WPS7744

Policy Research Working Paper 7744

How to Measure Whether Index Insurance Provides Reliable Protection

Karlijn Morsink
Daniel Jonathan Clarke
Shadreck Mapfumo

WORLD BANK GROUP
Finance and Markets Global Practice Group
July 2016

Policy Research Working Paper 7744

Abstract

Agricultural index insurance offers the promise of an affordable and sustainable insurance product for farmers that can help reduce their vulnerability to aggregate agricultural shocks such as large-scale drought or flooding. However, index insurance provides claim payments based on a trigger that is only imperfectly correlated with losses. This implies that it carries basis risk: it may provide claim payments in years when there are no losses, and no claim payments in years when there are losses. The impact of index insurance on poverty outcomes is highly sensitive to the degree to which the product offers reliable protection. Offering unreliable index insurance may lead to high reputation risk for donors, governments, and the private sector. This study proposes to measure the reliability of index insurance in terms of two policy objectives that stakeholders may have when offering index insurance: the extent to which the insurance captures losses caused by the peril covered by the contract (insured peril basis risk) and the extent to which the insurance covers losses from agricultural production (production smoothing basis risk). For both types of basis risk two indicators are proposed: the probability of catastrophic basis risk and the catastrophic performance ratio. Donors, governments, and insurers can use the proposed monitoring indicators without much prior technical knowledge. Although the indicators specifically focus on agricultural index insurance for low-income farmers, they can be applied to any context where payments are provided based on indices that are correlated with losses.

This paper is a product of the Disaster Risk Financing and Insurance Program (DRFIP), a partnership of the World Bank's Finance and Markets Global Practice Group and the Global Facility for Disaster Reduction and Recovery, with funding from the UK Department for International Development. It is part of a larger effort by the World Bank to provide open access to its research and make a contribution to development policy discussions around the world. Policy Research Working Papers are also posted on the Web at http://econ.worldbank.org. The authors may be contacted at dclarke2@worldbank.org.

How to Measure Whether Index Insurance Provides Reliable Protection[*]

Karlijn Morsink[1,2], Daniel Jonathan Clarke[3], Shadreck Mapfumo[3]

"If you can not measure it, you can not improve it." – Lord Kelvin

JEL classifications: G22, I38, O13

Keywords: Agriculture, Index Insurance, Reliability, Basis Risk, Monitoring Indicators

[*] This paper builds on work by the Disaster Risk Financing and Insurance Program, a partnership of the World Bank Group's Finance & Markets Global Practice and the Global Facility for Disaster Reduction and Recovery (GFDRR), and the Global Index Insurance Facility, a multi-donor trust fund managed by the Finance & Markets Global Practice. Funding from the UK Department for International Development, the United States Agency for International Development, the Netherlands Ministry of Foreign Affairs, the European Union, Japan, and GFDRR is gratefully appreciated. We would also like to thank Martin Buehler, Michael Carter, Chloe Dugger, Gilles Galludec, Huybert Groenendaal, Lena Heron, Vijay Kalavakonda, Felix Lung, Barry Maher, Michael Mbaka, Olivier Mahul, Andrew Mude, Michel Noel, Fredrick Odhiambo, Sharon Onyango, Gary Ruesche, Rachel Sberro, James Sinah, Quentin Stoeffler, Andrea Stoppa, Charles Stutley, Panos Varangis, Ruth Vargas Hill, Anita Untario, Jose Angel Villalobos, and Andriy Zaripov.
[1] Corresponding author: karlijn.morsink@economics.ox.ac.uk
[2] Centre for the Study of African Economies (CSAE), Economics Department, University of Oxford
[3] Finance & Markets Global Practice, World Bank Group

1. INTRODUCTION

Despite using a variety of risk-management strategies, low-income farmers[4] in developing countries remain vulnerable to shocks. Farmers in developing countries use a variety of strategies to mitigate, transfer and cope with risk such as crop diversification, vaccination of cattle, engaging in precautionary savings, taking emergency loans or relying on transfers from others with whom they informally share risk. Despite the use of this variety of strategies, evidence suggests that the extent to which farmers are able to manage risk and insure themselves informally is insufficient to fully protect them (Townsend, 1994; Udry, 1994; Dercon & Krishnan, 2000; Duflo & Udry, 2003).

An important explanation of the inability of farmers to protect themselves is the existence of aggregate agricultural shocks such as large-scale drought or flooding. The correlated nature of these shocks implies that farmers are all affected in the same way at the same time. This limits their ability to help each other in times when it is most needed. Empirical evidence shows that the threat of these aggregate shocks causes households to engage in costly risk management activities and invest in low risk, low return production practices (Rosenzweig & Binswanger, 1993; Morduch, 1995; Carter et al., 2007). Some studies estimate that average farm incomes could be significantly higher in the absence of downside risk (Gautam, Hazell and Alderman 1994; Sakurai and Reardon 1997). The investment in low return production activities implies that households, when confronted with repeated asset losses and income shocks, remain at a low-level equilibrium, potentially 'trapping' them in poverty (Barnett, Barrett and Skees 2008).

Agricultural risk may also negatively affect low-income farmers' development out of poverty by affecting supply and take-up of credit. For credit providers the correlated nature of agricultural risks implies that expected default rates for credit provided to low-income farmers are high. In combination with asymmetric information, imperfect enforcement of credit contracts and high transaction costs, this makes low-income farmers an unattractive target group (Rosenzweig and Binswanger, 1986). Furthermore, even if credit is supplied, agricultural risk often prevents low-income farmers from taking out loans because of their preference for low-risk, low-return production practices (Dercon and Christiaensen, 2008; Giné and Yang, 2009).

Agricultural insurance offers the dual promise of protecting low-income farmers against agricultural shocks while unlocking credit and productive investments. The theoretical proposition of insurance is that it provides claim payments to cover losses in bad years in exchange for regular premium payments in good years (Barré et al., 2015). As such it may smooth consumption levels and prevent the use of harmful risk coping strategies, such as selling production assets, which have serious negative consequences for future welfare. Index insurance, through providing protection against aggregate shocks, may actually complement protection provided against idiosyncratic shocks through informal risk-sharing arrangements and thereby substantially improve farmers' ability to smooth consumption after aggregate shocks (Mobarak and Rosenzweig, 2012; Dercon et al., 2014). Second, formal insurance may

[4] We define farmers as individuals engaged in activities in agriculture, e.g. forestry, hunting, and fishing, as well as cultivation of crops and livestock production following the divisions 1-5 of the International Standard Industrial Classification (ISIC) revision 3.

change investment behavior or encourage credit uptake before shocks occur through providing protection and therefore reducing the need for smoothing income through activities that depress risk. Finally, formal insurance against aggregate shocks may protect lenders by reducing default rates and thereby unlock the provision of credit to low-income farmers (Karlan et al, 2012).

Despite the potential of index insurance to contribute to poverty reduction, index insurance carries basis risk, which may challenge the reliability of index insurance protection, especially for low-income farmers. Basis risk arises because index insurance claim payments are based on a trigger that is correlated with losses, but imperfectly so. This implies that index insurance may provide claim payments in years when there are no losses; and no claim payments in years when there are losses.

From a poverty perspective the reliability of index insurance is important because the impact of index insurance on poverty outcomes is highly sensitive to the degree to which the product offers reliable protection, especially in the cases where farmers experience severe losses (Clarke 2016).

The reliability of index insurance is also important for donors, governments, the private sector, and other stakeholders involved in offering index insurance as basis risk may lead to high reputation risk with potential severe consequences for trust in market players and more generally for insurance demand.

Despite the importance of reliable protection, especially in a context where index insurance is offered to already low-income individuals, monitoring of reliability is rarely conducted. Monitoring basis risk requires a clear operational and measurable definition, and needs to be based on the use of appropriate statistical techniques. As explained in a recent Cornell University/ILRI working paper:

> *'To date, none of the studies associated with index insurance products in developing countries offer household—level estimates of basis risk. In fact, few studies explicitly include any measure of basis risk at all. The lack of empirical attention to basis risk is especially disturbing because without it, there is no guarantee that index insurance is risk reducing. In cases where an individual's idiosyncratic risk is high or if the index is inaccurate, index products can represent a risk increasing gamble rather than the risk reducing insurance they are advertised to offer. Discerning the magnitude and distribution of basis risk should be of utmost importance for organizations promoting index insurance products, lest they inadvertently peddle lottery tickets under an insurance label.' (Jensen, Barrett and Mude, 2014: p.2)*

In this paper we discuss the reliability of index insurance and propose a set of indicators, to measure this reliability. Donors and governments can apply the proposed indicators without much prior technical knowledge. The indicators can be used to compare agricultural insurance products against a benchmark, compare one product's value over time based on changes in indicators or compare different products with each other. They could be incorporated by governments or regulators as industry standards. Furthermore, donors, governments, and insurance providers can also incorporate the indicators in strategic planning processes to improve the quality of products, protect consumers, and reduce reputational risk (Jensen et al, 2014).

The principles and indicators to measure index insurance reliability can be applied to any context where claim payments are provided based on indices that are correlated with losses, even though the discussion in this paper is specifically focused on agricultural index insurance for low-income farmers. Examples of other indices where these principles can be applied are indices that protect microfinance organizations or countries against natural disasters.

The rest of this paper is organized as follows. In Section 2 the concept of the reliability of index insurance is defined. Section 3 discusses the measurement of the reliability of index insurance. In Section 4 the index insurance reliability indicators are presented. Section 5 and 6 explain how the index insurance reliability indicators can be calculated and used, respectively. The last section concludes.

2. DEFINING THE RELIABILITY OF INDEX INSURANCE

The reliability of index insurance is often loosely defined by the term 'basis risk', which is the risk that an index insurance product does not pay when it should. As an example Table 1 provides an overview of the classification of yields and claim payments to 2,430 farmers over a period of 9 years for 270 actual index products sold across one Indian state under the Weather Based Crop Insurance Scheme (WBCIS).[5] The WBCIS was a publicly subsidized program in India that insured 9 million Indian farmers through a rainfall index. This is, to date, one of the only products for which data is available. As we can see 75 farmers experienced a bad yield while receiving no or an insignificant claim payment. This is called downside basis risk. 801 farmers received a significant claim payment while have a good yield, which is called upside basis risk. The term basis risk has its foundation in the derivatives market where it is defined as the risk that there is a difference between the price of the asset to be hedged (such as a barrel of oil) and the price of the hedge (such as a forward contract on a barrel of oil).

TABLE 1: CLASSIFICATION OF 'GOOD' AND 'BAD' YEARS FOR 270 PRODUCTS (1999-2009)

	Good year >30% of average yield	Bad year ≤30% of average yield	Total
No or insignificant claim payment	1,481	75	1,556
Significant claim payment	801	73	874
	2,282	148	2,430

[5] Analyzed in Clarke et al. (2012).

Even though this definition may seem straight forward, different stakeholders may have different views as to when index insurance products 'should' pay. These views are better understood in terms of the objectives of the stakeholders who are supporting the insurance products. When the objective of index insurance is to contribute to the reduction of poverty or vulnerability, such as is often the case for donors, reliability is often considered as the extent to which the index insurance protects low-income individuals against losses from agricultural production (Barré et al., 2015). From the perspective of an insurance provider, which has legal obligations and may have profit or efficiency objectives, an index insurance contract is reliable when it pays out in case losses from production are caused by the perils that are clearly specified in the insurance contract.

When people refer to the concept of basis risk, what they often refer to is what we would like to more precisely define as 'insured peril basis risk.'[6] Insured peril basis risk compares claim payments with losses from perils explicitly named in the insurance contract. It asks whether an index insurance contract is paying in years it might reasonably be expected to by a policyholder who understands the basic concept but not the small print of the policy. As such, insured peril basis risk is similar to the concept of non-performance (Doherty and Schlesinger, 1991) or imperfect performance (Mahul and Wright, 2007) and has serious consequences for rational demand for insurance from the perspective of the consumer (Clarke, 2016). This clearly raises questions about consumer literacy and consumer expectations, and the responsibility of index insurance providers to manage these, especially when index insurance is offered to a low-income target population with low levels of financial literacy. Insured peril basis risk provides a good reflection of the extent to which the index is actually capturing the share of the losses in production that are caused by the insured peril mentioned in the contract.

Index insurance is especially useful for protection against progressive perils,[7] such as drought and flooding, where the impact on losses gradually builds up over time and is difficult to isolate from the effect of other perils and management related factors. Insuring an independently verifiable index based on rainfall or average losses provides a way to insure against a share of the losses. Insured peril basis risk reflects the extent to which the index insurance product actually captures losses caused by this particular peril. For example, imagine a rainfall index insurance covering rainfall deficit and consecutive dry days based on rainfall recorded at a local weather station that covers an area with a radius of 5 kilometers around the weather station. Insured peril basis risk refers to the extent to which rainfall deficit and consecutive dry days actually capture the effect of rainfall on crop production, and the extent to which rainfall experienced by farmers within the 5 kilometers radius is adequately reflected by the rainfall measures recorded at the weather station (which is often referred to as spatial basis risk).

If the objective of the index insurance is to contribute to poverty reduction reliability refers to the extent to which the insured peril in the contract is reflective of losses caused by agricultural production (Elabed et al., 2013,[8] Flatnes and Carter, 2016[9]). If losses from

[6] Within the World Bank Group basis risk refers to 'insured peril basis risk.'

[7] Index insurance also has the potential to overcome asymmetric information problems, such as moral hazard and adverse selection, inherent in multi-peril crop insurance (MPCI).

[8] Elabed et al., (2013) compare a single-scale and multi-scale index insurance product and compare claim payments to yield from agricultural production, not from losses caused by the peril in the contracts.

[9]Flatnes and Carter (2016) compare an index insurance which combines a satellite based index with

agricultural production are mostly caused by flooding, it would be irresponsible for the insurer to design and sell a drought contract just because that is the easiest to design and cheaper to sell. Despite being insured with a high quality drought cover, it would not protect farmers from experiencing severe shocks to their consumption.

An additional measure is needed to reflect the extent to which the index reliably protects against losses in production. For this we propose to use the term 'production smoothing basis risk'. Production smoothing basis risk compares claim payments with losses from agricultural production, such as crop losses for farmers and herd losses for pastoralists. A poverty reduction perspective of index insurance makes it especially important to consider production smoothing basis risk in addition to insured peril basis risk. This is highlighted in Box 1 below.

BOX 1: ILLUSTRATION OF 'PRODUCTION SMOOTHING BASIS RISK' VERSUS 'INSURED PERIL BASIS RISK'

An example that illustrates the difference between production smoothing basis risk and insured peril basis risk is the case of Angela, a farmer in Ghana's Northern Region who purchased rainfall-deficit index insurance for her rain fed maize crop. The main cause of Angela's crop losses in the past 10 years has been deficit rainfall so Angela decided to purchase the insurance and to take out credit and purchase a high-yielding variety of maize, in combination with fertilizers and pesticides. Angela may not have made this investment without the insurance. The insurance product was properly advertised as a rainfall-deficit index insurance product, and measures rainfall at a rain gauge station 2 kilometers away from Angela's field. It pays out based on a count of the number of dry days and the amount of rainfall deficit at the flowering stage. Angela bought the insurance to insure a sum of 1,000 Ghana cedi (GHS) for one hectare of maize and paid a premium of 100 GHS (10% premium rate). Angela was unlucky this season because a severe locust damaged the maize crop early in the season and excess rain and flooding prior to harvest led to full crop loss for all farmers in the village. Since the index was not triggered Angela and her neighbors did not receive claim payments. They are now facing problems with repaying their maize loans and Angela is worse off than she would have been without the insurance because she has paid a premium of 100 GHS, taken a loan to invest in seeds, fertilizer and pesticides and experienced full crop loss but did not receive a claim payment: the worst case scenario.

Since Angela incurred a catastrophic production loss but did not receive a claim payment this would count as a 'downside production smoothing basis risk' event. However, since the product was advertised as a rainfall deficit coverage Angela could not reasonably expect that the product would pay a claim and so it would not count as a 'downside insured peril basis risk' event. The index insurance product performed as intended and Angela will still renew her policy next year because she still has enough savings to pay for the premium and she believes that deficit rainfall is still the main cause of her crop losses. However, Angela pities her neighbor Astrid who does not have any savings and is faced with repaying the loan without having any revenue or a claim payment. Angela thinks it is unlikely that Astrid will be able to pay for the premium next year.

3. MEASURING THE RELIABILITY OF INDEX INSURANCE

the potential for a second-stage audit to panel data from a retrospective yield survey recording yield from agricultural production, not from losses caused by the peril in the contracts.

To measure the reliability of index insurance one would need data on claim payments and data on losses for the insurance coverage period. Claim payments data can be obtained from insurance providers. Data on losses from agricultural production is difficult to obtain and requires an assessment of current agricultural production relative to a historical average of production, in principle in the first stage, at the level of the individual consumer. In addition, to calculate insured peril basis risk, one would need to objectively assess the share of losses that are caused by the peril that is insured in the contract (see Appendix 1 for data requirements).

The challenge of acquiring data on agricultural production losses leads us to propose two methods for measuring agricultural production losses. The first method is the classification method. This method is based on farmer-level surveys with recall questions about a classification of historical agricultural production as either `good' or `bad'. The second method is the statistical method that is based on panel data collected through farmer-level surveys that have recorded agricultural production data over time. As recall data is often characterized by measurement error we are reluctant to ask farmers about their recall of actual production in quantity or income. However, we are confident that farmers can recall a classification of agricultural production in terms of 'good' or 'bad' years (De Nicola and Gine, 2014). We consider the statistical method to be more rigorous. Whenever production loss data are available, the statistical method is the preferred method. We strongly encourage better data collection on agricultural production so that we can increase the application of the statistical method to calculate the reliability of index insurance.

To measure the reliability of index insurance it is important to analyze the correlation between claim payments and losses of a portfolio of index insurance products and not of a single indexed agricultural insurance product. For example, for a single annual insurance product which pays out once every 10 years it will take decades to have seen enough claim payments to be able to understand whether claims are likely to be paid when they should be. In agriculture, where production practices and hazards change over time, by the time you have learned about the correlation between claim payments and losses, the risk profile of agricultural production will most likely be totally different, and so you will never really learn. However, as we will demonstrate in this paper it is sometimes possible to learn over a short time span from a collection of similar products, by making use of both temporal and spatial variation.

For both insured peril basis risk and production smoothing basis risk a challenge is to decide if losses should be defined as losses in assets, losses in output, or losses in expenditure. Asset measures of basis risk are likely to be most useful for livestock replacement index insurance; output measures of basis risk are likely to be most useful for crop index insurance; and expenditure measures of basis risk are likely to be most useful for index insurance products which pay early to finance early risk reduction actions. Just as poverty economists choose between measures of asset poverty and consumption poverty, depending on the question they are asking, the choice between asset and production measures of basis risk should be made based on the nature of what is being protected. For example, Jensen et al. (2014) and Chantarat et al. (2013) compare claim payments from livestock index insurance with livestock mortality rates (related to assets) whereas Clarke et al. (2012) compare claim payments from crop index insurance with crop losses (related to production). There will, of course, be exceptions to this rule. For example, livestock protection index insurance that pays early in drought years to help keep animals alive may be more usefully compared to expenditures.

For both insured peril and production smoothing basis risk one needs to decide if claim payments should be compared to the value of losses (e.g. in dollars) or just the amount of losses (e.g. bags of wheat or number of cows). Both Clarke et al. (2012) and Jensen et al. (2014) ignore prices and compare claim payments to the amount of losses. This is motivated by the fact that prices of agricultural commodities typically have high spatial correlation and are sticky over time, so that prices in two adjacent years are likely to be closer than prices in two distant years, and large price shocks can have a long term effect. Multiplying the amount of losses with the price to get the value of losses may therefore add temporally auto correlated, spatially correlated noise to a dataset relative to a dataset based on the amount of losses. Adding even a little auto correlated noise to the temporal dimension can make it much more difficult to learn about basis risk statistically. So in general, comparing claim payments to the amount of losses is most useful. Table 2 presents an overview of the different types of basis risk and definitions of losses.

TABLE 2: DIFFERENT OPERATIONAL DEFINITIONS OF BASIS RISK

Which correlation do you consider? How do you define losses?		Insured peril basis risk *Correlation between claim payments and losses due to insured peril*	Production smoothing basis risk *Correlation between claim payments and losses due to agricultural production*
Asset	Quantity	√	√
	Value	√	√
Output	Quantity	√	√
Revenue	Value	√	√
Expenditure	Quantity	√	√
	Value	√	√

Measuring losses is challenging because data on aggregate production, for example at community or district level, may hide losses experienced at the individual farmers' level. This would not be problematic if farmers would fully share idiosyncratic losses through informal risk-sharing arrangements. However, even though informal risk-sharing is substantial (Townsend, 1994; Udry, 1990), the strength of and commitment to informal risk-sharing arrangements is shown to vary significantly across contexts (Coate and Ravallion, 2003; Attanasio et al., 2012). In this case aggregate measures of losses mask the actual extent of basis risk due to averaging out of extremes while it is the extreme cases that should receive most concern, from poverty and reputational perspectives. If correlations based on aggregate data demonstrate high levels of basis risk then this will certainly be the case for farmer-level basis risk. However, low correlations on aggregate data may still imply high levels of basis risk at the farmer level if the extent of informal risk-sharing is low.

Both insured peril and production smoothing basis risk may capture moral hazard. For production smoothing basis risk this problem is more substantial because it compares claim payments to losses from agricultural production. However, even though insured peril basis risk only compares claim payments to the share of losses caused by the specific peril, because index insurance covers progressive perils it is still difficult to distinguish if the share of losses is purely caused by, for example, loss of rainfall, or also by a farmer choosing to expand more effort on his non-farm activities, and less effort on his farm, after observing low levels of rainfall because he believes there is going to be a drought and payout. For production smoothing basis risk it is more obvious that it may capture moral hazard. For example, if a farmer decides to take up a daily-waged labor job and therefore does not expend as much effort on her paddy crop, there might be loss of agricultural production while, based on the index trigger, there is no claim payment. The indicator records this as indistinguishable from a situation in which the farmer works hard and loses her crop through no fault of her own, and does not receive a claim payment. This discussion on moral hazard should not be confused with the incentivization of moral hazard, through for example multi-peril crop insurance. The authors posit that moral hazard is likely to be low because the design of index insurance, with claim payments based on independently verifiable indices, incentivizes farmers to expend effort on their farms.

For the purpose of monitoring the reliability of index insurance it is important that proposed indicators are simple to calculate and easy to understand, without much prior technical knowledge, by donors, governments and the insurance sector. More sophisticated measures, relying on a careful comparison of the extent to which the index insurance contract deviates from perfect production smoothing (which would be created by perfect insurance) at all potential realizations of the full yield distribution have recently been developed (Barré et al., 2015) but would require advanced prior technical knowledge.

Downside basis risk is much more of a concern from a poverty perspective than upside basis risk, suggesting that indicators to monitor the reliability of index insurance should definitely capture downside basis risk. Downside basis risk implies that farmers may be worse-off, in terms of poverty, than they would have been without the insurance because they may end up paying a premium, experiencing a loss, but getting no claim payment in return. Upside basis risk is also problematic from the farmers' perspective because claim payments to farmers with good production will increase the overall cost of the product and thereby increase the premium paid without offering additional protection for catastrophic loss events. However, from a poverty perspective downside basis risk is much more of a concern than upside basis risk (Clarke, 2016). Traditional basis risk measures, such as the Pearson's product moment correlation coefficient, are therefore not particularly useful from an index insurance reliability perspective since they weigh both downside and upside basis risk equally (Martyniak, 2007; Staggenborg et al., 2008).

To capture the reliability of index insurance it is therefore important to monitor the value of the index insurance especially in those situations where farmers experience catastrophic losses. In this way the value of the index insurance is assessed for years when there are large downward deviations from average production and not when these deviations are small. This is important because reliable insurance should focus on non-frequent and severe shocks. The exact definition of what constitutes catastrophic losses is a policy decisions that should be informed by the specific policy objectives and the characteristics of the losses and policyholders. This can for example be done by defining catastrophic losses as losses that lead farmers to use informal coping strategies that have negative consequences for future welfare (taking children out of school or selling assets). As an example we define catastrophic production losses as those losses of more than 70% of average historical yield. In the calculation of the indicators based on the statistical method the full distribution of deviations from losses relative to claim payments is used so one can easily change this percentage. For the classification method one can develop careful interpretations of what constitutes good and bad years.

We propose two indicators to assess the reliability of the insurance in the years with catastrophic losses: the *probability of catastrophic basis risk* and the *catastrophic performance ratio*. The former establishes the probability that a farmer experiences more than 70% loss of agricultural production, such as losing more than 70% of her average crop or average livestock, but because the index is not triggered, receives no claim payment. The latter reflects what, on average, a farmer gets back per $1 of commercial premium paid in the case that she experiences catastrophic crop loss. The calculation of the indicators will be explained in Section 5.

TABLE 3: INDICATORS TO MONITOR INDEX INSURANCE RELIABILITY

Indicator	Interpretation	Data collection method
Probability of catastrophic basis risk	Probability of not receiving a claim payment when a farmer has catastrophic losses	Classification method and Statistical method
Catastrophic performance ratio	On average, if the farmer experiences catastrophic losses, what does he receive back relative to the premium paid	Statistical method

4. CALCULATION OF INDEX INSURANCE RELIABILITY INDICATORS

To calculate the index insurance reliability indicators two different methods are proposed to get measures of losses. The first method is the classification method. This method is based on farmer-level surveys with recall questions about a classification of historical agricultural production as either `good' or `bad'. The second method is the statistical method that is based on panel data collected through farmer-level surveys that have recorded agricultural production data over time.

The calculation of indicators is illustrated by taking a look at the data that were presented in Table 1. The Government of India has committed to collect these data between 1999 and 2007 (9 years) on 270 actual index products sold across one Indian state under the Weather Based Crop Insurance Scheme (WBCIS).[10] The WBCIS is a publicly subsidized program insuring 9 million Indian farmers through a rainfall index. This is, to date, one of the only products for which data is available to conduct this analysis. The Government of

[10] Analyzed in Clarke et al. (2012). These 270 products fall under the same WBCIS scheme so are essentially the same product but are standardized based on the historical average yield and crops for 270 regions within the Indian state.

India (GoI) has been a pioneer in pushing the boundaries on monitoring the value of agriculture insurance products for farmer welfare. The GoI has turned the design of index insurance from an activity based on anecdotal evidence to one where statistics principles are used to monitor and improve crop insurance schemes. This approach is clearly represented in the evidence-based policy advice coming out of the review of the implementation of crop insurance schemes in India (Mishra, 2014).

For the classification method farmers are first asked for the past 10 years, which years they considered as `good' years and `bad' years in terms of agricultural production. For these same years, based on historical data it is calculated when consumers would have received claim payments. For production smoothing basis risk a classification of good and bad years would be sufficient. For insured peril basis risk the procedure would be to first ask farmers to recall good and bad years and then follow this question up with asking which of the bad years were caused by the peril named in the insurance contract. For the WBCIS product data have only been collected on losses from agricultural production not on the share of losses caused by rainfall. Therefore it is only possible to calculate the indicators for production smoothing basis risk but the procedure would be exactly the same for insured peril basis risk if we had data on which bad years were caused by lack of rainfall. As was already demonstrated in Table 1, the WBCIS yield data are classified into years with yield more than 30% of average agricultural production based on 9 years (good year) and years with yield lower than 30% of average agricultural production (bad years). The WBCIS claim payment data are classified into claim payments that are higher and lower than the commercial premium, implying that, at the minimum, the payout covers the insurance premium. Based on this classification it is possible to draw up the 2X2 grid that was presented in Table 1.

In the application of this method it is critical to carefully define catastrophic losses and significant claim payments. Farmers, in classifying bad years, may incorporate mild droughts that did not lead to catastrophic losses, in their classification. Therefore it is crucial to carefully classify good and bad years and potentially triangulate farmer recall data with data from FEWSNET and Ministries of Agriculture. In determining the level of catastrophic losses it is important to refer to the specific insurance contract. For example, in cases where index insurance is bundled with credit, farmers may consider significant claim payments as those claim payments that cover at least the insurance premium and the interest rate on the loan.

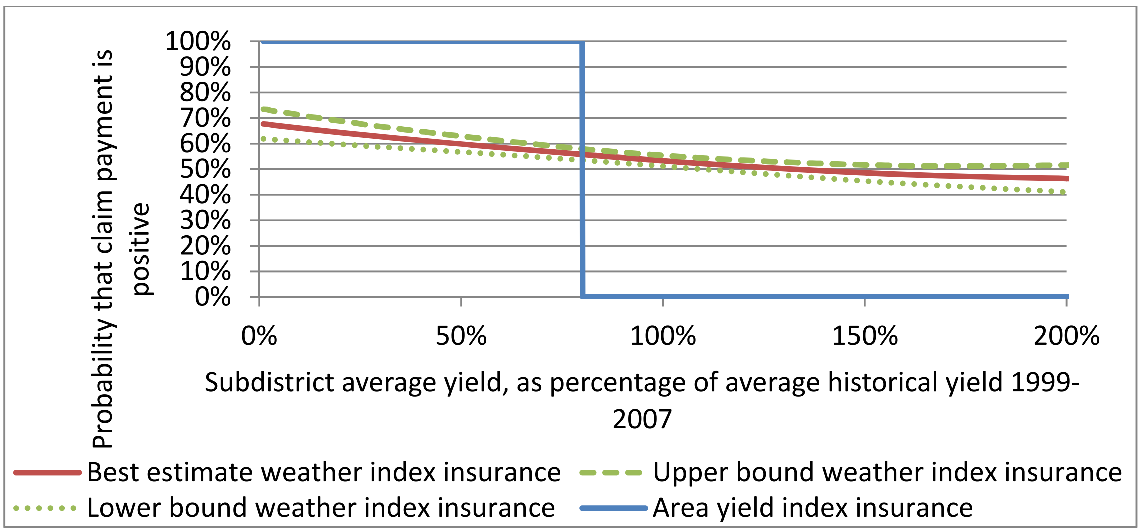
To calculate the probability of catastrophic basis risk of this product we divide the number of bad years with no or insignificant claim payments by the number of bad years where the yield was less than ≤30% of average yield. The probability of catastrophic basis risk of this product is 75/148=51%. This tells us that there is a 51% probability that the insurance will not pay out in years where farmers experience catastrophic losses.

To illustrate the calculation of indicators based on the statistical method we also use the Weather Based Crop Insurance Scheme (WBCIS) data from India. To illustrate how the probability of catastrophic basis risk is calculated the graph presented in Figure 1 is used. Appendix 2 describes how this figure can be produced. The x-axis presents the yields of farmers as a percentage of average yields. 100% on the x-axis implies that the farmer has an average yield while 50% implies that the farmer has lost 50% of her yield in comparison to the yield average over a number of years. A percentage above 100% implies that the farmer has a good yield while 0% implies total loss of agricultural production. A vertical line going through the

30% point on the x-axis is the threshold below which yields are defined as catastrophic losses (>70% loss). The y-axis presents the probability that the insured receives a claim payment (As opposed to the calculations for the classification method, claim payment refers here to any claim payment, not a claim payment higher than the commercial premium). The blue line in the figure represents an insurance contract with zero basis risk and a trigger level of 80% of the historical average area yield. It will provide a claim with a probability of 100% if the farmers' yield is below the trigger-level of 80% of the average yield and it will provide a claim with a probability of 0% if the farmers' yield is above the trigger-level of 80% of the average yield. The red line presents the relationship, inferred based on collected data on farmer yields and claim payments, between the average yields and the probability of a WBCIS claim payment. The green lines present the upper and lower bound of the 95% confidence intervals.

The graph shows that for catastrophic losses (30% of average yield) the probability of catastrophic basis risk is 33%. Drawing a vertical line through the x-axis at 30% of average yield shows that the probability of receiving a claim payment in case of catastrophic losses is 67%. This means that the probability of not receiving a claim payment in case of catastrophic losses is 100-67%=33%.

FIGURE 1: PROBABILITY OF CATASTROPHIC BASIS RISK OF WBCIS IN INDIA



Source: Adapted from Clarke et al. (2012)

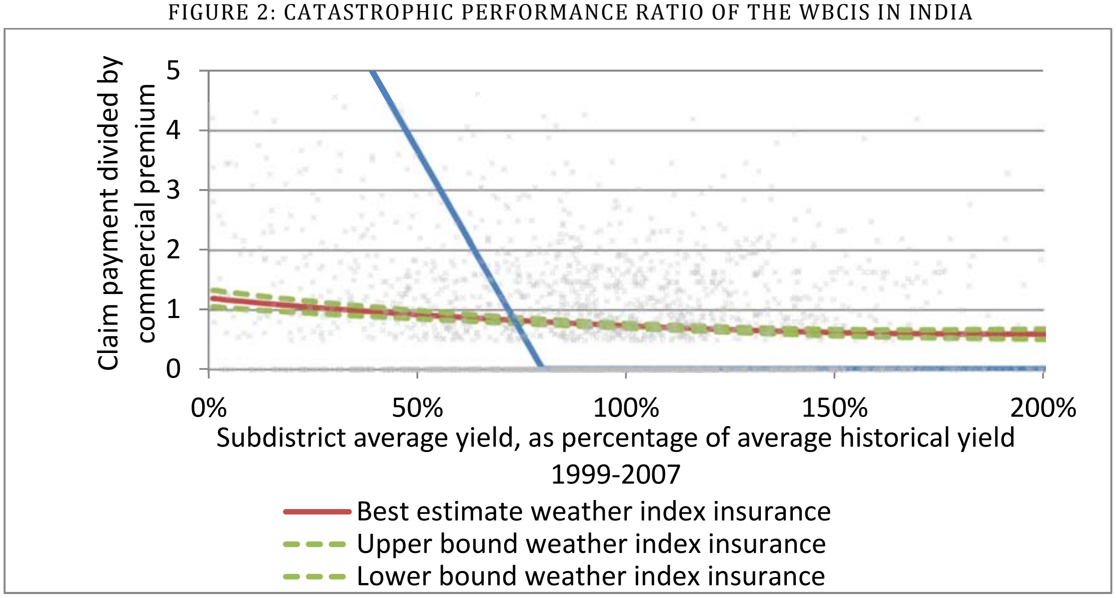
The catastrophic performance ratio can only be derived from the statistical method and is calculated by multiplying the probability of receiving a claim in case the farmer has catastrophic crop loss with the average amount of claim she receives in these cases and dividing this by the commercial premium.[11] To illustrate how this indicator can be measured

[11] The catastrophic performance ratio can be interpreted as the average payout in case of catastrophic losses per $1,- of premium paid. An alternative interpretation is to view the catastrophic performance ratio as the performance of the contract, by considering the average payout in case of catastrophic losses relative to the average payout in all years. The ratio can then be rewritten as: (Expected claim payment in case of catastrophic losses/ Expected average claim payment)*(Expected average claim payment/commercial premium). If the contract is designed to fully cover catastrophic losses the ratio would tend to 1 while if it performs poorly the ratio would tend to 0.

the graph presented in Figure 2 is used. Appendix 2 describes how Figure 2 can be produced. Statistical analysis can help to estimate 'on average' what the expected claim payment is in case a farmer experiences catastrophic crop loss. The x-axis again represents the yields of farmers as a percentage of average yield. The y-axis presents the Catastrophic Performance Ratio, which represents how much, on average, a farmer gets back for each $1 commercial premium paid. The blue line in the figure presents a perfect insurance contract. Under this contract the farmer does not receive any claim payment if her yields are above 80% of average losses but the insurance starts to gradually pay claims as soon as yields fall below the 80% trigger level. If the farmer has catastrophic losses and yields are at less than 30% of average yields a perfect area yield index insurance product would give an insured farmer $1 back for every $1 commercial premium paid. Also to illustrate the calculation of the Catastrophic Performance Ratio the data on the 270 products sold across one Indian state under the WBCIS are used. The red line in Figure 2 presents the inferred correlation between average yield and average claim payments per $1 commercial premium paid by the farmer for the 270 products. The green lines present the upper and lower bound of the 95% confidence intervals. As is seen the regression line is almost flat. For catastrophic crop loss (30% average yield) the Catastrophic Performance Ratio for production smoothing basis risk is 1.01, which means the farmer gets $1.01 back for each $1 commercial premium paid. Clarke (2016) demonstrates that a farmer who cares about catastrophic losses in agricultural production should not purchase the index insurance if the Catastrophic Basis Risk Ratio is below 1 for all potential levels of losses.

$$\text{Catastrophic performance ratio} = \frac{\text{Expected claim payment in case of catastrophic loss of agricultural production}}{\text{Commercial premium}}$$

FIGURE 2: CATASTROPHIC PERFORMANCE RATIO OF THE WBCIS IN INDIA



Source: Adapted from Clarke et al. (2012)

Empirical data on the extent to which farmers share agricultural losses are often unavailable but will lie somewhere between full sharing of losses and no sharing of losses. Therefore the basis risk indicators will be compared to aggregate-level average yields to reflect an upper-bound of full local risk-sharing and farm-level yields to reflect a lower-bound of no risk-sharing. If farmers fully share losses at aggregate-level (such as caste-level,[12] village-level, or farmer-association-level[13]) this implies that the aggregate-level average yields are an adequate reflection of the farmers' yields. A comparison of claim payments to the aggregate-level average yields to calculate the basis risk indicators would then be the best way to represent the value of the insurance for farmer welfare. However, if farmers don't share losses, a comparison to aggregate-level average yields would overestimate yields for some farmers and underestimate yields for other farmers. Especially an overestimation of yields is problematic for already vulnerable low-income farmers. In this latter case a comparison of claim payments to farmer-level yields to calculate the basis risk indicators would then be justified. In the example of the 270 WBCIS products, claim payments are compared to sub-district average yields and thus, assuming risk-sharing is partial, production smoothing basis risk can be assumed to be higher. The ratio of 1.01 thus provides an upper bound of the catastrophic basis risk ratio.

The calculation of basis risk indicators requires data on farmer-level yields and agricultural index insurance claim payments to be compiled from a portfolio of products and not from a single product. The low probability of agricultural shocks and the nature of basis risk imply that reliable estimates for the basis risk indicators based on a sufficient number of observations can only be collected within a reasonable time frame if data from a variety of products (preferably from within a larger program) are combined. For example, the Indian weather index-insurance data used to demonstrate the calculation of the basis risk indicators used 9 years of data for 270 products sold across one Indian state. The statistical analysis was possible especially because of the spatial and time variation created by jointly analyzing a large number of products under one scheme.

5. HOW TO USE THE INDEX INSURANCE RELIABILITY INDICATORS?

The indicators can be used to compare agricultural insurance products against a benchmark, compare one product's value over time based on changes in indicators or compare different products with each other. Indicators collected based on statistical methods are suitable to be incorporated by governments as industry standards, such as the Insurance Commission of the Government of the Philippines has done with 'The Performance Standards for Microinsurance'[14] or 'The Inter African Conference for the Insurance Market' has done with key performance indicators.[15] However, donors, governments, and insurance providers can also incorporate the indicators in strategic planning processes to improve the quality of products, protect consumers, and reduce reputational risk (Jensen et al, 2014). To

12 See for example Mobarak and Rosenzweig for caste-level sharing of agricultural shocks in India.

13 See for example Dercon et al. (2014) for farmer-association level risk-sharing (iddir) of agricultural shocks in Ethiopia.

14 http://www.insurance.gov.ph/htm/..%5C_@dmin%5Cupload%5Creports%5CCL%2005%20-%202011.pdf on 4 July 2014.

15 http://www.microfact.org/news/new-west-african-insurance-legislation-recognises-microinsuance-key-performance-indicators-/ on 4 July 2014.

develop a benchmark, stakeholders can establish the value of the indicators for a range of index insurance products in a high-quality data environment so that these values can serve as a benchmark.

It is important that stakeholders take into account that the indicators are based on data that are imperfectly measured and that efforts are required to standardize data quality. For example, noisy recall data may lead to an overstatement of basis risk but this should not lead to systematic bias when comparing products against each other or a benchmark, when standardized methods are used to collect the recall data. Furthermore, when comparing indicators over time, improvements in data quality may lead to more precise measurement of indicators.

The index insurance reliability indicators are best used jointly and preferably in combination with other insurance monitoring and performance indicators that focus on aspects of the performance of insurance products such as incurred expense ratio, renewal ratio, complaints ratio, insurance literacy rates, accessibility indicators (Wipf and Garand, 2010; Sandmark and Simanowitz, 2010; Matul, Tatin-Jaleran and Kelly, 2011). Box 2 provides an illustration of the value gained from the use of multiple indicators.

BOX 2: AN ILLUSTRATION OF HOW TO USE MULTIPLE INDICATORS TO UNDERSTAND A PORTFOLIO OF PRODUCTS

The insurance industry is accustomed to calculating the Incurred Claims Ratio. An incurred claims ratio of 80% for index insurance implies that on average 0.80$ per $1 commercial premium is given back to the farmer. Even though this indicator provides an average, it does not provide information about how much consumers get back, on average, for the situations when they experience loss of agricultural production. This is what is especially important when insuring already vulnerable farmers. This information is provided by the catastrophic performance ratio. A catastrophic performance ratio of 110% tells us that farmers only get 1.10$ back per $1 commercial premium paid in cases of catastrophic loss of agricultural production. This would be low value for a farmer who cares most about the worst-case scenario. A catastrophic performance ratio of 600% would imply that they get 6 times the commercial premium in case of the worst-case scenario. This would be a reliable cover for an affordable product from the perspective of the farmer. An incurred claims ratio of 80% and a catastrophic basis risk ratio of 600% may indicate a valuable product in terms of the benefits for every 1$ commercial premium paid.

In the insurance industry there are standards developing for the speed with which claims are paid. Even with an incurred claims ratio of 80% and a catastrophic basis risk ratio of 600%, an index insurance may still be of low value, especially for low-income, vulnerable farmers, if claim payments are made long after losses are incurred. The drop in consumption may lead farmers to sell off assets, reduce their food intake, or take children out of school to work, which can still have serious consequences for future welfare.

6. CONCLUSION

Agricultural index insurance offers the promise of an affordable and sustainable insurance product for farmers that can contribute to reducing poverty. However, index insurance provides claim payments based on a trigger that is correlated with losses, but imperfectly so. This implies that it carries *basis risk*: it may provide claim payments in years where there are no losses; and no claim payments in years when there are losses. Therefore, the impact of index insurance on poverty outcomes is highly sensitive to the degree to which the product offers reliable protection, especially in the cases where farmers experience severe losses. Offering unreliable index insurance may lead to high reputation risk for donors, governments, and the private sector. Despite its importance, monitoring of index insurance reliability is rarely conducted due to the lack of an operational and measurable definition of basis risk, and underutilization of appropriate statistical techniques. In this paper we propose two new indicators to measure index insurance reliability: the probability of catastrophic basis risk and the catastrophic performance ratio. The proposed indicators can be applied without much prior technical knowledge and may allow us to learn about the reliability of index insurance protection.

APPENDIX 1: DATA REQUIREMENTS

TABLE 4: ADDITIONAL DATA COMPUTED FROM INSURANCE PROVIDERS' ADMINISTRATIVE DATA

Indicator	Additional data to be calculated
1. Probability of catastrophic basis risk event	Area insured at farmer-level per commodity
	Pay-out received at farmer-level per commodity
2. The catastrophic performance ratio	Area insured at farmer-level per commodity
	Premium at farmer-level per commodity
	Sum insured at farmer-level per commodity
	Pay-out received at farmer-level per commodity

TABLE 5: ADDITIONAL DATA COLLECTION EFFORTS

Indicator	Data	Proposed collection methods
1. Probability of catastrophic basis risk event;	Production at farmer-level per agricultural commodity collected on a seasonal basis.	Survey after harvesting season
2. The catastrophic performance ratio		

APPENDIX 2: CALCULATION OF INDICATORS

For the indicators in Table 6 the time period n will typically be defined as one production season

TABLE 6: CALCULATION OF INDICATORS

Indicator	Calculation	Specific measurement
1. Probability of catastrophic basis risk		• To calculate this indicator a kernel-regression needs to be run with a statistical package such as STATA, SPSS or R. Before this can be done the independent variable (farmer yield as percentage of average farmer yield) and the dependent variable (probability that the claim payment is positive) need to be computed from the raw data. • **Computing independent variable 'Farmer yield as percentage of farmer average yield'** Sum of yearly farmer yield divided by number of years gives the farmer average yield. Each year's yield can be expressed as a percentage of average yields by dividing the yield in a specific year by the average yield. • **Computing dependent variable 'Probability that the claim payment is positive'** This variable is a binary variable indicating 1 if the farmer has received a claim payment (irrespective of the height of the claim payment) and 0 if the farmer has not received a claim payment. • Each farmer in each year is now an observation that can be used to run the kernel-regression with the preferred statistical package.
2. Catastrophic performance ratio		• To calculate this indicator a kernel-regression needs to be run with a statistical package such as STATA, SPSS or R. Before this can be done the independent variable (farmer yield as percentage of average farmer yield) and the dependent variable (claim payment as percentage of sum insured) probability that the claim payment is positive need to be computed from the raw data. • **Computing independent variable 'Farmer yield as percentage of farmer average yield'** Sum of yearly farmer yield divided by number of years gives the farmer average yield. Each year's yield can be expressed as a percentage of average yields by dividing the yield in a specific year by the average yield. • **Computing dependent variable 'Claim payment divided by commercial premium'** Divide the claim payment per farmer per year for the total sum insured by the commercial premium paid per farmer for the total sum insured. • Each farmer in each year is now an observation that can be used to run the kernel-regression with the preferred statistical package.

REFERENCES

Attanasio, O., Barr, A., Cardenas, J.C., Genicot, G. and Meghir, C., 2012. Risk pooling, risk preferences, and social networ. American Economic Journal: Applied Economics, 4(2), pp.134-167.

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

Barré, T., Stoeffler, Q., and Carter, M.R. Assessing index insurance: conceptual approach and empirical illustration from Burkina Faso. Internal.

Binswanger, H.P. and Rosenzweig, M.R., 1993. Wealth, Weather Risk and the Composition of Agriculture Investments. The Economic Journal, January, pp.1-24

Carter, M.R., Galarza, F. and Boucher, S., 2007. Underwriting area-based yield insurance to crowd-in credit supply and demand. Savings and Development, pp.335-362.

Chantarat, S., Mude, A.G., Barrett, C.B. and Carter, M.R., 2013. Designing index‐based livestock insurance for managing asset risk in northern Kenya. Journal of Risk and Insurance, 80(1), pp.205-237.

Clarke, D.J., 2016. A Theory of Rational Demand for Index Insurance. American Economic Journal: Microeconomics, 8(1), pp.283-306.

Clarke, D.J., K.N. Mahul, O. Rao, and N. Verma, 2012. Weather Based Crop Insurance in India. World Bank Policy Research Working Paper No. 5985.

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

De Nicola, F. and Giné, X., 2014. How accurate are recall data? Evidence from coastal India. Journal of Development Economics, 106, pp.52-65.

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

Dercon and Christiaensen, 2008

Dercon, S. and Krishnan, P., 2000. In sickness and in health: Risk sharing within households in rural Ethiopia. Journal of political Economy, 108(4), pp.688-727.

Doherty, N.A. and Schlesinger, H., 1991. Rational insurance purchasing: consideration of contract non-performance. In *Managing the Insolvency Risk of Insurance Companies* (pp. 283-294). Springer Netherlands.

Duflo, E. and Udry, C., 2004, Intra-household Resource Allocation in Cote d'Ivoire: Social Norms, Separate Accounts and Consumption Choices NBER Working Paper No. 10498

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

Flatnes, J.E. and Carter, M.R., 2016. Fail-safe index insurance without the cost: a satellite based conditional audit approach. Internal

Gautam, M., Hazell, P.B.R. and Alderman, H., 1994. Rural Demand for Drought Insurance. World Bank Policy Research Working paper 1383

Gine, X., and D. Yang. 2009. Insurance, credit, and technology adoption: Field experimental evidencefrom Malawi. Journal of Development Economics, 89, 1: 1–11.

Jensen, N.D., Barrett, C.B. and Mude, A., 2014. Basis risk and the welfare gains from index insurance: Evidence from northern Kenya. Available at SSRN 2505764.

Jensen, N.D., Mude, A. and Barrett, C.B., 2014. How basis risk and spatiotemporal adverse selection influence demand for index insurance: Evidence from northern Kenya. Available at SSRN 2475187.

Karlan, D., Osei, R. D., Osei-Akoto, I., & Udry, C., 2012.. Agricultural decisions after relaxing credit and risk constraints (No. w18463). National Bureau of Economic Research.

Mahul, O. and Wright, B.D., 2007. Optimal coverage for incompletely reliable insurance. *Economics Letters*, *95*(3), pp.456-461.

Matul, Michal, Clemence Tatin-Jaleran, and Eamon Kelly (2011), "Improving client value from microinsurance: Insights from india, kenya, and the Philippines." ILO Microinsurance Innovation Facility.

Martyniak, L., Dabrowska-Zielinska, K., Szymczyk, R. and Gruszczynska, M., 2007. Validation of satellite-derived soil-vegetation indices for prognosis of spring cereals yield reduction under drought conditions–case study from central-western Poland. Advances in Space Research, 39(1), pp.67-72.

Mishra, P.K. , 2014. Report of the Committee Constituted Under the Chairmanship of Dr P.K. Mishra, Ex-secretary, Department of Agriculture & Cooperation to Review the Implementation of crop Insurance schemes in India. Government of India, Ministry of Agriculture, 1 May 2014

Morduch, J., 1995. Income smoothing and consumption smoothing. The journal of economic perspectives, 9(3), pp.103-114.

Mobarak, A.M. and Rosenzweig, M. R., 2012. Selling Formal Insurance to the Informally Insured. Yale Economics Department Working Paper No. 97.

Sakurai, T. and Reardon, T., 1997. Potential demand for drought insurance in Burkina Faso and its determinants. American Journal of Agricultural Economics, 79(4), pp.1193-1207

Sandmark, T and Simanowitz, A (2010) Social Performance Indicators for Microinsurance. ADA, BRS and the Microinsurance Network.

Staggenborg, S.A., Taylor, R.K. and Maddux, L.D., 2004. Effect of planter speed and seed firmers on corn stand establishment. Applied engineering in agriculture, 20(5), p.573.

Townsend, R.M., 1994. Risk and insurance in village India. Econometrica: Journal of the Econometric Society, pp.539-591.

Udry, C., 1994. Risk and insurance in a rural credit market: An empirical investigation in northern Nigeria. The Review of Economic Studies, 61(3), pp.495-526.

Wipf, J. and Garand, D. (2010) Performance Indicators for Microinsurance – A Handbook for Microinsurance Practitioners (2nd Edition). ADA, BRS and the Microinsurance Network.