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WEATHER INDEXES, INDEX INSURANCE AND WEATHER INDEX FUTURES

Abstract

This paper compares the weather insurance, weather index insurance and index futures and focuses on why China needs to develop weather indexes and adopt and trade weather index futures. It further discusses how to construct the indexes and futures and how to price them.

Different from the Heating Degree Days (HDDs) and Cooling Degree Days (CDDs) used at Chicago Mercantile Exchange (CME), it develops the Extremely Heating Days (EHDs) and Extremely Cooling Days (ECDs) to derive relevant temperature-based weather index futures.

Recently China has started using weather index insurance to cover farmers' risk. Through comparisons of weather index futures with index insurance, this study shows the necessity and importance of using the weather index futures to better protect farmers and better develop China's financial markets.

Keywords catastrophic (CAT) insurance, financial futures, China's insurance market

JEL Classification G22, G28, Q14

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INTRODUCTION

Global warming has led to more severe weather and more losses of agricultural industry according to Swiss Re (2017). It is important to develop ways to better protect this crucial industry and particularly farmers' incomes. The agriculture industry is still significant and important to China's economy, although China's economic structure has changed significantly and manufacturing and service industries have become more important in the past two decades. The GDP share of the agriculture industry was 8.6% of its total GDP in 2016 and there were still about 25% of total employees in this sector in 2016. In most Western countries, agriculture GDP is about only 1% of its total GDP and employees in the agriculture sector are about 1-2% as well.

The US National Center for Atmospheric Research (NCAR) estimated that weather-related loss costed as much as 3.4 percent of the entire U.S. gross domestic product and the annual economic cost of the weather was about $485 billion.

The 2008 World Development Report finds about 2.5 billion people in low-income countries working in agriculture. The study by Dercon (2002) concludes that 78% of households in developing countries had financial hardships from bad weather. According to the Swiss Re (2017), China is among top three countries with the most losses from the natural disasters.

Traditionally, insurance has been used to protect losses associated with natural disasters and particularly agricultural losses. According

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to the NICA, from 1995 to 2014, the US insurance covered $395.6 billion of disaster losses. However, many disaster losses are not covered by the insurance. According to the Swiss Re (2017), China is among top three countries with the highest percentage of losses not covered by insurance.

In the past two decades, besides traditional disaster insurance, other financial derivatives have been added and used to better cover such losses. Creating and using weather indexes and its futures can be a good way to better protect the agriculture and other industries and at the same time that gives additional investment opportunities to investors. Weather index futures were first created in the US in 1999 based on ten US cities. Chicago Mercantile Exchange (CME) weather indexes currently list twenty five cities in the US, eleven in Europe, six in Canada, three in Australia, and three in Japan; and its annual trade is more than $30 billion.

The temperature-based indexes in the US are based on Heating Degree Days (HDDs) and Cooling Degree Days (CDDs). The major investors of these index futures are utility and energy companies in the US and other Western countries. To directly protect farmers in China, this study proposes to use the Extremely Heating Days (EHDs) and Extremely Cooling Days (ECDs) to derive the relevant temperature-based indexes and its futures.

Recently China has started offering weather index insurance. Swiss Re cooperated with two provinces in China to offer weather index insurance in 2016. Domestic insurance companies have also started to cooperate with local governments to offer similar weather index insurance. But, so far, yet there are no weather indexes publicly traded in China and especially no weather index futures.

Weather index insurance is offered by an insurance company to the local targeted farmers and is usually sponsored and supported by the local government. The United Nations, World Bank and other international organizations have been promoting and supporting this kind of insurance to help farmers in underdeveloped and poor countries.

Weather index futures are financial derivatives and they are publicly traded in the financial markets. These futures are supported by a country's government and regulated by its securities agents. Also, weather index futures are open not only to farmers, but also to all investors. Therefore, weather index insurance and its futures are quite different.

China has been developing and offering more weather index insurance. Following the Western countries' practices, it is the time for China to consider offering some weather-based financial derivatives and particularly index futures. This will give farmers more choices and so better protections and also provide more investment opportunities to the public. Index futures should be considered as the priority, because this concept of the futures is easy to be understood and accepted by the government and the public in China, compared with other weather index-based financial derivatives such as weather index options.

In this study, we suggest first to develop the weather indexes for county-level cities and then publicly trade these indexes as weather index futures. The selection of these cities is based on the significance of its agriculture industry to the local economy (at least 12% of its GDP from this sector). Theoretically, one can develop a weather index for any city and publicly trade that index as far as there is a market. Since the primary purpose of developing the weather index at the current stage in China is to help farmers, such an approach will be more feasible and practical. Particularly this will be much easier to receive the governments' support.

The rest of the paper is organized as follows: the next section reviews the literature; section 2 compares weather insurance, weather index insurance and weather index futures. Section 3 discusses different types of weather-based financial derivatives. Section 4 focuses on China's weather indexes and index futures and explains why China needs to develop and adopt weather index futures and how to do so. It particularly explains how the index futures should be valued or priced. Last section concludes the paper and discusses future research.

1. LITERATURE REVIEW

Weather affects an economy. Particularly weather factors like temperature, rainfall, humidity, and sunlight affect agriculture industry (Rosenzweig et al., 2001). Global warming has led to more extreme weather and increased weather fluctuations as expected (Easterling et al., 2000, Visser et al., 2014).

Traditional insurance can protect revenue losses or damages from weather-related events. But such protection has several drawbacks. First of all, weather-caused damages, to some extent, are social risk and many insureds may suffer simultaneously; as a result, the insurer who issued such policies may have its financial problem to reimburse all these losses. Therefore, insurers may withdraw from the markets when they find out that cumulative losses are too large (Chen & Hamwi, 2013). Secondly, insurers will encounter extra or unexpected losses from the financial markets when their insured disaster occurs and, as a result, many insurers may withdraw from the markets (Chen & Hamwi, 2013). Thirdly, insurance's payment is based on the condition that the policyholder had the proven loss as covered in the insurance; it usually only covers extreme weather and catastrophic losses (Barnett & Mahul, 2007; Fuchs & Wolff, 2011; Ender & Zhang, 2015); thus insureds are not fully protected.

Weather index insurance has been attractive to developing countries with small size of farms. Large farmers prefer buying traditional weather insurance because it can cover its actual loss. Also, large farmers pay lower insurance premiums per unit coverage than small farmers, since the insurer's underwriting cost will be lower due to the economies of scale and also because of less adverse selection and moral hazard problems (Boyd et al., 2011). In addition, large farmers receive huge government subsidies for its weather insurance and its premiums (Mahul & Stutley, 2010).

Weather index insurance has gained an increasing interest in insurance and agricultural research (Odening et al., 2007; Skees et al., 2001; Turvey, 2001). Berg and Schmitz (2008) studied how weather index insurance can help farmers better manage their whole risk. Goodwin (2001) and Ker and Ergun (2007) emphasized the benefits of using the index insurance in dealing with moral hazard and adverse selection problems. Collier et al. (2009) explored how weather index insurance can help farmers deal with the climate change and suggested that government and donor supports should focus on funding the start-up costs of developing weather index insurance markets and catastrophic layer of risk to avoid farmers' incentives to adapt the insurance.

Zhu (2011) studied the achievements and challenges of China's weather index insurance programs and found that farmers had weak demand for such insurance. Lin et al. (2015) found some factors affecting farmers' willingness to purchase weather index insurance in China and concluded that besides the recognition of risk itself, factors such as their type of agricultural products and farmers' trust to the insurer affect the farmers' willingness.

Weather index-related financial derivatives are based on the event of bad weather, not the outcomes or damages from the bad weather. Its contracts will also pay for less extreme events so better protection to the buyers/investors. Since the index is standardized and easy to measure, it will reduce participants' transaction and administration costs (Stoppa & Hess, 2003; Barnett & Mahul, 2007). Since insureds behaviors will not be related with the insurance payment, index related derivatives can eliminate adverse selection and moral hazard problems (Gronberg & Neilson, 2007).

Weather-related financial derivatives also provide investors with additional opportunities. Particularly weather indexes are not closely correlated with most stocks and stock market indexes such as NASDAQ or D&J indexes that give many investors great opportunities to diversify and improve its investment portfolios (Jewson, 2004; Mussoff et al., 2011; Ender & Zhang, 2015; Brockett et al., 2005; Yang et al., 2011).

As listed above, there have been some studies on China's weather index insurance; but there are no studies so far on China's weather index futures, and no advanced studies on China's weather indexes and particularly temperature-based county/city weather indexes. This study fills up the gap.

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2. METHODS

Methods used in this paper are mixed. It mainly uses a comparison method to compare different types of risk management of agricultural products, including traditional weather insurance, weather index insurance and weather index futures and explain why developing countries like China should develop and implement the weather index futures to better manage farmers' risk.

It is both theoretical and practical. It discusses features, advantages and disadvantages of different types risk management and particularly explores different types of financial derivatives in managing disaster risk. It is also practical, because it explains in detail how to calculate the weather index, how to price index futures and how to start-up the weather index futures market in China.

The paper has its unique contributions in terms of weather index and index futures. First, different from the Heating Degree Days (HDDs) and Cooling Degree Days (CDDs) used at Chicago Mercantile Exchange (CME), it suggests to use the Extremely Heating Days (EHDs) and Extremely Cooling Days (ECDs) to derive relevant temperature-based weather index futures; second, the CME weather indexes and its futures are based on weather conditions in metropolitan cities, but this paper focuses on the weather in county-level cities.

3. RESULTS

3.1. Weather insurance, weather index insurance and weather index futures

Traditional weather insurance is costly because of higher administration costs, like sales costs, loss measurement costs, moral hazard, and adverse selection. It typically covers high-risk, low-probability events, as defined in a highly tailored, or customized, policy. It fits large size farmers well.

Weather index insurance is based on the covered area's average weather condition and its payment is not directly related to the farms' actual losses. Its advantages are to lower the administrative costs and avoid potential moral hazard and adverse selection problems. It fits small size farmers better.

Weather-based derivatives such as weather index futures can cover high-probability events with low or medium risk. This is also based on the covered area's average weather conditions such as temperatures or rains. Its advantages are that they are publicly traded so that they are available not only to the farms, but also to all investors. The major difference between the weather futures/options and weather or weather index insurance is that in weather index futures/options, anyone can be the buyer or the seller, while in the weather or weather index insurance, an insurer will be the seller and the farms are the buyers. In other words, without an insurer, there is no weather or weather index insurance; but it is not necessary to have an insurer in the weather index futures/options.

Following is the summary of the weather insurance, weather index insurance and weather index futures. There are similarities between weather insurance and weather index insurance and between weather index insurance and weather index futures. But there are significant differences among them as discussed before. Compared with weather index insurance, the advantages of weather index futures are: (1) no reliance on insurers; (2) less reliance on governments; (3) open not only to farmers, but also to others; (4) lower average total start-up and administration cost because of large participants; (5) tradable and high liquidity.

3.2. Weather-based financial derivatives

Besides weather index futures, there are other types of weather-based financial derivatives. In this subsection, we review all relevant types of weather-based financial derivatives. One is called the post-loss stock issuing that allows insurers to issue additional stocks with the given price if the assumed CAT occurs that led the insurer to the loss above the given level.

The second approach is the CAT bonds. Reinsurers issue coverage to the primary insurer that issues weather related insurance; then it issues CAT-linked bonds. Proceedings of bonds will be put

Table 1. Summary of weather insurance, weather index insurance and weather index futures

	Weather insurance	Weather index insurance	Weather index futures
Issuer/Seller	Insurer	Insurer	Investors selling the Futures
Insured	Farmers	Farmers	Farmers or other investors
Target/coverage	Potential loss of agricultural product	Weather index changes	Weather index changes
Reimbursement	Based on the covered actual loss	Based on the actual Index and the contract	The difference of the actual index and the strike price of the index futures
Buyer's basis risk	Can be eliminated although usually not	Still existed	Still existed
Deductibles of loss	Yes	No	No
Issuer's risk	Potential huge exposure	Usually limited exposure	Always limited exposure
Typical risk covered	Low probability and often with high risk	High probability and often with low or medium risk	High probability and often with low or medium risk
Tradability	None tradable	None tradable	Public traded
Determinant of the price of the contract	Negotiated by the insured/insurer and often with the participation of the relevant government	Negotiated by the insured/ insurer and often with the participation of the relevant government	Determined by the market itself and fair price
Transparency	Low	Medium	Very high
Start-up cost	High	High	High
Loss measurement cost	Very high	Zero	Zero
Moral hazard/adverse selection problem	Serious	No	No
Government financial support	Needed and heavy	Needed strongly	Needed strongly to the farmers but no need to other investors

in a special purpose vehicle (SPV). According to the NICA, the US annual issues of the CAT bonds and Insurance Linked-Securities (ILS) are about $5-10 billion and its total outstanding is about $20 billion.

The third approach is the weather index options. In this case, traders can buy or sell the option contracts with specified dates and exercise (strike) price (specific weather index). For example, if weather index is higher than the expected, farmers will suffer; then they may buy a weather index call option that will allow them to buy weather index with lower price (call's strike/exercise price) or sell the put option. The fourth is the weather index futures. In this case, traders are allowed to buy or sell the future weather index.

The first type of the financial derivative is issued by a primary insurer and the second one is issued by a reinsurer. Therefore, these two types of weather-based financial derivatives are used to help insurers. The other two types of derivatives can be issued by any investors and both are based on the weather index in a specified location during the specified time period. Thus, they can be used to help not only farmers and insurers, but also other investors. Especially they can be used to help investors diversify their portfolios, since weather indexes are usually not correlated with other financial securities. These will be particularly valuable to mutual or hedge funds.

In 1999, Chicago Mercantile Exchange (CME) started trading of weather index futures based on ten US cities. Currently it lists twenty five cities in the US, eleven in Europe, six in Canada, three in Australia, and three in Japan; and its annual trade is more than $30 billion.

3.3. China's weather indexes and index futures

Several provinces and many cities in China have cooperated with insurance companies and offered weather index insurance. Following the Western countries' practices, China should consider of offering some weather-based financial derivatives and particularly weather index futures.

Previous experiences in developing weather index insurance can be used to derive a relevant weather index and then trade its index futures. The index futures will give farmers more choices and so better protections and also provide more investment opportunities to the public.

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Index futures should be considered as the priority, because this concept of the futures is easy to be understood and accepted by the government and the public in China, compared with other weather index-based financial derivatives such as weather index options.

As compared in the previous subsection, weather index futures can be best used to cover high probability events with low or medium risk. Thus, this can be the complements to the weather insurance and weather index insurance as tools to cover farmers' risks.

In order to form a futures market, there must be large enough participants. Current index insurance is usually based on a specific region/area and that will be too narrow to attract enough participants. A county-level weather index will be better. First, it is large enough to cover necessary farmers and attract other participants/investors; secondly it is narrow enough to have the similarities and avoid differentiations of weather conditions in different areas. Also, weather data are easy to collect at the county-level, since each has its weather station(s). We suggest first to select 20 county-level cities in which its agriculture industry is significant to the local economy (at least 12% of its GDP from this sector). This approach is necessary to start-up this proposed program, since its primary purpose is to help farmers and stabilize the agriculture industry. In the future, more cities can be added based on the needs.

To encourage farmers to buy this kind of weather index futures, governments need to subsidize these farmers, as they have been in weather-based insurance and weather index insurance. The suggested subsidy is 30% of the required premium/price of the futures contracts. To other types of investors, both buyers and sellers, any subsidies will not be necessary as long as the pricing of the futures contracts is fair. Also, governments should pay for start-up costs of developing the weather indexes.

3.4. Temperature-based weather indexes and futures

In the CME weather index futures and options market, temperature-based weather indexes and its futures and options are popular. Some others such as hurricane, snowfall, rainfall, frost index futures and options traded for several years, but in 2014, they were delisted due to insufficient demand.

The CME uses Heating Degree Day (HDD) and Cooling Degree Day (CDD) to derive futures and options. When the number of degrees that a day's average temperature is above 650°F (180°C), people start to use air conditioning to cool their buildings. The price of weather derivatives trading in the summer are based on an index made up of monthly Cooling Degree Day (CDD) values. The settlement price for a weather futures contract is calculated by summing a month's CDD values and multiplying by $20. To calculate the CDD, take the average of a day's high and low and subtract 65. For example, if the day's average temperature is 800°F, its CDD is 15. If everyday in a 30 day month had an average temperature of 80°F, the month's CDD value would be 450 (15 x 30). The nominal settlement value for its month's weather derivative contract would therefore be $9,000 (450 x $20).

For the winter's HDDs, its methods are the same. The HDD is the number of degrees that a day's average temperature is below 650°F, the temperature below which buildings need to be heated. The price of weather derivatives traded in the winter is based on an index made up of monthly HDD values. The settlement price for a weather futures contract is calculated by summing HDD values for a month and multiplying that sum by $20.

The major traders at CME weather index futures and options market are energy and utility companies plus some government funds and hedge funds. Farmers in the US or other Western countries do not participate in these trades much. The main reason is that big farmers prefer traditional agriculture insurance or traditional weather insurance as explained before. Small farmers are not interested in that neither, because this weather index is designed not to protect their risk, but to hedge electricity usage uncertainty.

For China's weather index futures, one may use RMB 100*HDD(CDD) as the value of the futures, where HDD is the Heating Degree Day and CDD is the Cooling Degree Day; RMB 100 is the multiplier. But in order to apply this valuation method,

one first needs to figure out the normal temperature during the summer or winter and particularly at which temperature, people will turn on the air conditioners. It can be a number around 200°C, instead of 180°C as in the US, given Chinese people generally prefer higher temperature than Americans.

As emphasized in the early section, this proposed weather index and futures in China are mainly for helping the agriculture industry. Then, instead of using the HDD and CDD, we suggest to use the Extremely Heating Days (EHDs) and Extremely Cooling Days (ECDs) to define relevant futures and its values. For example, for the summer, one may define 380°C as the maximum, then one can calculate how many days in a specific month above 380°C. Assume that in one month during the summer, there are 6 EHDs, then the value of this month's EHDs will be $\$500 \cdot 6 = \$3,000$, where \$500 is the multiplier. Similarly, one may define the ECDs and its futures value for winter.

The above approach is simple. A more complicated approach is to estimate or simulate the temperature's distribution first. Based on collected data of a selected city in a given time period such as a month, one can use the simulation method to estimate its appropriate probability distribution such as a normal distribution; then one can calculate or estimate its mean and standard deviation. Using the statistical theory, one can estimate or calculate a particular probability of its temperature at a specific point and its cumulative probability. Furthermore, one can estimate the relevant expected values and consequently its futures' value.

To capture temperature changes resulting from the global warming, one may further analyze the weather data using multiple regression models and figure out long-term trend of the temperature. Then it can be used to adjust or forecast the future normal temperature and its range. For example, if weather data indicates that the temperature has been 10°C degree higher each year in the past years, then the normal temperature for the future will be adjusted accordingly each year.

In addition, at CME, weather index and its futures/options are based on temperatures from each large metropolitan city such as Philadelphia or Tokyo. Since the purpose of developing China's weather index and its futures is to protect farmers, we suggest to collect weather data from a county/city in which the agriculture industry is significant. The agriculture sector shared 8.6% of China's total GDP in 2016. So the selected county/city for the weather index must have a higher GDP in agriculture such as 12% of its total GDP.

CONCLUSION AND FUTURE RESEARCH

This paper aims at explaining why China needs to develop weather indexes and adopt and trade weather index futures. It further proposes to use the EHDs and ECDs to develop temperature indexes and its futures and discusses how to price such futures contracts.

Weather indexes and its futures can be used to better protect not only agriculture industry, but also other industry and sectors like energy and utility. For example, during the winter season, if the temperature is not cold enough, the demand for electricity and other relevant energy will be low; then the relevant companies will be affected negatively. By purchasing or selling the weather index futures, these energy companies can hedge its potential risk.

Investors and especially mutual funds and hedge funds can also use weather indexes and its futures to diversify its investments and lower its risk. Generally, the weather indexes will have zero or very low correlations with other financial securities; as a result, including such an investment into the portfolio will lower and diversify the investors' risk.

The future research on this subject is to identify and select cities and collect its weather data from past many years (such as 20 years); then one can construct indexes for each of these selected cities and value its futures contracts.

In order to implement weather indexes and its futures, central and provincial/local governments

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must be very supportive. First, weather data are controlled by the governments. Second, governments need to subsidize farmers to encourage them to buy the futures contracts; third, the trading of the futures is regulated by the government offices.

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Insurance companies and mutual/hedge funds will be major participants of this futures market. They have responsibilities to further develop China's financial derivative markets and they also will directly benefit from that as discussed before.

REFERENCES

1. Alaton, P., Djehiche, B., & Stillberger, D. (2002). On modeling and pricing weather derivatives. *Applied Mathematical Finance, 90*(1), 1-20. https://doi.org/10.1080/13504860210132897
2. Barnett, B., & Mahul, O. (2007). Weather index insurance for agricultural and rural areas in low income countries. *American Journal of Agricultural Economics, 89*(1), 1241-1247. Retrieved from https://www.jstor.org/stable/30139468?seq=1#page_scan_tab_contents
3. Barthel, F. (2002). A trend analysis of normalized insured damage from natural disasters. *Climate Change, 113,* 215-237. Retrieved from https://link.springer.com/article/10.1007/s10584-011-0331-2
4. Benth, F. E., & Benth, S. (2007). The volatility of temperature and pricing of weather derivatives. *Quantitative Finance, 7*(5), 553-561.
5. Berg, E., & Schmitz (2008). Weather-based instruments in the context of whole-farm risk management. *Agricultural Financial Review, 68*(1), 119-133. https://doi.org/10.1108/00214660880001222
6. Bouwer, L. M. (2013). Projections of future extreme weather losses under changes in climate and exposure. *Risk Analysis, 33*(5), 915-930. https://doi.org/10.1111/j.1539-6924.2012.01880.x
7. Brockett, P., Wang, M., & Yang, C. (2005). Weather derivatives and weather risk management. *Risk Management and Insurance Review, 8*(1), 127-140. http://dx.doi.org/10.1111/j.1540-6296.2005.00052.x
8. Brockett, P., Wang, M., Yang, C., & Zhou, H. (2006). Portfolio effects and valuation of weather derivatives. *Financial Review, 41*(1), 55-76. https://doi.org/10.1111/j.1540-6288.2006.00133.x
9. Campbell, S., & Diebold, F. (2005). Weather forecasting for weather derivatives. *Journal of the American Statistical Association, 100,* 6-16. Retrieved from https://www.nber.org/papers/w10141
10. Chen, Y., & Hamwi, I. (2012). Why some disaster insurance does not exit? *Asia Pacific Journal of Risk and Insurance, 6*(1), 1-14.
11. Collier, B., Skees, J., & Barnett, B. (2009). Weather index insurance and climate change: opportunities and challenges in lower income countries. *The Geneva Papers on Risk and Insuarnce – Issues and Practice, 34,* 401-424. Retrieved from https://link.springer.com/article/10.1057/gpp.2009.11
12. Dercon, S. (2002). Income risk, coping strategies, and safety nets. *The World Bank Research Observer, 17*(2), 141-166. Retrieved from https://elibrary.worldbank.org/doi/abs/10.1093/wbro/17.2.141
13. Ender, M., & Zhang, R. (2015). Efficiency of weather derivatives for Chinese agriculture industry. *China Agricultural Economic Review, 7*(1), 102-121. https://doi.org/10.1108/CAER-06-2013-0089
14. Golden, L., Wang, M., & Yang, C. (2007). Handling weather related risks through the financial markets. *Journal of Risk and Insurance, 74*(2), 319-346. https://doi.org/10.1111/j.1539-6975.2007.00215.x
15. Goodwin, B. K. (2001). Problems with market insurance in agriculture. *American Journal of Agricultural Economics, 83*(3), 643-649. Retrieved from https://www.jstor.org/stable/1245093?seq=1#page_scan_tab_contents
16. Gronberg, T. J., & Neilson, W. S. (2007). *Incentives of weather derivatives vs crop insurance* (Working paper). Taxes A & M University, College Station.
17. Heimfarth, L. E., & Musshoff, O. (2011). Weather index-based insurance for farmers in the North China plain: an analysis of risk reduction potential and basis risk. *Agricultural Finance Review, 71*(2), 218-239. https://doi.org/10.1108/00021461111152582
18. Heimfarth, L. E., Finger, R., & Musshoff, O. (2012). Hedging weather on aggregated and individual farm-level – pitfalls of aggregation bias on the evaluation of weather index based

insurance. *Agricultural Finance Review, 2*(3), 471-487. https://doi.org/10.1108/00021461211277295

19. Jewson, S. (2004, Jan. 16). *Four methods for the static hedging of weather derivatives*. Social Science Research Network.
20. Lin, Jia et al. (2015). Factors affecting farmers' willingness to purchase weather index insurance in the Hainan Province in China. *Agricultural Finance Review, 75*(1), 103-113. https://doi.org/10.1108/AFR-02-2015-0007
21. Mahul, O., & Stutley, C. J. (2010). *Government Support to Agricultural Insurance: Challenges and Options for Developing Countries*. World Bank Publications: Washington, D. C.
22. Muller, A., & Grandi, M. (2000). Weather derivatives: a risk management tool for weather-sensitive industries. *The Geneva Papers on Risk and Insurance-Issues and Practice, 25*(20), 273-287. Retrieved from https://link.springer.com/content/pdf/10.1111/1468-0440.00065.pdf
23. Mussoff et al. (2011). Management of climate risks in agriculture – will weather derivatives permeate? *Applied Economics, 43*(9), 1067-1077. https://doi.org/10.1080/00036840802600210
24. Odening, M., Musshoff, O., & Xu, W. (2007). Analyses of rainfall derivatives using daily precipitation models: opportunities and pitfalls. *Agricultural Finance Review, 67*(1), 135-156. https://doi.org/10.1108/00214660780001202
25. Okhrin, O., Odening, M., & Xu, W. (2012). Systematic weather risk and crop insurance: the case of China. *Journal of Risk and Insurance, 80*(2), 351-372. https://doi.org/10.1111/j.1539-6975.2012.01476.x
26. Pelka, Niels and Musshoff, Oliver (2014). Hedging effectiveness of weather index-based insurance in China. *China Agricultural Economic Review, 6*(2), 212-228. https://doi.org/10.1108/CAER-11-2012-0124
27. Richards, T., Malfredo, M., & Sanders, D. (2004). Pricing weather derivatives. *American Journal of Agricultural Economics, 86*(4), 1005-1017.
28. Skees, J. R. et al. (2001). *Developing rainfall-based index insurance in Morocco* (Policy Research Working Paper No. 2577). World Bank, Washing, DC.
29. Stoppa, A., & Hass, U. (2003). Design and use of weather derivatives in agricultural policies: the case of rainfall index insurance in Morocco. Paper presented at *International Conference: Agricultural Policy Reforms and WTO: Where are We Heading? Capri*.
30. Swiss Re (2017). *Natural catastrophes and man-made disasters in 2016*. Swiss Re Sigma.
31. Torriani, D. S. et al. (2008). Hedging with weather derivatives to cope with climate variability and change in grain maize production. *Agricultural Finance Review, 68*(1), 67-81. https://doi.org/10.1108/00214660880001219
32. Torro, H., Meneu, V., & Valor, E. (2003). Single factor stochastic models with seasonality applied to underlying weather derivatives variables. *Journal of Risk Finance, 4*(4), 6-17. Retrieved from https://papers.ssrn.com/sol3/papers.cfm?abstract_id=264178
33. Turvey, C. G., & Kong, R. (2010). Weather risk and viability of weather insurance in China's Gansu, Shaanxi, and Henan provinces. *China Agricultural Economic Review, 2*(1), 5-24. https://doi.org/10.1108/17561371011017469
34. Vedenov, D. V., & Barnett, B. J. (2004). Efficiency of weather derivatives as primary crop insurance instruments. *Journal of Agricultural and Resource Economics, 29*(13), 387-403.
35. Visser, H., Petersen, A., & Ligtvoet, W. (2014). On the relation between weather-related disaster impacts, vulnerability and climate change. *Climate Change, 125,* 461-477. Retrieved from https://link.springer.com/article/10.1007/s10584-014-1179-z
36. Woodard, J. D. F., & Garcia, P. (2008). Basis risk and weather hedging effectiveness. *Agricultural Finance Review, 68*(1), 99-117. https://doi.org/10.1108/00214660880001221
37. World Bank (2008). *World Development Report 2008: Agriculture for Development*. Washington, DC.
38. Yang, C., Li, L. S., & Wen, M. (2011). Weather risk hedging in the European markets and international investment diversification. *The Geneva Risk and Insurance Review, 36,* 74-94. Retrieved from https://link.springer.com/article/10.1057/grir.2010.4
39. Zheng, Y., Zhang, J., & Wang, W. (2009). Study on public agricultural insurance in China-based on Xinjiang model. *Modern Applied Science, 3*(1), 71-74.
40. Zhu, Jun-Sheng (2011). Evaluation of an insurance scheme based on the weather index. *The Chinese Economy, 44*(6), 56-72.

http://dx.doi.org/10.21511/ins.09(1).2018.04