Creating safety nets through semi-parametric index-based insurance: A simulation for Northern Ghana

Vasco Molini, Michiel Keyzer, Bart van den Boom and Wouter Zant•

Abstract

In West Africa, farm income is highly exposed to risks from crop failure in the drier, inland areas, and from fluctuations in (world market) prices in the wetter coastal areas. As individuals and even extended families are poorly equipped to deal with these, provision of social safety nets is required Our paper reviews the situation in Ghana and the way in which the new financial instrument of index-based insurance might contribute to better it, focusing on the estimation of a crop indemnification scheme for farmers in Northern Ghana. It recalls that in a poor rural area like Northern Ghana, provision of social safety almost coincides with food security management, and must, therefore, distinguish three basic subtasks: distributing income entitlements (possibly indemnification payments from insurance) to the poor, ensuring collection of taxes (possibly insurance premiums) to fund the arrangement, and assuring delivery of staple goods, such as food to the all households, including the poor. We point out that crop insurance, in any form can at best entitle the poor, and with adequate premiums, become adequately funded, albeit that current experience suggests that farmers tend to be reluctant and to find it difficult to fulfill their obligations. Our main remark is, however, that unless the actual availability of goods is assured, the indemnification from crop insurance will under droughts only cause prices to rise and channel away scarce food from the uninsured to the insured. In short, in poor areas such as Northern Ghana co-ordinated food security management is key, particularly under severe droughts, with crop insurance possibly playing a role in the spheres of entitlement and taxation. Turning to the modalities of crop insurance, we mention the advantages of the index-based approach, which as compared to the individualized contracts of commercial insurance greatly reduces transaction costs by basing the indemnification payments on objectively and easily measurable variables, such as rainfall data collected at weather stations, and world prices of main export goods. Our contribution is an improvement of the indemnification schedules. Rather than specifying a synthetic schedule or estimating is as a parametric form, we estimate it as an optimal indemnification that minimizes farmers' risk of having their income drop below the poverty line, while restricting the indemnification to be an unknown function of index variables on weather and prices. We adapt kernel learning technique to conduct this estimation, so as to ensure that the schedule is self-financing, up to a subsidy. Our application is for Northern Ghana where poverty is highest and farming conditions are most risky. We test the scheme's performance as a social safety net in terms of its capacity to reduce basis risk and alleviate poverty. Although our schedule definitely outperforms the parametric forms, basis risk and associated poverty remain considerable.

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1. Introduction

Poor households in West Africa, most of whom depend on rain-fed agriculture for their livelihood, face substantial income risks of both idiosyncratic and covariate (systemic) nature. One major risk concerns crop failure due to adverse weather conditions. Fluctuations in input and output prices of both food and cash crops constitute another major risk that affects farm income. Also, the prices of cash crops tend to fluctuate independently from local circumstances and, therefore, to fail in providing compensation for crop failures.

Important modifications are changing the external conditions faced by West African farmers. The climate change, altering the rainfall pattern and augmenting its irregularity, has increased the volatility of yields, while, globalization by integrating local economies with the world market has increased farmers exposure to international price fluctuations. The risk faced by farmers is becoming more and more covariate, threatening communities as a whole (villages, regions, countries). Moreover, poverty is often geographically concentrated in villages with few rich and many poor households, while the poorest regions have least access to external resources (Whitehead, 2002). Therefore poor households often have little options that might cushion the shocks in crop income from other sources. At the same time, local and national institutions are generally insufficiently equipped to overcome this trap through safety nets or buffer stocks, while traditional safety nets that are effective against small-scale shocks are gradually loosing momentum.

From a historical perspective, this turn of events can be explained from many factors. We mention a few. First, colonisation and later on independence has weakened the position and the power to tax of the traditional village authorities, undermining their capacity to provide safety nets. Second, the mounting population pressure has made it more difficult to meet the needs. Third, it seems that climate change has impacted severely on the region over the past three centuries, with the part that borders the Sahara becoming drier, and rainfall patterns generally becoming more irregular. This aspect is of particular importance, since current predictions from climate change models indicate. Finally, increased orientation on international markets has increased farmers' exposure to price fluctuations of cash crops.

Safety nets that address covariate risks have a long history. The traditional safety nets have mostly been based on stocking staple crops at the village level. The size of local food stock though generally has a limited capacity to deal with an exceptional or a prolonged covariate shock. Also, as population is growing fast and the composition of households' income has changed considerably with an increased role of income from off-farm activities and from remittances, the traditional way to mobilize households' contribution to the stocks by claiming part of the harvest is under pressure.

At the level of the state, during the 1960s and 1970s marketing boards were the common arrangements to stabilize crop income of farmers and to provide cheap food when prevailing market prices were too high for the poor to buy their minimum requirements. Yet, in response to their poor functioning, starting in the 1980s, these arrangements have gradually been dismantled or considerably downsized.

The erosion of traditional safety nets based on self- and mutual insurance (Ligon et al., 2000) and the malfunctioning of state interventions (Bates, 2005) impact on farm households' response to prevailing and emerging risks. Some have developed new safety nets, mostly through rural-urban linkages that provide income from off-farm activities and remittances that are less risky than farm income or have an uncorrelated risk. At best, when negatively correlated with farm income, these income sources can act most effectively as a safety net. Other farm households, unable to establish such new safety nets, have continued to resort to low risk activities, but even

the least risky profiles are often exposed to income shocks that may bring them to extreme poverty with associated problems of destitiution and recovery.

Given the changing conditions and the persistence of poverty, there seems to be a need for the countries in West Africa, their government authorities in particular, to reassess their role as provider of social safety nets. Recent literature has studied pathways to better insure households trapped in poverty due to unmanageable covariate risk and deficiency of safety nets (Adams, 1998; Dercon, 2004). The premise is that a broadening of saftety nets is warranted, not only for equity reasons, but increasingly so to overcome welfare losses and poverty traps caused by farmers' response to uninsured risk (Elbers et al., 2007). Since arrangements that are entirely government and donor funded have been critisized for their limited success, an increasing amount of scholars and policy makers are focusing on arrangements in some mixed public-private form, blending the interest of households with the concerns of governments and donors.

One promising approach that has recently been proposed and piloted as a vehicle for public-private saftey nets is index-based insurance, in which poor farmers are offered a subsidized contract that supplements their income in case of price and weather shocks (Skees et al., 2005).

As a case study, the present paper considers the provision of social safety nets in Ghana and the way in which the new financial instrument of index-based insurance might contribute to better it, focusing on the estimation of a crop indemnification scheme for farmers in Northern Ghana.

The plan of the paper is as follows. Section 2 provides a historical background on safety nets in Ghana. Section 3 reviews the conditions for safety nets to function properly and discusses how crop insurance – the indexed-based crop insurance currently piloted in particular – could make a useful contribution to existing safety nets. Section 4 describes briefly the proposed technique to design risk minimizing index-based insurance through semi-parametric regression.

In section 5, focusing attention on a sample of farmers in Northern Ghana, we compute their ideal individualized insurance and estimate an index function that depends on a few selected price-weather variables and that is as close as possible to this ideal, in a specified risk minimizing sense.

Section 6 concludes by considering the capacity of the proposed scheme to reduce poverty and act as a safety net.

2. Brief history of safety nets in Ghana

Until the 16th century, climatic conditions of Ghana were particularly favourable for agriculture and there is little evidence of exposure to droughts or prolonged dry periods (**ref). The 1000 mm isohyte, which defines the border between savannah and woodland-savannah, passed through present Northern Burkina-Faso indicating that rainfall in Northern Ghana was adequate. The isohyte also marks the domain of the tsetse fly, within which most cattle will perish. Hence, at the time, farmers typically kept only tsetse resistant species known as the N'Dama breed. Since horses suffer as well, the tsetse frontier also provided a natural protection against slave-driving horsed warriors coming from the North.

Reconstructions of climate pattern (McCann 1999) identify from 1600 onwards the start of a drier period that, in about 250 years, moved the savannah zone approximately 200-300 km southward. This climate change deeply transformed the social and economic conditions in the area, forcing local population to move southward and through this to reach closer to the populations residing in the woodland area.

Starting from this period, one can think of Ghana as divided in three main parts – the Coast, the Central Forest and the Northern Savannah – reflecting a broad agro-ecological division of the country. The institutions that developed in the three parts reflect the type of problems posed by these agro-ecological conditions. Along the Coast, the arrival of Europeans in the late 15th century challenged the living conditions of the local population (Wilson, 1990). Portuguese, and from late 16th century Dutch and British, created *entrepôts* to trade both goods and slaves with the inner region. The presence of Europeans and the threat of slavery discouraged the formation of settlements and the Coastal area remained relatively under-populated, until the abolition of slavery.

In the central part of Ghana, where favourable rainforest conditions prevailed, local chiefs became powerful in the 16th century thanks to their capacity to provide protection against incursions of slave traders. In exchange, they would ask a share in the harvest or some *corvée* activity. In the late 17th century, with the introduction of new crops (cassava and maize) and the winning of gold deposits centralization took place and local chiefs lost influence as the wealthy and centralized Ashanti Kingdom developed that ruled over Central Ghana until the end of 19th century (Mc Caskie 1984).

By contrast, in Northern Ghana the population started to face recurrent droughts and a general worsening of the climatic conditions from the end of 17th century onwards. The need to cope with increasingly unpredictable weather conditions forced local populations to adapt by opting for subsistence crops (millet and sorghum), produced under shifting cultivation techniques. Closer to the Burkina's border, where livestock herding was possible, a more intensive system of farming prevailed. Land immediately surrounding the compounds inside the village was manured and cultivated without a fallow period. The rest of the area was under the system of crop rotation. (Speirs, 1991). However, this subsistence economy generated too little surplus to support the creation of structured public organizations (Sutton, 1989). Settlements typically consisted of farmers grouped around a cultivable area, protected by a wall (Hunter 1967). In these small communities, real small-scale states, the power was concentrated in the hands of the chief in association with the village elders (Hymar 1970).

As annual crops were predominant, every settlement had to store its harvest for the dry season (Whitehead 2002). Part was stocked in the family's own compounds and part was held in collective storage. The community store also received a share of this harvest as well as the crop of the communal land, cultivated by the villagers as a corvée. All collective storage was under the

control of the local chief. The stock served to cover the needs of the lean season but some was kept in reserve for emergencies such as crop failures, hence providing a basic social safety net to the villagers. In exchange, villagers received entitlement to this stock in case of need. The village chief was in charge of the whole process of collection, stockpiling and distribution. Since the chief's legitimacy critically depended on his performance, stock operations were generally conducted with care and entitlements respected. Nonetheless, the regime was precarious as the poor harvests would not sustain prolonged periods of drought. Living conditions improved after the introduction of more productive crops such as maize but caused population numbers to rise. At the same time, the presence of slave drivers made the establishment of new settlements particularly risky. This may explain that chiefs were entitled to sell villagers in exchange for food as an extreme measure to reduce the demographic pressure.

The lack of any centralized organization and the fight over scarce resources, including slaves, created persistent political instability, with villages and clans permanently challenging one another. In the last two decades of 19th century the Anglo-German political rivalries in the area worsened these struggles. It was not until the emergence of Britain as the dominating power that the situation became more stable and the conditions for the development of new settlements improved.

Independence

In 1957, Ghana became the first country in Sub-Saharan Africa to gain its independence from colonial rule. The new political leadership inherited a country with borders designed by colonial powers, and with a weak national identity as much of the executive power resided local chiefs, often in conflict with one another. Since these chiefs were also blamed to have collaborated with the colonizers (Addo-Sowatey 2005), and inspired by the experience of Soviet Union, the new leadership decided to promote growth and economic integration by concentrating the economic and political power at the national level. Hence, it deprived the chiefs of their powers of taxation, which greatly diminished their capacity to provide social safety nets (Baofo-Arthur 2003). At the same time cities developed rapidly due to the population pressure and the mirage of urban life, and migrants showed a much lower demand for chief protection in case of hardship.

In the spirit of central planning, government opted for price controls supported through buffer stocks. One step in this direction was to strengthen the Cocoa Board (Cocobod, established in 1947) and put in place various policies to stabilize and control other crop markets. The Cocobod acquired monopoly over domestic purchases and exports, and kept buffer stocks that bought up surpluses at floor prices and sold stocks at ceiling prices, supported by variable export tariffs. Besides serving as stabiliser of the main export market and as source of government funds, the Cocobod offered a rudimentary safety net for cocoa farmers, to replace traditional chief-controlled systems.

However, over time, the Cocobod became ever more ineffective as it acquired the classical inefficiencies of a monopolist, with increasing staff levels, decreasing service levels and mounting corruption. At the same time, indirect taxation became excessive, absorbing two thirds and more of the world market price in the late 1970s and early 1980s.

Not surprisingly, farmers reacted by opting for other crops. From an average production of 400,000 to 500,000 tons until the mid 1960s, production had dropped to as low as 150,000 tons by 1983, and Ghana's world market share fell to 15 percent, as compared to 26 percent in 1970.

Moeover, Cocobod was ill-equipped as a safety net. One reason was inequitable taxation, as only cocoa farmers were taxed while the entire nation was supposed to benefit from its revenues.

Also, the entitlements of individuals to these revenues were not well established, and assuring adequate deliveries and stable prices of staples never was the task of this agency. Hence, it did not perform effectively any of the three key elements of safety nets: assuring premium collection (cash and in kind) and entitlements, accumulating stocks to overcome shocks, and prompt distribution of stocks in accordance with entitlements.

In response to this mismanagement, the Economic Recovery Plan of 1983 started to transform the agency from a large monopolist marketing board into a much smaller regulatory and planning agency that provides services and support to cocoa farmers. Staff has been reduced from 48,000 in 1987 to around 10,000 nowadays. Cocoa purchasing has been liberalized (18 licensed buyers), though export marketing has remained exclusively under Cocobod control. Producer prices have increased to around two thirds of the world market price and official policies aim at a further increase. At the same time, the remaining one third is largely spent on direct support of the cocoa sector, leaving only a small portion of cocoa revenues for other public spending. Hence, Cocobod has become an agency of cocoa farmers for cocoa farmers.

The reforms that started in the mid 1980s also changed the marketing and pricing of other crops. For example, the Ghana Food Distribution Corporation was established in 1971 to buy and sell maize and rice on domestic as well as foreign markets, using guaranteed minimum prices. The Grain Warehousing Company, a subsidiary to the Bank of Ghana was put in place in 1975, to stabilize cereal markets through stocks. These parastatal agencies suffered from the same weaknesses as Cocobod, and by 1990, after 43 reforms, the guaranteed minimum price scheme for maize and rice was abolished and the grain trading by the two parastatals was brought to an end. Similarly, the Ghana Seed Company and the Livestock Marketing Board were closed down, and the monopoly of the Ghana Cotton Company in marketing and ginning cotton was broken.

A relatively new trend is that remittances from migrants both internal and overseas, have now come to play as major role as safety net of the extended family and currently play a major role rural areas. Foreign remittances are now risen to between 10 and 30 per cent of GDP (Mazzucato et al., 2007), and though more modest in size locally sent remittances are very important as well since they reach the poorer segments of the population. Yet, both the foreign and the local remittances are unevenly distributed across the regions. They mainly accrue to the centre and southern regions and hardly to the poorest regions in the North.

The almost complete elimination of the marketing boards has reduced transaction costs and improved market prices for farmers on average, while the rise in remittances has greatly contributed to the capacity of Ghana's population to absorb shocks. Yet, the reforms also led to dismantling of the market stabilization policies and to the abolishment of the admittedly few social services provided by the commodity boards. At risk is now especially the Northern part of the country, where farmers are particularly poor, face the most risky climate, and have least access to income from other sources such as remittances. Given the high population pressure, this part is left unprotected as the traditional forms of village- and family-based safety nets have become inadequate.

3. Safety nets and insurance

The brief overview on provision of social safety nets in Ghana may illustrate that the centralization process that took place after independence and later on the dismantling of marketing boards and other parastatals have left rural areas without well defined market stabilization policies and safety nets under the responsibility of the public sector. Fortunately, increases efficiencies and remittances from internal as well as overseas migrants have to a significant extent filled the void. Yet, several areas remain at risk, particularly in the North, and when complete villages are poor is without links to richer migrant, it only takes a modest drought to cause famine in the village.

Against the backdrop of these developments, it might seem that the country, in its attempts to foster growth and to eliminate poverty, now finds itself at crossroads between two strategies. One is the continued pursuit of the reduction of transaction costs, by fostering competition, by expanding the infrastructure and by improving the access to credit and insurance, including the opening up to international capital markets. The other would be to review the various functions that local and national government could play to complement the services that the private finds hard to deliver, and to ensure their provision by the public sector, focusing on regions with insufficient ties to migrant workers, such as the North.

In our view, the challenge would be to combine these strategies and tailor them to the institutional specificities of every region. Within this perspective, both the private arrangements such as commercial crop insurance and the public arrangements such as commodity boards are mechanisms within a safety net. Whether to operate them privately or publicly so as to make them function best is only one of the many issues in their connection. Far more important is to make sure that each of the three central components of the safety net will receive adequate attention: assuring entitlements of vulnerable groups and premium collection, managing stocks, and prompt delivery (in cash and in kind) during crisis.

As we concluded in the previous section, the setting up of new safety nets in rural West Africa seems very much needed, especially in the northern parts. Nevertheless, it is worth noting how complex becomes the coordination of the three components, once passing from the traditional village and extended family safety net framework to a national or regional one. Every component not only requires experienced and trained personnel but also a tight interconnection between the other two components of the safety net.

The present section discusses recent proposals and attempts to adapt classical market based insurance arrangements so that they can play a role in creating safety nets for the rural poor. In terms of the three components of the safety net, the new tools basically aim to enhance the entitlement of the poor, especially because the arrangements proposed and piloted so far are almost exclusively funded from donors. Consequently, this insurance in fact becomes a largely foreign sponsored public operation, with some involvement of farmers who might be able to contribute in good years and a role of private insurance companies at the stage of execution. Before turning to the specificities of these new tools, we briefly review their potential role in safety nets.

First, both local and national government have a role to play. We have seen that a crucial role in any safety net is assumed by the person or institution in charge of the operation of the stock. In the village, we have seen that the chief's legitimacy derived from his capacity to effectively manage the stock. Similarly, a governmental institution that is able to effectively manage a trust fund that pays out during a severe shock, self-legitimizes itself as a safety net (Goldsmith, 2001). Therefore the process of choosing and appointing trust fund managers is crucial and has strong political implications. It is commonplace to note that even the most market-oriented development

strategy will need effective government authorities to protect property rights and more generally to enforce the law. To operate without undue repression, these authorities need to gather public support. This will be easier for them if they are in a position to provide a range of public services beyond law enforcement. Of course, abuse of power is looming large but this risk has to be weighed against others, such as the collapse of local governance. In other words, specialisation is part of the development process, also when it comes to providing public services and social safety. At early stages of development, local government should not be forced to specialise too much, since this will tend to raise the transaction costs. In short, improving of the entitlements of the poor through some form of insurance should not be the exclusive responsibility of foreign agents, not even of national government.

Second, regarding the funding of the entitlements, issues of solidarity among the policy holders have to be taken into consideration. Differently from the village case, in which the social control and chief authority avoided the evasion, the premium-levying process is rather laborious. In general, West African governments have limited authority and lack operating facilities to impose and collect premiums. Quite often, the premium quantification is problematic in itself since it requires delicate political economy decisions. Specifically, if the safety net is required to be self-financing, it becomes crucial to define the contributors' pools. The more the pool will be broad and mix different risk profiles, the more affordable will be the premium.

However, this involves implicit transfers from the relatively rich to the relatively poor segments of the population, making it necessary that those less exposed to risk show solidarity with those more exposed. On the other hand, if the pool is restricted to risk profiles that are very similar, the premium for poor population groups increases and becomes unaffordable, unless the safety net can resort to subsidies from an external fund. In poor regions such as Northern Ghana, where good years generate insufficient surplus to cover for the bad ones, it may be expected that local self-financing is impossible.

Hence, for an arrangement to make a serious dent on poverty, significant subsidies will be required to supplement premiums, financed from the national budget as well as from foreign aid, implying that central government also has a role to play, and needs to receive adequate political credit for its contribution. Despite these subsidies, modest contributions from the local beneficiaries themselves should be required, partly to expand the financial basis of the arrangement but mainly to promote the cost-awareness among the participating farmers, and to reduce their tolerance for abuses.

Third, we briefly consider some issues at stake in the storing activity of a safety net. Typically, in a monetized economy, one would create a public-private managed trust fund and the most convenient way to preserve its reserves would be to keep them in a savings account, possibly in an international traded currency if the own currency is considered weak. Moreover, to increase the returns to the fund, one could invest part of it though one should keep in mind that the risk and the liquidity of the portfolio chosen must preserve the fund's capacity to promptly respond to a major shock. By the same token, and given the risk of an entitlement crisis described below, it would also be opportune to invest part of the fund in food stocks and put these as much as close to critical areas, to facilitate logistics during droughts.

Finally, and most importantly, there is a host of issues regarding entitlements and promptness of delivery during crisis. In a poor economy as in Northern Ghana, food is the keystone of the safety net as households spend more than 80 per cent of their income on food, of which about half derives from home produced cereals (GSS, 2000). The prompt provision of sufficient food to all after a crop failure is not an easy task. Not only might the reaction time be too long, but also the aid might be protracted beyond the period that the situation is critical (Syroka et al., 2006). Successful safety nets are characterized by their attractiveness in situation of crisis. Putting in

place a permanent safety net that can quickly respond to shocks could reduce the delay in the intervention and the costs of assessment and implementation typical of onetime operations. In this connection it may be noted that the World Food Program is currently exploring the possibilities to complement the traditional appeals-based financing by some forms of index-based financing. The promptness of index-based payments could improve the timeliness of emergency relief. For the case of Ethiopia, the time gain has been estimated to be four to five months (Gentilini, 2007).

In connection with the entitlements, we may recall the seminal contributions by Sen (1977, 1981) on the Bengal famines. In the region, floods occur every year, and are, therefore, built into the social fabric. However, in 1974 they lasted exceptionally long, and, governance was not yet well established as the country had just become independent two years earlier after a war, and very short of funds and expertise. Because of the floods, the field work was postponed, leaving many landless labourers who used to be paid in kind, without livelihood (Ravallion, 1987). At the same time, prices rose due to expectations of a poor harvest, which did not materialize as, partly thanks to the floods, paddy yields came out to be even higher than in the preceding and following years. This phenomenon was not well understood at the time by the donor community, which delivered massive food aid in kind that the poor were unable to buy.

While the situation would be quite different after a drought in Northern Ghana, the common elements remains that the key factor in avoiding famine would be to guarantee that the poor have sufficient purchasing power to acquire food. In Bangladesh the problem was that the poor lacked the cash to buy, and the employment to receive food in kind, while there was sufficient food available physically. In Northern Ghana, after the prolonged drought in 1983, physical availability became critical. Since most of the people produce for subsistence, the number of trucks and packing animals available in the area was commensurate with the usual flows of cash crops that leave the region, which were very small. Since the population had no means to buy food anyway, transport had not become scarce. However, with a region-wide and timely provision of income entitlements to all (small) farmers the situation would have become very different, and given the modest means of transport, cause staple prices to rise sharply.

As a result, a classical entitlement crisis would have come about, with those covered by the insurance getting the food available, while the people not covered by the arrangement would run the risk of disproportionate destitution. Conversely, after a bumper crop resulting from very good rainfall, prices might drop, leaving the farmers unable to contribute any premium but as mentioned earlier, this lack of self-financing may be less of an issue. Hence, to avoid an entitlement crisis occurring after a crop failure, the food deliveries should be managed as well as the cash indemnification.

It might be that private traders are best equipped for these stockholding and transport operations, but their commercial considerations make them less interested in taking precautions for rare events, unless public authorities subsidize them in maintaining strategic stocks of both commodities and vehicles. This confirms the need for co-ordination by local authorities and illustrates in another way that in a situation of underdevelopment the provision of safety nets, is a task that cannot be left fully to specialized agencies, private or public. Using Sen's terminology, safety nets that fail to account for shifting exchange entitlements might over-pay some categories and leave out others.

Be this as it may, there is definite merit in designing policies to provide cash entitlements of the poor under adversity, though one should be aware of the risk of an entitlement crisis when rolling out such an arrangement over a large region. In the mean time, pilot at smaller scales seems appropriate, since the problems of a prompt and inclusive delivery to all do not play a major role. Therefore, in the remainder of this paper we abstract from this issue, and focus on provision of cash entitlements through insurance, with some attention to the financing from

premiums. The issue is basically to find a way in which these cash entitlements can be modulated across farmers so as to meet their needs optimally, and with the lowest possible cost of implementation.

Individualized insurance

Markets for formal insurance and reinsurance are grossly underdeveloped in West Africa. Besides the classical reasons for market failure of asymmetric information and covariate risk among participants, both particularly prominent in rural Ghana, the lack of effective legal systems to enforce formal contracts severely discourages such arrangements (Barnett et al., 2006). In addition, monitoring costs are high, because of the large number of small farmers and the differences among them, making it costly for a commercial insurer to assess their risk profiles (Hazell, 1992). In response, the insurer will attempt to diversify the portfolio of policy holders, to maintain high financial reserves and to show a careful strategy towards new clients, focusing mainly on large commercial farms. At any rate small farmers generally lack the liquidity to pay the premium ahead of the harvest, and at harvest time have many ways to avoid such payments. In short, transaction costs of commercial insurance are often high and prohibitive.

Government sponsored financial institutions and marketing boards generally operate differently. They have a much wider clientele, including small farmers, offer standard packages combining fixed output prices with input and fertilizer subsidies, operate often on a crop specific basis and are inflexible in a number of respects. They though generally have a record of poor recovery rates. For a variety of reasons and in a variety of countries, publicly owned institutions providing agricultural insurance have deliberately moved beyond the boundaries of insurable risks and commercially viable insurance. Operating multiple peril crop insurance schemes contain a lot of uninsurable elements and include risks that are expensive to insure. Without exception, the indemnity payments of the evaluated schemes exceed the premium by far, entailing large costs for the government that eventually covers the loss[1].

Skees et al. (1999) list desirable features of crop insurance schemes. They should (i) be affordable and accessible to all farmers,(ii) compensate for catastrophic income losses so as to protect consumption as well as debt repayment capacity, (iii) be practical in implementation, (iv) be provided by the private sector with limited subsidy, and (v) minimize moral hazard and adverse selection. In fact, a scheme that satisfies these conditions would offer an ideal entitlement mechanism, provided it can disburse quickly enough in critical situations, and as mentioned earlier is not crippled by shortages in the physical sphere and can mobilize the necessary subsidies. Indeed, its mixed private public-nature will be helpful in avoiding misuse as customers will resent malpractices on funds they contribute to.

[1] For example PROPAGRO in Brazil, INS in Costa Rica, CCIS in India, ANAGSA in Mexico, PCIC in the Philippines and FCIC in the USA. Subsidy rates range from over 25% in the USA to around 80% in Mexico.

4 Index-based insurance for poor farmers

Index-based insurance is an attempt to design schemes that meet the listed features. It writes contracts against a specific index that depends on agreed upon variables recorded at certain locations, as opposed to individualized contracts that write against an assessed loss at the individual farm level. This decoupling from individual damage has several advantages: absence of moral hazard because indemnification payment is independent of individual performance; low cost because contracts are standardised and not individualised; potentially interesting for private insurers; possibly subject to reinsurance on international capital markets.

The most common examples of index-based insurance are arrangements triggered by the recorded rainfall at a weather station falling below a certain threshold, or, by the price at a local market, a port or some other relevant (international) exchange falling below a floor level. In case both weather and prices have to be accounted for simultaneously, some more elaborate schedule, in fact a function, has to be constructed that can generate indemnification payments under various possible price and weather conditions.

As indicated, index-based insurance focuses on providing cash entitlements. To be effective in this respect it has to overcome the problem of possibly high basis risk. Basis risk is the risk that cannot be eliminated through the arrangement. It arises because the indemnity payments triggered by the index cannot exactly match the actual income shortfalls faced by individual farmers. This basis risk might be particularly large when the payment predicted by the index underestimates the actual damage (Goodwin and Mahul, 2004; Barnett et al., 2006). This occurs for three reasons. One is that the index variables (rainfall and prices) are common to all farmers in a region and can, therefore, not address idiosyncratic shocks that affect individuals separately. A second reason is that these variables by themselves cannot represent all fluctuations of even the collective of farmers in a particular region. A third reason is that the indemnification schedule itself may not sufficiently match the income variability. This is the aspect we will focus on below. Finally, the arrangement can be costly and result in a wide gap between premiums collected and indemnifications paid .When basis risk is too high, insurance becomes unattractive to farmers.

Basis risk arises since indemnity payments triggered by the index cannot exactly match the actual income shocks faced by individual farmers. Hence, insurance might loose its attractiveness if basis risk is too high. Aggregation of the index over time and space may offset some of the basis risk. Conversely, spatial basis risk is less in size for producer associations and agro-industries, relative to individuals due to aggregation (Varangis et al. 2002; Glauber 2004). Even if basis risk is sufficiently low the insurance should be affordable. Actuarially fair premium rates, calculated on the basis of the frequency distribution and the trigger of the index, imply different rates of protection and the combination of the protection offered and individual risk aversion determines willingness to pay.

High levels of covariate risks improve the attractiveness of index-based insurance for the insured, but are potentially troublesome to the insurer because of the large imbalances between the payments during a crisis and the premium collected in that year. This is particularly troublesome in the initial stages of the arrangement when accumulated stocks are still small. The insurer may overcome this be diversifying its portfolio, by offsetting its risk position on the international re-insurance market or by hedging risks with financial instruments. Skees and Barnett (1999) propose the use of bonds and options for that purpose[2], while Skees et al. (2005)

[2] Contingent funding is feasible by selling catastrophe bonds (CAT bonds): if a specified natural disaster does not occur, investors earn a high interest and retain their initial investment. However, in the event of the disaster, investors have a zero return and possibly lose some of their initial investment.

explore the potential of global risk sharing by segmenting and layering weather risks in developing countries.

Rainfall insurance contracts constitute an important category of index-based insurance contracts. They are written against specific rainfall outcomes recorded at a local weather station. In a simple form, they offer indemnification once the rainfall in a specific month has fallen below a critical level. Of course, the contract must be written before season-specific information about the insured risk becomes available. Insurance companies may offset their risk exposure on international weather derivatives exchanges. Weather derivatives are essentially index-based options, the value of which derives from an underlying index that is determined by agreed upon variables measured by an agreed upon third party.

Naturally, rainfall insurance requires adequate measurements to take place on a sufficiently fine geographical grid and over an historical record of sufficient length. Fortunately, this is not a limitation in most African countries. Reliability of these measurements is important for the specification of the schedule itself, to secure observations in the future needed to trigger the payments, as well as to convince participants that the data on which indemnification will be based are truly objective.

Several studies report on the practical feasibility of specific index-based insurance contracts – both for price risks and weather risks – and investigate start-up and implementation of pilot schemes. Studies include natural rubber in Thailand (Gilbert et al. 2001), coffee in Kenya, Ethiopia, Uganda, Tanzania, Zimbabwe (Gilbert et al. 2002), cereals in Morocco (Skees et al. 2001), various crops in Mexico (Skees et al. 2002), various crops in India (Kalavakonda and Mahul, 2005; Veeramani et al., 2005; Zant, 2007), cocoa in Ghana (Sarris, 2002) and maize in Malawi (Hess and Syroka, 2005). Most of index-based insurance schemes address either production (yield) risk or price risk, and aim at a specific crop. This may in fact accentuate the variability in income, whenever price and yields are negatively correlated. Hence, an index-based should treat both in combination.

Indeed, reviews of revenue insurance indicate that it is not easy to piece together an index function that predicts well actual individual damages at the farm level, especially when the damage is defined as the shortfall of income below the poverty line (Mahul and Wright, 2003; Barnett et al, 2006). The fact that poor farmers' remain reluctant to buy index-based insurance, despite significant subsidies often offered on the premiums would seem to suggest that this might be a very practical problem. One reason might be that based on the indemnifications paid so far, they consider the basis risk relatively high under the proposed schemes, another that they do not see how the current participation by their neighbors could ever overcome the problems of covariate risk they so often faced under mutual insurance arrangements.

Nonetheless, if an index function with good predictive capacity could be designed, index-based insurance becomes an attractive option for creating safety nets and an attractive alternative for individualized insurance. Furthermore, the index-based insurance is transparent for policy holders in the sense that indemnity payments are not individualized. Therefore, we now focus on the task of defining and estimating a scheme for cash entitlements that for a given set of index variables may minimize the total basis risk of participating farmers, while meeting the budgetary restrictions following from their limited willingness and capacity to pay premiums and given availability of donor funds.

The scheme that we will propose below will be innovative from different points of views. Aware of the profound skepticism of donors and scholars for mechanisms purely based on public funds and operating in a non-transparent way, the scheme will combine efficiency and transparency with effectiveness in reducing poverty. To do that, we blend elements coming from

the index insurance experience with that on public safety nets. To remain sustainable over a prolonged period, a safety net should, besides addressing the problems of moral hazards and adverse selection, be interesting to farmers in its own right. For this, the indemnification schedules should on the one hand be kept sufficiently flexible to fit farmers' needs, and on the other apply to a pool of farmers willing to share risk with others having different risk profiles. Therefore, the design of a scheme will require the average income in a pool plus the net subsidy to equal at least the insured minimum income.

Consequently, an insurance against poverty for farmers who are structurally below the poverty line can only work in a pool that also comprises relatively rich farmers, or requires some financial support. For the proposed scheme, the premium, paid for example just after the harvest, will be such that the deficit is covered by a subsidy. Along these lines, we will let all farmers contribute to the scheme and have an incentive in monitoring the way in which the collected funds are administrated but at the same time, we will render it sufficiently inclusive to bring in also those who can afford only part of the premium. By the same token, if in a certain group to be insured all farmers fall below the poverty line, even in the most favorable year, then the group is unable to pay any premium and entirely depends on subsidies.

The capacity to include also those who cannot afford the full cost is an improvement over current practices in index-based insurance. Besides helping relatively rich farmers in smoothing their consumption and coping with risk, we will let the scheme act as a redistributive mechanism that enables farmers to escape from poverty, all this of course within the limits set by political realities.

On the storing side, we draw upon pre-existing experiences trying to combine the experience of insurance with that of food aid. The scheme considers a monetized premium and payments scheme and a liquid stock, also expressed as a monetary value. Nonetheless, one might also think of the premium, storage and payments as a combination of money and in kind. For example, for logistic reasons, a prompt response to disaster might require that part of the funds of the safety net is kept in the form of local food stocks. Similarly, putting part of the stock under the control of local authorities triggers a closer involvement of the premium payers, which might be necessary to get their support to the safety net.

Regarding the distribution function of a safety net it is worth mentioning two relevant aspects. The basic idea of index-based insurance is to condition indemnification on quickly assessable variables that are exogenous to farmers and insurers' decisions but sufficiently correlated with farm income, crop revenue or another component of farm income, nonetheless. Indeed, an index-based safety net offers the advantage that it enables insurers to operate on the basis of a limited set of data when monitoring and, thus, costs are reduced as well as the need of a complicated bureaucratic structure. At the same time, since the monitoring process is rapid and relatively cheap, the distribution of money and goods to those entitled can be quick as should be the case in the spirit of safety nets.

At the same time, on the side of the beneficiaries, the process of indemnification payment is simplified and can be checked reliably since the value of the anchor variables is published by third parties. For example, from the amount of rainfall at a particular station and the prices at a particular market, farmers could look up what will be their indemnity payment. This accessibility of the relevant information can be an important means to encourage the bottom up process of verification of entitlements.

Theory

Having discussed the relation between safety nets, individualized insurance and index-based insurance at some length, we can now turn to the relation in a more formal way. We use the risk-minimization framework developed in Keyzer et al. (2007). In particular, we consider the design of index-based crop insurance for farmers whose main risk is that income falls below a pre-specified poverty line. First, we characterize their ideal individual indemnification schedule, self-financed for those whose expected income exceeds the poverty line and subsidized for those who experience a gap between their expected income and the poverty line. Next, for a given set of agreed upon index variables, we discuss the capability of index-based insurance to fit the farmers' ideal individualized indemnification schedules, while retaining the required level of self-financing.

Consider an ideal insurance for an individual farmer. The premium that he has to pay is denoted with the non-negative scalar τ, and the gross indemnity payments of the insurance is denoted $y(\tau,\varepsilon)$, depending on the premium and on uncertain events ε. Additionally, we define the poverty line $\underline{r}$ and the income of the farmer $h(\varepsilon)$ $0 \le h(\varepsilon) \le \overline{h}$ with $\overline{h}$ being the income in the most favorable situation. Then, the gross indemnity needed to supplement farmer's income in case an event brings his income below the poverty line equals:

$$y(\tau,\varepsilon) = max[\underline{r} - h(\varepsilon) + \tau, 0] \,. \qquad (1)$$

Accordingly, insured income is defined as the income after payment of the fixed premium and receipt of an indemnification, when positive:

$$r(\tau,\varepsilon) = h(\varepsilon) + y(\tau,\varepsilon) - \tau \,. \qquad (2)$$

Clearly, $r(\tau,\varepsilon) \ge \underline{r}$ and the insured income under this arrangement will never fall below the poverty line. However, this is for given premium and the question arises whether the arrangement is self-financing. To answer this question we note that, for the insurer, the arrangement yields losses $[y(\tau,\varepsilon) - \tau]$. By definition of the indemnity payments these losses are bounded by the premium on the lower side and the income needed to reach the poverty line plus premium, on the upper side, or $-\tau \le [y(\tau,\varepsilon) - \tau] \le \underline{r} + \tau$. A positive value indicates that an event leads to an income below the poverty line and hence to an indemnity payment exceeding the premium $y(\tau,\varepsilon) > \tau$. Conversely, negative values will mostly correspond to the absence of claims $y(\tau,\varepsilon) = 0$, though may also reflect a relatively small claim $0 < y(\tau,\varepsilon) < \tau$ in case income is above the poverty line, but the payment of the premium would lead to poverty.

In order to make the arrangement self-financing its expected loss, defined as:

$$F(\tau) = \int y(\tau,\varepsilon) g(\varepsilon) d\varepsilon - \tau \,, \qquad (3)$$

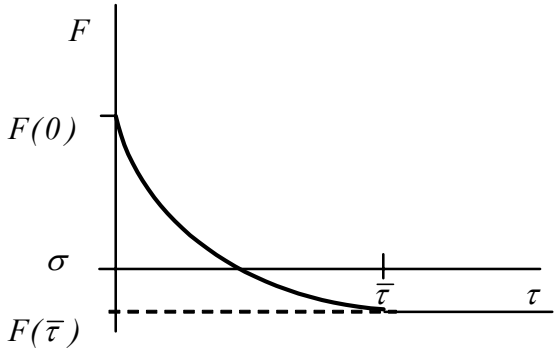
must equal zero. In other words, when $F(\tau) = 0$, the premium is actuarially fair and suffices to cover the expected indemnity payment. More generally, the financing might involve an exogenously given net subsidy, denoted σ, and the arrangement should satisfy:

$$F(\tau) = \sigma \,. \qquad (4)$$

If $\sigma = 0$, the constraint implies that the insurance is entirely self-financing. The situation that $\sigma > 0$ corresponds to a subsidized insurance with the subsidy σ possibly covering implementation cost or part of the expected indemnity payment[3].

The expected loss is illustrated in *Figure 1*, where $\bar{\tau} = max(\bar{h} - \underline{r}, 0)$ is the premium that the farmer could pay when his income would be at its maximum $\bar{h}$

Figure 1: Expected losses and self-financing of insurance against poverty



Next, we allow for solidarity through risk pooling among policy holders but still deal with ideal market insurance in the sense that every insured farmer holds a fully individualized contract. To represent this, we distinguish groups indexed *i*, consisting of N_i individuals with per capita income profile is $0 \le h_i(\varepsilon) \le \bar{h}_i$, poverty line is $\underline{r}_i$, and premium τ_i that provides access to indemnification $y_i(\tau, \varepsilon)$. The premium is set as a flat premium per hectare τ, equal across groups, implying a differentiation of the per capita premium $\tau_i = \gamma_i \tau$ in accordance with per capita farm size, denoted $\gamma_i > 0$. The indemnification profile is now

$$y_i(\tau, \varepsilon) = max(\underline{r}_i - h_i(\varepsilon) + \gamma_i \tau, 0), \tag{5}$$

and leads to the deficit for the insurer:

$$F(\tau) = \sum_i n_i \left(\int y_i(\tau, \varepsilon) g(\varepsilon) d\varepsilon - \gamma_i \tau \right), \tag{6}$$

where $n_i = N_i / N$ is the share of group *i* in risk pool $N = \sum_i N_i$. This deficit is to be covered from the subsidy, as in (3). To compute the ideal individual insurance we will approximate the distribution of events by equi-probable states of nature indexed $\ell = 1, ..., L$, as described by a historical record. We remark that the arrangement assumes solidarity in the sense that belonging to a household *i* with a particular household size and farm size is thought of as part of the risk. Hence, events comprise all states ℓ for each *i* and, for convenience, we denote these by $s = 1, ..., S$ with $S = I \cdot L$. Sorting first by group and then by state, the double index (i, ℓ) identifies the sample index $s = (i-1)T + t$.

[3] Conversely, $\sigma < 0$ could reflect a cost or a profit $-\sigma$ attached to the implementation of an arrangement.

Letting $\gamma = \sum_i n_i \gamma_i > 0$ be the average per capita farm size in the risk pool, we can compute the self-financing premium and corresponding indemnification scheme using the discretized version of (5) and (6) and solving the following $S+1$ equations for (y_s, τ):

$$y_s = max(\underline{r}_s - h_s + \gamma_s \tau, 0) \tag{7.1}$$

$$\frac{1}{L}\sum_s n_s y_s = \gamma\tau + \sigma \tag{7.2}$$

At this point, we recall from that the discussions earlier that in Sub-Saharan Africa, even if one would disregard problems with collecting the premium and paying the claims, the ideal individualized indemnity payment is beyond reach, if only because the costs of assessing claims at the farm level tend to be prohibitive. In fact, as we have seen in previous section, this has been a main ground for developing index-based insurance.

Hence, as the final piece of the theory, we consider the design of index-based insurance products that seeks to provide indemnification on the basis of a limited set of agreed upon observable variables, denoted x and generated by the same underlying distribution of events $s = 1,...,S$. The insurance will be required to obey the same level of self-financing as the ideal insurance (7) and to be optimally adapted to the ideal, in a specified sense. For this, following Keyzer et al. (2007), we propose a flexible semi-parametric function to fit observed indemnification needs y on observed variables x appearing in the index. For given kernel function k and given parametric forms $\phi_j(x)$ the function reads:

$$f(x;\alpha,\beta) = \sum_s \alpha_s k(x_s, x) + \sum_j \beta_j \phi_j(x). \tag{8}$$

We remark that the parametric term, the second part on the right hand, could be used to represent an a priori schedule, possibly with some unknown coefficients, and the non-parametric term becomes a measure of the inadequacy (or correction) of this schedule.

At given level x of the index variables and estimates (α,β) of the parameters, the function will lead to the payment:

$$z = max[f(x;\alpha,\beta),0] \tag{9}$$

To estimate the parameters we will employ a quadratic program as in Support-Vector regression, but incremented with financing constraints. The program derives from risk minimization, where the risk is inclusive of estimation errors ξ_s that represent the inadequacy of the payment (in absolute terms) and of two terms $\frac{1}{2}\sum_s \sum_r \alpha_s \alpha_r k(x_s, x_r)$ and η, (multiplied by a factor λ and ϑ, respectively) that, together, prevent that the estimation adds a fixed effect to each and every observation, whereby prediction outside the sample would become meaningless. This then leads to a linear-quadratic program for parameter estimation:

$$\min_{\substack{\xi,\eta\geq 0\\ \alpha,\beta\\ z\geq 0}} \quad \frac{1}{L}\sum_s n_s\xi_s + \lambda\tfrac{1}{2}\sum_s\sum_r \alpha_s\alpha_r k(x_s,x_r) + \vartheta\eta$$

subject to

$$\begin{aligned} y_s &\leq f(x_s;\alpha,\beta)+\xi_s+\eta \\ y_s &\geq f(x_s;\alpha,\beta)-\xi_s-\eta \\ z_s &\geq f(x_s;\alpha,\beta) \\ \frac{1}{L}\sum_s n_s z_s &= \gamma\tau+\sigma \end{aligned} \qquad . \qquad (10)$$

The problem (8)/(10) defines a semi-parametric regression of ideal payments y_s on index variables x_s and has various distinct features. It differs from the standard form of SV-regression because of the additional constraints that deal with self-financing. This possibility of inserting constraints during estimation is essential, since it makes it possible to ensure that the proposed arrangement will satisfy financing requirements. Furthermore, other constraints could be imposed as well. In this regard, solvency constraints would seem of relevance. The financing constraints only require the insurer to meet the contractual obligations in the mean, neglecting the fact that the he should be able to pay every year from the start of the arrangement, also in case of an initial period of adversity. Thus, in its present form, we assume that the arrangement enjoys a public guarantee, either from national government or from international donors, exempting it from solvency restrictions, which could though be incorporated as limits on the cumulative payments over specified sub-samples. Likewise, restrictions could be introduced to target payments in favor of relatively poor groups or to limit net contributions of relatively rich groups.

From a practical perspective, the key feature of regression problem (8)/(10) is that the constraints are linear and the objective is quadratic and convex. This enables us to estimate the parameters of the index-based insurance numerically by standard tools of quadratic programming, as is also usual in SV-regression. Finally, regarding the likely performance of the arrangement in the future on new observations for x, the technique's capacity to learn from past events is essential. As this is a rather technical issue, we only mention two properties inherited from SV-regression. The first is that minimization the sum of absolute values of errors amounts to estimating the conditional median (Koenker and Bassett, 1978), as opposed to the conditional mean estimated by least-squares methods, which makes it less sensitive to outliers. The second property is that, under appropriate reduction of the regularization factor and the soft margin, the estimate converges strongly to the true conditional median (Takeuchi et al., 2005; Norkin and Keyzer, 2007). Accordingly, the estimation errors will provide a consistent estimate of the basis risk that is unavoidable for the given variables that appear in the index.

5. Application in Northern Ghana

Dataset compilation

A dataset of 100 representative farm households for 26 different states of the world is then compiled combining survey data (four round of the Ghana Living Standards Survey, 1987/88, 1988/89, 1991/92 and 1998/99; GSS, 1989, 1995, 2000), time series data for monthly rainfall at 40 stations throughout Ghana and of Accra-prices for all main crops (GMI, 2006; GSS, 2005). The situation faced by our representative households, thus, reflects economic and weather conditions as these effectively occurred in the country. We treat them as iid (independent and identically distributed) observations from a stationary distribution.

Agricultural income data extracted from the survey proved to be inconsistent among rounds and weakly correlated with expenditures (Keyzer 2007). Hence, to obtain the income profile of each representative household under the respective states of the world, we proceeded as follows. From the four survey rounds we derived groups based on land per capita that show, on average, homogeneous characteristics across rounds. Land per capita seems to be a good identifier when constructing homogenous groups over the four rounds since, unlike income and expenditures classes, holding size classes tend to vary little across the four rounds. Land per capita proves to be highly correlated with expenditures in all survey rounds and its distribution relates well to the expenditures distribution.

After grouping households in quintiles of farm size per capita for each of Ghana's 10 regions, we arrived at 50 representative agents. This gives class bounds that are particularly stable over the four rounds, reflecting the stability of farming systems in Ghana. Then, we linked them over the rounds. Household characteristics such as crop income, household size, and land shares devoted to each crop were averaged, by group, over the four rounds. In this way, household groups with characteristics invariant across the 26 states of world were constructed as representative agents for the decennium (1988-1998).

The transition from around 2000 farm households in the surveys to 50 representative agents amounts to a reduction in variability within groups. We maintain major information on expenditures distribution within regions and quintiles, in two ways. First, we further subdivide the groups in two sub-groups say, one relatively poor, endowed with an amount of land per capita closer to lower bound of every quintile, and one richer, with an amount closer to the upper bound. This discards all other distinctive features across households within each quintile and region, but as discussed, maintaining differences in land holding size already keeps track of the major indicator of disparity.

Second, given this split in two representative agents for every group denoted by the population fractions P_G (poverty rate based on per capita expenditures) and $R_G = 1 - P_G$ (rich), their per capita land holding is obtained as:

$$\gamma_{PG} = (1 - P_G)\gamma_{LG} + P_G\gamma_{MG} \tag{5.1}$$

$$\gamma_{RG} = P_G\gamma_{UG} + (1 - P_G)\gamma_{MG}, \tag{5.2}$$

where subscripts *L*, *M* and *U* refer to lower, median and upper bound of every group. To the new representative agents is then attributed a new population weight.

To calculate yields and crop production we extracted information on the cropping pattern from survey rounds. Farmers cultivate a selection of 18 crops[4] in accordance to regional cropping patterns that reflect climatic variation in the country with predominance of tree crops like cocoa, oil palm and plantains in the south and of cereals like sorghum and millet in the North. To obtain yield in the different states of the world, we constructed time series of regional yields from climate and agronomic data (Chapagain and Hoekstra, 2004). These data were integrated with the information extrapolated from surveys on yield variability in order to maintain realistic differentiation in cropping patterns within and between groups.

Non-crop income is the closing item of the income-expenditure account in our data base, which is essential as it enables us to account for all risk coping actions undertaken by farmers, using sources external to their main activity, through remittances, seasonal jobs outside agriculture, retail trade activities etc. Non-crop income (actually non-crop sources of financing expenditures) makes it possible to assume that the actual income profile as measured is inclusive of all other risk management strategies such as joining a mutual insurance, irrigating, modifying the crop composition.

Ideal individualized indemnification for the Northern Ghana insurance pool.

In this section, we compute the premium and the indemnification needed to avoid all income shortfalls below the poverty line over the historical record, for imaginary contribuents' pools consisting of farmers in the northern and southern parts of Ghana, respectively. This amounts to solving equations (7), which is done iteratively through a Newton-Raphson line search. The corresponding per hectare premium τ is self-financing up to a given external subsidy σ.

The design of an ideal indemnification requires the average income in a pool plus the net subsidy to equal at least the insured minimum income. Consequently, an insurance against poverty for farmers who are structurally below the poverty line can only work in a pool that also comprises relatively rich farmers, or requires heavy financial support. The arrangement considered defines an insurance pool including farmers residing in the northern regions (Upper East, Upper West and Northern).

Under this intra-regional arrangement, the premium is about 50% of the income. Actually, the average income of all farmers is slightly above the poverty line of 700,000 cedi per capita per year. In such a situation, is possible to cover the risk of falling into poverty with local resources but is politically hardly sustainable in case of an implementation. Alternative forms can be thought as for example paying on behalf of farmers part of the premium in order to lower the premium directly paid by them. Table 1 shows the premium and some general characteristics of the pool.

[4] Cocoa, Oil palm, Plantains, Bananas, Oranges, Ground nut/peanut, Pineapple, Cassava, Yam, Cocoyam, Maize, Rice, Sorghum/Millet/Guinea corn, Tomato, Okro, Garden egg, Beans and peas, Pepper.

TABLE 1: NORTHERN REGIONS: SUMMARY STATISTICS AND PREMIUM

Region	Total income	Crop income per capita	Average shortfall below the poverty line	Land per capita in hectares	% of population on National total	LGP of annual crops	Premium
Northern	830	511	96	0.54	10.3	185	384.7
Upper East	718	395	123	0.47	8.2	142	384.7
Upper West	758	577	125	0.61	4.1	152	384.7

Source: GSS (1989, 1995, 2000) and authors' calculations.

6. Estimation and results

The present section reports on the results from estimation and simulation with index-based insurance schedules designed through semi-parametric regression of the ideal indemnification discussed above on specified price and weather variables and with farm size as basis for the contract, following program (10). The software package described in Keyzer (2005) is used for computation of the estimates.

The data comprise $I = 100$ households under $L = 26$ states of nature, leading to a sample size of $S = I \cdot L = 2600$. As index variables we use the Length-of-Growing-Period (x_1), six prices (x_{2-7}) covering both cash and staple crops (cocoa, cassava, yam, cocoyam, maize and tomatoes), and per capita farm size x_8. The parametric form is postulated to be linear $\phi_j(x) = x_j$ with an additional $\phi_0(x) = 1$ for the constant.

The estimation proceeds in three steps, as in the back-fitting procedure described in Schoelkopf and Smola (2002): (i) estimate the parametric part with coefficients β; (ii) keeping β fixed, estimate the coefficients α of the non-parametric part; (iii) joint estimation of α and, as in (3.13).

To estimate a purely parametric index $\sum_j \beta_j \phi_j(x)$ we implement program (3.13) keeping $\alpha = 0$, or, equivalently, taking the regularization factor so high that the non parametric part phases out. The program now defines a weighted Least-Absolute-Deviation (LAD) estimator of the insurance(e.g. Giloniaet al., 2006) but extended with financing constraint (10), and with a provision for a soft margin (η-insensitive risk), that decomposes the error into a common term, the η-margin that avoids penalization of indistinguishable observations within a band, and the remaining idiosyncratic error.[5]

Turning to the non-parametric part $\sum_r \alpha_r k(x_r, x)$, we estimate α in (10), this time keeping β fixed. We make use of the Gaussian kernel with a window width that is 30 % of the one that is optimal under Normally distributed samples (Haerdle, 1995). As discussed in section 3, this is done to keep program (10) tractable in size, at the expense of a reduced capacity of accounting for interdependencies in the data. Yet, although reduced in number, the remaining interdependencies show a meaningful pattern, maintained nonzero kernel terms among sites with

[5] In fact, the computations use a fixed instead of a soft margin, set at $\eta = 20{,}000$. The Lagrange multiplier it appeared that this level amounts to a penalization factor near unity.

similar rainfall pattern and similar land holding size. By contrast, extending the window size above the chosen value would overstate the interdependencies, allowing for very different circumstances to co-determine the indemnification.

Recall that the level at which regularization factor λ is kept acts central lever to modulate the performance of the semi-parametric regression. Therefore, we scan over various λ-values, starting from zero upwards to find the best value. At $\lambda = 0$, we have over-fitting and maximal fit inside the sample, but the nonparametric part becomes "bumpy" with large positive as well as negative α-values, which tends to imply poor out-of-sample performance. At the other extreme, $\lambda = \infty$, we return to purely parametric regression. We eventually select a λ-value as being optimal that is sufficiently high to reduce substantially the variability and the number of nonzero α_s on the one hand, and not too high to loose the flexibility of semi-parametric function (3.11) on the other. Specifically, the path for scanning is: $\lambda(1) = 0\ ;\ \lambda(2) = \delta\ ;\ \lambda(n) = \delta 2^{n-2}$ *for* $n = 3,4,5,6,7$. The main limit f this approach is that so far, we cannot test the out-of sample robustness of our choice. Although is clear that increasing the regularization and departing from the over-fitting case (Keyzer 2007) might increase the out-of sample performance of the index insurance, we still have to test the out-of-sample performance of our index given the actual regularization. Hence, in the proceeding of the paper we plan to check the robustness by bagging over the sample and study the performance of our index insurance.

Results from estimation

TABLE 2. ESTIMATED SEMI-PARAMETRIC INDEX FUNCTION, BACK-FITTING PROCEDURE (β FIXED)

n	R2	Poverty incidence (%)	Mean of α	Std dev of α	Mean of abs. errors	Regularization term
			Uninsured case			
	-	0.63	-	-	67.123	-
			Semi-Parametric index $\lambda(n)$			
1	0.99	0.27	-12.6	4161	6.2	6.9
2	0.99	0.27	-11.3	3764	6.2	34.1
3	0.98	0.27	-5.3	560	9.1	58.7
4	0.97	0.28	-8.4	253	10.6	262.9
5	0.86	0.39	-10.5	97	39.2	319.5

Source: GSS (1989, 1995, 2000) and authors' calculations.

Table 2 shows the ability of the semi-parametric index function to adapt to the index-based insurance. Without regularization, at n = 1, the fit is very good (R^2 of 0.98) but as expected, it gradually decreases with an increasing regularization. By the same token at moderate levels of regularization, the poverty incidence is substantially lowered to around 27 per cent (column 3).

We also remark that the index function estimated at $\lambda(1) = 0$ can be given a particular interpretation. As mentioned in section 3, the results are indicative of the minimum level of farmers' basis risk of any index function based on the selected weather and price variables and satisfying the self-financing constraint. In the prevailing case, this minimum is 24,000 cedi, comprising an assumed 20,000 induced by the assumed η-margin plus an average absolute error

of only about 4,000 from the ideal indemnification payment (column 6 An even lower η-margin would definitely reduce the value further, but eventually hit the limits of the spread in *x*-values.

The table also shows how, under regularization, the mean and standard deviation of the parameters α decline significantly, reducing both the contribution and the bumpiness. At the same time, the mean absolute error (first part of the objective) increases.

In Table 3, after having selected the optimal λ-value, we report on results of the joint estimation of α and β.

TABLE 3. . COEFFICIENTS AND ELASTICITIES OF PARAMETRIC PART, FOR JOINT ESTIMATION OF α AND β (CONSTANT: $\beta_0 = 628$)

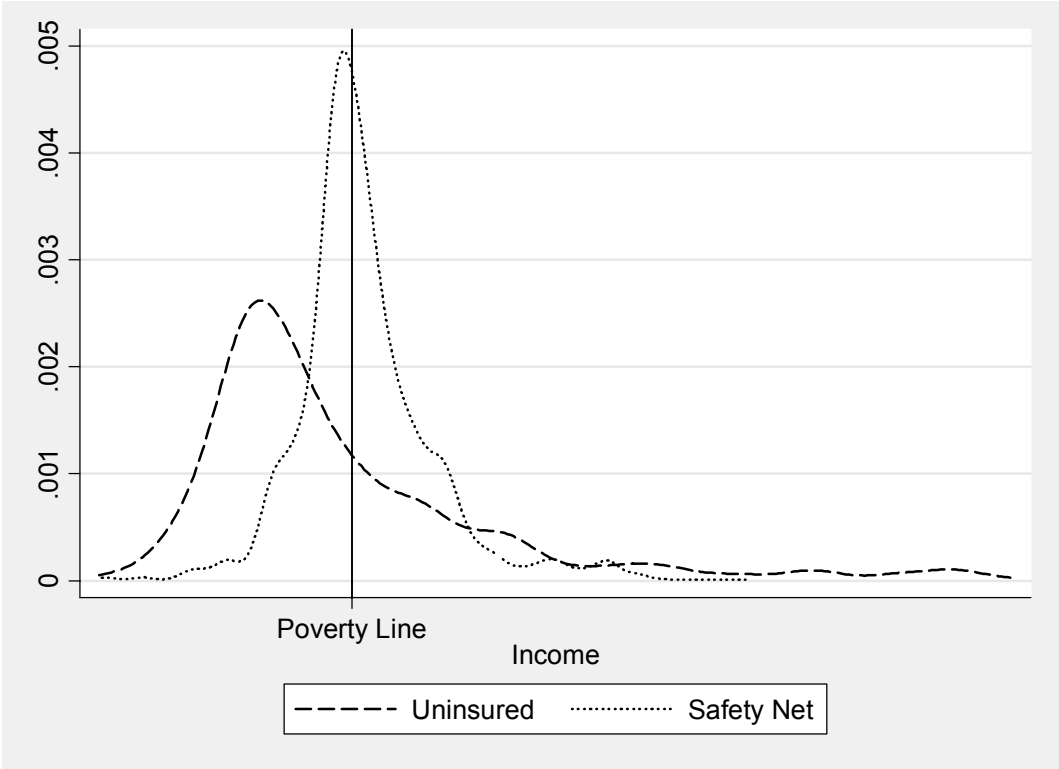
β	LGP of annual crops	Yam	Cocoyam	Maize	Tomatoes	Farm size
Effect	-0.608	-0.081	-0.054	-0.365	-0.043	-0.015
Mean	160	338	302	471	886	2753
Elasticity	1.46205	0.09	0.07	0.29	0.02	0.002

Source: GSS (1989, 1995, 2000) and authors' calculations.

It appears that the parameters have the expected negative sign, indicating that a prolonged growing season, higher prices and an increased farm size all tend to lessen the need for indemnification. As regards the magnitude of the effects, the elasticity estimates (Table 3, row 3) indicate that indemnification is more responsive to weather than to price shocks. With respect to prices, it appears that the index function is most responsive to the price of maize (elasticity of 0.29), followed by yam and tomatoes, while the price of tomatoes have less effect. This agrees with the relatively high vulnerability of staple crop producing farmers in the northern parts of Ghana. Similar results persist if we replace the maize price by the highly correlated prices of other staple crops, such as millet or sorghum.

As a further illustration of the performance under the various arrangements, Figure 2 compares the (kernel-smoothed) income distribution between the semi-parametric index function (the dotted line) and the semi-parametric index function (the dashed-dotted line). Some interesting aspects come to the fore. Comparing the uninsured case with the two index-based insurances, we see a tendency for shortfalls to be diminish significantly but obviously much less than in the ideal case, where all shortfalls are eliminated: poverty prevalence decreases (Table 2) and the depth of poverty is reduced as well, as can be seen from the narrowing of the right-hand side tails.

FIGURE 2: INCOME DISTRIBUTION BEFORE AND AFTER THE INDEX-BASED INDEMNIFICATION



Source: GSS (1989, 1995, 2000) and authors' calculations.

7 Conclusion

On the basis of a brief review of the ways in which Ghana has coped with covariate risk and managed its social safety nets in the past, we conclude that throughout the years but especially since Independence, the responsibilities and powers of the local leaders, traditionally in charge of social safety, have been eroded, while the commodity boards that replaced them have malfunctioned, and are by now largely extinct. Hence, a void is left that could only partly be filled by the rising levels of remittances from migrant workers both domestic and overseas. Northern Ghana is a particularly problematic case in point, since it is poor, receives few remittances and regularly suffers from drought.

The problem is not specific to this area, though, and has become subject of intense debate among the development community. We have reviewed the three main components of any social safety net arrangement: (i) entitlement of vulnerable households, (ii) mobilization of taxes to fund the arrangement; (iii) safeguarding the delivery of goods, and discussed their interdependencies. We emphasized the need for well-coordinated policies that can simultaneously control all three components, short of which interventions might easily become counterproductive, say, with cash entitlements from insurance causing food prices to flare up and losing all their purchasing power.

Next, we have studied the scope for application of index-based crop insurance, a modern form of insurance. in particular, its role as an entitling device that might combine elements of market efficiency, such as re-insurance of risks, and greater transparency with considerations of equity and inclusiveness. Specifically, our paper specifies an indemnification schedule for index-based crop insurance that prevents rural incomes from dropping below the poverty line.

Index-based insurance has the advantage over the individualized contracts of commercial insurance greatly that it reduces transaction costs by basing the indemnification payments on objectively and easily measurable variables, such as rainfall data collected at weather stations, and world prices of main export goods.

Our contribution is an improvement of the indemnification schedules. Rather than specifying a synthetic schedule or estimating is as a parametric form, we estimate it as an optimal indemnification that minimizes farmers' risk of having their income drop below the poverty line, while restricting the indemnification to be an unknown function of index variables on weather and prices. We adapt kernel learning technique to conduct this estimation, so as to ensure that the schedule is self-financing, up to a subsidy.

Our application is for Northern Ghana (Upper East, Upper West and Northern) where poverty is highest and farming conditions are most risky. We test the scheme's performance as a social safety net in terms of its capacity to reduce basis risk and alleviate poverty. Although our schedule definitely outperforms the parametric forms, basis risk and associated poverty remain considerable.

Regarding work in progress, we intend to assess the robustness of our estimates by applying bagging through a series of sub-samples implemented with a broader window size that explores more interdependencies in the data.

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