Abstract: Risking-sharing Efficiency of Hedging Strategies

Changhao Guo, Baojing Sun and G. Cornelis van Kooten
Department of Economics, University of Victoria

Financial weather derivatives are efficient instruments for potentially hedging weather risks in agriculture. Initially, weather derivatives were only traded in over-the-counter (OTC) markets. Then the Chicago Mercantile Exchange (CME) launched the first weather derivative in 1999 and introduced heating degree days (HDD) and cooling degree days (CDD) derivatives for U.S cities in 2005, with HDD and CDD derivatives for six Canadian cities added one year later. (The weather indexes are temperature based because precipitation can vary too much across a landscape.) The HDD index measures the need for heating, and is obtained by subtracting realized average daily temperature from a benchmark of 18^{o}C and summing these differences over the number of days used to construct the index (e.g., one week, one month). Likewise, CDD measures the extent to which average daily temperature exceeds 18^{o}C, again summing daily differences over the relevant number of days used to construct the index.

An agricultural producer could use either exchange-based or OTC financial weather derivatives to hedge weather risks. Weather derivative contracts in exchange markets are standardized and easy to write (as they are based on HDD and CDD), but they can be subject to large basis risk. The specific basis risk associated with weather derivatives arises because the location where the weather index is measured does not match the farm's location. The great majority of farms located quite some distance from the city used by CME to construct the weather derivative, so most farmers encounter significant basis risk when using exchange markets to hedge weather risk. In contrast, there is no basis risk for an OTC weather derivative that uses a weather index measured at the farm's location. Nevertheless, in the absence of efficient regulatory control, there is some probability that the counterparty to the OTC contract defaults (does not settle the contract) – OTC contracts invariably carry some credit risk. Thus, there exists a tradeoff between basis risk and credit risk.

Other than OTC and exchanged-based derivatives, Considine (2000) and Golden et al. (2007) recommend the use of a novel hedging instrument referred to as a *basis derivative*. The basis derivative is essentially an OTC contract based on the difference in the weather index at the farm's location and the related exchanged-based weather contract. Such an OTC instrument

carries less risk for the counterparty and thus reduces credit risk. A hedging portfolio can be constructed by the purchase of an exchanged-based derivative plus an OTC basis derivative. As a hedger, the agricultural producer aims to minimize the risks associated with the financial derivatives. The purchase of an OTC basis derivative that hedges the difference between the exchange weather index and the value of a weather index at another location lessens the credit risk, compared with a single OTC contract written on a local weather index. At the same time, the OTC basis derivative reduces basis risk. Thus, the portfolio of the exchange-based option and the OTC contract reduces overall risk. Nonetheless, there remains a potential tradeoff between the reduction in credit risk and the reduction in basis risk.

Further, the CDD index used in exchange-traded contracts differs from growing degree days (GDD), which is the temperature index relevant for crop growth. GDD uses a benchmark temperature of $5^{o}C$ (or sometimes $10^{o}C$), cumulating the actual average daily temperature minus $5^{o}C$ through the growing season. In spite of their similarity, GDD is the more straightforward and precise index for crop growth than CCD, and this needs to be accounted for in the analysis.

To hedge against the potential risk of crop loss due to insufficient heat (too few GDDs), an agricultural producer can choose among several strategies. The first is to use an OTC transaction to purchase (long) a GDD put option based on local temperatures, which exposes the agricultural producer solely to credit risk. Another strategy is to rely in the exchange market only and purchase a CDD put option that exposes the farmer to basis risk. A third joint strategy is to write a CDD put option in the exchange market and a basis GDD put option on the OTC market simultaneously. A CDD put option based on the closest city assigned by CME could reduce credit risk. As a complement, a basis GDD put option is written on a compound difference between GDD at the farmland and CDD in exchange markets. This strategy could simultaneously lessen basis risk and credit risk.

The purpose of this paper is to compare hedging strategies and discuss whether the combination strategy improves risk-sharing efficiency. First, we derive a relation between GDD and CDD. For a growing season from May to August, the relation of weather indexes can be expressed as $\text{GDD} \approx \text{CDD} - \text{HDD} + 13n$, where n is the number of days in the growing season.

Then, following Doherty and Richter (2002) and Golden et al. (2007), we employ mean-variance analysis, obtaining an optimal hedging ratio and hedging strategy by maximizing the expected return of a hedging portfolio. To quantify credit risk, we introduce a dummy variable θ and the probability of default could be represented by $(1 – p)$. Suppose W is the eventual wealth of a risk-averse farmland owner and λ is her risk aversion parameter. The objective mean-variance function is given by $V=E(W) – \lambda Var(W)$, which is the difference between the expectation and variance of eventual wealth adjusted by λ. The eventual wealth is the initial wealth at the beginning of the year plus the net return from a financial hedge, which is the difference between the payoff to the chosen strategy and its cost (premium). Assuming no borrowing, the initial wealth at the beginning of the year equals last year's revenue. As a consequence, a linear relationship between initial wealth and one-year lagged weather index is assumed for simplicity. By maximizing the objective function, the first-order conditions solve for the unknown optimal hedging ratios. The farmer's eventual wealth under each hedging strategy could be derived as a function of credit risk, the optimal hedging ratio, initial wealth, and the payoffs of a CDD or a GDD put option. The criterion used here to conclude a better strategy is a hedging effectiveness parameter, defined as one minus the ratio of variances of eventual wealth under two strategies (Kumar 2008). A positive parameter reveals that the joint strategy of CDD and GDD put options is much more effective as a hedging strategy, compared with a single OTC GDD put option.

Finally, empirical analysis is used to test whether the joint strategy is effective. The study region is a typical rural municipality in Saskatchewan (RM 280) for which there are good quality spring wheat yield data and weather information. CME offers both HDD and CDD derivatives for Calgary. The farmer can either write an OTC GDD contract or combine a CDD contract based on Calgary with an OTC GDD basis contract. Burn analysis is used to determine the payoffs and premiums of put options. Analysis indicates that the hedging effectiveness parameter is approximately 0.39 under the condition that the probability of default is 0.05 without additional information on the counterparty. The joint strategy carries smaller variance and is significantly more effective than a single OTC strategy. Further, as credit risk rises, the magnitude of the hedging-effectiveness parameter increases, meaning an OTC contract carries more risks. A CDD and GDD joint strategy could eliminate part of credit risk and reduce the variance of net returns. In conclusion, the joint strategy of a exchanged-based CDD contract and an OTC GDD contract can reduce credit risk and stabilize the farmer's revenue more efficiently, compared with a single OTC GDD contract.

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