, but the farmer obtains 0 tonnes with locust attack. With a 50% chance of locust attack, the farmer receives $400 in the absence of the pest attack, or $0 when there is an attack. On average, the farmer is expected to incur losses of $200 for cultivating plot B. Given that cultivating plot B is associated with uncertainties, and an insurer is willing to pay $400 in case of crop failure, a risk-averse farmer will be willing to pay up to the difference between $400 and her certainty equivalence[2] in premiums to hedge against this potential crop failure (**Figure 2*b***). A more risk-averse farmer will have a more concave curvature in the utility function, implying a higher difference between the actuarially fair premium and the certainty equivalent; therefore, the maximum willingness to pay for the insurance will be higher. Thus, higher risk aversion is expected to lead to higher demand for insurance.

[2]The concept of certainty equivalence refers to an amount of money (income) that is equivalent in an individual's mind (in utility terms) to a given uncertain situation. It is the subjective value one attaches to a certain outcome relative to a given uncertain outcome.

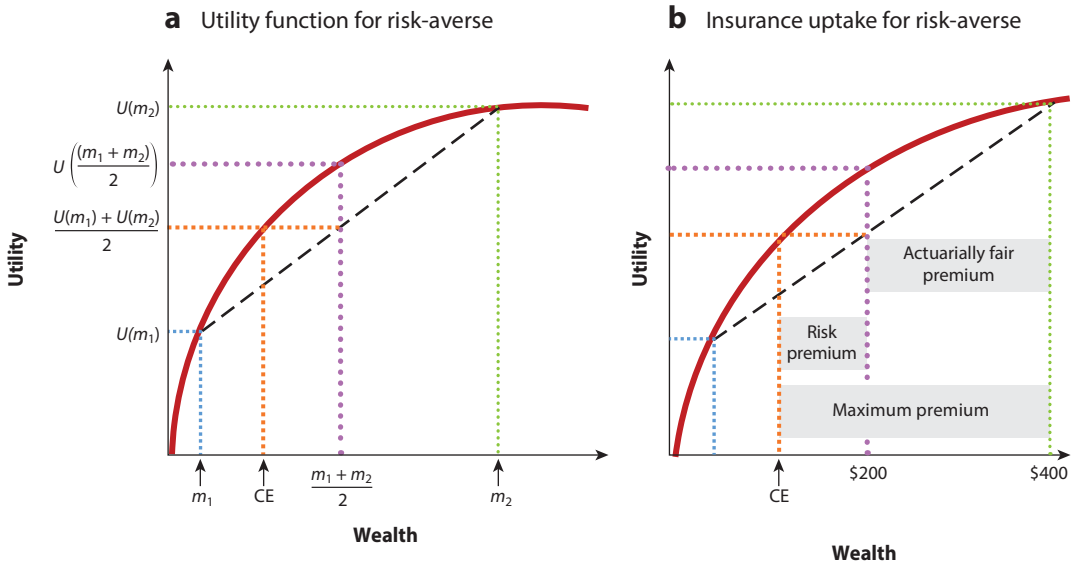

Figure 2

An illustration of expected utility theory explanation for demand for insurance by the risk-averse individual. If we assume a 50% probability, the expected value of m_1 and m_2 is $(m_1 + m_2)/2$ on the horizontal line (*a*). The utility of the expected value of wealth is strictly greater than the expectation of utilities $U(m_1)$ and $U(m_2)$ because of concavity of the utility function, i.e., $U[(m_1 + m_2)/2] > \frac{U(m_1)+U(m_2)}{2}$. To obtain the utility of the expected value of wealth, the risk-averse will be willing to pay a positive price difference between her expected value of wealth and her certainty equivalent (CE), known as risk premium. Tracing to panel *b*, the maximum premium is the sum of the risk premium and the actuarially fair price. Generally, the more risk averse an individual, the more concave the utility function and the larger the risk premium, and by extension, the higher the maximum premium she will be willing to pay to be insured. Adapted with permission from Patt et al. (2009).

The rational theory of demand for insurance explaining that risk aversion is monotonously increasing in demand for insurance is generally consistent with indemnity-based insurance. However, recent evidence on index insurance in some DEMCs shows significant inconsistencies. Numerous studies on index insurance demand show evidence that contradicts the rational demand for insurance (e.g., Giné et al. 2008, Cole et al. 2013, Hill et al. 2016). Building upon the study of Doherty & Schlesinger (1990), Clarke (2016) shows that a more specific contract nonperformance (i.e., basis risks) creates additional risks. Hence, the disutility from this additional risk dominates for individuals with higher risk aversion, resulting in risk aversion decreasing the demand for index insurance. As shown in **Figure 2**, a risk-averse individual will always demand insurance coverage by being willing to pay a positive price to avoid risks. However, recent studies show that demand for index-based insurance by risk-averse individuals initially increases with risk aversion up to a point and starts declining thereafter (Clarke 2016, Hill et al. 2019).

Among the nonexpected utility theories, prospect theory is considered the most convincing in emphasizing three main factors to explain the inconsistencies inherent in the expected utility theory: loss aversion, reference dependence, and probability weighting. At the core of prospect theory is the argument that for the same amount, the disutility from losses is higher than the utility of gains. Thus, contrary to the EUT that apportions equal weights to disutility from losses and utility of gains, the prospect theory points out that this cannot be the situation. From a series of experiments, Kahneman & Tversky (1979) concluded that to the extent that the disutility from avoiding losses is higher than the utility from gaining the same amount, individuals are averse to

losses. It is worth mentioning that in prospect theory, relatively higher aversion to losses makes insurance valuable, as compared to the concavity of the utility function in EUT, because of the higher associated disutility from losses. A related issue, probability weighting, is the tendency for individuals to distort objective probabilities by overweighting worst case scenarios. This is quite intuitive, as given the increasing incidence of extreme weather conditions, the tendency for individuals to overweight events that hitherto were quite rare is now common. Prospect theory incorporates this tendency of overweighting rare events in contrast to the EUT. Finally, in their production processes, it is often common for farmers to have some reference points for valuation. Most farmers produce with target prices for their output in mind. The utility from gains beyond this reference is comparatively lower than the disutility from obtaining less than this reference point. In some developed countries, for example, this occurs through the farmer's target on the futures markets (Kim et al. 2010).

Individuals' aversion to uncertainties on the distribution of outcomes has been attributed to the low demand for agricultural insurance. Following Ellsberg's (1961) distinction between uncertainties with known and unknown probabilities, economists have demonstrated the relevance of the distribution of uncertain outcomes on agricultural insurance demand. Although they appear similar, ambiguity aversion is different from risk aversion: While an individual who is ambiguity averse always prefers an uncertain outcome whose probability is known, a risk-averse individual tends to dislike uncertainties outright. The mechanism through which ambiguity aversion affects insurance demand is better represented in index insurance, where payouts are based on the outcome of an exogenous factor. To the extent that this exogenous factor does not perfectly correlate with observed outcomes at the farmer level, the distribution of farmers' losses will thus likely be different from that of the indemnity-triggering index. It is, therefore, often difficult for farmers to perfectly predict the result of this compound probability that arises from these two distributions (Elabed & Carter 2015). In a recent empirical study on farmers in three African countries, Bryan (2019) demonstrates that ambiguity aversion matters in crop insurance adoption decisions.

The role of credit constraints on the demand for agricultural insurance has long been of significant interest to researchers, given its multidimensional potential impact on insurance demand. On the one hand, the liquidity-constrained individuals are expected to value insurance to stabilize their incomes, given the adversarial effects of fluctuating incomes on consumption. On the other hand, these farmers are unable to convert potential desires into purchases, not only because of issues of costs, but also the time farmers are expected to make these purchases. Because farmers often have to pay for insurance up front at the commencement of the farming season, when they are often cash strapped, they may be less willing to pay for insurance. Although insurance purchasing decisions aim at reducing risks, the insurance product, and index-based programs in particular, come with additional risks because farmers are not entirely certain that indemnities will be paid. When farmers are liquidity constrained, they often tend to pursue less-risky investments, thereby forgoing purchasing insurance due to the uncertainties of receiving payments (Rampini & Viswanathan 2010). These mechanisms through which liquidity constraints influence agricultural insurance have been extensively explored in the empirical literature. Some findings from these empirical studies are discussed below.

3.1. Basis Risk and Insurance (Index-Based) Demand

The widespread challenges of informational gaps, in particular, adverse selection and moral hazard that characterize the indemnity-based insurance, necessitated by the design of an alternative program aimed at minimizing these challenges, led to index-based insurance. The index-based insurance where payouts depend on an exogenous and publicly observable index (measure) has

mostly been successful in addressing the challenges of moral hazard and adverse selection. However, given the potential for farmers to incur losses, and yet the index's failure to trigger payments, farmers' demand for index insurance has been disappointingly low. This probably might have informed Binswanger-Mkhize's (2012) cautious note to not overhype index insurance and that farmers must be studied on a case-by-case basis. Over the past decades, there has been increasing attention in the theoretical literature to describe and explain the mechanisms through which basis risk affects insurance uptake in developing and emerging economies (e.g., Clarke 2016, Jensen et al. 2016).

To motivate the discussions, we briefly present some theoretical implications of basis risk on insurance uptake. Clarke (2016) demonstrates in his theoretical article that the presence of basis risk can worsen farmers' income through premium payments to the insurer in an adversarial state of nature and yet not receive indemnities. Thus, in a bad state of nature (i.e., yield losses), farmers who purchase insurance but find themselves in a situation where the index fails to trigger payouts are much worse off compared to counterparts who did not purchase; the same applies to those farmers had they not purchased insurance. Given the uncertainty associated with the likelihood of receiving payouts, although cost would have been incurred, the farmers may be reluctant to purchase the insurance product. Clarke further points out that the lower demand for index insurance coverage, even among risk-averse farmers, could be partly explained by basis risk. For this reason, index-based insurance is often less valued by farmers, resulting in low demand.

3.2. Social Networks and Insurance Demand

In most rural settings, families often interact. These social interactions have been shown to have consequences on economic outcomes. Understanding the nature and mechanisms underlying the role of social networks on agricultural insurance demand is of significant relevance, given the prevailing weak formal institutions in promoting and delivering alternative means of insurance against shocks. The economic literature has identified two main mechanisms through which social networks influence agricultural insurance demand: risk-sharing and information-sharing networks.

The literature on measuring and modeling the impact of social networks on demand for agricultural insurance has primarily focused on either the nonstrategic or strategic roles. While the nonstrategic role of social networks mainly focuses on network structures as conduits for information transmission, the strategic mechanism entails how farmers share resources in times of shocks in addition to the network structure. This has been found to play a significant role in the demand for agricultural insurance in most DEMCs, where social networks tend to serve an essential ex post risk-coping role in the absence of a formal insurance system. In this section, we address some emerging issues regarding the role of these two social network mechanisms in agricultural insurance demand.

3.2.1. The information diffusion role of social networks. Cai et al. (2015) argue that financial decisions—in particular, decisions to purchase insurance—are quite complex, and frequently, potential buyers of these products either learn about the products through their friends or are sometimes influenced by their friends' choices. However, an important observation was made that friends' decisions to purchase did not have any significant impact on one's purchasing decisions. Instead, when these same individuals were informed of the decisions of their peers, it significantly influenced their own insurance uptake. The authors therefore concluded that the primary mechanism through which social networks affect insurance uptake is through social learning and not necessarily a friend's purchasing decision. Using a randomized experimental design approach in Indian villages, Banerjee et al. (2013) show that the most important channel for individuals to

participate in microfinance programs was acquiring information from friends. This indicates that social networks are quite relevant in influencing participation through information sharing. These studies indicate the knowledge acquisition mechanism of insurance purchases, rather than imitating friends' actions.

3.2.2. The risk-sharing role of networks. In the absence of formal insurance, people may rely on informal risk-sharing mechanisms in coping with risks. It is often common to observe people in rural areas helping one another whenever disastrous events occur. However, it has been argued that these risk-sharing networks often occur at a limited level among family and friends, without extending to all inhabitants in the entire village (Fafchamps & Gubert 2007), thereby rendering it less effective in achieving full insurance. Even in situations where risk-sharing exists in the village, it is often inefficient at achieving the desired impact because of ineffective enforcement and limited commitment (Barr & Genicot 2008, Attanasio & Pavoni 2011).

It has been largely debated in the economic literature as to whether the informal risk-sharing networks play a substituting or complementary role to formal insurance. Fafchamps (1992), for example, argues that risk-sharing networks can serve as a substitute and a complement to formal insurance. He argues that as a complement, informal risk-sharing networks are able to provide some coverage to the residual risk because of the imperfect correlation between farmers' observed losses and the indemnity-activating indices for index-based insurance. However, the same informal risk-sharing may play a substituting role to the formal insurance, if leaving the group decreases the risk-pooling ability of the group. Dercon et al. (2014) offer a theoretical explanation for only the former, arguing that informal risk-sharing networks complement formal insurance by mitigating the inherent basis risks associated with index-based insurance.

Takahashi et al. (2018) argue that in index-based insurance, for example, where the presence of basis risk has been observed to significantly decrease the demand for formal insurance, informal risk-sharing networks and formal insurance reinforce each other. First, they argue that given that index insurance may fail to trigger payment even though a farmer incurs losses, an informal risk-sharing group can fill this gap. On how formal insurance can also complement risk sharing, they argue that these groups are often able to mitigate the effects of idiosyncratic risks. However, these risk-sharing groups are often ineffective in mitigating covariate shocks because a larger number of households are affected at the same time. Hence, formal index insurance could play the important role in reducing this covariate risk.

In a recent study, Berg et al. (2017) contribute to the debate on the relationship between risk sharing and formal insurance. In particular, they demonstrate how risk-sharing networks decrease the demand for indemnity insurance but increase the demand for index-based insurance. In an artifactual field experiment in Ethiopia, the authors empirically test the role of risk sharing on both indemnity-based and index-based insurance. Their findings indicate that risk sharing decreases units of indemnity insurance purchases by 27%, while increasing the uptake of index-based insurance by 130%. These findings further stress the relevance of designing an insurance product to minimize residual risks inherent in index-based insurance as much as possible to improve the welfare of poor farmers in developing countries.

4. EMPIRICAL EVIDENCE ON THE DRIVERS OF AGRICULTURAL INSURANCE DEMAND

Several studies have analyzed the drivers of farmers' participation in agricultural insurance programs in developing and emerging economies. The various methodologies employed in these empirical analyses range from observational through quasi-experimental to experimental.

However, given the recent increase in evidence from experimental studies, the sections below focus on these examples.

4.1. Credit or Liquidity Constraints

A growing body of literature shows the relevance of the timing when insurance products are offered to farmers on their uptake. A characteristic feature of most farmers in developing countries is the possession of cash at harvest from sales of farm products, which tends to decrease as the planting season approaches because of purchases of farm inputs. To the extent that many farmers tend to be liquidity constrained during the planting season, an up-front payment for agricultural insurance is often a challenge to these poor farmers. Several studies have analyzed these insurance up-front payment problems and explored the potential of offering insurance with delayed payments that take place during the harvest period.

In a recent study, Casaburi & Willis (2018) employ a randomized control trial to examine how delayed insurance programs to Kenyan sugarcane farmers interlinked with contract farming impacted insurance uptake. They hypothesize that selling insurance products to these farmers during harvest will increase uptake because they are less liquidity constrained after receiving incomes from their harvests. Consistent with their hypothesis, they find that only 5% of farmers who had to pay the insurance premium upfront opted for the insurance product, while 72% of the farmers who were offered the insurance at the harvest period took up the product. Even with a 30% discount provided to farmers who paid up front, the insurance uptake only increased to 6%. In a more recent study, Belissa et al. (2019) also use a randomized control trial to test a similar hypothesis. They argue that, given the relatively low amount of contract farming in most developing countries, offering similar products devoid of contract farming was more externally valid. After offering insurance products with delayed payment until harvest, they observe a significant increase in uptake of the product. Specifically, uptake increased by threefold from 8% to 24% with insurance premium payment delays. At a disaggregated level, they observe higher uptake among farmers who were liquidity constrained, though this difference was not statistically significant.

Even though we set out to review studies that employed experimental approaches, we nevertheless point out one particular study that sought to test poor farmers' preferences for an alternative means of paying for insurance programs other than using cash. Using the stated preference approach in rural Ethiopia, Tadesse et al. (2017) assess farmers' willingness to pay for weather insurance with cash alone, labor (work) alone, or a combination. One of their main findings is that farmers were willing to offer their labor for the insurance program at wages lower than the going rates on public work programs. They conclude that these farmers were severely cash constrained and more willing to pay with their labor, which they have in abundance compared to cash.

4.2. Rates of Time Preference

An increasingly abundant literature explores the role of how farmers discount future benefits on insurance uptake. Despite the primary purpose of insurance in reducing risks through the transfer of incomes from high-income states to low-income states, some researchers have found evidence of the investment appeal of insurance (Connor 1996). In addition to the nature of insurance that requires an up-front payment for a premium, this has necessitated the increased attention on the role of farmers' discounting of future benefits on agricultural insurance adoption in most developing countries. In an experimental study in Bangladesh, Hill et al. (2019) randomly assign villages to discounts and rebates to examine how farmers' time preferences affect their demand for agricultural insurance. Their empirical results reveal that discounts tend to stimulate insurance

demand more than rebates. Their findings give further credence to the notion that farmers in DEMCs prefer current benefits compared to future ones.

4.3. Trust

When farmers have doubts about either the insurance product design itself or the likelihood of receiving payment when they incur losses, they tend to be hesitant in taking up insurance products. These attitudes often originate from the weaker formal institutions involved in the enforcement of contracts in most DEMCs. Literature on the impacts of trust on insurance uptake has mostly been centered on three main themes: the product itself, institutions responsible for the management of the insurance product, and the degree of interpersonal trust. These dimensions of farmers' trust behavior continue to attract the attention of empirical economists, given the relevant role trust plays in insurance demand.

Most studies attribute the distrust of the insurance product itself to the farmers' misunderstanding of the insurance product. Given the generally low level of formal education of rural individuals in developing countries, most farmers tend to have minimal knowledge of the concept of insurance. If not properly understood, these farmers often consider insurance products to be similar to investment options, which, when they fail to receive payouts, generally lead to distrusting behavior. Distrust emanating from the insurance product has been found to diminish and subsequently increase uptake when farmers witness payouts. In Ghana, Karlan et al. (2014) use a randomized control trial and find that the demand for insurance increases when farmers observe payouts for members in their social networks or when they experience payment from the insurance. As already indicated, in the absence of formal institutions to enforce contracts in most developing countries, trusted informal institutions tend to fill the void. Following a randomized control trial in Ethiopia, Belissa et al. (2019) report that although index insurance uptake was only 8% in the standard marketing channel, when it was marketed through an informal institution called *Iddir*, whose leaders are generally well trusted, uptake doubled to 15%. This finding supports the importance of trust in the institutions involved in scaling up the uptake of insurance products.

4.4. Basis Risk

As discussed in the theoretical review in Section 3.1, basis risk presents a major challenge to farmers in their adoption decisions of index-based insurance. It appears to represent one of the most significant risks to the development of index-based insurance markets. In a comparative study of the cost-effectiveness of indemnity-based and index-based insurance in China, Ye et al. (2019) find that the positive price advantage from index-based insurance may not be sufficiently large to offset the costs associated with its basis risk. These findings further highlight the reason underpinning the continuous and sustained interests in understanding and minimizing basis risks. In an earlier innovative study to test the impact of basis risks on weather index insurance, Mobarak & Rosenzweig (2013) randomize weather station placements in Indian villages. This study was among the first to empirically test the impact of basis risk on index-based insurance demand. Their findings show that basis risk significantly decreases the demand for weather index insurance. In a panel study on the Kenyan IBLI program, Jensen et al. (2018) report a significant decrease in both the uptake and level of coverage of the insurance program. Note that while other studies have often relied on proxies as their measure of basis risk, Jensen et al. (2018) use actual data from farm purchases.

Given the important role of basis risk on index-based insurance demand, some researchers have proposed innovative insurance products that aim at addressing the problem. For example,

Elabed et al.'s (2013) study on cotton farmers in Mali recommends a multilevel yield index, one at the village level and the other at the regional level to increase demand. Other studies have proposed and implemented a hybrid index to minimize basis risks. The study by Hill et al. (2019) on Bangladesh implements index-based insurance that is triggered by both the area yield and the rainfall index. This insurance program is expected to decrease both upside and downside basis risk.

By exploring how to minimize basis risk from the product design perspective, Xiao & Yao (2019) investigate three index-based insurance products triggered by two indices (i.e., weather and area yield) under different scenarios. The first is the superimposition type that separately incorporates indemnity payments from the weather index and the area-yield index at the same time. With this, if either the weather or area-yield index is triggered, the farmer receives payments. In supplement type, payments are made only when the weather index fails to trigger payments, but farmers still incur losses to such a point that the area-yield index triggers payment. For this, as the name suggests, the area-yield index supplements the weather index. Finally, there is the rebate type in which premiums that farmers paid are returned to them when the weather index fails to trigger payments, but the area-yield index triggers payments because of poor yields. This can be a common scenario when the total amount of rain required for a given crop is enough but is poorly distributed. Xiao and Yao's simulations and empirical findings show improved performance of the supplementary type of insurance. Findings from this study provide relevant information to inform the design of indices for future index-based insurance.

5. EVIDENCE OF THE IMPACTS OF AGRICULTURAL INSURANCE

To the extent that agricultural insurance has been identified as one primary way of reducing the risks and uncertainties faced by farmers in DEMCs, many studies have also analyzed the determinants of uptake and welfare impacts of these insurance products. These studies have primarily been undertaken with diverse approaches, including the use of experimental and observational data. In this section, we discuss some of the recent findings from studies that have examined the impacts of agricultural insurance on well-being indicators. We first briefly review studies that used simulations and then delve deeper into those that used either observational or experimental approaches.

In the absence of rigorous experimental methods of assessing the impacts of insurance on some welfare measures, researchers have long relied on either simulations or observational data. Carter et al. (2007) for example, applied the simulation method to show that insurance provision significantly improves farmers' welfare as well as their access to and supply of loans and repayments in Peru.

5.1. Ex Ante Impacts of Investment Decisions

Karlan et al. (2014) investigate the investment response of relaxing the binding uninsured risks and liquidity constraints of maize farmers in northern Ghana. After randomly assigning farmers to either cash grants, index insurance, or both, they observed that investments in chemical fertilizers significantly increased for farmers who purchased insurance in a similar proportion to those who received cash grants. Spending on fertilizer is a risky investment, given that in a bad state of nature, particularly the lack of rain, farmers are not likely to reap the benefits from the fertilizer applied. The authors conclude that uninsured risks present a significant drawback to farmers' investments and that when relaxed through the purchase of insurance, farmers are able to find the needed resources to achieve this objective.

Using a natural experimental approach, Cai (2016) demonstrates that Chinese farmers can expand land allocated for the production of tobacco by about 16% after purchasing an

indemnity-based insurance product from the government. Similarly, an earlier study by Cai et al. (2015), also using a randomized field experiment in Southern China, showed that investments in sows increased significantly after the purchase of insurance. Recognizing the hindrances of uninsured risks, the authors conclude that insurance can play an equally important role as microfinance in increasing the production of risky sows. A comparative study on cash transfers and index-based insurance in Kenya by Jensen et al. (2017) also reveals that investments in livestock increase significantly after farmers purchase livestock insurance. This was mainly through increased expenses on veterinary services that are expected to increase livestock productivity because of improved health.

Using a natural experimental design, Freudenreich & Mußhof (2018) also contribute evidence of the ex ante impacts of insurance by analyzing how insurance purchase influences the adoption of improved varieties by Mexican farmers. Their findings show that purchasing insurance significantly affects the adoption of improved maize varieties. However, in an earlier study, Brick & Visser (2015) find no evidence of adoption of improved varieties after farmers purchased partial insurance in South Africa. Despite this limited evidence to the contrary, it is apparent that when risks are adequately addressed through the provision of insurance, farmers can increase investments in risky production practices, which is expected to generate higher returns and improvement in welfare.

5.2. Ex Post Impacts of Insurance

Economists have often argued that when poor farmers adopt agricultural insurance, it has the potential to reduce the fluctuations often associated with their incomes and consumption because of their continuous exposure to uninsured risks. Indeed, most studies have shown the negative repercussions when farmers have minimal mitigations to risks (Rosenzweig & Binswanger 1993, Dercon 2004, Barnett & Barrett 2008). However, what is lacking is convincing evidence from DEMCs showing that purchasing agricultural insurance has income and consumption smoothing effects. As Cole & Xiong (2017) rightly point out, answering this question requires first establishing that risks induce income fluctuations in the absence of insurance. Second, farmers should either partially or fully be unable to mitigate these income fluctuations to smooth their consumption. Finally, payouts from the coverage should be sufficiently large to cover the losses farmers incur from their exposure to these risks.

In their recent study on Ethiopian livestock owners, Gebrekidan et al. (2019) demonstrate that the purchase of index-based insurance contributes to a decline in distress sale of livestock. This is extremely important because, in times of extreme weather shocks, farmers without any insurance product or other means of coping with this shock tend to sell their livestock. With a significantly large number of livestock owners willing to sell, prices will naturally decrease because of the increased supply. This action presents double jeopardy to owners of these livestock. On one hand, they tend to lose their productive assets, which makes it difficult for them to cope with future shocks; on the other hand, doing so at a lower prevailing price will generate inadequate income for them to fully cope with the current shocks.

5.3. Some Topical Policy Issues

There is an ongoing policy discussions on where to situate agricultural insurance towards the achievement of broader developmental goals in DEMCs. For example, should agricultural insurance be subsidized? What role should agricultural insurance play in achieving broader welfare policy objectives? We briefly shed light on how these questions have been discussed in the policy literature in the ensuing section.

5.3.1. Premium subsidies and agricultural insurance. Farm input subsidies have long been a major policy instrument in a number of DEMCs to increase input demand. The empirical evidence largely shows higher fertilizer application rates in countries with subsidies (Sheahan & Barrett 2017). Garrido & Zilberman (2008) develop a theoretical framework to show how premium subsidies, like other farm inputs, incentivize farmers to participate in agricultural insurance programs. Consistent with the authors' theoretical model, premium subsidies increase insurance participation among Spanish farmers. However, evidence from developing country context has been mixed and inconclusive. For example, in their studies in India, Giné et al. (2008) and Cole et al. (2013) report low participation even after heavily subsidizing premiums. In China, however, the evidence appears to suggest improved participation decisions with subsidies (Cai et al. 2015, Cai 2016). This clearly indicates a careful case-by-case study of insurance subsidy programs in DEMCs because of the potential of other equally relevant variables in influencing participation decisions.

5.3.2. Agricultural policies and insurance. Improving the incidence of food and nutrient security, increasing farm incomes and decreasing income variability are among the key policy objectives pursued by most policy makers in DEMCs. To achieve these objectives, policy makers often have at their disposal a number of instruments in their toolbox to choose from. We briefly document how agricultural insurance may complement or substitute other policy instruments in achieving these policy objectives.

The role of risks and uncertainties as a disincentive to poor farmers investing in risky agricultural inputs is well known in the literature. Incentivizing farmers to purchase these risk-increasing inputs may be achieved through the provision of input subsidies or relaxing the binding uninsured risk through the provision of insurance. Indeed, many studies have documented the investment-enhancing role of providing input subsidies (Sheahan & Barrett 2017, Holden 2019). Although the provision of input subsidies may be viewed as a direct solution to addressing the low investments in risk-increasing agricultural inputs, relaxing these risks through the provision of insurance may be an option. Karlan et al. (2014), for example, report increased investments in fertilizer expenditure after a sample of Ghanaian farmers were offered weather-based insurance. To this end, agricultural insurance and input subsidies play a substituting role in achieving increased fertilizer applications, which will eventually lead to improved productivity gains. However, what is not known is the extent to which agricultural insurance can substitute for fertilizer subsidy.

Increasing poor farmers' incomes continue to be at the forefront of most agricultural and development policies of DEMCs. Universal basic income has been proposed as an option. However, the challenge of justifying the prudent use of scarce resources has contributed to only three[3] known DEMCs who have implemented a true unconditional universal incomes, whereas the others are often targeted, with conditionalities (Banerjee et al. 2019). As previously indicated, farmers' incomes can be increased when the binding uninsured risk is relaxed to spur investments in inputs such as fertilizer to enhance productivity. Here again, agricultural insurance could be considered as an indirect substitute for universal basic income.

6. CONCLUSIONS AND FURTHER RESEARCH

Even though farmers in most DEMCs are highly exposed to risks and uncertainties in the agricultural production, they often lack better tools to manage these risks. Researchers and policy makers

[3]These include some nine villages in the Indian state of Madhya Pradesh, two villages in Namibia, and Iran, which implemented a nationwide cash transfer in response to the withdrawal of food and fuel subsidies (Banerjee et al. 2019).

have long proposed and implemented agricultural insurance as a tool to mitigate risks that farmers face, with high anticipation of uptake. Yet uptake of insurance has been far below expectations. Given the significance of designing policy measures to minimize the risks involved in agricultural production in DEMCs, several studies have sought to understand the main drivers of low uptake. Many of the studies identified lack of trust, liquidity and credit constraints, partial coverage of risks, lack of understanding of the insurance products, and some behavioral factors such as rate of time preference as the main drivers of the low demand for agricultural insurance. Despite the increasing body of research on the topic, some knowledge gaps can be explored in future studies.

It appears that most index-based insurance programs in most DEMCs have largely focused on annual crops, with little attention paid to perennial crops. Despite the fact that designing an index-based insurance program for perennial crops may be technically more challenging, it is still an important avenue for consideration, given that farmers who cultivate perennial crops have an additional challenge of less flexibility in adjusting their production under risky conditions.

Lack of trust has been largely cited as a cause of low demand for agricultural insurance in most DEMCs. Farmers' nontrusting behavior has developed through their past experiences. Thus, path dependence plays a significant role in individuals forming beliefs about an innovation they have little information on. However, the literature on trust has been silent on investigating farmers' path-dependent processes in forming their distrusting behavior. Therefore, studies should explore how these past experiences inform farmers' trusting behavior and how to address them to improve insurance uptake.

As research continues on agricultural insurance, particularly index-based insurance, there is the need to collect rich panel data sets to examine the relationship between indices and actual losses incurred in order to improve the prediction accuracies of indices. This would go a long way to reducing the incidence of basis risk that is a critical disincentive factor for farmers in taking up index-based insurance. To the extent that index-based insurance appears to be the future for the agricultural insurance sector, undertaking this research to refine the indices would improve its uptake and subsequently contribute to the improvement of farmers' welfare.

DISCLOSURE STATEMENT

The authors are not aware of any affiliations, memberships, funding, or financial holdings that might be perceived as affecting the objectivity of this review.

ACKNOWLEDGMENTS

W. Ali and A. Abdulai gratefully acknowledge financial support from the German Research Foundation (DFG), grant number AB 288/9-1.

LITERATURE CITED

Alderman H, Paxson CH. 1994. Do the poor insure? A synthesis of the literature on risk and consumption in developing countries. In *Economics in a Changing World*, ed. EL Bacha, pp. 44–78. London: Palgrave Macmillan

Attanasio OP, Pavoni N. 2011. Risk sharing in private information models with asset accumulation: explaining the excess smoothness of consumption. *Econometrica* 79(4):1027–68

Banerjee A, Chandrasekhar AG, Duflo E, Jackson MO. 2013. The diffusion of microfinance. *Science* 341(6144):1236498

Banerjee A, Niehaus P, Suri T. 2019. Universal basic income in the developing world. *Annu. Rev. Econ.* 11:959–83

Barnett BJ, Barrett CB. 2008. Poverty traps and index-based risk transfer products. *World Dev.* 36:1766–85
Barr A, Genicot G. 2008. Rish sharing, commitment, and information: an experimental analysis. *J. Eur. Econ. Assoc.* 6(6):1151–85
Bates BC, Kundzewick ZW, Wu S, Palutikof JP. 2008. *Climate change and water*. Tech. Pap., IPCC, Geneva
Belissa T, Bulte E, Cecchi F, Gangopadhyay S, Lensink R. 2019. Liquidity constraints, informal institutions, and the adoption of weather insurance: a randomized controlled trial in Ethiopia. *J. Dev. Econ.* 140(3):269–78
Berg E, Blake M, Morsink K. 2017. *Risk sharing and demand for insurance: theory and experimental evidence from Ethiopia*. CSAE Work. Pap., Cent. Study Afr. Econ., Univ. Oxford
Binswanger-Mkhize HP. 2012. Is there too much about index-based agricultural insurance? *J. Dev. Stud.* 48(2):187–200
Brick K, Visser M. 2015. Risk preferences, technology adoption and insurance uptake: a framed experiment. *J. Econ. Behav. Organ.* 118:269–78
Bryan G. 2019. Ambiguity aversion decreases the impact of partial insurance: evidence from African farmers. *J. Eur. Econ. Assoc.* 17(5):1428–69
Cai H, Chen Y, Fang H, Zhou L-A. 2015. The effect of microinsurance on economic activities: evidence from a randomized field experiment. *Rev. Econ. Stat.* 97(2):287–300
Cai J. 2016. The impact of insurance provision on household production and financial decisions. *Am. Econ. J. Econ. Policy* 8(2):44–88
Cai J, de Janvry A, Sadoulet E. 2015. Social networks and the decision to insure. *Am. Econ. J. Appl. Econ.* 7(2):81–108
Carter MR, Galarza F, Boucher S. 2007. Underwriting area-based yield insurance to crowd-in credit supply and demand. *Savings Dev.* 31(3):335–62
Casaburi L, Willis J. 2018. Time versus state in insurance: experimental evidence from contract farming in Kenya. *Am. Econ. Rev.* 108(12):3778–813
Ceballos F, Kramer B, Robles M. 2019. The feasibility of picture-based insurance (PBI): smartphone pictures for affordable crop insurance. *Dev. Eng.* 4(1):100042
Clarke DJ. 2016. A theory of rational demand for index insurance. *Am. Econ. J. Microecon.* 8(1):283–306
Cole BS, Giné X, Tobacman J, Topalova P, Townsend R, Vickery J. 2013. Barriers to household risk management: evidence from India. *Am. Econ. J. Appl. Econ.* 5:104–35
Cole SA, Xiong W. 2017. Agricultural insurance and economic development. *Annu. Rev. Econ.* 9:235–62
Connor RA. 1996. More than risk reduction: the investment appeal of insurance. *J. Econ. Psychol.* 17:39–54
de Brauw A, Eozenou P. 2014. Measuring risk attitudes among Mozambican farmers. *J. Dev. Econ.* 111:61–74
Dercon S. 2004. Growth and shocks: evidence from rural Ethiopia. *J. Dev. Econ.* 74:309–29
Dercon S, Christiaensen L. 2011. Consumption risk, technology adoption and poverty traps: evidence from Ethiopia. *J. Dev. Econ.* 96(2):159–73
Dercon S, Hill RV, Clarke D, Outes-Leon I, Taffesse AS. 2014. Offering rainfall insurance to informal insurance groups: evidence from a field experiment in Ethiopia. *J. Dev. Econ.* 106:132–43
Doherty NA, Schlesinger H. 1990. Rational insurance purchasing: consideration of contract nonperformance. *Q. J. Econ.* 105(1):243–53
Elabed G, Bellemare MF, Carter MR, Guirkinger C. 2013. Managing basis risk with multiscale index insurance. *Agric. Econ.* 44(4/5):419–31
Elabed G, Carter MR. 2015. Compound-risk aversion, ambiguity and willingness to pay for microinsurance. *J. Econ. Behav. Organ.* 118(10):150–66
Ellsberg D. 1961. Risk, ambiguity and the savage axioms. *Q. J. Econ.* 75(4):643–69
Fafchamps M. 1992. Solidarity networks in preindustrial societies: rational peasants with a moral economy. *Econ. Dev. Cult. Change* 41(1):147–74
Fafchamps M, Gubert F. 2007. The formation of risk sharing networks. *J. Dev. Econ.* 83(2):326–50
FAO (Food Agric. Organ.). 2013. *Climate-Smart Agriculture Sourcebook*. Rome: FAO
Flatnes JE, Carter MR. 2015. *Fail-safe index insurance without the cost: a satellite based conditional audit approach*. Work. Pap., Univ. Calif., Davis
Freudenreich H, Mußhoff O. 2018. Insurance for technology adoption: an experimental evaluation of schemes and subsidies with maize farmers in Mexico. *J. Agric. Econ.* 69(1):96–120

Garrido A, Zilberman D. 2008. Revisiting the demand for agricultural insurance: the case of Spain. *Agric. Finance Rev.* 68(1):43–66

Gebrekidan T, Guo Y, Bi S, Wang J, Zhang C, Wang J. 2019. Effect of index-based livestock insurance on herd offtake: evidence from the Borena zone of southern Ethiopia. *Climate Risk Manag*. 23:67–77

Giné X, Townsend R, Vickery J. 2008. Patterns of rainfall insurance participation in rural India. *World Bank Econ. Rev.* 22(3):539–66

Guan K, Berry JA, Zhang Y, Joiner J. 2016. Improving the monitoring of crop productivity using spaceborne solar-induced fluorescence. *Glob. Change Biol.* 22:716–26

Hess U, Hazell P. 2016. *Innovations and emerging trends in agricultural insurance*. Rep., GIZ, Bonn, Ger.

Hill RV, Hoddinott J, Kumar N. 2013. Adoption of weather-index insurance: learning from willingness to pay among a panel of households in rural Ethiopia. *Agric. Econ.* 44(4–5):381–84

Hill RV, Kumar N, Magnan N, Maghija S, de Nikola F, et al. 2019. Ex ante and ex post effects of hybrid index insurance in Bangladesh. *J. Dev. Econ.* 136:1–17

Hill RV, Robles M, Ceballos F. 2016. Demand for simple weather insurance product in India: theory and evidence. *Am. J. Agric. Dev.* 98(4):1250–70

Holden S. 2019. Economics of farm input subsidies in Africa. *Annu. Rev. Resour. Econ.* 11:501–22

Iturrioz R. 2009. *Agricultural insurance*. Primer Ser. Insur. 12, Int. Bank Reconstr. Dev./World Bank, Washington, DC. **http://documents.worldbank.org/curated/en/985551468150558970/pdf/625120NWP0Agri00Box0361486B0PUBLIC0.pdf**

Jensen ND, Barrett CB, Mude AG. 2016. Index insurance quality and basis risk: evidence from northern Kenya. *Am. J. Agric. Econ.* 98(5):1450–69

Jensen ND, Barrett CB, Mude AG. 2017. Cash transfers and index insurance: a comparative impact analysis from northern Kenya. *J. Dev. Econ.* 129:14–28

Jensen ND, Mude AG, Barrett CB. 2018. How basis risk and spatiotemporal adverse selection influence demand for index insurance: evidence from Northern Kenya. *Food Policy* 74(1):172–92

Kahneman D, Tversky A. 1979. Prospect theory: an analysis of decision under risk. *Econometrica* 47(2):263–91

Karlan D, Osei RD, Osei-Akoto I, Udry C. 2014. Agricultural decisions after relaxing credit and risk constraints. *Q. J. Econ.* 129(2):597–652

Kim HS, Brorsen BW, Anderson KB. 2010. Profit margin hedging. *Am. J. Agric. Econ.* 92:638–53

Krychevska L, Shynkarenko I, Shynkarenko R. 2017. *Agricultural insurance in China: history, development and success factors*. Rep., Agroinsur. Int., Kiev/Tblisi. **http://agroinsurance.com/wp-content/uploads/2017/04/Agricultural-insurance-in-China-Agroinsurance-International.pdf**

Kumar S, Tiwari S, Singh SK. 2016. Face recognition of cattle: Can it be done? *PNAS India Sect. A Phys. Sci.* 86(2):137–48

Löw P. 2019. The natural disasters of 2018 in figures. *Munich RE*, Jan. 8. **https://www.munichre.com/topics-online/en/climate-change-and-natural-disasters/natural-disasters/the-natural-disasters-of-2018-in-figures.html**

Mahul O, Stutley CJ. 2010. *Government Support to Agricultural Insurance: Challenges and Options for Developing Countries*. Washington, DC: World Bank

Miranda MJ, Farrin K. 2012. Index insurance for developing countries. *Appl. Econ. Perspect. Policy* 34(3):391–427

Miranda MJ, Mulangu FM. 2016. *Index insurance for agricultural transformation in Africa*. Rep., Afr. Cent. Econ. Transform., Accra, Ghana

Mobarak MA, Rosenzweig MR. 2013. Informal risk sharing, index insurance and risk taking in developing countries. *Am. Econ. Rev.* 103(3):375–80

Patt A, Peterson N, Carter M, Velez M, Hess U, Suarez P. 2009. Making index insurance attractive to farmers. *Mitig. Adapt. Strateg. Glob. Change* 14(8):737–53

Rampini AA, Viswanathan S. 2010. Collateral, risk management and the distribution of debt capacity. *J. Finance* 65(6):2293–322

Rosenzweig MR, Binswanger HP. 1993. Wealth, weather risk and the composition of agricultural investments. *Econ. J.* 103:56–78

Sheahan M, Barrett CB. 2017. Ten striking facts about agricultural input use in sub-Saharan Africa. *Food Policy* 67:12–25

Smith VH, Watts M. 2019. Index based agricultural insurance in developing countries: feasibility, scalability and sustainability. *Gates Open Res*. 3. **https://doi.org/10.21955/gatesopenres.1114971.1**

Swiss Re Inst. 2013. *World insurance in 2013: steering towards recovery*. Rep. sigma 03/2014, Swiss Re. Inst, Zurich, Switz.

Swiss Re Inst. 2016. *Agricultural insurance in Latin America: taking root*. Rep., Swiss Re Inst., Zurich, Switz.

Tadesse MA, Alfnes F, Erenstein O, Holden ST. 2017. Demand for a labor-based drought insurance scheme in Ethiopia: a stated choice experiment approach. *Agric. Econ.* 48:501–11

Takahashi K, Barrett CB, Ikegami M. 2018. Does index insuance crowd out informal risk sharing? Evidence from rural Ethiopia. *Am. J. Agric. Econ.* 101(3):672–91

Vargas R, Angelino H. 2012. A field experiment on the impact of weather shocks and insurance on risky investment. *Exp. Econ.* 15:341–71

von Neumann J, Morgenstern O. 1944. *Theory of Games and Economic Behavior*. Princeton, NJ: Princeton Univ. Press

World Bank. 2010. *Agricultural Insurance in Latin America: Developing the Market*. New York: World Bank

Xiao Y, Yao W. 2019. Double trigger agricultural insurance products with weather index and yield index. *China Agric. Econ. Rev.* 11(2):299–316

Ye T, Hu W, Barnett BJ, Wang J, Gao Y. 2019. Area yield index insurance or farm yield crop insurance? Chinese perspectives on farmers' welfare and government subsidy effectiveness. *J. Agric. Econ.* 71(1):144–64