Group-based agricultural index insurance

Combining informal networks with formal insurance

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Abstract

Weather represents the major source of uncertainty in crop production. With climate change, weather fluctuations are expected to increase. Traditionally, smallholder farmers tried to protect themselves against income shocks through informal risk-management strategies such as informal networks. These offer inadequate protection. More recently, researchers and development organizations have proposed to combine index insurance products with pre-existing networks. The social capital emerging from relations within networks can help index insurance prevail its major issues, i.e., basis risk, a lack of trust, and limited understanding. However, the nature of these networks, which is informal, reintroduces problems regarding moral hazard and adverse selection that saw the demise of conventional indemnity-based agricultural insurance.

Keywords – Agricultural insurance, informal networks, index insurance

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1 Introduction

The prevalence of risk in agriculture is not new and farmers have, over generations, developed informal risk-management strategies. Farmers use a variety of ex-ante and ex-post measures to reduce risk exposure. However, these strategies offer inadequate risk protection against widespread catastrophic weather events (Hazell, 1992; Miranda and Farrin, 2012; Di Marcantonio and Kayitakire, 2017). Agricultural insurance holds a special appeal to researchers and policymakers seeking to reduce vulnerability and promote productivity growth among poor rural populations in regions where rain-fed agriculture is widespread and financial market failures are common (Jensen and Barrett, 2017). In the future, households in developing countries are expected to suffer the most from climate-related extreme events due to their heavy dependence on the traditional subsistence agricultural sector (Aryal et al., 2014; Budhathoki et al., 2019).

The early development and subsequent transformation and industrialization in most of today's high-income countries have had successful productivity growth in agriculture as roots for growth. For countries with a high contribution of agriculture to GDP growth and a high share of their poor in the rural sector, agriculture still remains the expected engine of growth. The main message from The World Development Report *Agriculture for Development* is that agriculture-based countries should invest more in agriculture to fully capture its potential for growth and poverty reduction (The World Bank, 2007; Hazell et al., 2010; De Janvry and Sadoulet, 2020).

Access to financial services in the developing world has increased in the last two decades. Still, the usage of formal insurance services as protection against income risks remains low across many developing countries. Data from almost 66 thousand households in developing countries reveals that only 1.82% of farmers are covered by agricultural insurance. Roughly three-fourths of the 1.3 billion people living on less than US$1 per day are depending on agriculture for their livelihoods (Ravallion and Chen, 2007; Mobarak and Rosenzweig, 2013; De Janvry et al., 2014; Panda et al., 2020). The ever-increasing average temperature from climate change reduces agriculture productivity (Burke et al., 2015). Furthermore, climate change increases the frequency of weather extremes, e.g., droughts, floods, and windstorms, making poor households more prone to income shocks pushing households

further into poverty traps from which it will be difficult to escape (Isik and Devadoss, 2006; Musshoff et al., 2011; Field et al., 2012).

Index-based insurance [1] has received considerable interest from academic researchers, multilateral international non-government organizations, and national governments for the past twenty years. Index insurance is a financial product linked to an index that is a random variable that is reliably measurable, objectively observable, and highly correlated to agricultural yields. Payouts occur when the contracted threshold is reached, e.g., amount of rainfall. By indemnifying the insured based on an index, index-based insurance alleviates the problems of moral hazard and adverse selection suffered by conventional agricultural indemnity-based insurance, as farmers cannot influence index-based indemnities (Hazell et al., 2010; Miranda and Gonzalez-Vega, 2011). Weather stations across areas where index insurances are applied collect data to form indices (Jensen and Barrett, 2017).

Impacts of index insurance have generally been positive where uptake has occurred, while uptake has been low and in most cases under conditions that were not sustainable (Carter et al., 2014). Despite its high appraisal, index insurance has not taken off as expected due to the presence of basis risk, a lack of trust, and limited understanding of the insurance product. Basis risk occurs when the index does not reflect farmers' actual loss, which can be the case if the yield loss is a result of something else than rainfall or because the heterogeneity of farms is not reflected in the index, i.e., a weak correlation between the index and loss outcomes (Miranda and Farrin, 2012; Cole et al., 2013; Vasilaky et al., 2020). Additionally, by constructing an index product to solely address covariate risks, idiosyncratic risks are left uninsured, which in turn, is a source to basis risk (Clement et al., 2018). Demand is especially low among low-income farmers due to basis risk (Clarke, 2016; Clarke and Dercon, 2016; Tang et al., 2021).

Informal networks are widespread in developing countries partly due to the historical lack of access to formal institutions. An example of such a network stems from Ethiopia, where households struggled to finance their much-celebrated and costly funerals after the sudden death of a loved one, which has led to the creation of informal burial groups (Dercon et al., 2006). Another example is the many different rotating savings and credit associations (ROSCAs) across the developing world. These informal networks provide

[1] Index-based insurance included: area-yield index insurance, satellite-based index insurance, and weather index insurance products. The latter will receive considerable attention in this thesis.

savings and access to credit in times of need for the group members (Banerjee and Duflo, 2007). Emphasizing that the outspread of informal networks is present and due to a number of reasons, where financial market failure is the common denominator. However, informal networks lack resilience against highly covariate shocks, i.e., shocks that are strongly correlated across households within a community or region (Hazell et al., 2010).

These informal networks open up the opportunity to provide index insurance to groups rather than to individuals. The social capital arising from pre-established networks can help index insurance overcome its major issues, i.e., group-based index insurance may alleviate the above-mentioned problems related to individual index insurance. By offering index insurance to groups, informal risk-sharing pools can average out basis risk in a given moment. The imperfect relationship between the index and losses creates scenarios where some farmers might receive an indemnity while not experiencing any loss and vice versa, and this could partly be remedied by the opportunity to transfer excessive payouts to a common risk-sharing pool, and, thereby, potentially offer a more attractive insurance product to smallholder farmers (Trærup, 2012; Clarke, 2016; Santos et al., 2021).

The high information flow within informal networks can be beneficial for group-based insurance since most members are based in the same geographical area and facing similar production issues. Insurance is new to most farmers in developing countries, especially index insurance, where knowledge about the payout requires an additional understanding of how the index works. Sharing past experiences and learning from each other can potentially make farmers less reluctant to purchase coverage. Trust is not a trivial piece of the decision to purchase insurance and must not be ignored, and pre-established networks provide the simplest form of trust. Offering index insurance to groups opens new design possibilities for insurance products that are both attractive and easy to implement in developing countries (Cai et al., 2009; Patt et al., 2009; Trærup, 2012; Dercon et al., 2014; Cai et al., 2015; Santos et al., 2021).

Within the development community, there has been a growing interest to explore possibilities to tailor insurance to the needs of the poor, and hence, potentially cover smallholder farmers against climate variability (Churchill and Matul, 2006; Hellmuth et al., 2007). If a farmer is expected to be indemnified against crop loss, he is more likely to adopt higher-risk investment alternatives (Eswaran and Kotwal, 1990; Holzmann and Jørgensen,

2001; Carter and Barrett, 2006; Barnett et al., 2008; Mobarak and Rosenzweig, 2012; De Janvry et al., 2014), thus encouraging the adoption of new technologies and facilitating growth, emphasizing the importance of developing an adequate insurance product. With this thesis, I wish to highlight the role that informal networks can have in the agricultural insurance market and discuss the benefits, disadvantages, and opportunities informal networks can contribute to the challenge of providing agricultural insurance.

This paper is organized as follows. Section 2 provides an overview of informal risk-management strategies. This section also lays the foundation for further discussion of group-based index insurance by presenting problems related to conventional indemnity-based insurance and social capital through informal networks. Section 3 highlights how index insurance alleviates the problems that plagued conventional insurance and provides an example of index insurance. Subsequently, problems with index insurance are reviewed, which will follow throughout this thesis. Section 4 explains group-based index insurance and what issues it solves, and, similar to the preceding sections, problems are presented. This section also provides a parallel to community-based health insurance. Section 5 shifts focus to the supply side. Section 6 summarizes and discusses. Lastly, section 7 concludes.

2 Background

2.1 How farmers manage risks

Risk is inherent in agriculture, and poor farmers are faced with a myriad of risks, [2] e.g., markets risks, production risks, resource risks, health risks, asset risks, and other risks. Crops may be destroyed by droughts, harvests may rot in storage, selling prices may plummet, or a family member may become ill. And, in many cases, farmers may be confronted by a natural catastrophe. These risks create an uncertain income each year, which has led to a wide array of risk management strategies. These can be divided into the two following categories; risk-reducing strategies and risk-coping strategies (Hazell, 1992; Coate and Ravallion, 1993; Rosenzweig and Wolpin, 1993; Townsend, 1994, 1995; Barnett et al., 2008; Hazell et al., 2010). An overview of these risk-management strategies is presented in figure 2.1, which is a slightly modified version of a figure presented in Di Marcantonio and Kayitakire (2017).

2.1.1 Risk-reducing strategies

Risk-reducing strategies can be categorized as ex-ante measures. This includes crop diversification, intercropping, farm fragmentation, diversification into non-farm contracts, and participation in informal risk-sharing networks. Even though these strategies may prove efficient in risk reduction they can have high opportunity costs and can potentially lead to under-investment and under-adoption of improved agricultural production technology because it requires farmers to forgo their most profitable investments (Hazell et al., 1978; Hazell, 1992; Binswanger-Mkhize, 2012; Hansen et al., 2019).

2.1.2 Risk-coping strategies

Risk-coping strategies, or ex-post strategies, become relevant for farmers once they have experienced an income loss. Farmers may rely on new credit, liquidating productive assets, sale of livestock, defaulting loans, reducing nutrient intake, withdrawing children

[2] This thesis distinguishes between idiosyncratic risk as household-level shocks unrelated to one's neighbor versus covariate risk as community shock whereby households suffer similar shocks as their neighbor.

from school to work on farms or tend livestock, and over-exploiting natural resources to meet the repayment of loans and essential living costs. Similar to the above-mentioned risk-reducing strategies, risk-coping strategies can also be costly. The reason why these ex-post measures may be especially costly is that informal strategies cannot efficiently deal with the covariability problem that characterizes most agricultural risks. Within one community, market risks and production risks affect nearly all farmers simultaneously, resulting in higher local interest rates since many farmers seek credit at the same time (Hazell, 1992; Hansen et al., 2019).

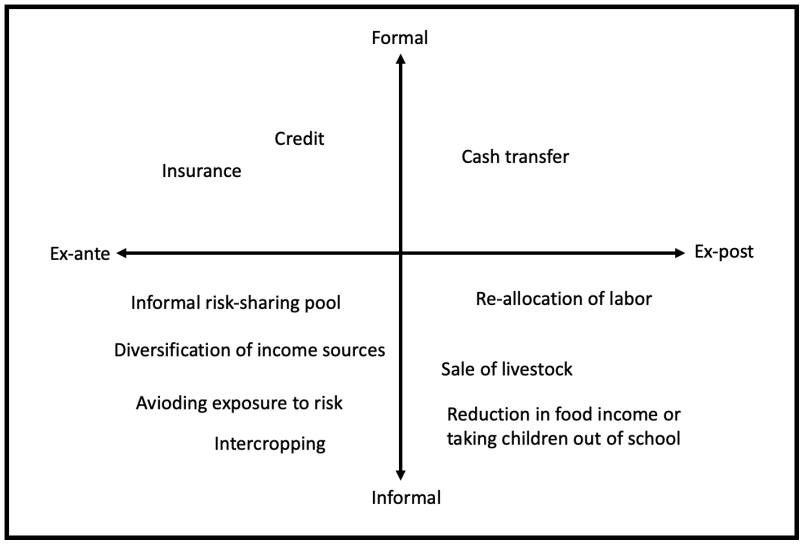

Figure 2.1: Risk management strategies in agriculture

2.1.3 Problems with informal risk-management strategies

Although the above-mentioned informal risk-management strategies enable farmers to sustain a crisis in the short term, they often reduce the farmers' capacity to build a better life in the future by eroding productive assets and human capital, thus reproducing poverty across generations. When the insurance product transfers a portion of the income risk out of the farmers' portfolio, they are able to increase in higher-risk-higher-yielding production technologies. When shocks inevitably hit, farmers that anticipate and receive indemnity payments have more response options. The high opportunity costs may exclude the poorest from using these strategies (Rosenzweig and Wolpin, 1993; Morduch, 1995; Carter, 1997; Skees et al., 2001; Alderman and Haque, 2007; Barrett et al., 2007; Binswanger-Mkhize, 2012; Jensen and Barrett, 2017). Emphasizing the importance of creating a reliable insurance product.

Informal networks lack resilience against highly covariate shocks, i.e., the degree to which the shocks are correlated across households within a community or region. Weather-related risks are covariate by nature, and the frequency is set to increase with global change (Hazell et al., 2010).

2.2 Conventional agricultural insurance

Conventional agricultural insurance has historically been considered too expensive for farmers in the developing world. It indemnifies policyholders based on verifiable production losses arising from multiple perils. The problems with indemnity-based agricultural insurance are two-fold. First, since indemnification is based on verifiable losses it requires high administrative costs to collect evidence and tailor each individual contract, meaning that economies of scale are difficult to achieve. Second, conventional agricultural insurance possesses some structural problems, such as moral hazard, adverse selection, and systematic risk (Valdés et al., 1986; Miranda and Glauber, 1997; Skees et al., 2006; Miranda and Farrin, 2012; Elabed and Carter, 2015). The above-mentioned problems are especially acute for crop insurance. Insurance providers can cope with these structural problems by either increasing the premium or decreasing the value of the insurance for the consumer, which will be discussed in the following subsections.

2.2.1 Moral hazard

Moral hazard, also known as the ”hidden action” problem, arises when farmers engage in risk sharing under conditions such that their privately action affect the probability of the outcome. Farmers' actions cannot be observed and hence contracted upon (Hölmstrom, 1979). E.g., an insured farmer alters his production practices in a manner that increases his chances of collecting an indemnity, i.e., buying a cheaper and less efficient fertilizer because the farmer is covered by the insurance or the farmer untruthfully reports his losses. The problem of moral hazard leads to increased excepted indemnities for the insurer. This can be solved by claiming deductibles in the insurance contract, requiring the farmer to absorb part of the loss giving the farmer an incentive to continue using risk-reducing production. However, this addition to the insurance contract limits the coverage and reduces its value to the farmer (Chambers, 1989; Smith and Goodwin, 1996;

Coble et al., 1997; Miranda and Farrin, 2012).

2.2.2 Adverse selection

Adverse selection, also known as the ”hidden information” problem, arises when farmers with higher relative risk have the opportunity to purchase the same insurance at the same cost as farmers with relatively lower risk (Skees and Reed, 1986). The insured are better informed about their own distribution of production losses, and thus, be better able to assess the actuarial fairness of their premiums compared to the insurer. A farmer that recognizes that his indemnity is higher than the cost of the premium is more likely to purchase insurance compared to a farmer with an actuarially high premium. The asymmetric information may lead to a situation where only the farmers that expects the indemnity to be higher than the premium (lemons) purchase the insurance, while those farmers that expect the opposite (peaches) does not purchase insurance, characterized as the ”market for lemons” (Akerlof, 1978). Because of adverse selection, the insurer's expected indemnity outlays exceed total premium income in the long run. Actions from the insurer to avoid this problem is to raise the cost of the premium, only resulting in smaller and more adversely selected pools of participants. The problem of adverse selection can be especially acute in developing countries, given that most farmers do not maintain adequate production records that could be used to accurately rate a conventional agricultural insurance contract (Quiggin et al., 1994; Miranda and Farrin, 2012).

2.2.3 Systematic risk

An efficient and functioning insurance market is conditioned on the fact that each individual risk is independent of the other. However, this is not the case for agricultural insurance (Miranda and Glauber, 1997), given the aforementioned covariability problem. With catastrophic weather events, there is a presence of systematic risk in agricultural production that cannot be fully diversified. Any private insurer puts themselves in jeopardy of bankruptcy by offering agriculture insurance with the presence of systematic risk. As a result, the cost of reinsurance must be passed on to the consumer via increased premium rates, decreasing the value and demand for the insurance (Miranda and Farrin, 2012). Reinsurance will be a topic of a later discussion.

2.3 Informal networks

Historically, there has been a lack of access to insurance from formal institutions in developing countries, despite farmers throughout much of the developing world live in poor, high-risk environments (Townsend, 1994) as argued through the failure of conventional insurance in the preceding section. This has led to a widespread of informal networks throughout rural areas as a means to reduce risks for smallholder farmers, informal networks are a valuable source for households to access risk-sharing institutions. These networks may strengthen their resilience to extraordinary or unexpected costs through risk-sharing among the members, thus, provide protection against idiosyncratic risks. This type of risk refers to the particular situation where one household's experience is typically unrelated to others in the same community, e.g., death of a family member, sickness, or unemployment (Trærup, 2012; Pradhan and Mukherjee, 2018). But, when a serious covariate hardship occurs, affecting whole villages, these informal networks provide insufficient protection (Hazell et al., 2010), these types of risks are set to increase with climate change, emphasizing the need for a prominent formal sector in agricultural insurance.

The most prominent approaches to the reduction of risk exposure from risk-sharing and self-protection are via informal family structures and communities. Risk-sharing, as such, usually focuses on self-enforcing arrangements, where incentive constraints and binding participation typically imply limited mutual insurance possibilities (Fafchamps, 1992; Coate and Ravallion, 1993; Di Falco and Bulte, 2013).

2.3.1 Group-based funeral insurance

The creation of group-based funeral insurance further emphasizes the historical lack of supply of formal insurance in rural areas and the need for insurance. Subsequently, how this has led to a risk-reducing strategy in the form of informal networks.

Funeral expenditure in the developing world is usually large and the financial stress related to funerals depletes household resources. Funerals are very expensive in terms of mortuary costs, costs of food, and other items. In some cultures, a funeral can last several days and households may expect condolence visits for several months, adding substantially to the

costs, making funerals highly costly occasions. A funeral is a highly insurable event, given that there is a relativity high mortality rate, death a common event in families with low covariance and moral hazard is unlikely to be relevant to funeral insurance (Dercon et al., 2006; Banerjee and Duflo, 2007).

Dercon et al. (2006) study rural areas in Tanzania and Ethiopia, where the creation of these funeral groups really has taken off. These associations are known as iddir [3] and they ensure reimbursements both in cash, as well as in-kind, at the time of a funeral. The number of funeral groups within communities is remarkable, and findings suggest that most people have a membership of at least one group. In Sirbana Godeti in Ethiopia, from a total of about 400 households, there are about 30 groups. These associations have helped poor households in Ethiopia and Tanzania for several decades. Members of the groups have faith and trust in one another that is built over time. Funerals and their preparation bring people together, and the meetings related to the groups are an important means of social interaction, well beyond a simple insurance function. Iddirs will receive considerable attention throughout this thesis, as they are a great fit for a group-based index insurance scheme.

2.3.2 Social capital

The norms of reciprocity, information, and trust that arise from informal networks can be characterized as social capital (Woolcock, 1998; Trærup, 2012). In a similar fashion, Putnam (1993) argues that social capital facilitates cooperation and coordination, improving the efficiency of society. The value of social capital can be concretized by considering a hypothetical village where a family's house has been destroyed. If this village has no social capital, the family has to rebuild their house from the ground up, however, with social capital, this unlucky family will receive help from fellow villagers (Krishna, 2000; Uphoff and Wijayaratna, 2000). Much like the "safety net" that Woolcock and Narayan (2006) refers to when people fall on hard times.

The group-based funeral insurance is a great example of the ability to form local groups to cooperate to avoid the negative consequences that would occur from purely individualistic behavior. Following the death of a family member, a household may not afford the funeral

[3] "Iddir" is the generic name. In some areas, other local names are used, such as "kire" in parts of Wollo. They are all referred to as iddir in this thesis.

costs, similar to the unlucky family in the preceding hypothetical example. But, through collective action, money can be collected from a common pool.

Social capital is of particular value in low-income countries where formal insurance is generally unavailable and institutions for contract enforcement are weak. According to economic theory, repeat interactions among individuals can help build and maintain social capital. Encouraging interaction may be an effective tool for development policy (Feigenberg et al., 2013), especially within the agricultural sector (Brown and Ashman, 1996; Narayan and Pritchett, 1999; Trærup, 2012).

There are several dimensions of social capital at different levels within the social capital theory. These dimensions can be divided into two main kinds of relations, called bonding and bridging. Bonding can be characterized as social relations between people within an informal network while bridging is the relations between different informal networks (Trærup, 2012). How these relations can be of an advantage for index insurance will be discussed later.

3 Index insurance

3.1 The promise of index insurance

As emphasized, there are many different risks that can affect agricultural crop yield. Indemnifying smallholder farmers against crop loss is infeasible due to information problems (Bryan, 2019). This is why partial insurance, e.g., rainfall index insurance, is a solution. Index-based insurance indemnifies the insured based on an index rather than verifiable losses (Barnett and Mahul, 2007; World Bank, 2011; Miranda and Farrin, 2012).

Index insurance is designed to overcome many of the issues related to conventional agricultural insurance. First, index insurance is essentially free of moral hazard because the insured part cannot influence the index through his own actions. Second, since the contracted premium of index insurance is based on publicly available information, not privately held information, there is little or no reason to believe that policyholders have better information than the insurers, thus, little potential for adverse selection. Third, since the insurance is based on a reliable and independently verifiable index, it allows transferring a part of the risk to the international reinsurance market in an efficient manner, even for covariate risks. Fourth, there is no on-site inspections or individual loss assessment to perform so economies of scale are achievable. Index insurance can be offered at a lower price, which potentially can benefit poor farmers substantially (Barnett et al., 2005; Alderman and Haque, 2007; Barnett and Mahul, 2007; Bryla and Syroka, 2007; Skees, 2008; Skees et al., 2008; Hazell et al., 2010; Binswanger-Mkhize, 2012; Carter et al., 2014; Clement et al., 2018; Fisher et al., 2019).

3.2 Weather-based index insurance

Rainfall is the most widely used index in index insurance contract designs due to a number of reasons. First, the amount of rainfall is highly measurable. Second, rainfall data is likely to be available in developing countries. Third, rainfall is correlated with agricultural production (Bardsley et al., 1984; Miranda and Farrin, 2012; De Janvry et al., 2014; Dercon et al., 2014). Cole et al. (2013) study different risks faced by smallholders, the most cited determinant of income variability was rainfall. Insurance contracts only conditioned on

weather indices can be fairly cheap whilst still offering much-needed protection against extreme weather events (Hess et al., 2005; Clarke, 2016).

Karlan et al. (2014) study agricultural decisions and find that farmers invest more in their farms and take riskier production choices when offered rainfall index insurance. The fact that rainfall insurance is not more common in developing countries is a puzzle. Since farmers are often exposed to weather risk and such risk is not generally subject to asymmetric information. Weather risks are different from other risks, e.g., illness or death in the family because it is not idiosyncratic, and therefore cannot be easily insured away within villages (Kremer et al., 2019). This puzzle will receive further attention later in the thesis.

3.2.1 Payment structure

The contracts for weather index insurance specifies a threshold and a limit that establishes the range of values over which indemnity payments will be made (Barnett and Mahul, 2007). Payouts can be structured in a variety of ways. The most basic is a simple zero/one contract where the payout is 100% once the threshold is crossed. While a proportional payment schedule increases the payout proportionally with the deviation from the indexed threshold. A layered payment schedule is a middle ground between the two (Hazell et al., 2010). Miranda and Farrin (2012) uses a hypothetical example of a layered indemnity rainfall micro-insurance contract that is designed to protect farmers against droughts to illustrate the notion of an index insurance contract. A farmer elects a liability of $50, prior to a specific closing date which grants the farmer with maximum protection. The farmer pays a premium of $5, given the premium rate of 10%. In return, the insurer promises to pay the insured an indemnity that depends on the total rainfall measured at the specified nearby weather station during the following months. In this hypothetical example, the contract does not pay an indemnity if total rainfall were to exceed 550mm but would pay $10 it total rainfall were between 500 and 550mm, $25 if total rainfall were between 450 and 500mm, and the insured farmer would receive the maximum liability of $50 if total rainfall were less than 450mm, hence the layered contract.

3.2.2 Weather index insurance in Kenya

Since the late 1990s, several index insurance feasibility studies and pilot projects have been undertaken across the developing world (Miranda and Farrin, 2012). One of them being Kilimo Salama,[4] which launched in Kenya in 2009 by the Syngenta Foundation for Sustainable Agriculture and is considered to be one of the most successful index insurance projects. [5] Most crop production in Kenya takes place under rain-fed conditions, with weather fluctuations having a major impact on agricultural productivity. Initially, Kilimo Salama was offered as a small initiative with only 200 farmers. By 2013, this small initiative had grown to cover close to 200,000 farmers in Kenya, Rwanda, and Tanzania, with a total sum of US$12.3 million. Despite this impressive and rapid growth, only a small fraction of the total farmers have adopted weather index insurance (Greatrex et al., 2015; Sibiko et al., 2018).

Kilimo Salama offers rainfall-based index insurance, covering Kenyan farmers against drought and excess rain, this scheme relies on data from automated weather stations to monitor local rainfall. Farmers are allowed to choose the station that best represents their farm conditions. The contracts were originally designed to cover maize and wheat, but products for other crops have also been developed. Kilimo Salama contracts divide the crop season into three phases, early growth, flowering, and grain filling, which vary in duration and rainfall thresholds. Contracts are location-specific, and threshold levels reflect the minimum agronomic requirements for normal plant growth during each particular phase. If total rainfall in a given phase either falls below or exceeds the threshold, a payout is triggered for all farmers holding a contract with reference to the particular weather station. Payouts are calculated per millimeter of rainfall, below or above the threshold, and it increases proportionally up to the maximum payout. However, farmers are rarely aware of the exact details of the payout functions, despite all data being publicly available information. Payouts are transferred to farmers through a safe mobile money transfer service called M-PESA at the end of the contract period (Sibiko et al., 2018).

As mentioned above, this Kenyan insurance scheme is considered one of the most successful index insurance projects. Households' relationship to M-PESA, which Kilimo Salami

[4]The phrase *Kilimo Salama* means safe agriculture in Swahili.
[5]After 2014 it was rebranded as Agriculture and Climate Risk Enterprise (ACRE).

cooperates with, might be one of the explanations. M-PESA allows for safe transfers of money between Kenyans and this money transfer service, in which many Kenyans have established their trust, have revolutionized the Kenyan economy since its launch (Mas and Morawczynski, 2009; Mas and Radcliffe, 2010). The combination of index insurance and M-PESA can create trust in two ways. First, since M-PESA is a renowned service among the Kenyan population, a collaboration may transfer generalized trust from M-PESA to the insurance product. Second, the efficiency of M-PESA allows for safe and rapid disbursements, which poor farmers value heavily (Morawczynski and Miscione, 2008; Trærup, 2012).

3.3 Problems with index insurance

Despite its potential, high appraisal, and practical feasibility of index insurance, demand has been lower than expected. The various candidate causes of low demand are a lack of trust, limited understanding of the insurance product, and basis risk (Binswanger-Mkhize, 2012; Trærup, 2012; Cole et al., 2013; Clarke, 2016; Platteau et al., 2017; Sibiko et al., 2018). These barriers or limitations of index insurance will follow through throughout this thesis when arguing how a collective approach to index insurance might be a solution for an increased uptake for smallholders.

3.3.1 Basis risk

Index insurance suffers from basis risk, which is the failure to provide an indemnity that perfectly matches the loss of the insured. Since indemnification is based on a pre-defined index threshold, and not verifiable losses, there is no guarantee for the farmer to receive an insurance payout when suffering a loss (Miranda, 1991; Doherty and Richter, 2002; Miranda and Farrin, 2012; Clement et al., 2018).

Basis risk can stem from two potential sources. First, farm losses may be caused by other determinants than what the index is based on. And, as earlier mentioned, there are many different risks that can alter agricultural production. Unless the contracted index is based on a weather variable that is the dominant cause of farm loss in a given region, basis risk will be unacceptably high. Second, the measures of the weather variable at the weather station may be quite different than the at the farm, i.e., the correlation between the index

and losses. Basis risk can be reduced if the index insurance is offered in areas where a particular weather variable is the dominant cause of loss (Barnett and Mahul, 2007; Clement et al., 2018).

The correlation between rainfall and agricultural production is crucial. The potential of index insurance ultimately depends on this relationship. The greater the correlation, the lesser degree of basis risk, and thus, the greater the potential benefit (Miranda and Farrin, 2012). Demand for index insurance decreases with basis risk (Giné et al., 2008). However, basis risk may increase with global change due to difficulties in actuarially calculate expected losses. This will receive further attention in the section of supply-side challenges.

3.3.2 Limited understanding

The concept of insurance is new to many farmers in developing countries, especially index insurance, where knowledge about the payout requires an additional understanding of how the index works (Dercon et al., 2009; Patt et al., 2009). Agricultural insurance adoption in the developing world has experienced a low outspread and adoption rate (Giné et al., 2008; Mobarak and Rosenzweig, 2012), further emphasizing that the concept of insurance is indeed new to most smallholder farmers. Additionally, insurance products are complex, and low levels of financial literacy among target populations, implying that not all potential beneficiaries understand its logic (Belissa et al., 2019). A lack of understanding has been found to correlated with a low willingness to purchase insurance (Patt et al., 2010; Trærup, 2012).

The market for index insurance suffers from a sincere information gap. Both farmers and insurers lack access to information that can establish the value of the index insurance products. Index insurance can be categorized as a credence good, i.e., a good whose quality is not observable before purchase and at best partially observable after purchase (Darby and Karni, 1973). Thus, it is a risk of arriving at a ”market for lemons”, where insurers do not invest in costly but low-risk indices, as there is no market incentive for them to do so because farmers are unable to sort low-quality products from high-quality products. This can create adverse incentives, and it becomes difficult to establish ex-ante whether costly investments in index insurance really improve product design (Jensen and

Barrett, 2017), which may lead to serious market failures if index insurance is left purely to private actors (Clarke and Wren-Lewis, 2013).

3.3.3 A lack of trust

Trust is not a trivial piece of the decision to purchase insurance and must not be ignored, making it a crucial design element of an insurance product (Patt et al., 2009). As emphasized in the preceding subsection, farmers are not used to formal insurance being available. Hence, they have historically not been dependent on formal institutions, but on informal risk-management strategies. As a consequence, farmers do not fully trust the product or the institutions involved, which in turn have a negative effect on demand (Cole et al., 2013). A lack of trust is a barrier to insurance adoption for smallholder farmers (Trærup, 2012).

Trust can be divided into generalized and particularized trust. Where the latter is households' faith in other households, but only those in their own community. And, generalized trust is characterized as a households' trust in the institutions involved with the insurance (Uslaner, 2002; Cassar et al., 2007; Trærup, 2012).

4 Group-based index insurance

4.1 A collective approach to index insurance

Due to the inefficiency and failure of index insurance uptake, researchers have proposed to offer index insurance to groups rather than to individuals. In this way, the social characteristics of the informal networks and particularized trust are maintained. This approach ensures that members may continuously benefit from informal risk-sharing alongside formal protection against covariate risks. Potentially increasing farmers' resilience to climate change impacts (Trærup, 2012; De Janvry et al., 2014; Dercon et al., 2014; Santos et al., 2021). The premise of insuring groups is that superior information held by group members allows payouts to be adjusted to reflect the actual losses experienced (McIntosh et al., 2019). Sibiko et al. (2018) argues that offering insurance contracts to small groups rather than individual farmers may increase uptake. The subsequent subsections suggest how an index insurance product may be enhanced by adopting the strengths of social capital in the form of informal networks.

4.1.1 Dynamic of informal risk-sharing in the collective approach

As opposed to indemnity-based insurance, it is worth pointing out that an index insurance payout will happen irrespective of any actual loss. There is no guarantee of receiving an insurance payout when experiencing a loss with the presence of basis risk. By making use of within-group informal transfers it is possible to circumvent basis risk. The joint probability structure of the index insurance product and the farmer's loss creates four possible scenarios:

1. A farmer experience a loss and the index insurance triggers a payout.
2. A farmer experience a loss but the index insurance does not trigger a payout.
3. A farmer does not experience a loss but the index insurance triggers a payout.
4. A farmer does not experience a loss and the index insurance does not trigger a payout.

The proposition by Santos et al. (2021) relies on farmers truthfully reporting their amount

of loss experienced and the indemnity received. These within-group informal transfers, are the pillars of the collective approach, and they happen indirectly between those farmers who have received an excessive payment and those who have an uncovered loss through a common risk-sharing pool. Farmers with an excessive payment (scenario 3) transfer a fraction of this to the common risk-sharing pool. This allows farmers in scenario 2 to receive a payment from the common pool when the index insurance fails to provide it, this is distributed by group leaders. These within-group transfers allows to average out basis risk in a given moment, not just across time. The alleviation of basis risk can make this design of an index insurance product more attractive to risk-averse smallholder farmers. For risk-averse farmers, the utility gain of receiving a proportion of the common risk-sharing pool (scenario 2) is larger than the utility loss associated with contributing the same amount of an excessive payout (Clarke, 2016; Pacheco et al., 2016).

However, the potential to alleviate basis risk through within-group transfers introduces a coordination dilemma of insurance adoption. Socially optimal outcomes are obtained when everyone adopts insurance. A minimum fraction of contributors is necessary before the effects of basis risk can be averaged out and individuals start taking up insurance. If farmers are free to defect on their informal contributions, they will most likely do so. That is, each individual farmer maximizes their utility, in a given moment, by defecting on pool contributions while still having the pool benefits, given that the other members contribute. There needs to be a probability that defecting farmers are caught, this is achieved by peer monitoring. Subsequently, farmers that defect and are caught are excluded from future pool benefits as a punishment, which provides farmers with incentives to cooperate. Peer monitoring and exclusion from future pool benefits are necessary for the stabilization of informal transfers (De Janvry et al., 2014; Santos et al., 2021). This issue will receive further attention.

4.1.2 Bonding and bridging

The basic idea of the collective approach presented in Trærup (2012) is that the index insurance provider targets an existing informal network as one insurance taker. The informal network pays the insurance provider one collective premium and also receives one payout as one insurance taker. Based on the information flow within the network, the informal network distributes the payout among its members.

The collective approach to index insurance can be characterized as vertical bridging since bridging is created between different levels in society, i.e., between informal networks and formal institutions. Figure 4.1, which is a reconstruction from a figure presented in Trærup (2012), illustrates the relationship between the different dimensions of social capital and the resilience to shocks. The opportunities of bridging and bonding are two-fold with regard to climate change resilience. First, members strengthen their resilience to idiosyncratic shocks by bonding within an informal network. Second, bridging among informal networks and an index insurance provider has the potential to strengthen members' resilience to weather-related shocks, which by nature will be covariate. The collective approach to index insurance strengthens the vertical bridging between formal index insurance and informal networks (Gittell and Vidal, 1998; Woolcock and Narayan, 2006).

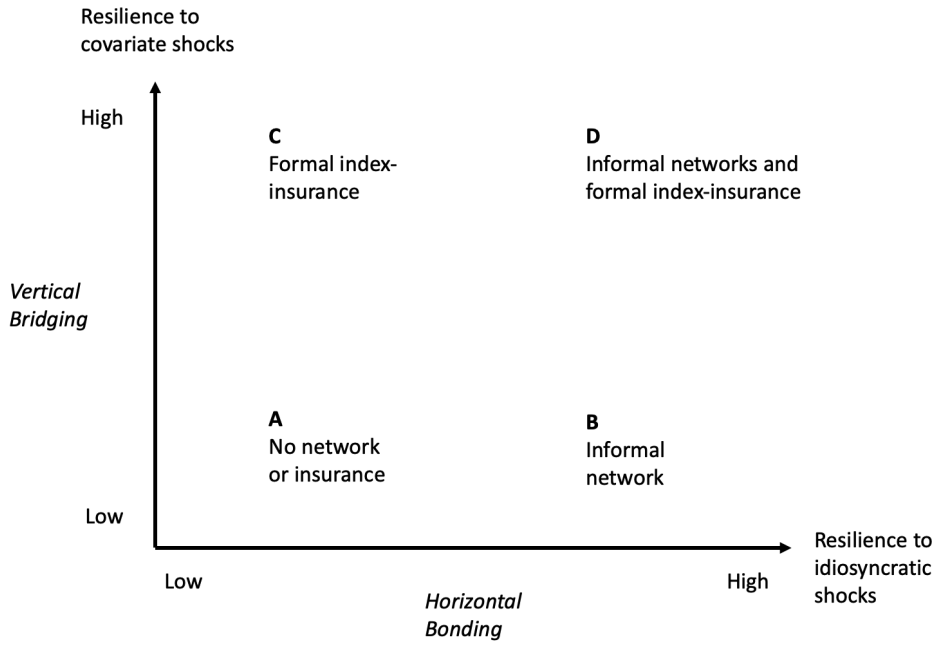

Figure 4.1: Dimensions of social capital and resilience to shocks at the household level

4.1.3 Understanding

The low outspread and adoption rate of agricultural insurance across developing countries emphasizes that insurance products are indeed new to most smallholder farmers. Insurance products are complex, and low levels of financial literacy among target populations, implying that not all potential beneficiaries understand its logic (Giné et al., 2008; Mobarak and Rosenzweig, 2012; Cole et al., 2013; De Janvry et al., 2014; Sibiko et al., 2018).

The aforementioned group-based funeral associations, i.e., the iddirs, appear suitable for formal insurance products as they tend to understand their function since they were created on precisely that basis. Dercon et al. (2014) carried out training sessions and found that in situations where iddir leaders were trained in the benefits of group-based insurance, there were substantially higher uptake rates compared to leaders who received training on individual benefits of insurance, in accordance with the findings of Belissa et al. (2019). The idea is that through mobilizing and training customary leaders, the groups can effectively share knowledge and leverage trust. The leaders of iddirs were informed how the index insurance worked, the trustworthiness of the insurance company, and they were encouraged to share their knowledge with members of their iddir and endorse the insurance product. The mechanism described may be referred to as the spillover effect, i.e., diffusion of knowledge of insurance benefits among farmers, informal networks effectively transfer information about the benefits and functions of the insurance product (Gine et al., 2013; Cai et al., 2015). Sibiko et al. (2018) conclude that better training farmers on weather index insurance are needed and that groups can provide more efficient training. The efficiency of the spillover effect, that is, its potential to share benefits and knowledge of group-based insurance, is dependent on the level of trust within networks, i.e., particularized trust. The leaders of iddirs are trusted individuals for members within a network (Belissa et al., 2019), providing a smooth transition to the next subsection.

4.1.4 Trust

Trust is a crucial design element of an insurance program. This has to do with the farmers' trust in the insurance product and the organizations involved (Patt et al., 2009), i.e., generalized trust. It is assumed that there is a high level of particularized trust in communities but a lack of generalized trust (Cassar et al., 2007; Trærup, 2012).

Lyon (2000) uses case studies of agricultural production, marketing, and financing systems to document how trust is created among farmers. The mechanisms include formal and informal networks of working relations, customer friendship, and intermediaries, whereas the simplest form of trust is based on existing networks. According to the study, trust is a necessity for the development of a vibrant private sector.

The social capital arising from informal networks may overcome trust-related barriers

between insurance buyers and insurance providers. Assuming that information flow is high within a network, it will create trust (Trærup, 2012).

Trust can be built through a link to a common person. Trusted members of a community can work as intermediaries and create trust in an insurance product to other members, as iddir leaders were in the previous subsection. Intermediaries appear as links between networks and can play an important role for an insurance provider to create a relationship between farmers and the provider (Lyon, 2000). Another use of intermediaries, stressed by Skees et al. (2001), Giné et al. (2008), and Elabed et al. (2013) is the importance of including feedback from community members in the design face. In Mali, for instance, local leaders helped design a multi-scaled index insurance pilot at the village level. Cooperation at this level may create solutions to reduce the problem related to basis risk, the cooperation may build a stronger bond between farmers and the institution that provides insurance (Elabed et al., 2013; Clement et al., 2018).

4.2 Problems with group-based index insurance

Binswanger-Mkhize (2012) sets up an equation explaining the conditions for index insurance uptake. Equation 4.1 incorporates the two sources of change in the farmer's utility. The demand side conditions are twofold. As a prerequisite, farmers need to understand insurance, i.e., the insurance product that is being offered and the corresponding payoffs that they can expect when different events materialize (Barnett and Mahul, 2007). In addition, the farmers' expected utility with formal insurance needs to be higher than without. The utility gained from insurance, in general, is income stabilization, where agricultural insurance is no exception.

Since the networks are informal by nature, they work under their own rules and norms. Due to differences in membership and leadership structures, not all informal networks are equally suitable for affiliation to an index insurance scheme, and, the differences in the history, longevity, and nature of activities within the networks, further empathize the differences across networks (Trærup, 2012).

Additionally, in an economy with heterogeneous agents, (i. e., heterogeneity with respect to correlation of income streams, information flows, trust, norms, etc.), a household forming its network will not consider all other households to be equally suited as insurance

partners. Close neighbors or households who engage in the same livelihood activities are likely to share information and join the same network. Poorer households have less dense networks than the rich, making them more vulnerable in the face of idiosyncratic risk (Rosenzweig and Stark, 1989; De Weerdt, 2002; De Weerdt and Dercon, 2006).

$$\text{Expected utility without formal insurance} \leq \text{expected utility with the formal insurance} \tag{4.1}$$

The following subsections argue for what determines farmers' expected value for group-based index insurance.

4.2.1 Contract enforcement

The informality of the typical risk-sharing contracts means that issues of contract enforcement and dynamic consistency will be important. There is an issue when the contract is not formalized, pooling will only occur if those who have the capacity to pay do not seek to renegotiate the contract after shocks have been realized (McIntosh et al., 2019).

However, there is a lack of empirical findings on the extent that social networks can substitute for formal contract enforcement. Even less about how the introduction of contract enforcement affects transactions traditionally mediated informally through the social network. This is mainly due to the variation in the contracting environment across networks. Socially close individuals maintain high levels of cooperation even when contract enforcement is removed, as opposed to more distant individuals. Individuals with partners with high centrality behave more cooperatively when enforcement is removed. Lack of enforcement is more damaging when individuals are socially distant and when their partners are not socially central (Chandrasekhar et al., 2018).

4.2.2 Group negotiations

The group negotiation process is not frictionless. A successful risk-sharing group is dependent on members actually sharing risk, i.e., transferring the excessive payment to the common pool or truthfully reporting actual losses. Thus, the vulnerability of risk pooling

arrangements to ex-post renegotiation is relevant. Social costs and distrust can make group negotiations an unattractive way to provide smoothing. McIntosh et al. (2019) find that a high-trust individual do have a significantly higher demand for group insurance, but this effect appears to be small. Distrust can account for about one-fifth of the secular dislike of group insurance.

4.2.3 Risk pooling

The group becomes more attractive as its degree of loss adjustment increases. Even groups that have the capacity to pool risk may fail to do so. And, if members' risk exposure is too dissimilar groups may struggle to maintain pooling. Different risk exposure can stem from farm size, crop, wealth, etc. If farmers' risk exposure within informal networks is heterogeneous it can be expected that some members systematically making larger claims on the group than others. The issue of heterogeneity in expected risk exposure introduces a redistributive element into group risk-pooling contracts. This is indeed a concern (McIntosh et al., 2019).

How much loss adjustment is believed to be conducted and the influence that the heterogeneity within groups has on pooling ability is noticeable threats to a successful risk-sharing group McIntosh et al. (2019). Additionally, the already established networks, which group-based insurance is based on, may not be designed to pool risk (Fafchamps and Gubert, 2007; Pan, 2009).

4.2.4 Cooperation

According to Santos et al. (2021), there are a minimum fraction of individuals required for a population to evolve towards adopting group insurance. Individual sacrifices are necessary to reach the collective target. The dilemma and risk of failure occur when individuals are tempted to contribute less and save money to induce others to contribute more (Milinski et al., 2008). That is, incentives for individuals are misaligned with group interests, a social dilemma occurs (Hilbe et al., 2018b).

It is possible to look at the collective approach through the lens of a game of cooperation. If there is only one realization of the insured event, e.g., drought, a self-interested farmer would have no incentive to share his excessive payout or truthfully report his losses, and

so, would renege on any prior non-binding agreement (Coate and Ravallion, 1993). A game of such characteristics is the Prisoner's Dilemma, a game with two players that can either cooperate or defect. If both cooperate, they each get the reward R, which exceeds the punishment payoff, P, when both defect. But, if one player defects while the other cooperates, the defector gets the highest payoff T, whereas the cooperator ends up with the lowest payoff S. The game is a prisoner's dilemma if $T > R > P > S$, which can be presented in a two-by-two payoff matrix, as Figure 4.1. An individual farmer would maximize its utility by defecting on the contribution to the common risk-sharing pool, given that the other player contributes. No matter what player 1 does, player 2 maximizes his payoff by defecting. Thus, not contributing to the common risk-sharing pool is the only Nash equilibrium (Hilbe et al., 2018a).

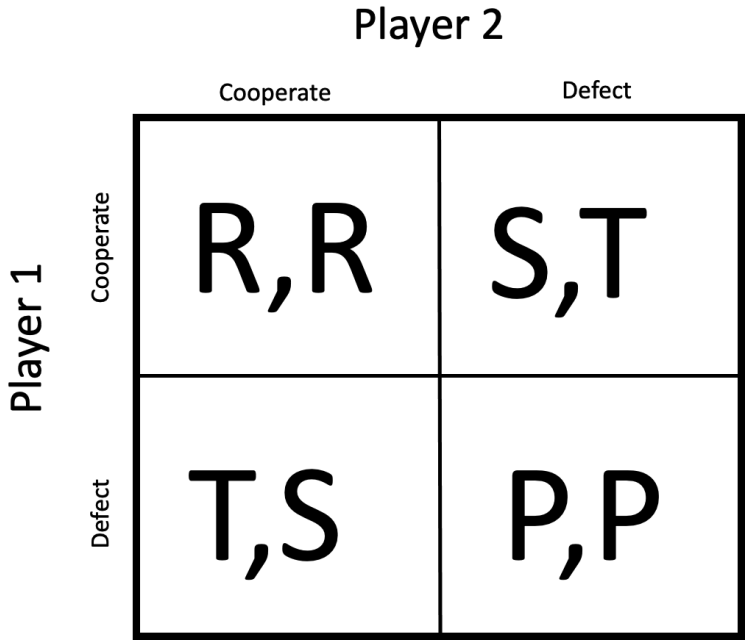

Figure 4.2: Prisoner's dilemma: payoff matrix

However, repeated games allow for reciprocity, creating incentives for farmers to cooperate. Reciprocity is a powerful mechanism of cooperation on the basis of repeated interactions (Hauser et al., 2019). A game that represents the real-world scenario of group index insurance adoption is the Public Goods Game, where possible heterogeneous farmers need to merge their individual efforts to avoid a common risk. Heterogeneity can result from different levels of risk exposure (to natural hazards), such as wealth and distance to the nearest river. Merhej et al. (2021) study how wealth inequalities impact cooperation and overall group achievements of a population involved in a threshold public goods game

with a collective risk. They conclude that wealth inequalities lower overall achievement rates of a population.

4.2.5 Group characteristics

Informal groups across developing countries vary in size. According to Sibiko et al. (2018), small groups are better-suited platforms for learning about complex innovations due to the fact that larger groups often lack the necessary cohesion. If groups become too large they become more difficult to coordinate which, in turn, creates incentives to free-ride. However, larger groups seem to encourage more intensive participation in collective actions (Fischer and Qaim, 2014). Different proximity to nearest weather station varies between farms, the consequences of this will be a topic when discussing product design.

As emphasized by Santos et al. (2021), cooperation is dependent on peer monitoring. Local networks may be in a prime position to establish peer monitoring. Leaders carry a lot of financial responsibilities, so training is, therefore, in most cases, required on the role and responsibilities of these persons (Trærup, 2012). Yet another challenge is that farmers do not fully understand when they will receive a payment, i.e., when the index is triggered, despite the fact that the index threshold is clearly stated in the contract (Sibiko et al., 2018). Training farmers and creating a better understanding of index insurance matters for adoption, which is consistent with the documented role of financial literacy training in increasing awareness of formal financial products (Carpena et al., 2011; Gaurav et al., 2011; Gine et al., 2013; Dercon et al., 2014). Farmers who are informed about the real disaster probability are almost 30 percentage points more likely to buy the insurance (Cai and Song, 2017). Training is essential both for the adoption of index insurance and for the group leaders to efficiently working the group scheme.

The effectiveness of the training between group leaders and members may be dependent on the trust between the two parties. There can be several disadvantages in targeting informal networks as insurance takers. It can lead to or increase conflicts and divisions within the community or network if the informal network is exploited to serve the interests of the better households. This can be the case where some better of households in an informal network decide to exclude a number of households for some reason, e. g., if some households are carrying a greater risk than the majority of the networks' members. This

will in turn making some households worse off compared to a situation solely relying on informal risk-sharing (Tabor et al., 2005; Kamuzora and Gilson, 2007; Trærup, 2012). The unequal risk between farmers may lead to exclusion of the most vulnerable and poor.

Risk reduction from weather-based insurance varies between farmers depending on what crop is insured and the location of weather stations (Heimfarth and Musshoff, 2011; Clement et al., 2018). Even though farmers have similar risk profiles, they may live at different distances to the nearest weather station, thus, some farms may structurally have less basis risk than others (Sibiko et al., 2018). And, heterogeneity in farmers' risk exposure affects demand for insurance (Ceballos and Robles, 2020).

Relatives are more likely to join the same risk-sharing pool, as both friends and relatives group assortatively on risk attitudes, that is, informal networks are expected to contain farmers with similar traits (Attanasio et al., 2012).

It is more costly finding mutually beneficial and acceptable agreements when members are heterogeneous of any sort, also, sociocultural heterogeneity may reduce the efficacy of social sanctioning and trust among group members. On the other hand, networks benefit from heterogeneity through diversifying members' risk exposure, pooling risk is more efficient when members' incomes are not correlated (Easterly and Levine, 1997; Dercon et al., 2008).

4.2.6 Farmer characteristics

Farmers are constrained on both the cash availability side, as well as the credit side (Binswanger-Mkhize, 2012; Platteau et al., 2017). Farmers' liquidity constraints are found to have an effect on the demand for weather index insurance products, it limits the demand (Cole et al., 2013; Casaburi and Willis, 2018; Tang et al., 2021). Smallholder farmers may be unable to mobilize the resources needed to pay for the insurance premium upfront. Standard insurance schemes are usually based on farmers paying the premium when their disposable income is at its lowest (Duflo et al., 2011; Belissa et al., 2019). Belissa et al. (2019) tests if farmers are credit constrained by allowing smallholders to postpone the payment of the insurance premium until after harvest. Index insurance uptake went from 5% to 24% when the insurance was offered with delayed payment, similar to the findings of Casaburi and Willis (2018), indicating that farmers are, in fact, credit constrained.

The uncertainty of the payout with basis risk is among the contributors to farmers preferring to self-insure (Platteau et al., 2017). The demand for insurance is very price-sensitive (Cole et al., 2013; Hill et al., 2019). The reduced premium of both individual and group index insurance compared to indemnity-based insurance is one of the reasons for the attention drawn towards this insurance design.

Demand for index insurance seems to be particularly low from the most risk averse due to basis risk, there is a negative relationship between demand and risk aversion for poor farmers in developing countries. Optimal demand is zero for infinitely risk-averse individuals following the risk of contractual nonperformance (Hill et al., 2013; Clarke, 2016). Basis risk is even more important to the decision of index insurance uptake than firstly predicted due to strong ambiguity aversion and a corresponding revealed preference for certainty in indemnity payments. Existing research claims ambiguity aversion as a possible explanation for the tepid demand for index insurance (Giné et al., 2008; Cole et al., 2013; De Janvry et al., 2014; Cai et al., 2015). Ambiguity aversion can generally be thought of as an increased degree of risk aversion when a farmer is facing a specific source of uncertainty, i.e., a preference of known risks over unknown risks (Ellsberg, 1961; Bryan, 2019).

Due to strong ambiguity aversion and uncertainty about whether the insurance provides an indemnity or not, an index insurance contract may appear as a compound lottery to farmers. With uncertainty about individual production outcome and about the validity of the index as a true reflection of yield losses. This compound lottery will lessen index insurance demand (Elabed and Carter, 2015).

Time inconsistencies may also be a contributor to the lack of demand, and, as with the purchase of fertilizer, index insurance purchase is an investment. Farmers may procrastinate, delaying the purchase until later periods (Duflo et al., 2011).

4.3 Community-based health insurance

Similar to agricultural risks, health problems are often cited as a major risk faced by rural households, which has led to some experimenting with the design of health insurance. The strengths of community financing are based on three common factors as group-based insurance. First, social capital, second, the preexistence of community institutions that

cultivate reciprocity, and third, inter-connectivity between local communities and external institutions (Dror and Preker, 2002). Like agricultural index insurance, community-based health insurance (CBHI) is a form of micro insurance targeted to people in low-income populations. CBHI has been developed to address the lack of credit in times of need, which is found to be catastrophic in the sense of aggravating poverty. CBHI partly relieves insured members of their duties to search for credit or sales of livestock to fund care, thus, recovering more effectively from illness. Additionally, CBHI schemes are characterized by community members pooling funds to offset the cost of healthcare, similar to the risk-sharing pool in the collective approach to index insurance. Members that share common characteristics, e.g., occupation or geographical location, pool health risks (Ekman, 2004; Jütting, 2004; World Health Organization, 2020).

CBHI received much anticipation, however, evidence suggests moderate financial protection for those involved. The poorest usually left excluded, it is oftentimes the poorest and most vulnerable who are in most need of such insurance, due to their lack of appropriate risk management instruments (Gilson et al., 2000; Holzmann and Jørgensen, 2001; Jütting, 2004; World Health Organization, 2020).

CBHI is, like most other insurances, based on relatively small contributions from all members, which in turn results in a smaller fee when the incident occurs. Entitlements to benefits are generally linked to contributions. Some people may have poorer health than others and might benefit more from this insurance. Subsequently, this may lead to a problem of adverse selection, where the value of the insurance is dependent on the quality of the pool, i.e., more people with bad health reduces its value. Additionally, critical decisions within communities or networks may not take the interest of the poorest into account, exclude them from important decision-making, thus, community structures may not reflect the wider population (Gilson et al., 2000; Ekman, 2004; World Health Organization, 2020). Jütting (2004) argues that the risk pool is often too small, that adverse selection problems arise.

5 Supply-side challenges

Although much of the focus so far has been on the consumer side, the effects of catastrophic weather are also propagated through the agricultural marketing chain via contractual relationships (Miranda and Farrin, 2012). It should be mentioned that the appropriate target market for index insurance may not only be individual farmers but reinsurers and local-level risk aggregators. E.g., microfinance entities and other formal or informal lenders, farmers' cooperatives, output processors, input suppliers, mutual-aid associations, and even local governments or disaster relief providers (Skees et al., 2006; Barnett and Mahul, 2007). [6]

5.1 Reinsurance

Index insurance is often promoted as a solution to many of the barriers that are thought to limit the supply of formal insurance coverage to smallholder farmers (Jensen and Barrett, 2017). As index insurance relies on an index reliably measurable, objectively observable, and highly correlated with the loss, these characteristics may be valuable to insurance providers as a reinsurance instrument. Allowing insurance companies to transfer part of their risk to the international market in an efficient manner (Bryla and Syroka, 2007; Hazell et al., 2010; Binswanger-Mkhize, 2012; Carter, 2013), even for covariate risks (Alderman and Haque, 2007).

Because systematic weather effects induce a high correlation among farm-level yields, private crop insurance markets are doomed to fail without affordable reinsurance. That is, without proper reinsurance, crop insurers would have to pass on the cost of bearing the additional risk onto smallholder farmers, subsequently, crop insurance would be too expensive. Providers of agricultural index insurance prefer to have reinsurers take on the majority of the insured risk (Miranda and Glauber, 1997).

However, with climate change, there is a rise in a specific form of uncertainty aversion and associated insurance markups. Typically, index insurance products are priced using historical data series to estimate the magnitude and frequency of prospective indemnity

[6] Local-level risk aggregators are organizations that do business with many households in the local area and thus are highly exposed to covariate weather risks.

payments, requiring a significant number of observations. But, concerns that climate change has shifted permanently lead some actuarial consultants to add an ”ambiguity wedge” to estimate payouts. Additional historical data are unable to overcome this bias in the estimates, and thus, the downscaling of climate forecasts have proven to be too coarse to enable out-of-sample validation against established climate change models (Mahowald et al., 2012; Jensen and Barrett, 2017). This potential change in the long-term trend due to global change contributes to weather risks, which, in turn, increases basis risk (Norton et al., 2013).

Evidence suggest that those at risk have a tendency to ignore to probability of the most infrequent and extreme loss events (Kunreuther and Slovic, 1978; Kunreuther, 1996). However, this is not the case for reinsurers and insurers. The providers of the insurance cannot afford to ignore the potential for such events. Donors and governments should assist insurance providers with contingent capital to address this market failure (Barnett and Mahul, 2007).

5.2 Regulatory environments

Just like with conventional insurance, index insurance needs a regulatory framework to provide standards for consumer protection. Clear index certification processes, minimum capital-to-liability holding requirements for insurer and reinsurers, and a process for speedy and accessible disputed settlement resolutions should all be included in a standard insurance regulatory framework. In some cases, the potential clients of index insurance are illiterate, so these clients have little understanding of formal financial tools, making complicated contracts a barrier to insurance coverage while adding little consumer protection. Much like with microfinance products, the characteristics of index insurance are in need of special consideration. Allowing for unconventional insurance agents such as NGOs or microfinance institutions and setting appropriate policies on reserve holding and documentation requirements should be considered. An index insurance provider can potentially face regulatory risk, i.e., an interaction of uncertainty and regulation that changes the cost of financing. In countries where existing legal and regulatory systems are highly developed, index insurance may not be supported because losses and indemnity payments are not necessarily tied (Ergas et al., 2001; Barnett and Mahul, 2007; Hazell

et al., 2010; Jensen and Barrett, 2017).

5.3 Product design

Designing index insurance contracts are extremely complex, partly due to the effort required to identify an index that highly correlates with agricultural yields (Barnett and Mahul, 2007; Hazell et al., 2010). Weather-related shocks appear to be the main focus for many index insurance products as exogenous rainfall and temperature levels and timing pose a primary risk for smallholder farmers, as mentioned earlier. Index insurance explicitly insures against covariate shocks, e.g., rainfall and temperature, so the nature of weather-related shocks is well-suited. Additionally, the data required for the insurance product is typically available at low or no cost to researchers and insurance providers from satellite platforms and terrestrial meteorological station networks. The data available is abundant, high-frequency historical and near-real-time weather data, so the availability of accurate historical data is critical. Developing a high-quality index insurance product requires signals that are highly correlated with covariate losses. Actuarial calculations require long series of historical data, up to 30-50 years of data are often cited as the minimum requirement for high-accuracy estimates. This requirement largely excludes indices that use newer, more sophisticated data, remotely sensed data, and the option of building indices from data generated by newly installed weather stations (Jensen and Barrett, 2017). Historical weather data are the primary pre-requisite for designing and pricing weather-based index insurance. However, low-income countries may have a limited number of weather stations and thus lack complete rainfall data (Clement et al., 2018).

One of the major challenges for index insurance is the presence of basis risk, it is a direct result of the reduced data and monitoring requirements for index insurance, i.e., basis risk arising from design error. Basis risk causes both unindemnified losses and unwarranted indemnity payments. An index that is highly correlated with the insured risk is necessary to offer a product with minimized basis risk. Using rainfall-based index insurance has shown a very considerable risk-reducing effect when the contracted weather station is located in close proximity. However, this positive effect is reduced when due to basis risk when the distance increases slightly (Musshoff et al., 2011).

It is crucial to maintain cost savings, but high coverage and low costs are, in general, in

conflict with each other. The index needs to be exogenous. Even if an index perfectly covers all covariate risks, the insurance product leaves households vulnerable to idiosyncratic risks. Farmers in a heterogeneous population have different vulnerabilities to idiosyncratic shocks and may value the insurance product differently. Due to a moderate correlation between losses and payouts, an index insurance product could potentially be more of a lottery ticket than an insurance policy when adding the errors in the index estimates and the coverage of the costs and profit margins of the insurer (Miranda, 1991; De Janvry et al., 2014; Jensen et al., 2016; Jensen and Barrett, 2017). It is expected to encounter basis risk when the index is only dependent on one variable (i.e., rainfall) and there are missing values in weather data (Kellner and Musshoff, 2011; Clement et al., 2018).

The aforementioned ambiguity may once again be of relevance. Developers of the insurance use historical data to estimate farm-level losses, however, since climate change may increase the frequency and vigor of the shocks, it may be hard to make an actuarial estimate. Revisiting the example of the pilot program in Mali, where feedback from community members was a part of the design face. Establishing a dynamic relationship between the insurance providers and the community may improve the actuarial estimates through cooperation.

According to Musshoff et al. (2011), different valuation methods for weather indices can provide different prices. Consequently, no unique price is found that market participants regard as fair. This may provide a hurdle for orientation for other potential market participants.

Clement et al. (2018) recommend improving policyholders' access to information about their risk and measures they can take to limit risk. By approaching informal networks as one insurance taker, group leaders can receive training on this knowledge and efficiently, via the spillover effect, provide smallholder farmers with a greater understanding of the risks. Thus, create an enabling environment for a well-functioning insurance market.

5.4 Implementation

Even though the concept of index insurance is fairly simple, effective implementation of index insurance is not at all simple. The challenges regarding the implementation of index insurance are two-fold.

First, insurance products are somewhat new to many smallholder farmers in rural areas, especially index insurance. In addition, urban insurers are typically unfamiliar with the rural customer base they are trying to offer these products to. Prior to the sale of any insurance product, both sales agents and potential clients need to be educated on the new product. The potentially illiterate customer base can again pose a challenge. To further complicate it, local clients may not trust insurance agents from different ethnic groups or other regions, i.e., lack of generalized trust. There is a need for insurance firms with both the desire and capacity to sell insurance on the ground in rural communities. Many of these issues are already covered in the preceding sections (Barnett and Mahul, 2007; Jensen and Barrett, 2017).

Second, the implementation of an insurance scheme faces a free-rider problem, i.e., sunk costs related to the implementation triggers incentives to let other firms lay the groundwork, thus, many rural areas become trapped in a low-level equilibrium with no available insurance product. [7] This explains why governments and donors have funded pilot projects and studies of weather-based index insurance products throughout its start-up phase (Barnett and Mahul, 2007; Jensen and Barrett, 2017).

However, a pilot program that was successfully able to implement index insurance was Kilimo Salami in Kenya. This can partly be due to smallholder farmers' relationship with M-PESA, which was created based upon a consumer need, the trust related to this institution may be transferred to the index insurance product (Morawczynski and Miscione, 2008; Sibiko et al., 2018).

[7] Similarly, potential clients for index products also often report the desire to wait and see how the product performs as their reason for not purchasing index insurance coverage.

6 Summary and discussion

6.1 Summary

Informal risk-management strategies alone will eventually come up short with the reported higher frequency of weather extremes and increased average temperature affecting whole villages. The message from the *Agricultural for Development* report is that developing countries need to invest more in agriculture to reach their growth potential and poverty reduction (The World Bank, 2007). Access to insurance seems to encourage farmers to adopt higher-yielding and higher-risk investment alternatives (Eswaran and Kotwal, 1990; Barnett et al., 2008; Mobarak and Rosenzweig, 2012; De Janvry et al., 2014). Index-based weather insurance is very much a work in progress. The gap between high promises and low take-up remains large, creating one of the most fascinating current puzzles in developing countries (De Janvry et al., 2014). Relying on social networks to rapidly multiply their effect on knowledge by other members can be an effective strategy to increase the adoption of new insurance products (Cai et al., 2015).

To successfully scale up an index insurance product, it is expected to have minimal basis risk, be affordable and easy to understand, provide extensive coverage, and deliver this against a background of limited capacity, weak distribution and regulatory systems, and limited contract skills (Hellmuth et al., 2009). Developers and providers of insurance products face challenges in terms of weak regulatory environments, covariate risks that need to be re-insured, designing a product with minimal basis risk, and implementing a product in markets that lack experience with insurance (Jensen and Barrett, 2017).

The low outspread and adoption rate of agricultural insurance across developing countries (Giné et al., 2008; Mobarak and Rosenzweig, 2012; Cole et al., 2013) emphasizes that the concept of insurance is indeed new to most smallholder farmers. Additionally, financial illiteracy is common among farmers in rural areas across the developing world, which has led to a lack of trust and limited understanding of insurance being general explanations to the low insurance uptake rates (Cai et al., 2009; Dercon et al., 2011, 2014). Index insurance also faces a crucial challenge in basis risk, i.e., contractual non-performance. The not-perfect correlation between the contracted index and yield creates scenarios where

farmers might not receive indemnification that matches their losses. A farmer who is extremely risk-averse will put a lot of weight in the event of being absolutely worse off, i.e., purchasing insurance and suffering a crop loss but receiving no indemnity (Doherty and Schlesinger, 1991; Giné et al., 2008; Binswanger-Mkhize, 2012; Cole et al., 2013; Clarke, 2016), where ambiguity aversion act as an increased degree of risk aversion (Cai et al., 2015; Elabed and Carter, 2015; Bryan, 2019).

Offering index insurance to already established informal networks, such as the funeral societies in Ethiopia (Dercon et al., 2006, 2014), creates new possibilities for the insurance product design that is both attractive and easy to implement in developing countries (Santos et al., 2021). Group-based index insurance has the potential to reduce barriers related to a lack of trust, creating a better understanding of the insurance product, and alleviating basis risk (Trærup, 2012). Within a social network, farmers can diffuse knowledge on insurance benefits and share experiences among members (Cai et al., 2015). Insurance has shown to have substantially higher take-up rates when group leaders have been trained about insurance benefits (Gaurav et al., 2011; Gine et al., 2013; Dercon et al., 2014). Limited trust can be viewed as a transaction cost between the provider and purchaser of insurance, which is why building stronger trust is a key component of a successful insurance product. Trust can be built through several pathways, whereas the simplest form of trust is based on pre-existing networks (Lyon, 2000). There are major information advantages with the collective approach, knowing when and how much assistance each member needs can lead to more rapid payouts, which has shown to establish trust. Rapid disbursements are heavily valued by poor and liquidity-constrained farmers. Identifying networks with a strong trust base appears to be a key to the success of a collective approach to index insurance (Giné et al., 2008; Trærup, 2012).

It is possible to use the superior information held by group members to allow payouts to be adjusted to reflect actual losses in group index insurance. Alleviating the much troublesome basis risk by averaging it out over time. This can happen through a redistribute element like an informal risk-sharing pool or by targeting informal networks as one insurance taker (Trærup, 2012; McIntosh et al., 2019; Santos et al., 2021).

6.2 Discussion

A long-standing hypothesis is that pre-existing informal risk-sharing arrangements in poor populations either reduce the demand for formal insurance or prevent markets from being established. If the informal risk-management strategies work so well that they fully insure farmers' consumption levels and are inexpensive, farmers would have little demand for agricultural insurance. However, if informal networks are better able to monitor risk behavior than formal insurers, then both formal and informal insurance contracts can coexist and increase welfare. Informal networks may be in a prime position to create incentives to cooperate through peer monitoring, exclusion from future pool benefits, and norms of reciprocity. However, the relationship between actions and outcomes may be imperfectly known, creating imperfect monitoring, subsequently, moral hazard remains a problem (Binswanger-Mkhize, 2012; Mobarak and Rosenzweig, 2012).

Index insurance may have a crowding-out effect on informal risk-sharing, which in turn, will lead to reduced risk-taking. If risk-taking is not contractible among members of the informal network, the residual idiosyncratic risk that the index insurance does not cover may be plagued by hidden actions among members, thus, the introduction of formal index insurance may change the degree of risk-sharing. It may impose a negative externality on other farmers in the group when one farmer increases his risk-taking as they share risk. Also, index insurance may have unintended and adverse consequences as the reduction of covariate risk provides incentives for individual farmers to increase their risk-taking. To counter this, informal risk-sharing arrangements need to mitigate the higher residual idiosyncratic risk by reducing the amount of idiosyncratic risk pooling (Arnott and Stiglitz, 1991; Boucher and Delpierre, 2014). De Janvry et al. (2014) argues that the existence of an informal risk-sharing network increases the demand for index insurance when the informal risk-sharing covers idiosyncratic risks, which reduces basis risk. According to Santos et al. (2021) the interplay between formal and informal instruments, particularly knowing whether one crowds out the other, remains an open question and is the subject of extensive research.

When a member of a risk-sharing group purchases insurance, this can have a dynamic effect on the group, which in turn, can have an effect on demand. An insured member is better protected against shocks and could potentially help the group more often, thus being

more interesting for the group. In that way, insurance participation could be encouraged by group members. However, members might have incentives to leave the group because formal insurance and informal risk-sharing are substitutes, which in turn reduces the effectiveness of the risk-sharing agreement (Fafchamps, 1992; De Bock and Gelade, 2012). Additionally, purchasing weather index insurance may lead to a free-rider problem, where one farmer reduces its investment in social capital after purchasing the index insurance (De Janvry et al., 2014; Nigus et al., 2018).

For group-based index insurance to be a valid risk-management option for farmers it needs to provide value, this can be reflected through the willingness to pay. McIntosh et al. (2019) study the demand for group insurance. By presenting farmers with a group index insurance product that is precisely comparable to an individual index insurance product they were able to estimate that the willingness to pay is $5.21 lower for group insurance than for individual index insurance. Farmers would prefer to be insured individually, ceteris paribus. This finding entitles to question the different factors determining the demand for group insurance. Reasons for the dislike can be any of the issues that have been highlighted in earlier sections.

However, willingness to pay studies that are not backed with an actual insurance product suffer one major drawback, they do not necessarily reflect actual behavior. Farmers may, in fact, act very differently when faced with an actual insurance product (Breidert et al., 2006; Hill et al., 2013; McIntosh et al., 2013). This survey bias is highly relevant for group-based index insurance in developing countries due to the lack of experience, limited knowledge of index insurance products, and few pilot programs. Sibiko et al. (2018) argues that choice experiments of farmers' actual response to contractual designs of weather index schemes would provide important insights, but acknowledges the lack of availability of observational data.

While it is accepted that informal networks are important for the creation of social capital, there is a danger for a romanticized view of networks. It is important to state the fact that civil society is an arena for social contestation in which power struggles exist and affect which groups control which resources and what they do. Additionally, there is an issue of who is included and excluded in certain groups or networks. Trust is generally viewed as positive, but it does possess some liabilities. Trust can be misused and create

the opportunity for cheating where information on the other party is a key resource (Amin, 1996; Lyon, 2000; Granovetter, 2018).

There may be individual farmers adopting formal insurance while defecting on their contributions to the informal risk-sharing pool (Santos et al., 2021). While index insurance is based on formal contract enforcement, these informal within-group transfers depend on honest behavior from members. Informal networks use norms of reciprocity and social exclusion as contract enforcement, however, this may vary in efficiency depending on group size and relations between members (Greif, 1993; Chandrasekhar et al., 2018).

The socially optimal outcome is achieved when everyone adopts the collective approach and contributes to the common risk-sharing pool, in this way, farmers that do not receive indemnification for their losses can potentially be compensated via within-group transfers (Santos et al., 2021). However, as the "tragedy of commons" insinuates, farmers may act independently according to their own self-interest (Ostrom, 1990; Narayan and Pritchett, 1999; Hilbe et al., 2018b). If farmers do defect on contribution, the benefits of group-based insurance are hampered, this reintroduces problems related to basis risk.

The lack of pilot programs for group-based index insurance has made it useful to draw a parallel to a similar design of health insurance. But, despite much hope, community-based health insurance, according to World Health Organization (2020), has contributed only to moderate access to health care. This is, among other things, due to adverse selection, showing that the reintroduction to this problem could be a threat against group-based insurance products.

The attractiveness of group insurance is dependent on the extent it can pool risk, i.e., a higher degree of loss adjustment result in a more attractive product. Larger groups have a higher degree of loss adjustment. However, there is no guaranteed degree of this loss adjustment because it depends on the size of the payout (McIntosh et al., 2019). Ambiguity-averse farmers may struggle to assess whether group-based index insurance actually reduces risk, given the uncertainty related to the degree of loss adjustment (Elabed and Carter, 2015; Bryan, 2019).

Group size is also a variable in the degree of learning within groups (Sibiko et al., 2018) and the incentives to participate in collective actions (Fischer and Qaim, 2014). Farmers

within the same groups have shared interests, which means that a farmer's insurance purchase may exert positive externalities on fellow farmers. Larger groups may create greater incentives to free-ride, i.e., a farmer reducing its investment in social capital ex-post of an index insurance purchase (De Janvry et al., 2014; Nigus et al., 2018).

There is an issue that some farmers may systematically make larger claims on the common risk-sharing pools than others, stemming from the dissimilarities in risk exposure (McIntosh et al., 2019).Those farmers that systematically lose on the group contract may prefer individual insurance, thus, potentially creating a "market for lemons" where superior information held by individual farmers leaves only farmers with high exposure to basis risk left in the group, i.e., "lemons" (Akerlof, 1978). However, this is only speculative, and, as Attanasio et al. (2012) find, individuals with similar attitudes tend to form groups, leaving less room for dissimilarities.

Binswanger-Mkhize (2012) ends on a pessimistic note where standard recommendations for improved index-based insurance are presented, i.e., reducing basis risk, moving to broader indices, improving farmers' understanding of the insurance, improving weather data, and transaction costs. It is argued that none of the above will do anything to overcome the inability of the poor farmers to buy insurance. The price of the premium and the value of the insurance may, respectively, be increased and decreased as a response to the reintroduction of moral hazard and adverse selection. The puzzling low demand for index insurance may be a result of insurance that is simply too expensive for the poorest farmer. Insurance participation is, in fact, not cost-free, requiring a minimum of income that the most disadvantaged often do not have at their disposal, possibly excluding the poorest and most vulnerable. Additionally, better-off farmers may already be well insured via informal mechanisms, leaving only farmers with intermediate values of wealth suitable for purchasing insurance. A possible solution, and what donors and policymakers should be aware of, is interlinking insurance with social funds (Jütting, 2004).

7 Conclusion

Index insurance may be improved by adopting some of the strengths of social capital in the form of informal networks. A lack of trust and limited understanding of the insurance product are important barriers that need to be crossed for insurance adoption by smallholder farmers. Additionally, within-group risk transfers seem to alleviate basis risk, but only to a certain extent and with no guarantees. The nature of these networks reintroduce problems regarding moral hazard and asymmetric information that led to the demise of conventional agricultural insurance, albeit at a smaller scale and in easier monitored conditions.

References

Akerlof, G. A. (1978). The market for "lemons": Quality uncertainty and the market mechanism. In Diamond, P. and Rothschild, M., editors, *Uncertainty in economics*, pages 235–251. Amsterdam: Elsevier.

Alderman, H. and Haque, T. (2007). Insurance against covariate shocks: The role of index-based insurance in social protection in low-income countries of africa. *The World Bank Working Papers*.

Amin, A. (1996). Beyond associative democracy. *New Political Economy*, 1(3):309–333.

Arnott, R. and Stiglitz, J. E. (1991). Moral hazard and nonmarket institutions: Dysfunctional crowding out of peer monitoring? *The American Economic Review*, 81(1):179–190.

Aryal, S., Cockfield, G., and Maraseni, T. N. (2014). Vulnerability of himalayan transhumant communities to climate change. *Climatic Change*, 125(2):193–208.

Attanasio, O., Barr, A., Cardenas, J. C., Genicot, G., and Meghir, C. (2012). Risk pooling, risk preferences, and social networks. *American Economic Journal: Applied Economics*, 4(2):134–67.

Banerjee, A. V. and Duflo, E. (2007). The economic lives of the poor. *Journal of economic perspectives*, 21(1):141–168.

Bardsley, P., Abey, A., and Davenport, S. V. (1984). The economics of insuring crops against drought. *Australian Journal of Agricultural Economics*, 28(1):1–14.

Barnett, B. J., Barrett, C. B., and Skees, J. R. (2008). Poverty traps and index-based risk transfer products. *World Development*, 36(10):1766–1785.

Barnett, B. J., Black, J. R., Hu, Y., and Skees, J. R. (2005). Is area yield insurance competitive with farm yield insurance? *Journal of Agricultural and Resource Economics*, pages 285–301.

Barnett, B. J. and Mahul, O. (2007). Weather index insurance for agriculture and rural areas in lower-income countries. *American Journal of Agricultural Economics*, 89(5):1241–1247.

Barrett, C. B., Barnett, B. J., Carter, M. R., Chantarat, S., Hansen, J. W., Mude, A. G., Osgood, D., Skees, J. R., Turvey, C. G., and Ward, M. N. (2007). Poverty traps and climate risk: limitations and opportunities of index-based risk financing. *IRI Technical report*, (07-02).

Belissa, T., Bulte, E., Cecchi, F., Gangopadhyay, S., and Lensink, R. (2019). Liquidity constraints, informal institutions, and the adoption of weather insurance: A randomized controlled trial in ethiopia. *Journal of Development Economics*, 140:269–278.

Binswanger-Mkhize, H. P. (2012). Is there too much hype about index-based agricultural insurance? *Journal of Development studies*, 48(2):187–200.

Boucher, S. and Delpierre, M. (2014). The impact of index-based insurance on informal risk-sharing arrangement. *Luxembourg Institute of Socio-Economic Research (LISER) Working Paper Series*, 13.

Breidert, C., Hahsler, M., and Reutterer, T. (2006). A review of methods for measuring willingness-to-pay. *Innovative Marketing*, 2(4):8–32.

Brown, L. D. and Ashman, D. (1996). Participation, social capital, and intersectoral problem solving: African and asian cases. *World development*, 24(9):1467–1479.

Bryan, G. (2019). Ambiguity aversion decreases the impact of partial insurance: Evidence from african farmers. *Journal of the European Economic Association*, 17(5):1428–1469.

Bryla, E. and Syroka, J. (2007). Developing index-based insurance for agriculture in developing countries. *Sustainable Development Innovation Brief*, 2.

Budhathoki, N. K., Lassa, J. A., Pun, S., and Zander, K. K. (2019). Farmers' interest and willingness-to-pay for index-based crop insurance in the lowlands of nepal. *Land Use Policy*, 85:1–10.

Burke, M., Hsiang, S. M., and Miguel, E. (2015). Global non-linear effect of temperature on economic production. *Nature*, 527(7577):235–239.

Cai, H., Chen, Y., Fang, H., and Zhou, L.-A. (2009). Microinsurance, trust and economic development: Evidence from a randomized natural field experiment. *National Bureau of Economic Research*.

Cai, J., De Janvry, A., and Sadoulet, E. (2015). Social networks and the decision to insure. *American Economic Journal: Applied Economics*, 7(2):81–108.

Cai, J. and Song, C. (2017). Do disaster experience and knowledge affect insurance take-up decisions? *Journal of Development Economics*, 124:83–94.

Carpena, F., Cole, S. A., Shapiro, J., and Zia, B. (2011). Unpacking the causal chain of financial literacy. *World Bank Policy Research Working Paper*, (5798).

Carter, M. (2013). Sharing the risk and the uncertainty: public-private reinsurance partnerships for viable agricultural insurance markets. *I4 Index Insurance Innovation Initiative Brief*, 1.

Carter, M., De Janvry, A., Sadoulet, E., Sarris, A., et al. (2014). Index-based weather insurance for developing countries: A review of evidence and a set of propositions for up-scaling. *Development Policies working paper*, 111.

Carter, M. R. (1997). Environment, technology, and the social articulation of risk in west african agriculture. *Economic development and cultural change*, 45(3):557–590.

Carter, M. R. and Barrett, C. B. (2006). The economics of poverty traps and persistent poverty: An asset-based approach. *The Journal of Development Studies*, 42(2):178–199.

Casaburi, L. and Willis, J. (2018). Time versus state in insurance: Experimental evidence from contract farming in kenya. *American Economic Review*, 108(12):3778–3813.

Cassar, A., Crowley, L., and Wydick, B. (2007). The effect of social capital on group loan repayment: evidence from field experiments. *The Economic Journal*, 117(517):F85–F106.

Ceballos, F. and Robles, M. (2020). Demand heterogeneity for index-based insurance: The case for flexible products. *Journal of Development Economics*, 146:102515.

Chambers, R. G. (1989). Insurability and moral hazard in agricultural insurance markets. *American Journal of Agricultural Economics*, 71(3):604–616.

Chandrasekhar, A. G., Kinnan, C., and Larreguy, H. (2018). Social networks as contract enforcement: Evidence from a lab experiment in the field. *American Economic Journal: Applied Economics*, 10(4):43–78.

Churchill, C. and Matul, M. (2006). Protecting the poor. *A Micro Insurance Compendium, Genf: ILO*.

Clarke, D. and Wren-Lewis, L. (2013). Learning from lemons: the role of government in index insurance for individuals. *FERDI Policy Brief*, (70).

Clarke, D. J. (2016). A theory of rational demand for index insurance. *American Economic Journal: Microeconomics*, 8(1):283–306.

Clarke, D. J. and Dercon, S. (2016). *Dull Disasters? How planning ahead will make a difference*. Oxford: Oxford University Press.

Clement, K. Y., Botzen, W. W., Brouwer, R., and Aerts, J. C. (2018). A global review of the impact of basis risk on the functioning of and demand for index insurance. *International Journal of Disaster Risk Reduction*, 28:845–853.

Coate, S. and Ravallion, M. (1993). Reciprocity without commitment: Characterization and performance of informal insurance arrangements. *Journal of development Economics*, 40(1):1–24.

Coble, K. H., Knight, T. O., Pope, R. D., and Williams, J. R. (1997). An expected-indemnity approach to the measurement of moral hazard in crop insurance. *American journal of agricultural economics*, 79(1):216–226.

Cole, S., Giné, X., Tobacman, J., Topalova, P., Townsend, R., and Vickery, J. (2013). Barriers to household risk management: Evidence from india. *American Economic Journal: Applied Economics*, 5(1):104–35.

Darby, M. R. and Karni, E. (1973). Free competition and the optimal amount of fraud. *The Journal of law and economics*, 16(1):67–88.

De Bock, O. and Gelade, W. (2012). The demand for microinsurance: A literature review. *ILO Microinsurance Innovation Facility Research Paper No*, 26.

De Janvry, A., Dequiedt, V., and Sadoulet, E. (2014). The demand for insurance against common shocks. *Journal of Development Economics*, 106:227–238.

De Janvry, A. and Sadoulet, E. (2020). Using agriculture for development: Supply-and demand-side approaches. *World Development*, 133:105003.

De Weerdt, J. (2002). Risk-sharing and endogenous network formation. *WIDER Discussion Paper*, (2002/57).

De Weerdt, J. and Dercon, S. (2006). Risk-sharing networks and insurance against illness. *Journal of development Economics*, 81(2):337–356.

Dercon, S., De Weerdt, J., Bold, T., and Pankhurst, A. (2006). Group-based funeral insurance in ethiopia and tanzania. *World development*, 34(4):685–703.

Dercon, S., Gunning, J. W., and Zeitlin, A. (2011). The demand for insurance under limited credibility: Evidence from kenya. In *International Development Conference, DIAL*.

Dercon, S., Hill, R. V., Clarke, D., Outes-Leon, I., and Taffesse, A. S. (2014). Offering rainfall insurance to informal insurance groups: Evidence from a field experiment in ethiopia. *Journal of Development Economics*, 106:132–143.

Dercon, S., Hoddinott, J., Krishnan, P., and Woldehanna, T. (2008). Collective action and vulnerability: Burial societies in rural ethiopia. *Available at SSRN 1260274*.

Dercon, S., Kirchberger, M., Gunning, J. W., and Platteau, J. P. (2009). *Literature review on microinsurance*. ILO.

Di Falco, S. and Bulte, E. (2013). The impact of kinship networks on the adoption of risk-mitigating strategies in ethiopia. *World Development*, 43:100–110.

Di Marcantonio, F. and Kayitakire, F. (2017). Review of pilot projects on index-based insurance in africa: Insights and lessons learned. In Tiepolo, M., Pezzoli, A., and Tarchiani, V., editors, *Renewing Local Planning to Face Climate Change in the Tropics*, pages 323–341. Cham: Springer.

Doherty, N. A. and Richter, A. (2002). Moral hazard, basis risk, and gap insurance. *Journal of Risk and Insurance*, 69(1):9–24.

Doherty, N. A. and Schlesinger, H. (1991). Rational insurance purchasing: Consideration of contract non-performance. In Cummins, D. J. and Derrig, R. A., editors, *Managing the Insolvency Risk of Insurance Companies*, pages 283–294. Dordrecht: Springer.

Dror, D. M. and Preker, A. S. (2002). *Social reinsurance: a new approach to sustainable community health financing*. The World Bank.

Duflo, E., Kremer, M., and Robinson, J. (2011). Nudging farmers to use fertilizer: Theory and experimental evidence from kenya. *American economic review*, 101(6):2350–90.

Easterly, W. and Levine, R. (1997). Africa's growth tragedy: policies and ethnic divisions. *The quarterly journal of economics*, 112(4):1203–1250.

Ekman, B. (2004). Community-based health insurance in low-income countries: a systematic review of the evidence. *Health policy and planning*, 19(5):249–270.

Elabed, G., Bellemare, M. F., Carter, M. R., and Guirkinger, C. (2013). Managing basis risk with multiscale index insurance. *Agricultural Economics*, 44(4-5):419–431.

Elabed, G. and Carter, M. R. (2015). Compound-risk aversion, ambiguity and the willingness to pay for microinsurance. *Journal of Economic Behavior & Organization*, 118:150–166.

Ellsberg, D. (1961). Risk, ambiguity, and the savage axioms. *The quarterly journal of economics*, pages 643–669.

Ergas, H., Hornby, J., Little, I., and Small, J. (2001). Regulatory risk. *Available at SSRN 1928292*.

Eswaran, M. and Kotwal, A. (1990). Implications of credit constraints for risk behaviour in less developed economies. *Oxford economic papers*, 42(2):473–482.

Fafchamps, M. (1992). Solidarity networks in preindustrial societies: Rational peasants with a moral economy. *Economic development and cultural change*, 41(1):147–174.

Fafchamps, M. and Gubert, F. (2007). The formation of risk sharing networks. *Journal of development Economics*, 83(2):326–350.

Feigenberg, B., Field, E., and Pande, R. (2013). The economic returns to social interaction: Experimental evidence from microfinance. *Review of Economic Studies*, 80(4):1459–1483.

Field, C. B., Barros, V., Stocker, T. F., and Dahe, Q. (2012). *Managing the risks of extreme events and disasters to advance climate change adaptation: special report of the intergovernmental panel on climate change*. Cambridge University Press.

Fischer, E. and Qaim, M. (2014). Smallholder farmers and collective action: what determines the intensity of participation? *Journal of Agricultural Economics*, 65(3):683–702.

Fisher, E., Hellin, J., Greatrex, H., and Jensen, N. (2019). Index insurance and climate risk management: Addressing social equity. *Development Policy Review*, 37(5):581–602.

Gaurav, S., Cole, S., and Tobacman, J. (2011). Marketing complex financial products in emerging markets: Evidence from rainfall insurance in india. *Journal of marketing research*, 48(SPL):S150–S162.

Gilson, L., Kalyalya, D., Kuchler, F., Lake, S., Oranga, H., and Ouendo, M. (2000). The equity impacts of community financing activities in three african countries. *The International journal of health planning and management*, 15(4):291–317.

Gine, X., Karlan, D., and Ngatia, M. (2013). *Social networks, financial literacy and index insurance*. Washington, DC: World Bank.

Giné, X., Townsend, R., and Vickery, J. (2008). Patterns of rainfall insurance participation in rural india. *The World Bank Economic Review*, 22(3):539–566.

Gittell, R. and Vidal, A. (1998). *Community organizing: Building social capital as a development strategy*. Thousand Oaks, Calif.: Sage.

Granovetter, M. (2018). Economic action and social structure: The problem of embeddedness. In Granovetter, M. and Swedberg, R., editors, *The sociology of economic life*, pages 22–45. Boulder, Colo: Routledge.

Greatrex, H., Hansen, J., Garvin, S., Diro, R., Le Guen, M., Blakeley, S., Rao, K., and Osgood, D. (2015). Scaling up index insurance for smallholder farmers: Recent evidence and insights. *CGIAR Research Program on Climate Change, Agriculture and Food Security*, (14).

Greif, A. (1993). Contract enforceability and economic institutions in early trade: The maghribi traders' coalition. *The American economic review*, 83(3):525–548.

Hansen, J., Hellin, J., Rosenstock, T., Fisher, E., Cairns, J., Stirling, C., Lamanna, C., van Etten, J., Rose, A., and Campbell, B. (2019). Climate risk management and rural poverty reduction. *Agricultural Systems*, 172:28–46.

Hauser, O. P., Hilbe, C., Chatterjee, K., and Nowak, M. A. (2019). Social dilemmas among unequals. *Nature*, 572(7770):524–527.

Hazell, P., Anderson, J., Balzer, N., Hastrup Clemmensen, A., Hess, U., and Rispoli, F. (2010). The potential for scale and sustainability in weather index insurance for agriculture and rural livelihoods. Technical report, World Food Programme (WFP).

Hazell, P. B. (1992). The appropriate role of agricultural insurance in developing countries. *Journal of International Development*, 4(6):567–581.

Hazell, P. B., Norton, R., Parthasarathy, M., and Pomareda, C. (1978). *The importance of risk in agricultural planning models*. World Bank.

Heimfarth, L. E. and Musshoff, O. (2011). Weather index-based insurances for farmers in the north china plain. *Agricultural Finance Review*, 71(2):218–239.

Hellmuth, M. E., Moorhead, A., Thomas, M. C., and Williams, J. (2007). Climate risk management in africa: Learning from practice. *Climate and Society*, (1).

Hellmuth, M. E., Osgood, D. E., Hess, U., Moorhead, A., and Bhojwani, H. (2009). Index insurance and climate risk: Prospects for development and disaster management. Technical report, International Research Institute for Climate and Society (IRI).

Hess, U., Skees, J., Stoppa, A., Barnett, B., and Nash, J. (2005). Managing agricultural production risk: Innovations in developing countries. *Agriculture and Rural Development (ARD) Department Report*, (32727-GLB).

Hilbe, C., Chatterjee, K., and Nowak, M. A. (2018a). Partners and rivals in direct reciprocity. *Nature human behaviour*, 2(7):469–477.

Hilbe, C., Šimsa, Š., Chatterjee, K., and Nowak, M. A. (2018b). Evolution of cooperation in stochastic games. *Nature*, 559(7713):246–249.

Hill, R. V., Hoddinott, J., and Kumar, N. (2013). Adoption of weather-index insurance: learning from willingness to pay among a panel of households in rural ethiopia. *Agricultural Economics*, 44(4-5):385–398.

Hill, R. V., Kumar, N., Magnan, N., Makhija, S., de Nicola, F., Spielman, D. J., and Ward, P. S. (2019). Ex ante and ex post effects of hybrid index insurance in bangladesh. *Journal of development economics*, 136:1–17.

Hölmstrom, B. (1979). Moral hazard and observability. *The Bell journal of economics*, pages 74–91.

Holzmann, R. and Jørgensen, S. (2001). Social risk management: A new conceptual framework for social protection, and beyond. *International Tax and Public Finance*, 8(4):529–556.

Isik, M. and Devadoss, S. (2006). An analysis of the impact of climate change on crop yields and yield variability. *Applied Economics*, 38(7):835–844.

Jensen, N. and Barrett, C. (2017). Agricultural index insurance for development. *Applied Economic Perspectives and Policy*, 39(2):199–219.

Jensen, N. D., Barrett, C. B., and Mude, A. G. (2016). Index insurance quality and basis risk: Evidence from northern kenya. *American Journal of Agricultural Economics*, 98(5):1450–1469.

Jütting, J. P. (2004). Do community-based health insurance schemes improve poor people's access to health care? evidence from rural senegal. *World development*, 32(2):273–288.

Kamuzora, P. and Gilson, L. (2007). Factors influencing implementation of the community health fund in tanzania. *Health policy and planning*, 22(2):95–102.

Karlan, D., Osei, R., Osei-Akoto, I., and Udry, C. (2014). Agricultural decisions after relaxing credit and risk constraints. *The Quarterly Journal of Economics*, 129(2):597–652.

Kellner, U. and Musshoff, O. (2011). Precipitation or water capacity indices? an analysis of the benefits of alternative underlyings for index insurance. *Agricultural Systems*, 104(8):645–653.

Kremer, M., Rao, G., and Schilbach, F. (2019). Behavioral development economics. In Bernheim, D. B., DellaVigna, S., and Laibson, D., editors, *Handbook of Behavioral Economics: Applications and Foundations 1*, volume 2, pages 345–458. Amsterdam: Elsevier.

Krishna, A. (2000). Creating and harnessing social capital. In Dasgupta, P. and Serageldin, I., editors, *Social capital: A multifaceted perspective*, pages 71–93. Washington, DC: The World Bank.

Kunreuther, H. (1996). Mitigating disaster losses through insurance. *Journal of risk and Uncertainty*, 12(2):171–187.

Kunreuther, H. and Slovic, P. (1978). Economics, psychology, and protective behavior. *The American Economic Review*, 68(2):64–69.

Lyon, F. (2000). Trust, networks and norms: the creation of social capital in agricultural economies in ghana. *World Development*, 28(4):663–681.

Mahowald, N., Harrison, L., Shukla, S., and Funk, C. (2012). Can earth system models be used for impact studies? In *AGU Fall Meeting Abstracts*, volume 2012, pages GC32B–02.

Mas, I. and Morawczynski, O. (2009). Designing mobile money services lessons from m-pesa. *Innovations: Technology, Governance, Globalization*, 4(2):77–91.

Mas, I. and Radcliffe, D. (2010). Mobile payments go viral: M-pesa in kenya. In Chuhan-Pole, P. and Angwafo, M., editors, *Yes, Africa Can (Success Stories from a Dynamic Continent)*. Herndon: World Bank Publications.

McIntosh, C., Povel, F., and Sadoulet, E. (2019). Utility, risk and demand for incomplete insurance: Lab experiments with guatemalan co-operatives. *The Economic Journal*, 129(622):2581–2607.

McIntosh, C., Sarris, A., and Papadopoulos, F. (2013). Productivity, credit, risk, and the demand for weather index insurance in smallholder agriculture in ethiopia. *Agricultural Economics*, 44(4-5):399–417.

Merhej, R., Santos, F. P., Melo, F. S., and Santos, F. C. (2021). Cooperation between independent reinforcement learners under wealth inequality and collective risks. *Proc. of the 20th International Conference on Autonomous Agents and Multiagent Systems*.

Milinski, M., Sommerfeld, R. D., Krambeck, H.-J., Reed, F. A., and Marotzke, J. (2008). The collective-risk social dilemma and the prevention of simulated dangerous climate change. *Proceedings of the National Academy of Sciences*, 105(7):2291–2294.

Miranda, M. J. (1991). Area-yield crop insurance reconsidered. *American Journal of Agricultural Economics*, 73(2):233–242.

Miranda, M. J. and Farrin, K. (2012). Index insurance for developing countries. *Applied Economic Perspectives and Policy*, 34(3):391–427.

Miranda, M. J. and Glauber, J. W. (1997). Systemic risk, reinsurance, and the failure of crop insurance markets. *American journal of agricultural economics*, 79(1):206–215.

Miranda, M. J. and Gonzalez-Vega, C. (2011). Systemic risk, index insurance, and optimal management of agricultural loan portfolios in developing countries. *American Journal of Agricultural Economics*, 93(2):399–406.

Mobarak, A. M. and Rosenzweig, M. R. (2012). Selling formal insurance to the informally insured. *Yale Economics Department Working Paper*, (97).

Mobarak, A. M. and Rosenzweig, M. R. (2013). Informal risk sharing, index insurance, and risk taking in developing countries. *American Economic Review*, 103(3):375–80.

Morawczynski, O. and Miscione, G. (2008). Examining trust in mobile banking transactions: The case of m-pesa in kenya. In *IFIP International Conference on Human Choice and Computers*, pages 287–298. Springer.

Morduch, J. (1995). Income smoothing and consumption smoothing. *Journal of economic perspectives*, 9(3):103–114.

Musshoff, O., Odening, M., and Xu, W. (2011). Management of climate risks in agriculture–will weather derivatives permeate? *Applied economics*, 43(9):1067–1077.

Narayan, D. and Pritchett, L. (1999). Cents and sociability: Household income and social capital in rural tanzania. *Economic development and cultural change*, 47(4):871–897.

Nigus, H. Y., Nillesen, E., Mohnen, P., et al. (2018). The effect of weather index insurance on social capital: Experimental evidence from ethiopia. *UNU-MERIT Working Paper*, (2018-007).

Norton, M. T., Turvey, C., and Osgood, D. (2013). Quantifying spatial basis risk for weather index insurance. *The Journal of Risk Finance*.

Ostrom, E. (1990). *Governing the commons: The evolution of institutions for collective action*. Cambridge university press.

Pacheco, J. M., Santos, F. C., and Levin, S. A. (2016). Evolutionary dynamics of collective index insurance. *Journal of mathematical biology*, 72(4):997–1010.

Pan, L. (2009). Risk pooling through transfers in rural ethiopia. *Economic Development and Cultural Change*, 57(4):809–835.

Panda, A., Lambert, P. J., and Surminski, S. (2020). Insurance and financial services across developing countries: an empirical study of coverage and demand. *Centre for Climate Change Economics and Policy Working Paper*, 367.

Patt, A., Peterson, N., Carter, M., Velez, M., Hess, U., and Suarez, P. (2009). Making index insurance attractive to farmers. *Mitigation and Adaptation Strategies for Global Change*, 14(8):737–753.

Patt, A., Suarez, P., and Hess, U. (2010). How do small-holder farmers understand insurance, and how much do they want it? evidence from africa. *Global Environmental Change*, 20(1):153–161.

Platteau, J.-P., De Bock, O., and Gelade, W. (2017). The demand for microinsurance: A literature review. *World Development*, 94:139–156.

Pradhan, K. C. and Mukherjee, S. (2018). Covariate and idiosyncratic shocks and coping strategies for poor and non-poor rural households in india. *Journal of Quantitative Economics*, 16(1):101–127.

Putnam, R. (1993). The prosperous community: Social capital and public life. In Blair, K., Murphy, R. M., and Almjeld, J., editors, *Cross Currents: Cultures, Communities, Technologies*, volume 13. Wadsworth: Cengage Learning.

Quiggin, J., Karagiannis, G., and Stanton, J. (1994). Crop insurance and crop production: an empirical study of moral hazard and adverse selection. In Hueth, D. L. and Furtan, W. H., editors, *Economics of agricultural crop insurance: theory and evidence*, pages 253–272. Dordrecht: Springer.

Ravallion, M. and Chen, S. (2007). *Absolute poverty measures for the developing world, 1981-2004*. The World Bank.

Rosenzweig, M. R. and Stark, O. (1989). Consumption smoothing, migration, and marriage: Evidence from rural india. *Journal of political Economy*, 97(4):905–926.

Rosenzweig, M. R. and Wolpin, K. I. (1993). Credit market constraints, consumption smoothing, and the accumulation of durable production assets in low-income countries: Investments in bullocks in india. *Journal of political economy*, 101(2):223–244.

Santos, F. P., Pacheco, J. M., Santos, F. C., and Levin, S. A. (2021). Dynamics of informal risk sharing in collective index insurance. *Nature Sustainability*, pages 1–7.

Sibiko, K. W., Veettil, P. C., and Qaim, M. (2018). Small farmers' preferences for weather index insurance: insights from kenya. *Agriculture & Food Security*, 7(1):1–14.

Skees, J. R. (2008). Innovations in index insurance for the poor in lower income countries. *Agricultural and Resource Economics Review*, 37(1):1–15.

Skees, J. R., Barnett, B. J., et al. (2006). Enhancing microfinance using index-based risk-transfer products. *Agricultural Finance Review*, 66(2):235.

Skees, J. R. et al. (2001). *Developing rainfall-based index insurance in Morocco*, volume 2577. World Bank Publications.

Skees, J. R. et al. (2008). Challenges for use of index-based weather insurance in lower income countries. *Agricultural Finance Review*, 68(1):197.

Skees, J. R. and Reed, M. R. (1986). Rate making for farm-level crop insurance: Implications for adverse selection. *American Journal of Agricultural Economics*, 68(3):653–659.

Smith, V. H. and Goodwin, B. K. (1996). Crop insurance, moral hazard, and agricultural chemical use. *American Journal of Agricultural Economics*, 78(2):428–438.

Tabor, S. R. et al. (2005). Community-based health insurance and social protection policy. *World Bank, Washington: Social Protection Discussion Paper Series*.

Tang, Y., Cai, H., and Liu, R. (2021). Farmers' demand for informal risk management strategy and weather index insurance: Evidence from china. *International Journal of Disaster Risk Science*, pages 1–17.

The World Bank (2007). *Agriculture for development*. Washington DC: The World Bank.

Townsend, R. M. (1994). Risk and insurance in village india. *Econometrica: Journal of the Econometric Society*, pages 539–591.

Townsend, R. M. (1995). Consumption insurance: An evaluation of risk-bearing systems in low-income economies. *Journal of Economic perspectives*, 9(3):83–102.

Trærup, S. L. (2012). Informal networks and resilience to climate change impacts: a collective approach to index insurance. *Global Environmental Change*, 22(1):255–267.

Uphoff, N. and Wijayaratna, C. M. (2000). Demonstrated benefits from social capital: the productivity of farmer organizations in gal oya, sri lanka. *World development*, 28(11):1875–1890.

Uslaner, E. M. (2002). *The moral foundations of trust*. Cambridge University Press.

Valdés, A., Hazell, P., and Pomareda, C. (1986). *Crop insurance for agricultural development: Issues and experience*. IICA Biblioteca Venezuela.

Vasilaky, K., Sáenz, S. M., Stanimirova, R., and Osgood, D. (2020). Perceptions of farm size heterogeneity and demand for group index insurance. *Games*, 11(1):15.

Woolcock, M. (1998). Social capital and economic development: Toward a theoretical synthesis and policy framework. *Theory and society*, 27(2):151–208.

Woolcock, M. and Narayan, D. (2006). Social capital: Implications for development theory, research, and policy revisited. *The search for empowerment: Social capital as idea and practice at the World Bank*, pages 31–62.

World Bank (2011). *Weather index insurance for agriculture: guidance for development practitioners*. World Bank.

World Health Organization (2020). Community-based health insurance. Obtained from: https://www.who.int/news-room/fact-sheets/detail/community-based-health-insurance-2020. Read: 2021.05.26.