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Agricultural insurance—and other risk management approaches—can contribute to improving the productivity of agriculture, through helping producers invest in more productive, but potentially riskier, agricultural practices.

By Lysa Porth and Ken Seng Tan

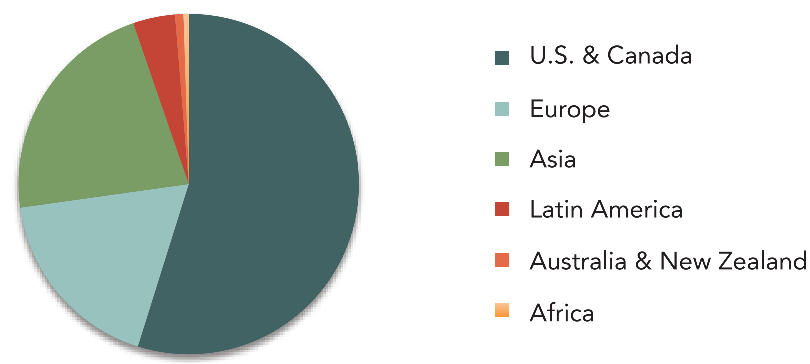
AGRICULTURE, THE WORLD'S LARGEST INDUSTRY

Agriculture is often recognized as the world's largest industry, and is of major social and economic significance. As populations continue to grow, a substantial global transformation must take place in order to increase food production by 70 percent by 2050, the estimated figure needed to feed the future population (FAO, 2009). In developing countries agriculture is of special importance, as it is a main source of economic growth and food security, and it can be one of the most effective approaches to reducing poverty (compared to nonagricultural gross domestic product (GDP) growth) (World Bank, 2008). In Africa, about 30 to 40 percent of GDP is due to agriculture, and almost 60 percent of total export earnings (Fan, 2009). Comparatively, in Canada the Agriculture and Agri-Food System (AAFS) accounts for approximately 6.7 percent of GDP. Improving the productivity of the agricultural sector, therefore, is a key goal for both developing and developed nations.

Agricultural insurance (and other risk management approaches) can contribute to improving the productivity of agriculture, through helping producers invest in more productive, but potentially riskier, agricultural practices. Adverse weather events are the primary driver of crop loss, and in the case of extreme events, such as drought and floods, producers face the prospect of entire crop failure. Coupled with an environment that is rapidly changing, due to a more complex agri-supply chain, climatic changes that may be increasing the frequency and severity of natural disasters, and increased price volatility due to changes in market structure and sensitivity, this causes concern for farmers, governments, insurers and reinsurers alike. Therefore, agricultural insurance is an important part of ensuring long-term stability and growth of the agriculture sector, and facilitating access to credit, helping to reduce the negative impacts of natural catastrophes, and encouraging investment in improved production technology.

Global agricultural insurance premiums have increased considerably over the past decade. The increased market size can partially be attributed to increases in commodity prices, and in the last five years a major driver has been emerging markets. Direct global agricultural insurance premiums written in 2011 were US$23.5 billion (Swiss Re, 2013), and in 2013 estimates were almost US$30 billion (Schneider and Roth, 2013). This is a substantial increase from 2005, where agricultural insurance premiums worldwide were US$8 billion. While emerging markets account for approximately 70 percent of food production worldwide (Baez and Wong, 2007), in 2005 only 13.4 percent of global agricultural insurance premiums were from emerging markets. Since 2005, however, the share of emerging market premiums has increased, and in 2011 they were 22 percent, driven largely by major growth in Brazil, China and India (Swiss Re, 2013). The figure above shows the share of agricultural insurance premiums worldwide.

SHARE OF AGRICULTURAL INSURANCE PREMIUM (2011)



Source: Adapted from Swiss Re, 2013.

As shown in the figure above, North America accounts for the majority of global agricultural insurance premium written. The agricultural insurance program in the United States is the largest in the world, and in 2012 the U.S. Federal Crop Insurance Corporation (FCIC) reported total premiums of US$11.7 billion with an insured value of US$117 billion (Shields, 2013). Comparatively, crop insurance premiums in Canada in 2011 were about CA$1.6 billion, and payouts to farmers were CA$1.3 billion.

Given that systemic risk can be very difficult for an insurer to manage when severe weather scenarios occur, reinsurance is often an important risk transfer mechanism for insurers. In 2013, Q-Re examined the role of reinsurance in global agricultural insurance, and reported that the total downside risk for agricultural insurance was more than US$20 billion, and almost 80 percent of this was reinsured. North America alone accounted for downside of more than US$12 billion. As an example, severe drought in the U.S. Midwest in 2012 led to near-record crop insurance indemnity payments in excess of US$14.2 billion, and much of this loss was paid by the reinsurance sector.

REGION	DOWNSIDE RISK (US$, BILLIONS)	REINSURED (%)
North America	12.3	74
Europe	3.6	76
Asia	4.2	81
Latin America	0.7	92
Africa	0.3	89
Total/weighted average	**U$21.1 billion**	**76%**

Source: Adapted from Schneider and Roth, 2013.

UNIQUENESS OF AGRICULTURAL INSURANCE AND CHALLENGES OF INSURABILITY

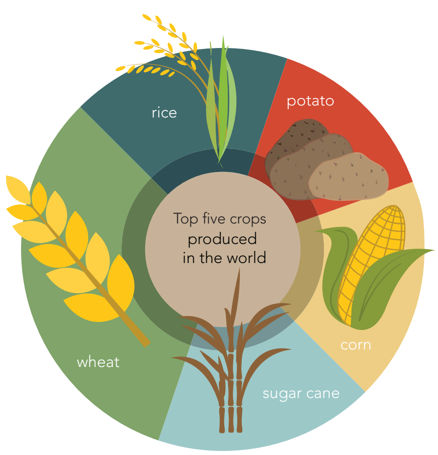
Agriculture is faced with a number of challenges related to insurability (Porth, Zhu and Tan, 2014), and often a public-private partnership (PPP) approach is necessary. In Canada, for example, provincial crop insurance companies deliver crop insurance, and premiums are cost-shared at 24 percent and 36 percent with provincial and federal governments, respectively, with farmers responsible for the remaining 40 percent of premiums. In addition, crop insurance delivery costs are 100 percent subsidized by provincial and federal governments proportionately. Comparatively, crop insurance in the United States is serviced through 18 approved private insurance companies, and premiums are subsidized on average 62 percent by the federal government, with farmers paying the remainder. The insurance companies' losses are reinsured by the U.S. Department of Agriculture (USDA), and administration and operating costs are also fully reimbursed by the federal government.

Adverse weather events tend to be infrequent, yet severe, and at times correlated across geographic regions. This can make insurability more difficult, as losses cannot be easily pooled and diversified (Porth, Pai and Boyd, 2014). Further, adverse selection and moral hazard are often cited as major causes of private insurance market difficulties. Adverse selection refers to higher-risk farmers that are more inclined to seek insurance, while moral hazard is a tendency to take on greater risk once insured. In developing countries, reinsurance capacity tends to be more limited, primarily due to insufficient market infrastructure, lower producer risk awareness, lack of insurance culture, and other regulatory impediments. In most countries, crop insurance contracts tend to be indemnity-based, where farmers are paid an indemnity according to the actual loss experienced on the farm. Often, however, farm characteristics differ substantially across developed and developing countries. For example, in developed markets farms tend to be quite large and specialized, and in developing markets the vast majority tend to be smallholder farmers that cultivate less than two hectares of land. As a result, another difficulty with indemnity-based insurance contracts can be relatively high administration and underwriting costs, particularly in developing countries with primarily small-scale farmers, which makes associated costs prohibitively high relative to the insurance benefit in many cases.

THE POTENTIAL OF INDEX-BASED INSURANCE (IBI)

In response to many of the shortcomings of traditional indemnity-based insurance, where indemnities are paid according to a farmer's actual losses, the concept of IBI was first introduced by Halcrow (1948) and Dandekar (1977). In more recent years IBI has received a renewed interest, largely driven by advances in infrastructure (i.e., weather stations), technology (i.e., remote sensing and satellites), as well as computing power, which has enabled the development of new statistical and mathematical models. With an IBI contract, indemnities are paid based on some index level, which is highly correlated to actual losses. Possible indices include rainfall, yields, or vegetation levels measured by satellites. When an index exceeds a certain predetermined threshold, farmers receive a fast, efficient payout, in some cases delivered via mobile phones. Administration costs are low since there is no need to measure actual losses, and this may be a key benefit of IBI for developing countries with smallholder farmers. Additionally, there is significantly less adverse selection and moral hazard since farmers are unlikely to be more informed about the index than the insurer, and have no control over the outcome of the underlying index. Moreover, since IBI is derived from an independently verifiable index, insurers can efficiently transfer their risk to reinsurers in international markets.

IBI is still primarily in development or pilot stages, rather than widespread commercial stages, and has been attempted in some markets around the world, including Canada, Mexico, Morocco, India, Rwanda, Tanzania, the United States, etc. India's Weather Based Crop Insurance Scheme (WBCIS) provides a strong example of the potential of IBI, sold by a commercial insurer, ICICI Lombard. The WBCIS in India covered more than 9 million farmers from 2010 to 2011, with premium of US$258 million and total liabilities of US$3.17 billion (World Bank, 2012).



The top five crops produced in the world are sugar cane, corn, wheat, rice and potatoes with annual production of 1.8 billion, 8.8 million, 7.2 million, 7.0 million and 3.7 million tons, respectively, in 2012.

Source: Food and Agricultural Organization.http://faostat.fao.org/site/339/default.aspx. Accessed March 5, 2015,

EXPERIENCE WITH IBI AND THE SHORTCOMINGS OF BASIS RISK

While promising, IBI faces a number of challenges, and in practice demand for this type of insurance product has been low. While there are a number of possible explanations for low demand for IBI contracts, such as the farmers' lack of understanding or trust, the most prevalent is likely attributed to the exposure faced in terms of basis risk (Chantarat et al., 2013; Deng et al., 2007). Basis risk has also been cited as a primary concern for the implementation of weather hedges and examined in several research papers (Turvey, 2001; Brockett et al., 2005). Basis risk refers to the situation when the underlying risk is not perfectly correlated to the actual loss. This may lead to circumstances where farmers are not indemnified for an actual loss, or, conversely, are paid an indemnity despite having no actual loss.

When developing agricultural indices, historical data must be available, objective and reliable. In addition, the relationship between the loss exposure and the peril (in many cases a weather factor) is often complex and must be carefully explored. For agricultural production, this relationship is not always straightforward since many factors, such as variance in crops, growth phases, soil textures, etc., to some extent, can cause a variance in responses to the same weather factor. In order to be successful and reduce basis risk, the index must be able to explain a very high portion of the variability in production. Therefore, minimizing basis risk is critical because evidence suggests that farmers will not fully insure if basis risk is present even when rates are actuarially sound (Mobarak and Rosenzweig, 2012).

In general, there are three main categories of basis risk.

1. Variable basis risk: when the relationship between the loss and the indexed weather peril is not straightforward, due to the presence of other important risks. For example, yield loss may be more due to wind speed during flowering rather than quantity of rainfall or relative humidity.
2. Spatial basis risk: when the outcome at the farm differs from the measure based on the index. In this case there is low sensitivity between the farm yield and the weather data generated from meteorological stations, which may be situated at considerable distances from the farm.
3. Temporal basis risk: when there is low correlation between the weather index and crop yield due to the timing of the occurrence of the insured event. The temporal component of the basis risk is related to the fact that the sensitivity of yield to the insured peril often varies over the crops' stages of growth. Factors such as changes in planting dates, where planting decisions are made based on the onset of rains, for example, can have a substantial impact on correlation as they can shift critical growth stages, which then do not align with the critical periods of risk assumed when the crop insurance product was designed.

It is impossible to completely eliminate basis risk. Given that IBI policies cover multiple farmers in a region, and these farmers likely have different losses to some degree, there will always be some level of mismatch between the measured peril and the actual losses on a farm. As a result, farmers must assess the limitations of the insurance contract, and the value the farmer places on the product will largely depend on the perception on basis risk. In the case where the farmer experiences significant negative shock, yet, the IBI product does not trigger and pay the farmer for the loss suffered, then the farmer will find this situation too uncertain and likely would not buy insurance. Following the idea of compound risk or ambiguity aversion (Ellsberg, 1961; Elabed and Carter, 2014), the farmer may actually find himself worse off in this situation, as he suffered a loss without receiving an indemnity, and paid the premium.

CURRENT RESEARCH: AN EXAMPLE FROM CANADA ON FORAGE IBI

Ontario designed and offered one of the first forage rainfall derivative plans, beginning with a pilot from 2000 to 2002, and launching a full-scale program in 2005. This product has since been modified and adopted by other provinces in Canada. In general, national participation in forage insurance plans is low with only 20 percent of all forage acres, and 12 percent of pasture acres, being insured. This low take-up is despite premium subsidy of approximately 60 percent, and a number of different insurance schemes offered. For example, the provinces of Manitoba, Saskatchewan and British Columbia offer indemnity-based forage yield coverage at the farm level, and in Quebec insurance is offered via a simulated forage plan.

Under the forage IBI scheme in Ontario, farmers can insure against insufficient and/or excess rainfall with several options. Customers identify their crop in proportions of hay and pastureland and value accordingly. A given contract payout is based on weather data professionally collected from one of 350 stations across the province. Customers must select a station located in their township or one adjacent. Despite the flexibility of the program and several choices available, only 10 percent of forage acres are insured in Ontario, compared to 90 percent of annual crop acres insured. Of those who insure, the average customer selects about 80 percent of available coverage.

In addition to forage being the basis of Canada's livestock industry, where 80 percent of Canada's beef production and 60 percent of a dairy cow diet depend on forages, it is also very important in soil conservation, as they are used in crop rotation to improve soil structure and add nitrogen to the soil (AAFC, 2014). Forages are produced across all agricultural regions of Canada, and represent about 44 percent of Canada's total farm area (Sask Forage Council, 2010). Forage is a non-traded or semi-traded commodity. Crop management tends to be more complex with forages compared to many other crops, for several reasons:

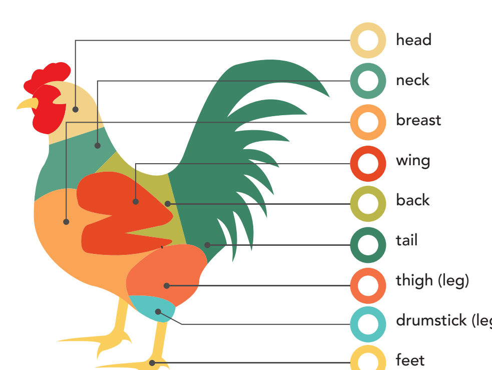
- Forage usually consists of a mixture of different species.
- Forage may be used as either stored feed or pasture.
- There is a wide range of harvest and storage systems used.
- Perennial crops require management to ensure over-winter survival.

Some farmers may self-insure (e.g., save forage or change cutting times) rather than participate in IBI coverage, as premiums may be higher than the perceived cost of self-insurance. The intended use of a farmer's forage (hay vs. pasture) may make a difference in demand. Other factors such as cultural and behavioral issues may explain some of the variations in forage insurance demand. One possibility is that some farmers may be culturally averse to the idea of forage insurance. Nationally, forage remains a focus of production insurance discussions due to lower participation rates (compared to other crops such as grains and oilseeds) and requests for ad hoc support, demonstrating the need for an insurance product.

Given the low uptake of the forage IBI plan in Ontario, the objective of our research was to better understand the possible issues contributing to the low demand. Particularly, the study considers the concept of ambiguity/compound-risk aversion, which is tested using the smooth model of ambiguity aversion developed by Klibanoff et al. (2005), which is used to express how much farmers are willing to pay (WTP) to reduce basis risk. The WTP measure is estimated empirically using framed field experiments with farmers in Ontario, revealing the prevalence and

Livestock farming feeds billions of people and employs 1.3 billion people. That means about 1 in 5 people on Earth work in some aspect of livestock farming.

Source: Lynette, Rachel. 2013. *Producing Meat: The Technology of Farming*. Chicago, IL: Heinemann Library.



Despite the fact that agriculture employs over one-third of the world's population, agricultural production accounts for less than 5 percent of the gross world product (an aggregate of all gross domestic products).

Source: Food and Agricultural Organization. *http://faostat.fao.org/site/339/default.aspx*. Accessed March 5, 2015.

degrees of compound risk aversion present. The distribution of compound risk aversion is then used to simulate the impact of basis risk on demand for an IBI contract structure that mimics the actual IBI contract distributed in Ontario.

Given that different growth stages have different needs, it is possible to assume that a simple cumulative index might not completely frame the relationship between the growth and weather factor. Therefore, this research also examines approaches to reduce basis risk, with a focus on temporal basis risk, an area of research that has received considerably less focus relative to spatial and variable basis risk. Using farm-level forage data from Ontario, including forage yield, soil zone, descriptive farm statistics and weather station data, a detailed analysis of crop cycles is conducted with the intent of designing an improved multi-trigger forage IBI product for Ontario. Using weighted optimization to reflect different growth phases, and considering planting techniques and personal crop cycle information of farmers through surveys, preliminary results find that significant improvement in tracking the weather factor-yield relationship can be achieved. Designing contracts that minimize basis risk under an assumption of compound-risk aversion would not only enhance the value of IBI, but would also help to ensure that the contracts are popular and have the anticipated impacts. This research would set a framework for further testing in Canada and other countries, including developing countries, in order to determine model transferability. The IBI model developed in this research may also be useful for other crop and livestock insurance applications and weather-linked derivative securities where basis risk is a concern.

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Both Porth and Tan are the conference co-chairs of the International Agricultural Risk, Finance, and Insurance Conference (*www.iarfic.org*), which will be held on June 7-9, 2015 in Washington, D.C.