JP1.6 WEATHER DERIVATIVES AS A VEHICLE TO REALISE THE SKILL OF SEASONAL FORECASTS

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1. INTRODUCTION

1.1 *Historical Note*

More than ten years ago, the application of financial market mathematics to quantify weather risk was proposed for the first time (Stern, 1992). The particular aspect of weather risk addressed at that time was associated with climate change. Option-pricing theory (Black and Scholes, 1973) was used to quantify the risk.

1.2 *Managing Weather Risk*

Since then, what became known as "weather derivatives" have grown to rapidly become an important tool for managing the risks associated with uncertainty in weather and climate (Clemmons, 1999; Dischell, 2000,2002; Geman, 1999). In most situations, the term 'weather (and climate) risk' relates to the exposure of a firm's earnings or revenues to the effect of meteorological phenomena such as, for example, un-seasonal temperatures or rainfall.

1.3 *Definition*

Weather derivatives are a form of financial instrument similar in nature to the commodity futures contracts and options, but their price is tied to some facet of the weather (and climate) such as temperature, precipitation, wind, and heating (and cooling) degree-days.

Firms that participate in weather derivative markets are often involved in activities that are weather sensitive. Through weather derivatives, these firms seek to reduce their weather related risks. Some participants use these markets to speculate on the future weather.

Weather derivative contracts are traded both "over the counter" through some intermediary, such as a merchant bank, and also via open markets. The settlement of a weather derivative contract is entirely dependent upon the relevant weather outcome. The demonstration of financial loss is not required.

1.4 *Legal Issues*

A number of legal issues arise when providing data for the settlement of derivatives contracts. These include the quality control of data, changes in the characteristics of observation sites, and the security of the data collection processes. The practice overseas has been to undertake settlement on the basis of the official observations, partially settling contracts almost immediately, and then awaiting confirmation (following quality control procedures). Employees of the observing authority are not permitted to trade in weather contracts.

1.5 *Industry Growth*

The Weather Risk Management Association's Media Release of 5 June, 2003 (WRMA, 2003), notes that 11,756 weather risk management contracts were transacted from April 2002 through March 2003. The notional value of these contracts, reported at nearly $4.2 billion, varied slightly from the previous year. This indicates a surge in smaller contracts and a broader spectrum of users. Last year's survey recorded 3,937 contracts with a notational value of $4.3 billion. The North American market is the industry's largest, but the market is growing elsewhere.

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Temperature-related protection continues to be the most prevalent, comprising more than 85% of all contracts, but the market is diversifying, with rain-related contracts accounting for just under 10%.

At present the weather derivatives market in Australia is relatively small when compared with the US and European markets. In Australia, the agriculture industry has the potential to be a major user of weather derivatives.

1.6 ***Role of Government***

The weather forecast information, and the climate data and products produced by the Commonwealth Bureau of Meteorology (CBoM) in Australia, and other service providers, are potentially key elements of the weather risk market. The lack of bias in weather and climate products produced by a government provider , and the equal access to products and services, are of crucial importance in providing a 'level-playing-field' for the weather risk market.

The weather derivatives industry uses current and historical weather data, and the associated meteorological information, in analysing and predicting the risks faced by weather sensitive industries and firms. Hence the accessibility and the degree of accuracy of such information is a key factor in identifying and managing weather risks. Associated with that, is the growing importance of forecast verification with regard to key meteorological information. The easy and ready availability of economically accessible weather data could play a key role in the growth of the weather derivatives market in general.

The CBoM has had a multi-faceted role in the field of weather derivatives since the early 1990s - conducting research, presenting workshops and talks to user groups and conferences, providing weather and climate data, and establishing relationships with academia and industry. Bureau personnel have taken a lead role in publishing work in weather derivatives, describing methodologies for value hedging and speculative financial market instruments that might be applied to climate fluctuations (Stern, 2001a,b,c; Stern 2002a,b; Stern and Dawkins, 2003a,b).

2. BACKGROUND

2.1 ***Seasonal Outlooks***

The CBoM has provided seasonal climate outlooks to the Australian public since 1989.

2.2 ***Mostly Significant Skill***

Verification statistics demonstrate that the forecasts display significant skill at most localities. For example, the matrix table (Table 1), forecast vs observed, for rainfall outlooks on a three-category basis for the central Victorian city of Melbourne suggests substantial skill over the period forecasts have been provided (1989-2003).

Table 1. The matrix table, forecast vs observed, for rainfall outlooks on a three-category basis for the CENTRAL Victorian city of Melbourne.

Forecast Observed	Below	Normal	Above
Below	**15.8%**	**17.7%**	**6.8%**
Normal	**6.8%**	**25.9%**	**4.5%**
Above	**1.5%**	**17.7%**	**6.4%**

A randomly generated outlook would be correct on 33% of occasions, whereas the verification statistics show that the actual outlooks were correct on 48% of occasions (refer to the data in the diagonal of Table 1).

Fig 1 shows that the skill varies with the time of the year, forecasts for the spring and early summer period year being more successful than forecasts for other seasons.

2.3 ***Pockets of Marginal Skill***

Substantial skill is not found for all localities. There are "pockets" of the country, where only marginal skill is found. One of these places is the northwest Victorian town of Mildura. There, by contrast to Melbourne, the matrix table (Table 2), forecast vs observed, for rainfall outlooks for Mildura suggests only marginal skill over the period forecasts have been provided (1989-2003).

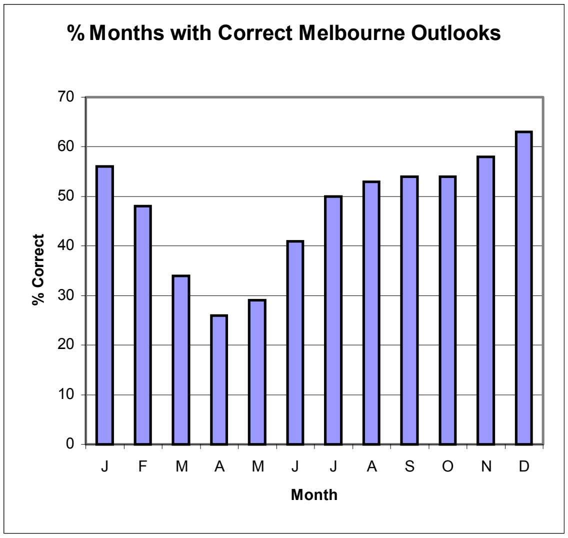

Fig 1. Annual variation of the skill displayed by seasonal climate outlooks of rainfall for Melbourne.

Nevertheless, some skill is demonstrated. A randomly generated outlook would be correct on 33% of occasions, whereas the verification statistics show that the actual outlooks were correct on 36% of occasions (refer to the data in the diagonal of Table 2).

Table 2. The matrix table, forecast vs observed, for rainfall outlooks on a three-category basis for the northwest Victorian town of Mildura.

Forecast / Observed	Below	Normal	Above
Below	**10.9%**	**17.4%**	**8.0%**
Normal	**6.2%**	**17.8%**	**9.4%**
Above	**5.8%**	**17.8%**	**6.9%**

3. PURPOSE

It may be shown that, in some scenarios, should a user of seasonal forecasts be required to make categorical strategic decisions on the basis of those forecasts, the forecasts need to be substantially better than climatology if benefit is to be realised from them.

However, it may also be shown that, in some scenarios, should a user of seasonal forecasts be able to apply a partial hedge with weather derivatives, the forecasts only need to be marginally better than climatology if benefit is to be realised from them.

It is the purpose of the paper to demonstrate this concept, which is not intuitive.

4. PROVIDING HEDGES AGAINST DROUGHT

4.1 *Two Approaches*

There are two approaches one might apply, in order to realise (in financial terms) the skill displayed by seasonal forecasts. By "realising the skill", one is referring to making decisions on the basis of the forecasts that improve the financial outcome.

4.2 *The Physical Hedge*

One approach is that of the "physical hedge". An example of a "physical hedge" is where the farmer might decide to only plant the highest yielding crop over part of his land holding, planting a hardier, but lower yielding crop, over the remainder. Should there be inadequate rainfall, the hardier crop would survive, allowing the return of some income for the farmer.

4.3 *The Financial Hedge*

An alternative approach is that of the "financial hedge".

In its 3 September 2003 media release, the National Australia Bank (NAB, 2003) provides a practical illustration of how one might hedge against drought using products available in the financial markets.

The release describes the writing of its first "Precipitation Option", in order to protect a customer against low rainfall in the critical growing month of September. Under the deal, the customer is to receive a payment for every mm (or part thereof) that September rainfall falls below the agreed strike of 21.19mm.

The wheat grower who bought the product is quoted as saying that it was an ideal way to help ensure cash flow. The wheat grower indicated that he had used hedges and currency swaps to manage price risk in the past, but saw this product as a means to help offset the adverse impact on his wheat yield if there was insufficient rain. He recognised that should rainfall in excess of the strike fall, the increased wheat yield should more than compensate for his upfront option premium.

The wheat grower showed interest in hedging against too much rain in November, and in other variations to his strategy, such as deferring option premium payment until after harvest.

The NAB saw the sale of its product as indicative of a trend among primary producers to adopting more sophisticated risk management services. The NAB noted that regulatory qualifying criteria applied, including specified asset and turnover levels.

One may also refer to the website, http://www.guaranteedweather.com, for a broad view of this approach to weather risk management.

5. APPLYING DATA ABOUT THE ACTUAL SEASONAL FORECASTS

5.1 *"Fair Value"*

One may utilise historical rainfall statistics from a climate database to calculate the "fair value" price of the aforementioned option.

However, if the seasonal forecasts display skill, the "fair value" price of the option should vary, depending upon the seasonal forecast. To illustrate, if a dry season is forecast, and it is known that that forecast has a "better than random" chance of success, then the aforementioned option should have a higher price. That price may be calculated utilising forecast verification data.

5.2 *The Strategy*

Let us take the example of a seasonal rainfall forecast that is expressed in one of three categories - below normal, normal, above normal.

1. Suppose the strategy of the farmer is to always plant a drought resistant crop (that displays adverse sensitivity to excess rainfall, but that thrives in relatively dry seasons), should below normal rainfall be forecast. Suppose further that, by following this strategy, the financial outcomes are +$300,000 (if below normal rainfall is observed), +$150,000 (if normal rainfall is observed), and minus $150,000 (if above normal rainfall is observed).

2. Similarly, suppose the strategy is to plant a moderate yielding crop should normal rainfall be forecast, with the financial outcomes of +$80,000 (below normal rainfall observed), +$200,000 (normal rainfall observed), and +$80,000 (above normal rainfall observed).

3. Similarly, suppose the strategy is to plant a high yielding crop (that displays adverse sensitivity to drought, but that thrives in relatively wet seasons) should above normal rainfall be forecast, with the financial outcomes of minus $150,000 (below normal rainfall observed), +$150,000 (normal rainfall observed), and +$300,000 (above normal rainfall observed).

The above strategy is summarised in Table 3.

Table 3. Financial outcomes ($000s) for various combinations of crop type and observed rainfall.

Crop Type Observed Rainfall	Drought Resist.	Moderate Yield	High Yield
Below	**+300**	**+80**	**-150**
Normal	**+150**	**+200**	**+150**
Above	**-150**	**+80**	**+300**

5.3 *The Contrasting Strategy*

By contrast, were the farmer always to plant the most suitable crop for the normal climate conditions that prevail in the region, the average financial outcome would be the average of the three financial outcomes for the strategy of planting a moderate yielding crop:

(($80,000+$200,000+$80,000)/3) =

an expected return of $120,000.

5.4 *The Case of Forecasts Displaying Marginal Skill*

Suppose the matrix table, forecast vs observed, suggests marginal skill:

Table 4. A hypothetical matrix table, forecast vs observed, that suggests marginal skill.

Forecast / Observed	Below	Normal	Above
Below	12%	11%	10%
Normal	11%	12%	11%
Above	10%	11%	12%

This suggests a slightly reduced outcome of

($300,000[1]x0.12[2])+
($80,000[3]x0.11[4])+
(-$150,000[5]x0.10[6])+

($150,000x0.11)+
($200,000x0.12)+
($150,000x0.11)+

(-$150,000x0.10)+
($80,000x0.11)+
($300,000x0.12) =

an expected return of $116,600.

[1] $300,000 is the return if a crop suitable for below normal rainfall is planted and below normal rainfall is observed

[2] 12% is the probability of below normal rainfall being observed at the same time as below normal rainfall is forecast

[3] $80,000 is the return if a crop suitable for below normal rainfall is planted and normal rainfall is observed

[4] 11% is the probability of below normal rainfall being observed at the same time as normal rainfall is forecast

[5] There is a loss of $150,000 if a crop suitable for below normal rainfall is planted and above normal rainfall is observed

[6] 10% is the probability of below normal rainfall being observed at the same time as above normal rainfall is forecast

5.5 *The Case of Forecasts Displaying Substantial Skill*

Suppose the matrix table forecast vs observed suggests substantial skill:

Table 5. A hypothetical matrix table, forecast vs observed, that suggests substantial skill.

Forecast / Observed	Below	Normal	Above
Below	18%	11%	4%
Normal	8%	18%	8%
Above	4%	11%	18%

This suggests a much-increased outcome of

($300,000x0.18)+
($150,000x0.08)+
(-$150,000x0.04)+

($80,000x0.11)+
($200,000x0.18)+
($80,000x0.11)+

(-$150,000x0.04)+
($150,000x0.08)+
($300,000x0.18) =

an expected return of $173,600.

5.6 *The Case of Melbourne*

For Melbourne under the above scenario, once again an outcome of $120,000 is suggested under the assumption of climatology (normal):

($80,000+$200,000+$80,000)/3) =

an expected return of $120,000.

Using data about the ACTUAL Melbourne forecasts (Table 1), a greatly increased outcome is suggested:

($300,000x0.158)+
($150,000x0.068)+
(-$150,000x0.015)+

($80,000x0.177)+

($200,000x0.259)+
($80,000x0.177)+

(-$150,000x0.068)+
($150,000x0.045)+
($300,000x0.064)=

an expected return of $151,220.

5.7 ***The Case of Mildura***

For Mildura under the above scenario, once again an outcome of $120,000 is suggested under the assumption of climatology (normal):

($80,000+$200,000+$80,000)/3) =

an expected return of $120,000.

However, using data about the ACTUAL Mildura forecasts (Table 2), a very slightly reduced outcome is suggested:

($300,000x0.109)+
($150,000x0.062)+
(-$150,000x0.058)+

($80,000x0.174)+
($200,000x0.178)+
($80,000x0.178)+

(-$150,000x0.080)+
($150,000x0.094)+
($300,000x0.069)=

an expected return of $119,860.

5.8 ***Writing a Weather Derivative (Case of Mildura)***

Suppose now that a weather derivative is written that pays $60,000 every time above normal rainfall is observed (the "fair value" price would be $20,000, as payment would occur on one-third of occasions).

Suppose also, that a weather derivative is purchased that pays $60,000 every time below normal rainfall is observed (similarly, the "fair value" price would be $20,000, as payment would occur on one-third of occasions).

Furthermore, suppose that this combination is only entered into whenever below normal rainfall is forecast. Once again using data from Table 2, it may be seen that the outcome is now adjusted upwards:

($340,000x0.109)+
($130,000x0.062)+
(-$170,000x0.058)+

($80,000x0.174)+
($200,000x0.178)+
($80,000x0.178)+

(-$150,000x0.080)+
($150,000x0.094)+
($300,000x0.069)=

an expected return of $121,820.

The component of forecast skill that is being realised here is that related to the prediction of below normal rainfall. When such a forecast is made (22.9% of all cases), nearly half of them, 10.9%, are correct. A randomly generated forecast would only have been correct on one-third of occasions.

6. SUMMARY

It has been shown that, in some circumstances, a user of seasonal forecasts requires those forecasts to be substantially better than climatology to realise benefit from them. It has also been shown that the application of a partial hedge with weather derivatives would enable benefit to be realised, even should the forecasts be only marginally better than climatology.

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