Developing Weather-Based Financial Risk Management Solutions for the Agricultural Markets

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The energy sector has traditionally been the primary focus of the weather risk management industry. Energy companies have quantified their exposure to weather in terms of Heating Degree Days (HDDs) and/or Cooling Degree Days (CDDs), two temperature-based indices designed to reflect heating and cooling demand in winter and summer, respectively.

In recent years, however, the participation in the weather market of hedge funds that trade weather-dependent energy commodities such as natural gas, heating oil and electricity has fuelled growth, particularly in the US market. These new market entrants, in combination with the standardisation of contracts, the ability to trade electronically, and the clearing capabilities of the Chicago Mercantile Exchange triggered a period of rapid expansion for the weather market between 2003 to 2006, when the notional volume traded increased from USD 4 to 45 billion.

To realize the full potential of the market, a wider application of weather-based financial products tailored to the agricultural sector is required. Even though agricultural businesses have a direct exposure to weather, their risks are not concentrated on one specific weather peril or location. This dilemma makes it difficult to create standardised weather contracts that can be used to hedge their exposure.

A sector under pressure

In recent years, drought and increased consumption rates from fast-growing middle classes in India and China have significantly fuelled volatility in agricultural markets worldwide. The production of ethanol and other types of agri-energy have driven increased demand for crops such as corn and sugar. Money management firms have increased their asset allocation to the commodity sector, including the agricultural markets.

All these developments have significantly changed the market dynamics in the agricultural sector. Decisions such as crop switching are now more difficult for the farmer, and analysts find it more difficult to predict market direction than in the past. Additionally, many farmers depend upon pre-financing against their future revenue stream. In the instance of dramatically reduced yield due to weather, financial institutions and companies that offer financing and other related services to farmers are exposed to significantly higher default rates on their loans. Food processing companies need to purchase commodities in the spot market in case of a bad harvest, when prices are likely to spike. Input costs such as fertilizers and natural gas (in the case of irrigated farms) have also been very volatile, increasing the need for comprehensive risk management solutions. All of these factors have increased the need for agribusinesses to hedge their weather and commodity price-related risks.

Figure 1: Wheat (red) and Corn (blue) Futures Prices History

Fig. 1 shows the run up in agricultural prices in 2007, due in part to the overall run up in commodity prices and droughts in Australia and Canada. Global economic weakening in the latter half of 2008 triggered a steep drop in prices. This price history mimics that of the crude oil market and shows the greater global interdependence of the agricultural markets. As a result of the initial price spike, various national governments instituted protectionist measures such as banning crop exports or levying new taxes to appease public outrage caused by steep increases in food prices.

Weather products for agricultural markets: hedging positions

Several factors have suppressed the growth of weather risk management products in the agricultural sector. In recent years, however, structural changes and innovations have helped to ease these obstacles, including:

Basis risk: A major obstacle to the more active use of weather products to hedge agricultural risk is basis risk. Basis risk is the difference between the actual crop output at a farm unit level and the output that would be projected by a weather index (ie, precipitation, temperature, etc) at the reference weather station that is used to create and settle the payout on the hedge. Although crop output is ultimately the result of the interaction of a myriad of variables (weather being the most influential), there are several factors - such as disease and fire - which are not directly related to weather production.

Crop yield, at a farm unit level or averaged across a county or state level, is highly correlated with weather variables, particularly during extreme weather phenomena such as droughts, floods and heat waves. As an example, the deviation in corn yield has been plotted against the average temperature during the summer at a basket of locations in the US Midwest (Fig. 2). Combining temperature with additional weather variables such as precipitation can further improve this relationship. Similar relationships exist for other crops.

Figure 2: Relationship between corn yield and average summer temperature at a basket of weather stations in the US Midwest region.

Using actual crop yield at an individual farm unit level as the index instead of weather-based variables can eliminate basis risk for a producer. Risk takers need to establish additional measures to minimize moral hazard-related risk and ensure that farmers follow best accepted farming practices. Alternatively, if the farm unit performs similarly to other units in the same county, coverage could be based on the yield for the entire county, instead of the individual farm unit.

Risk management firms, such as Swiss Re, now offer an add-on yield product in derivative form to supplement the government insurance programme that covers wheat, soybeans and corn crops. The yield is measured at the farm unit level or county level and the product covers shortfall levels from 90 to 75% of the planted yield. To qualify for protection at the farm unit level, a verifiable performance record of at least five years is required.

Historical data quality and moral hazard: In several developing countries, reliable historical figures for pricing weather transactions do not exist due to large gaps in data, poor recordkeeping, or changes in instrumentation. Additionally, the data may not be digitised or easily obtainable. These data issues are also true of second and third order weather phenomena such as droughts, floods and heat waves. As an example, the deviation in corn yield has been plotted against the average temperature during the summer at a basket of locations in the US Midwest (Fig. 2). Combining temperature with additional weather variables such as precipitation can further improve this relationship. Similar relationships exist for other crops.

The development and growth of weather-based financial products have been at least partly hindered by a lack of historical data. Reliable data is not always available. For example, the Cooperative Observer Program (COOP) in the United States. Often monitored by volunteers, data from COOP stations is not always reported on a daily basis. However, these stations are often closer to the farm units, thereby minimising basis risk. While it is certainly possible to fill in or create synthetic historical data sets for pricing transactions using nearby neighbouring station data, the issue of moral hazard remains. A good network of fallback stations, proper security measures such as the installation of barricades and motion...
sensor cameras can minimize this risk. However, unless there is large concentrated exposure at a specific weather station, these measures are cumbersome and not practical.

The use of satellite imagery to calculate weather indices is a recent development and, in many instances, can help overcome these issues. Since they are available globally, updated in real-time and have a reliable historical database, satellite imagery-based indices eliminate the moral hazard risk involved in manual data measurement and observation. A common satellite-based index related to agricultural risk is the Normalized Difference Vegetative Index (NDVI). The NDVI values are calculated from visible and near infrared light reflected by vegetation. This is a useful indicator for lack of vegetation and drought.

Several recent transactions in the market have used these indices, including the 2007 deal between Swiss Re and the Millennium Promise Alliance covering shortfall in rainfall in Kenya, Mali and Ethiopia. A pilot programme targeting the apiculture industry as well as pasture, rangeland and forage currently being conducted by the Risk Management Agency, a division of the USDA, also uses indices based on satellite-derived rainfall estimates.

**Perception of high risk premiums:** The risk premium that the weather market requires is often perceived as high. While this may have been the case in the early days of the market, risk margins have reduced considerably over the years. Attracted by the lack of correlation between weather risk and the broader capital markets, as well as the ability to offset positions through commodity trading, hedge funds, insurers and other risk takers have made additional risk capital available to the weather sector in recent years. This additional capital has stimulated competition, improved pricing and increased transparency.

**Distribution channels:** To target the agribusiness sector, the weather market needs to develop alternative distribution channels. In the last few years, involvement from participants such as the World Bank and the International Monetary Fund has helped educate and spread awareness regarding these products, particularly in developing nations. Microfinance institutions can also play an important role in providing a sustainable distribution channel by including weather insurance products in addition to the other credit, savings and insurance products they currently offer.

**Traditional suite of weather-index solutions**

The traditional suite of available weather products range from relatively simple temperature and precipitation solutions to more complicated structured alternatives focusing on various developmental phases in the crop cycle or based on agricultural yield on a farm unit, county, state or regional level. These products can incorporate agricultural price risk, while also reducing the amount of basis risk.

1. **Precipitation-based products:** These include lack of rainfall or excess rainfall-based structures, as well as event-based precipitation structures.

   For example, to protect against excess precipitation at harvest, a Canadian wheat producer could purchase a hedge against excess precipitation based on a weather station in close proximity to their farm for the harvest period starting August 20 through September 10. This coverage can be structured as a call option on rainfall, based on a graduated scale of, for instance, CAD 20,000 per millionlitre in excess of a strike at 10% above the long term average or a digital payment once the strike has been exceeded.

2. **Temperature-based products:** Extreme cold weather can cause winter kill during the crop emergence phase. Additionally, early frost can also cause damage and/or premature death of the crop. Inversely, extreme heat during the critical phase of pollination can halt the reproductive process, significantly reducing the crop yield. Extreme heat can also affect the grain-filling phase and further reduce the yield.

   As an example, a corn producer in the US Midwest could purchase a Variable Degree Day (VDD) call option for the June through August time period based on a weighted basket of locations in Iowa. A VDD is similar to a CDD and is calculated as the maximum of zero and the difference of maximum temperature over a reference threshold, generally around 85°F (30°C).

3. **Structured products:** Based on a combination of temperature and precipitation, structured weather products take into account the entire crop cycle.

   Most crops follow a typical developmental cycle, with key weather-related risks during the various phases. For instance, the pre-sowing phase is when the farmer typically prepares to plant the seeds. If there has been a dry period or prolonged drought, the farmer will need to choose between waiting until conditions improve or going ahead and sowing the seeds. In either situation, this generally leads to reduced yields. During the germination/seedling phase, the plant emerges from its protective seed coat and develops from an embryo to a young plant.

The vegetative phase begins at germination and continues through tillering. This phase is characterised by the production of leaves. During tiller production, wet conditions following a drought can cause increased late stem development, whereas cold and drought conditions can cause slow stem elongation.

**Figure 3: Crop calendar and rainfall pattern**

A sample developmental cycle is shown below in Fig. 3 with the normal expected crop output shown towards the right and normal rainfall required for this shown in blue.

Weather conditions can have a major impact on the decision of choosing when to begin the harvest, which is the process of gathering a mature crop. Frost, hail, excessive rain or wetness of the soil or extreme heat waves can cause lower yields and lower crop quality. Harvesting earlier can help the farmer avoid these damaging weather conditions, but will also likely result in lower yield and crop quality. Harvesting later will extend the exposure to weather, but offers the potential for increased yield and higher crop quality.

**Figure 4: Hedging reduced yield through combination of weather structures**

In Fig. 4, for the lower than normal, actual rainfall recorded outcome as shown in red, the corresponding output is reduced as well. A weather hedge can be structured to compensate for this so that the payout will depend on the precipitation values for each of the major developmental phases of the crop. In such a situation, clients retain an amount of initial loss in output with which they are comfortable. If losses exceed this predefined threshold or strike, the weather hedging programme would kick in. In the above example, the weather hedge will cover - in financial terms - the amount of precipitation and output depicted in green. The perils covered under the hedging programme can also be expanded to include temperature-related risks, since excessively hot or cold weather can also reduce yield.
Untapped potential
Risk taking firms in the weather market now offer several innovative solutions for the agricultural sector, which address most of the issues that have hindered growth in the past. These include satellite-based weather index protection, as well as yield-based protection - which can be structured on a farm unit or county level. Additionally, given the recent volatility in agricultural prices, the need for more comprehensive hedging programs has increased dramatically. Structured solutions, such as the grain revenue floors that companies such as Swiss Re offer, combine agricultural price risk in addition to yield/volume exposure to provide an integrated solution to agribusinesses.

The weather market is likely to experience significant expansion potential in the agricultural markets in the short term. It has also the potential to stabilize the current distribution of risk more uniformly over the calendar year, as agricultural risks tend to be concentrated over summer months whereas the energy risks are more concentrated over winter months.

The rewards for the insurance and financial services industry in general and the weather market in particular will be equally attractive and can be accomplished through innovation, new product development, as well as coordinating and leveraging unconventional marketing and distribution channels.