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Social safety nets and index-based crop insurance: historical assessment and semi-parametric estimation for Northern Ghana

by

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Abstract

Our paper considers past and present social safety net arrangements in Northern Ghana, where village communities are poor and tend to face risks that affect virtually all members and, consequently, call for safety net arrangements beyond individual and mutual insurance. After a brief review of history, we assess the possible contribution of index-based crop insurance in this respect that bases its indemnification on objectively and easily measurable variables, such as rainfall data and prices at major markets, unlike standard insurance contracts which are individualized and have much higher transaction costs. After noting that safety net arrangements should be effective, timely and well-coordinated in securing (i) entitlements (in kind, cash or as indemnification payments from insurance) for the poor, (ii) funding (through taxes or private contributions, possibly insurance premiums), and (iii) delivery of necessities such as staples to all households, we observe that index-based insurance could play a useful role in entitlement and to a lesser extent in funding but that it does not in itself provide for adequate delivery, meaning that under supply shocks such as droughts the indemnity payments could cause prices to rise and channel away scarce food from the uninsured to the insured. This is particularly relevant in Northern Ghana, where rainfall varies strongly, subsistence farming is dominant and few remittances flow in. Turning to the modalities of index-based insurance, we seek to improve on existing indemnification schedules that are commonly specified synthetically or estimated in a simple parametric form. Via an adaptation of available kernel learning techniques, we can estimate a schedule that minimizes farmers' risk of seeing their income drop below the poverty line. This schedule depends on selected index variables through a perfectly flexible functional form that maintains self-financing up to a prespecified subsidy. We test the scheme's performance as a safety net for Northern Ghana on the basis of the size of its basis risk and its capacity to reduce poverty through full sample estimation as well as bagging. Although our schedule reduces by 20 percent points the poverty incidence from an initial level of 63 percent, and proves to be quite robust under bagging, basis risk and associated poverty remain considerable, reflecting the limited capacity of the variables selected to eliminate it.

1. Introduction

Most poor households in West Africa depend on rain-fed agriculture for their livelihood and face substantial income risks of both idiosyncratic and systemic nature, due to crop failure under adverse weather conditions as well as to strong fluctuations in prices of cash crops independently from local circumstances and, therefore, failing to provide compensation for climatic variability.

Specifically, in the case of Ghana, poverty is often geographically concentrated in villages with few rich and many poor households, while the poorest regions have least access to external resources, particularly in the North (Whitehead, 2002) that remained dependent on rainfed agriculture whereas the rural areas in the South developed more off-farm activities and could mobilize more remittances from migrants.

Historically, several factors have contributed to this situation. Mounting population pressure is one (Caldwell, 2002), another is that climate change has impacted severely on the region over the past three centuries, particularly at the fringes of the Sahara where rainfall diminished and became more irregular (McCann, 1999). Current predictions from climate change models suggest an amplification of these effects (Thornton et al., 2006; Voortman et al., 1999). Furthermore, increased orientation on international markets has increased farmers' exposure to fluctuations in prices of their cash crops, and more strongly linked prices of traded crops to world markets, implying that farmers face less compensating variation in prices under variations in crop output.

At the same time, local and national government institutions are generally unable to provide sufficient protection against these covariate risks, traditionally part of their core tasks of offering security where individual and mutual arrangements fail. Originally, stockpiling of staple crops and regulated distribution at village level were the key social safety mechanisms at local level, albeit that these commonly failed under extreme or prolonged droughts. However, colonisation and subsequent independence weakened the position of the traditional village authorities and reduced their power to tax and hence their capacity to keep stockpiles for times of hardship (Baofo-Arthur, 2003). In the 1960s and 1970s state marketing boards were set up with the task 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, poor performance led to their gradual dismantling or downsizing in the 1980s and 1990s.

In reaction to the erosion of traditional safety nets based on mutual insurance (Ligon et al., 2000) and the malfunctioning of state interventions (Bates, 2005) farm households have developed risk coping strategies, mostly through rural-urban linkages that provide income from off-farm activities and from remittances, possibly from abroad. Empirical studies (Mazzucato et al., 2007; Yang and Choi, 2007) find that remittances, particularly from overseas, tend to be negatively correlated with farm income, suggesting that they are effective as safety nets. The population groups who remain without such external linkages have continued to resort to low risk farming that nonetheless suffers from crop failure now and then. Unable to generate sufficient surplus in good years, they are most prone to destitution (Dercon 1996).

At present, 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 (Adams, 1998; Dercon, 2004, 2006), also to overcome welfare losses and poverty traps caused by farmers' reluctance in the absence of safety nets to venture into riskful but on average more productive options (Elbers et al., 2007).

As arrangements that are entirely government and donor funded have been criticized for their high cost and limited success, many scholars and policy makers are now focusing on arrangements in some mixed public-private form. One promising approach that has recently been proposed and piloted as a vehicle for public-private safety nets is index-based insurance, in which poor farmers are offered a subsidized contract that supplements their income in case of adverse price and weather conditions (Skees et al., 2005). Clearly, this can only be part of the answer, as income per se will not ensure that the necessary supplies will be available where they are needed. Under drought, unless local supply levels are maintained through inflows of goods, compensating price rises will to a large extent neutralize the net indemnity payments of any insurance with wide coverage.

Against this background, our paper discusses the possible role of index-based crop insurance as component of a social safety net arrangements in Northern Ghana, and develops a case study to obtain an adequate indemnification schedule for this purpose applicable at an initial stage, when the fraction of farmers covered by the insurance is too small to have price effects, or, alternatively, under the assumption that another agency assures adequate provision of goods at local level.

The paper proceeds as follows. Section 2 provides some historical background on safety nets in Ghana. Section 3 reviews the conditions for safety nets to function properly, while section 4 discusses how crop insurance – the indexed-based crop insurance currently piloted in particular – could make a useful contribution in this respect. Section 5 describes briefly the adaptation of kernel learning techniques proposed to design risk minimizing index-based insurance whose indemnification is estimable through semi-parametric regression. In section 6, focusing attention on farmers in Northern Ghana, we compute their ideal individualized insurance. In section 7, we apply the proposed technique to estimate an index function that depends on a few selected price-weather variables and that is as close as possible to this ideal. We also conduct bagging and parametric variations to assess the stability of the function estimates. Section 8 concludes.

2. Brief history of safety nets in Ghana

Until the 16th century, climatic conditions in Ghana were particularly favourable for agriculture and there is little evidence of exposure to droughts or prolonged dry periods (McCann, 1999). The 1000 mm rainfall isohyte, which defines the border between savannah and woodland-savannah, passed through present Northern Burkina-Faso indicating that rainfall in Northern Ghana was adequate. This 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 patterns (Nicholson, 1979; Webb, 1995) 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 into 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 these 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 time that slavery was abolished.

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 by 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. In the meantime the Ashanti Kingdom developed and 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 could be cultivated permanently. The remainder was kept under crop rotation (Speirs, 1991). 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), without payment of tribute to higher level authorities (Sutton, 1989).

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 claims 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 absence of co-ordinating authority and the competition for scarce resources, including slaves, created persistent political instability, with villages and clans permanently challenging one another (Dickson, 1968; Kusimi et al., 2006). In the last two decades of 19th century these struggles worsened through the Anglo-German political rivalries in the area. It was not until the emergence of Britain as the dominating power that the situation stabilized 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. Actual executive power largely resided with local chiefs, often in conflict with one another. Since these chiefs were also blamed to have collaborated with the colonizers (Addo-Sowatey, 2005) they were too weak to resist the new leadership's reforms that, inspired by the experience of Soviet Union, chose to concentrate the economic and political power at national level so as to promote growth and economic integration. Chiefs were deprived of their powers of taxation, and, consequently, lost most of their capacity to provide social safety nets (Baofo-Arthur, 2003). At the same time, cities developed rapidly, particularly in the Middle and South, due to the population pressure and the mirage of urban life. Gradually migrants asked for less chief protection in case of hardship.

In the spirit of central planning, the leadership 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 power over domestic purchases and exports, and kept buffer stocks, buying up surpluses at floor prices and selling stocks at ceiling prices, supported by variable export tariffs. Besides absorbing price shocks from the world market and serving as source of government revenue, the Cocobod offered a (partial) safety net for cocoa farmers by purchasing cocoa beans at floor prices, thereby replacing traditional chief-controlled systems.

However, over time, the Cocobod became ever more ineffective as it acquired the classical inefficiencies of a monopolist, with rising staff numbers on its wage-sheet, decreasing service levels and mounting corruption (O'Mara et al., 1990). 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. Moreover, 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 the agency did not monitor social needs.

In response to this malfunctioning, 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, producer prices increased and the 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 (Teal and Vigneri, 2004). 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, while the Grain Warehousing Company sought to stabilize cereal markets through buffer stock operations. These parastatal agencies suffered from the same weaknesses as Cocobod (Wetzel and Islam, 1991), and by 1990, after 43 reforms, the minimum prices for maize and rice were abolished. 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.

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 that gave some protection against income shocks, and were at least in principle concerned with the entitlements of the population and adequate provision of staples.

Regarding entitlements, 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 central and southern regions and hardly to the poorest regions in the North.

North South divide

This strong North-South divide for remittances repeats itself in practically all aspects of economic life. Because of the greater distance from the coast and the less dependable climate there are much less export crops cultivated in the North. Historically, ethnicity also plays a role as the Akan from the South have long dominated the Mole-Dagbani in the North. Until the present day Northerners occupy relatively few key administrative and political posts, and as migrant workers in the south generally fulfil less prestigious positions. Furthermore, the north frequently finds itself divided by sometimes violent disputes between kingdoms and tribes over the control of land, which deter investments (Kusimi at al., 2006). All this is reflected in the various development indicators that consistently come out considerably lower for the north, with for example, per capita income about three times higher in the south and literacy rates at least twice as high (GSS, 2000). Likewise, infant mortality rates range from less than 50 per 1000 live births in Accra to well over 100 in the northern regions (GSS, 2004).

Consequently, the Northern part of the country is now particularly at risk, with respect to entitlements because its farmers are particularly poor, face the most variable climate, and have least access to income from other sources such as remittances, and with respect to delivery because the region lacks the stockpiles and means of transport to cushion major supply shocks without serious reductions in food consumption and price adjustments. Indeed, the famines in the early 1970s and 1980s when millions suffered and thousands died (Derrick, 1977, 1984) have not reoccured so far with similar severity, but as population pressure has only mounted since and climate change studies predict more frequent droughts in this area, it would seem that this part of the country is left unprotected, also because the traditional forms of village- and family-based safety nets have become inadequate.

3. Modern safety nets

The brief overview on provision of social safety nets in Ghana has shown that the centralization process that took place after independence and the subsequent 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, remittances from internal as well as overseas migrants have significantly filled the void but did so unevenly across the population and more in the South than in the North. Hence, several areas remain at risk, particularly in the North. When complete villages are poor and have few links with richer migrants who could help in dire times, it only takes a modest drought to cause famine in the village, unless public safety nets are being provided.

Overall, modern public safety nets programs tend to include cash transfers, food stamps, food for work programs, maximum prices and food subsidies, micro-credit, school vouchers or scholarships and fee waivers for health care services. Hence, they consist of transfers in cash or in kind that are intended to protect people from severe income shocks and to prevent both transient and persistent poverty. Furthermore, the presence of a safety net enables people to engage in more risky activities (Carter and Barrett, 2006; FAO, 2006), for farmers say, by planting riskier but also more remunerative crops, which particularly when population pressure is rising often is the only way out of poverty within agriculture (Elbers et al., 2007).

In a nutshell, the safety net arrangements should be effective, timely and well-coordinated in securing (i) *entitlements* (in kind, cash or as indemnification payments from insurance) to the poor, (ii) *funding* (through taxes or private contributions, possibly insurance premiums), and (iii) *delivery* of necessities such as staples to all households. Adequate management of each of the components is critical, and so is the co-ordination between them, and the more centralized the system the higher the co-ordination requirements become. In the remainder of this section we review major issues at stake in entitlement, funding, delivery and overall co-ordination.

Entitlement. The critical role of entitlement was brought to international attention by Sen (1977, 1981a,b) who in his assessment of the Bengal famines of 1943 and 1974 found that the major cause of starvation was lack of purchasing power rather than the lack of food availability on the market (delivery). Specifically, in 1974, floods caused a delay in planting that left the landless rural labourers without employment and hence without revenue. Indeed, Sen considers a situation where food distribution rather than availability is the key issue. As all landless labourers lacked purchasing power, mutual arrangements among them could never bring relief, and the actual problem was, therefore, lacking solidarity between farmers and labourers, and more generally, between the have and the have-not's, and hence raises the issue of funding.

Funding. The funding problem is inherent in any safety net construct. Whereas mutual insurance arrangements naturally come about among households with similar risk profiles, the range of events that creates covariate shocks is by definition wider for such a group than for a larger risk pool with a broader range of risk profiles. This is one of the basic justifications for centralized institutional arrangements. Yet, to enforce these agreements at higher level, the institutions in charge of coordinating the process have to be authoritative. While in the village case, the funding was effectively carried out by the chief as part of his overall social duties, modern West African states often lack the authority as well as the operational capacity to collect taxes. Furthermore, groups who on average receive more from these arrangements than they contribute will have to accept that the net contributors are compensated in the form of special privileges in exchange, and patron-client relations result (Bates, 2005). Naturally, funding of safety nets by foreigners has a similar effect and tends to weaken the authority of local institutions. To avoid this, governments sometimes take refuge in abstaining from adequate funding, letting money creation and associated inflation take care of the deficits.

In Ghana, these aspects of funding are strongly associated to the North-South divide and less to disparity among social classes within a region. At the same time, the North of the country is not as destitute as the landless rural workers of Bangladesh. It could in principle build up physical stocks or financial funds in good years for use in bad years, as it did in the past. Clearly, as infrastructure has improved somewhat, these stocks might be supplemented by purchases from elsewhere through accumulated funds. Yet, whether this is possible depends on two factors. The first is how much surplus the region can produce, or that is how much average income exceeds an accepted poverty line. This will be looked into in detail in the empirical sections of this paper but we mention already here that under present circumstances, the surplus from good harvests is too small for the region to reach appreciably above the poverty line, implying that even with perfect consumption smoothing it could not address the covariate shocks on its own. The second factor is whether it has sufficient stockpiling and transport capacity for timely delivery of necessities in particular of staples, to which we now turn.

*Delivery. A*fter the prolonged drought in 1983, Northern Ghana lacked food in physical sense, and international agencies, particularly the World Food Program were called in. Since the region's population largely consists of subsistence farmers, the number of traders, trucks and packing animals available in the area was only commensurate with the usual flows of cash crops that leave the region, and hence very low. Yet, as the population lacked the means to buy food anyway, trade and transport did not become very scarce but physical unavailability of food was the problem, nonetheless, and deliveries in kind would have been needed. Indeed, a prompt disbursement of cash would not have been sufficient to avoid the famine, as trade and transport constraints would have caused staple prices to rise sharply with a very limited supply response. As a result, the combination of crop failure and cash indemnity payments could have made things worse, with those receiving the cash of the arrangement getting the food available, and those not reached running the risk of disproportionate destitution. In Sen's terminology, safety nets that fail to account for shifts in the value of entitlements might over-pay some categories and leave out others. In positive terms, adequate delivery needs to strike a balance between holding of emergency stocks for immediate distribution and emergency funds for buying staples on possibly distant markets, leaving the logistics of transport and stockholding to private traders. As is well known, stocks only depreciate through spoilage while the funds when well invested can grow. Yet, a judicious choice requires accounting for price changes under emergencies as well as for the limited availability of vehicles, and the generally poor condition of packing animals after droughts. The extent to which aid in kind is needed to complement entitlement has been the source of long and still ongoing debate in the sphere of food aid (e.g. Coate, 1989) and raises the issue of co-ordination.

Co-ordination. The previous discussion already points to the need for policy makers to co-ordinate the operation of the three components of the safety net, short of which entitlement crises, or financial crises or physical shortages or gluts will occur. The co-ordination problem is especially difficult because timeliness is of essence, and delays costly, up to the point of making activation of the safety net counterproductive (Dercon, 2005). While actual funding could be phased through credits and liquidity management, entitlement and delivery obviously cannot. Disbursements should be prompt and based on a quick assessment of damage followed by an equally fast distribution of claims (vouchers, stamps, banknotes) (Syroka et al., 2006). In this connection, it may be noted that the World Food Program is currently exploring the possibilities to complement the traditional appeals-based financing and physical delivery by some forms of index-based financing. The promptness of index-based payments could improve the timeliness of emergency relief. For Ethiopia, the time gain has been estimated to be four to five months (Gentilini, 2007).

Similarly, actual deliveries cannot wait, and should, therefore, rely on adequate levels of local stockholding in tune with the stock of vehicles and packing animals available to supply a sufficiently dense distribution network with basic necessities. There obviously is also a need for overseeing these processes to avoid misappropriation of funds and goods, and, tightly connected to this, for well administered funding. West Africa suffers from serious limitations in this respect, and Ghana is no exception. Traditionally in the village, the chief's legitimacy largely derived from his capacity effectively to manage the collective stock. Villagers could see whether they were well governed and exercise some countervailing power in case of abuse. The commodity boards of the 1960s and 1970s typically operated beyond the villager's sight without such controls, and malfunctioned.

Modern safety net arrangements also need adequate supervision, and the more they operate in cash as opposed to kind, the more demanding this task becomes. In fact, it cannot be conducted without involvement of local and national government authorities. Conversely, a local or national government that fully delegates the provision of safety nets to the market and foreign donors will find it hard to maintain its authority and legitimacy (Goldsmith, 2001). Therefore, modern safety net arrangements even when they involve the private sector say, via crop insurance schemes that are largely funded by international agencies and foreign donors, cannot bypass the public sector altogether. By the same token, any such arrangements should require financial contributions from the local beneficiaries to enhance their cost-awareness and reduce their tolerance for abuses.

In conclusion, modern safety nets need to be well-balanced in their emphasis on each of the three key elements of entitlement, funding and delivery that require careful coordination, involving the private sector as well as government institutions. Over the past decade, a dedicated branch of insurance literature has developed around this question that focuses on entitlement and funding aspects. It considers offering farmers a contract that supplements their income in case of a yet uninsured adversity and that is financed partially from premium payments and partly from a subsidy. Having expressed the basic qualification that foreign funded crop insurance arrangements can at best address the entitlement aspect of the problem, to such insurance contracts we now turn, distinguishing between common insurance contracts that pay according to an assessment of the actual damage of the individual policy-holder and index-based contracts that pay according to some index supposedly indicative of actual damages.

4. Insurance in developing countries: the record so far

Markets for formal insurance and reinsurance are grossly underdeveloped in West Africa. Apart from the classical reasons for market failure related to 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, insurance providers 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 that are practically absent in West Africa. 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, and mostly work on a crop specific basis. For a variety of reasons publicly owned institutions providing agricultural insurance have in many countries deliberately moved beyond provision of commercially viable insurance. Not surprisingly, the indemnity payments of such arrangements exceed the premium by far, and losses have to be covered via the government budget.[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 as discussed in the previous section, provided it can disburse quickly enough in critical situations, 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 more strongly resent malpractices in arrangements they contribute to.

Index-based crop insurance

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 becomes independent of individual performance, low cost because contracts are standardized and not individualized, potentially interesting for private insurers and opening up possibilities for 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

[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.

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 through some funding arrangement. Although relatively simple in principle, its management is relatively demanding, nonetheless. In relation to the customers it should be able to distribute quickly the agreed cash payments to the insured people, and only to them. It should also be able to collect reliably and at low cost the premiums from them. Moreover, it should manage the funds in the meantime through re-investment, and other financial operations, possibly extending to the international re-insurance market. This is not easy, since the more covariate the risk, the more the associated total net payment position will vary across years. Also, for new crop insurance arrangements it may be difficult to obtain money as long as the fund of accumulated premiums is low, particularly there is no other collateral available.

Skees and Barnett (1999) propose the use of bonds and options for that purpose,[2] while Skees et al. (2005) explore the potential of global risk sharing by segmenting and layering weather risks in developing countries. Furthermore, the insurer can reduce the variability over time by reducing the relative share of covariate risks in contracts, involving for example producer associations and agro-industries jointly with individual farmers within a single arrangement (Varangis et al., 2002; Glauber, 2004). This can be particularly effective in situations where technological dependence of the industry on primary producers can substitute for solidarity but in general it will be difficult without government intervention to insure groups with different risk profiles within a common contract.

Besides the financial management task related to funding, index-based crop insurance also has to address entitlement aspects so as to keep as low as possible the basis risk of the arrangement. High basis risk amounts to a poor matching of the indemnity payments triggered by the index to the actual income shortfalls faced by individual households (Goodwin and Mahul, 2004; Barnett et al., 2006) and may have various causes. One may be 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 cause is that these variables by themselves cannot represent all fluctuations facing even the collective of farmers in a particular region. Finally, the indemnity schedule may not be adapted closely enough to the actual income shortfalls. Addressing these issues will be our main concern in the next sections.

Rainfall contracts

Indexing on rainfall is a common form of index-based crop insurance. Such contracts are written against specific rainfall outcomes recorded at a local weather station. In the simplest 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.

[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.

Naturally, rainfall insurance requires adequate measurements to take place on a sufficiently fine geographical grid and over a sufficiently long historical record. 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.

The record so far

Several studies have by now assessed the practical feasibility of specific index-based crop insurance in 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). It appears that most of the 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.

Generally, review studies find 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). They also note that poor farmers are reluctant to adopt index-based insurance products by poor appears limited, despite significant subsidies (see for example Bhise et al., 2007[3]).

Apart from the general lack of confidence they might put in this type of collective arrangement, often resulting from bad experiences in the past, one explanation might be that the basis risk they are left with under the indemnifications offered so far is too high. This motivates our attempt in the next sections to arrive at more flexible schedules.

[3] This study provides a rich overview of experiences of crop insurance in India since the 1920s. Currently implemented schemes cover some 80 million farmers and have an average subsidy rate of almost 70%.

5. Design of an index-based price-weather insurance for poor farmers

In this section we present an indemnification schedule for price weather insurance that provides cash payments and for a given set of index variables minimizes the estimated basis risk of participating farmers, while meeting the budgetary restrictions following from their capacity to pay premiums and given the availability of external funds.

Relative to the insurance schemes reviewed in the previous section, the proposed arrangement possesses innovative features in relation to entitlement as well as funding.

With respect to entitlement, it applies new estimation techniques to let indemnity payments adapts optimally the farmers needs. In this connection, one innovation is that we insure the income shortfall below poverty line, as opposed to insuring average income. Another innovation is that we apply special techniques to find a compromise between flexibility of the schedule in terms of its adaptation to past data, and its robustness with respect to new information.

Regarding funding, the arrangement is taken to operate within a prespecified intertemporal budget whose resources are obtained from private contributions as well as public subsidies, possibly originating from foreign donors. Obviously, the budget holds for the collective of policy holders covered by the contract. In this paper, we concentrate on a regional pool for Northern Ghana but wider pools with less covariate risk and more inter-regional solidarity can be considered as well. It assumes that all the financial management operations mentioned in the previous section are conducted well, particularly the timely provision of cash to the insured farmers and the reinvestment of the accumulated funds.

Finally, we remark that with respect to delivery, our implicit assumption will be that the arrangement does not raise any particular problem, meaning that we suppose that other institutions take care of it, or that the number of farmers covered under the insurance is too small to affect prices in the region.

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 having probability measure $g(\varepsilon)$. Additionally, we define the poverty line $\underline{r}$ and the income of the farmer $h(\varepsilon)$ $0 \leq h(\varepsilon) \leq \overline{h}$ with

$\bar{h}$ 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:

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

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

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

Clearly, $r(\tau,\varepsilon) \geq \underline{r}$ 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 $-\tau \leq [\,y(\tau,\varepsilon) - \tau\,] \leq \underline{r} + \tau$. 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:

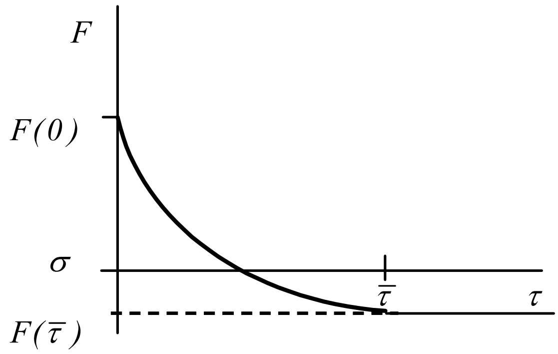
$$F(\tau) = \int y(\tau,\varepsilon) g(\varepsilon) d\varepsilon - \tau , \quad (3)$$

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 subsidy, denoted σ, and the arrangement should satisfy:

$$F(\tau) = \sigma . \quad (4)$$

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 $0 \le h_i(\varepsilon) \le \overline{h}_i$, 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 $s = (i-1)T + t$.

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 West 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 step of model formulation, 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:

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

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:

$$z = max(f(x;\alpha,\beta),0) \qquad (9)$$

To estimate the parameters we make use of 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:

$$\begin{aligned}
&\min_{\substack{\xi,\eta\geq 0\\ \alpha,\beta\\ z\geq 0}} \quad \frac{1}{L}\sum_s n_s \xi_s + \lambda \tfrac{1}{2}\sum_s \sum_r \alpha_s \alpha_r k(x_s,x_r) + \vartheta\eta \\
&\text{subject to} \\
&\quad y_s \leq f(x_s;\alpha,\beta) + \xi_s + \eta \\
&\quad y_s \geq f(x_s;\alpha,\beta) - \xi_s - \eta \\
&\quad z_s \geq f(x_s;\alpha,\beta) \\
&\quad \frac{1}{L}\sum_s n_s z_s = \gamma\tau + \sigma
\end{aligned} \qquad . \qquad (10)$$

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 (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.

6. Application for Northern Ghana

Dataset compilation

A dataset of 30 representative farm households for 26 different states of the world (780 observations) 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 10 stations throughout Northern 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 area. We treat the data as an independent and identically distributed sample from a stationary distribution.

Agricultural income data extracted from the survey proved to be inconsistent among rounds and weakly correlated with expenditures (Keyzer et al., 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 the 3 northern regions (Upper East, Upper West and Northern), we arrived at 15 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 600 farm households in the surveys to 15 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 for the 30 farm groups we extracted information on the cropping pattern from survey rounds. Farmers cultivate a selection of crops in accordance to regional cropping patterns that reflect climatic variation in the area[4]. 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 household budget in our data base, which is essential as it enables us to account for all risk coping actions undertaken by farmers, generating income sources external to their main activity. By inclusion of this item we may assume that the actual income profile as estimated 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 Ghana, respectively. Table 1 shows some general characteristics of the considered pool. To calculate the premium it requires 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.

Under this scheme, we calculated different premiums by modifying the reference poverty line. The more the poverty line increases the more are needed additional resources to bring all farmers in the pull above it. In Figure 2, we plotted the results of our calculations letting the 700.000 cedi poverty line gradually decline towards 500.000 cedi. Actually, the per hectare premium as a percentage of average income passes from being about 5% with a poverty line of 500.000 cedi to about 17% with a poverty line of 600.000 cedi and finally to 50% for the poverty line of 700.000.

In such a scenario, it would be possible to cover the risk of falling into poverty without the need of an external subsidy but the size of the premium will clearly be prohibitive in case of implementation. Yet, lowering the target poverty line and asking a lower premium shows the disadvantage of limiting the potential of the safety net. As matter of fact, calculating the ideal indemnification for a lower poverty line, say 600.000 cedi, implies that farmers will receive an indemnity payment that brings their per capita income to 600.000 cedi.

Yet, alternative designs could be envisaged should one stick to the 700.000 cedi poverty line as the distinctive welfare target. For example, we can think a mixed public and private scheme, in which government or external donors do pay part of the premium in order to lower the premium directly paid by farmers. In this way, the available amount for indemnification would not decrease but at the same time the efforts required from farmers to pay the premium would be diminished.

[4] Ground nut, Yam, Cocoyam, Maize, Rice, Sorghum/Millet/Guinea corn, Tomato, Beans and peas, Pepper.

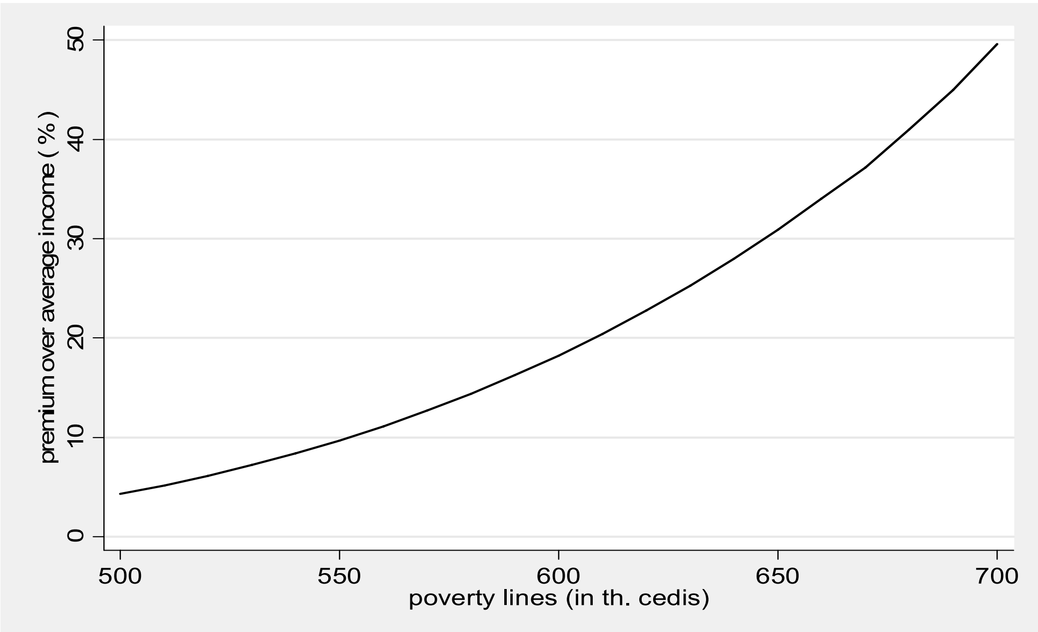
However, from a purely technical point of view, the results in this scenario do not vary as compared to the 700.000 poverty line's case. The ideal indemnification and the per hectare premium are the same, what differs is the share of government involvement and the amount of external funds to be injected in the scheme. Hence, this decision regards more the political sphere and its discussion goes beyond the scope of the paper. Going back to the methodological aspects, in the following section we used as ideal indemnification that calculated for a poverty line of 700.000 cedi, corresponding to a per hectare premium of 387.140 cedi.

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	LGP of annual crops	Percentage of farmers population
Northern	830	511	96	0.54	185	10.3
Upper East	718	395	123	0.47	142	8.2
Upper West	758	577	125	0.61	152	4.1

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

FIGURE 2: PREMIUM VARIATION AS A FUNCTION OF INSURABLE POVERTY LINES



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

7. 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 $I = 30$ households under $L = 26$ states of nature, leading to a sample size of $S = I \cdot L = 780$. As index variables we use the Length-of-Growing-Period (x_1), two prices (x_{2-3}) representative of the typical cropping pattern of Northern farmers (millet as staple crop and groundnuts as cash crops), 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 (10).

To estimate a purely parametric index $\sum_j \beta_j \phi_j(x)$ we implement program (10) 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 (4), 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 to account for interdependencies in the data. Yet, although reduced in number, the remaining interdependencies show a meaningful pattern as they maintain nonzero kernel terms among sites with 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 as 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 overfitting 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

[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.

nonzero α_s on the one hand, and not too high to lose 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* $n=3,4,5,6$. Although it is clear that increasing the regularization and departing from the overfitting case (Keyzer et al., 2007) might improve the out-of sample performance, we actually assess this performance bagging. The results from the bagging exercise already appear in Table 2 but we postpone discussion of this part of the table.

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	-	-	-	-
			Semi-Parametric index (λ^n)			
3	0.99	0.27	-8.79	7680	5.8	9.6
4	0.99	0.27	-5.67	3290	6.3	27.9
5	0.97	0.28	-0.05	68.1	14.4	12.1
6	0.91	0.39	-0.08	20.25	39.3	11
			Bagging results (standard deviation in brackets)			
6	0.92 (0.013)	0.40 (0.02)	0.142 (0.100)	57.4 (38.2)	37.4 (2.39)	11.4 (0.97)

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

Table 2 shows how well the semi-parametric index function can 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. For the same reason, 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 25,800 cedi, comprising an assumed 20,000 induced by the assumed η-margin plus an average absolute error of only about 5,800 from the ideal indemnification payment (column 6, row 5). 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, and again postpone discussion of the bagging part.

TABLE 3. COEFFICIENTS AND ELASTICITIES OF PARAMETRIC PART

β	LGP of annual crops	Groundnuts	Millet	Farm size	Constant
Effect	-0.920	-0.130	-0.210	-0.015	692.9
Mean	160	991	685	5300	-
Elasticity	0.725	0.635	0.709	0.392	-
Bagging results (standard deviation in brackets)					
Effect	-0.914 (0.2)	-0.119 (0.03)	-0.205 (0.05)	-0.015 (0.000)	680 (47.4)

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 equally responsive to weather and to price shocks. Thus, as suggested in previous contributions (Zant, 2007), the construction of a scheme based on a multiple index (price and weather) seems to work better than those based only on either of these. With respect to prices, the index function is most responsive to the price of millet (elasticity of 0.709), followed by that of groundnuts. 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 millet price by the highly correlated prices of other staple crops, such as maize or sorghum. Finally, the negative sign of land dimension indicates a certain degree of solidarity that is implicit in the scheme and by which smaller farms (those having a smaller per capita farm size) receive a higher per capita indemnity payment.

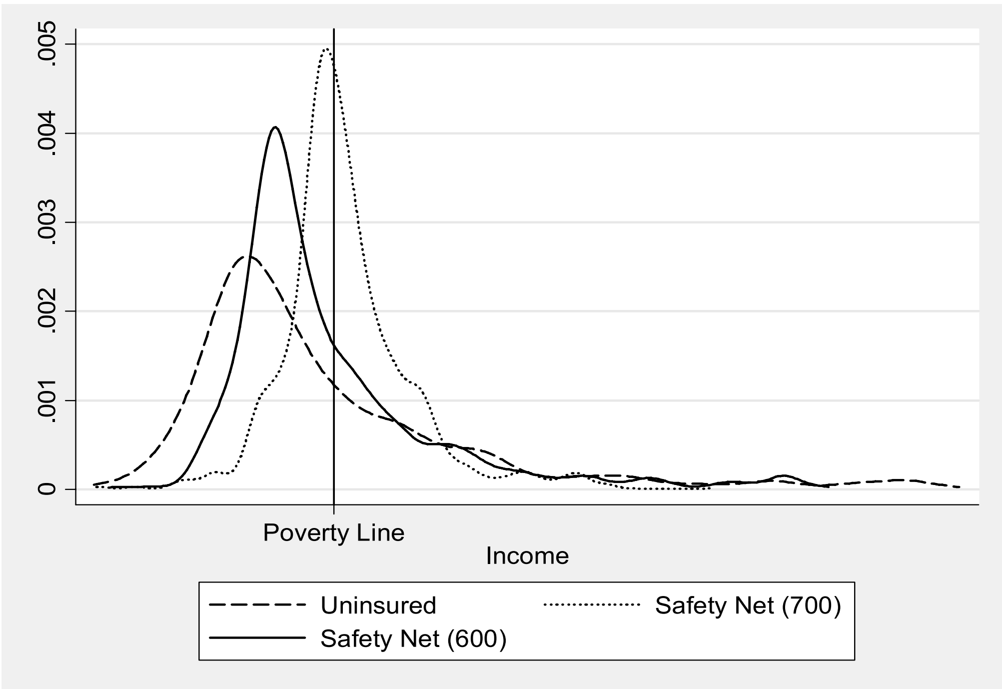
Bagging and simulation

The bagging exercise reported on in tables 2 and 3 for fixed $\lambda(n)=\lambda(6)$ proceeds as follows. Randomly selecting with replacement ¾ of observations in our sample and creating 50 random sub-samples, we estimate our index-based function and measure the variability of the findings. In both tables, comparing the results from the full sample with those obtained from averaging the results from the 50 bags, strong similarity emerges. For example, in Table 2 , the R-square, the regularization term and the poverty incidence calculated on the full sample and averaging the 50 bags differ only by 1 % or less. Moreover, the standard deviation from the mean is particularly low. In the remaining cases, the results obtained from bagging depart from those on the full sample, but the deviation stays well within the bounds of one standard deviation. Finally, the estimated effects of weather and price variables shown in Table 3 also remain practically the same under bagging.

We may also remark that the stability of these parameter estimates and of the good out-of-sample performance depend on the choice of regularization. At lower regularization, say at $\lambda(n)<\lambda(6)$, the performance deteriorates, with increasing standard deviation of the parameters and poorer out-of sample fit. Indeed, the extreme case of zero regularization (λ =0) the parametric part becomes insignificant and the simulated poverty rate becomes extremely unstable. Results not included here show that the poverty rate ranges from 0.35 in the best case to 0.63 in the worst case, exactly corresponding to the uninsured case. This confirms that out-of-sample performance can be quite sensitive to regularization, and that the issue of proper regularization is a key element of the design of an index-based safety net, particularly because in search of a low basis risk the modeller might be tempted towards overfitting.

Finally, in Figure 3 we compare the (kernel-smoothed) income distribution under two index based safety nets targeted at a poverty line of 700,0000 (the dotted line) and 600,000 cedi (the continuous line) respectively, with the case without safety net. Some interesting aspects come to the fore. Comparing the uninsured case with the two index-based insurances, we see a tendency for shortfalls to diminish significantly. The poverty prevalence decreases (see also Table 2) and the depth of poverty is reduced as well, as can be seen from the narrowing of the right-hand side tails. Indeed, the safety targeted at the 600,000 cedi line is much less capable to redistribute income since, by construction, it pays out less frequently, but has a less prohibitive premium (17% of the average income, see Figure 2).

FIGURE 3: INCOME DISTRIBUTION BEFORE AND AFTER THE INDEX-BASED INDEMNIFICATION: SAFETY NETS WITH POVERTY LINES AT 700.000 AND 600.000 CEDIS



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

8. Conclusion

Our discussion of social safety nets in Northern Ghana has pinpointed three main critical functions in safety net management that need to be carefully addressed and co-ordinated: entitlement, funding and delivery. We have seen that over the past centuries the capacity of local institutions in Ghana to provide social safety has been subject to secular decline, partly because of past climate change, partly because of political developments and urbanization that weakened the position of local leaders. In recent decades, remittances from migrants, domestic as well as overseas, have increasingly substituted for local arrangements in the southern part of Ghana but the North where poverty is high and farming conditions are most risky has benefited much less and is now left unprotected, and more explicitly so since various marketing boards have been dismantled and downsized that at least in principle had to fulfil a role in this respect. We stressed the critical importance of the delivery element, particularly in Northern Ghana, where droughts are more frequent while few stocks are kept and not many vehicles are available to distribute supplies to the needy in case of crop failure.

Next, we focused on the entitlement and funding elements, and considered the use of index-based crop insurance as component of a social safety net, while abstracting from problems in delivery. Applying concepts from the poverty reduction and social safety net literature we could generate entitlements that cover the income shortfall below the poverty line. At the technical level, the main innovations relative to other index based insurance schemes are with respect to funding that arrangement exactly meets a prespecified intertemporal budget whose resources are obtained from private contributions as well as from public subsidies, possibly originating from foreign donors. With respect to entitlement, we insure the income shortfall below poverty line, as opposed to insuring average income, and can apply new techniques to find a compromise between flexibility of the schedule in terms of its adaptation to past data, and its robustness with respect to new information. Specifically, rather than specifying a synthetic schedule or estimating it 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 and apply various sensitivity tests and bagging to assess robustness.

We have presented an application for Northern Ghana and tested the scheme's performance on the basis of its capacity to reduce poverty in terms of the basis risk remaining. Although our schedule reduces the poverty incidence from an initial level of 63 percent by 20 points, and proves to be quite robust under bagging, basis risk and associated poverty remains considerable, reflecting the limited capacity of the variables selected to eliminate it.

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