Independent Final Report

Temperature-based Derivatives for Vietnam cities: Insuring Farmers Against Changing Climate

by

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Certification Page

I, Tran Do Thinh Hoang (Student ID 52117005) hereby declare that the contents of this Independent Final Report are original and true, and have not been submitted at any other university or educational institution for the award of degree or diploma.
All the information derived from other published or unpublished sources has been cited and acknowledged appropriately.

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TRAN, DO THINH HOANG
2018/11/11

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Summary

The purpose of this paper is to test a temperature-based pricing model of Alaton (2002) in case of main rice-growing cities in Vietnam. The results of the test are then used to make practical implications for Vietnamese farmers, investors and related parties. Data is collected from General Statistics Office of Vietnam, and Vietnam Meteorological and Hydrological Administration, with a reference to acuweather.com, on which the Alaton model is ran. Descriptive results are illustrated by figures and tables to serve a base for implications and recommendations. The author suggests that temperature-based options will be great tools for Vietnamese farmers to hedge unfavorable weather risks, and for investors to earn speculative profits. The great geographic diversity among Vietnam cities show that there is a great potential to expand option contracts nationwide.

By far, the author acknowledges that, findings are limited by the limited temperature data in Vietnam, and the lack of comparable market prices. Furthermore, the pricing model itself assumes normal distribution, which might not fully capture the evolution of daily and seasonal temperature.

Weather derivatives, especially the covered temperature-based options are potential insurance for farmers and agricultural manufacturers besides existing price subsidiaries. From a policy perspective, the establishment of an active trading market can support the

expanded use of weather derivatives in and outside the agriculture sector.

1. Introduction

a. Slow adaption to the changing weather

Agriculture is essential for countries through which the river flows through. Delta people, of different cultures, share almost same agriculture products: ranging from rice, fruits to fishes and shrimps. Vietnam shares the downstream parts of the Mekong River and the Red River, which provide the country rich soiled basin for growingly abundant amount of rice for national food security and export. For many years, generations of Vietnamese have been growing plantation mostly on the southern and northern deltas of our countries; creating a complex system of dams and irrigation systems to help moderate annual water flows and ease temperatures.

However, as Vietnam and other neighboring countries' economies grow, electricity is of excess demand to supply and push China, Laos, Thailand, Cambodia, Vietnam…to build massive dams on the up and middle streams. In addition, the effects of global warming are getting more serious in rural, agriculture cities across the country. From 2010 onwards, several reports indicate higher than usual temperature and less precipitation in both Winter-Spring and Summer-Fall harvests – two main harvests.

Vietnamese farmers have been struggled to come up with better solutions to mitigate the effects of unfavorable weather patterns, with several agricultural cities and provinces adopting new planting technology, receiving government's price subsidiaries and credit extension. However, due to the unexpected nature of weather, crop production is still dangerously vulnerable to changing climate patterns that usually lead to droughts, floods or plant-diseases which might send Vietnam's national food security to an alarm level.

b. Robust, promising equity market

On the other hand, on pace with a rapid GDP growth (6.79% in 2017), the financial market in Vietnam is developing at a promising rate. For instance, in 2016, according to Vietnam State Security Commission, the country general stock index – VN-index grew 15% year-over-year; recording jumping figures of market capitalization value of up to 42% of GDP. In 2016 and 2017, more than 350 companies registered for listing, and already-listed companies successfully call for over VND380 trillion (USD16.3 billion). Moreover, with efforts to reduce or 100% withdrawal of government equity from state-owned firms and welcome foreign strategic investors, the equity market becomes progressively attractive to both domestic and foreign investors.

Taking this advantage, the two stock exchange: Hanoi Stock Exchange (HNX) and the Ho Chi Minh city stock exchange (HoSE) simultaneously act to improve Vietnam equity market rating from frontier to emerging (according to Morgan Stanley Capital International – MSCI rating). Apart from requirements for several listed companies to free up space for foreign room, the two exchanges have introduced more advanced financial products to offer investors with greater flexibility in investments. From 2016, the HNX started futures contracts; while from mid-2017, the HoSE offers warrants for large-cap stocks in the country. These financial derivatives receive positive welcome from domestic investors from launch, with transaction volume boasts at an amazing compound growth rate of 21.5% over the 2016-2018 period. Securities companies also start to offer exchange-traded fund certificates whose portfolios include futures and warrants. Despite the trade war happening between the US and China recently, hopes are still flying in the market for recognized emerging markets with more complex tools for investments.

c. Weather derivatives: hedging the unexpected

Given the developments in both the agriculture and finance industries of Vietnam, the author sees imminent opportunities to create strong bonds between the seemingly unrelated two, with the ultimate goals of: 1) helping farmers hedge losses against growingly unstable weather, 2) bringing more non-agricultural players to promote the growth of Vietnam still-immature agriculture, and 3) providing shares of financial gains to the key players just mentioned. The appropriate tool for achieving those goals are weather derivatives.

Firstly, the primary purpose of financial derivatives is hedge of risks – or measurable uncertainties. The risks include, but not limited to, business risk, price risk, inflation risk, systematic and non-systematic risk. A futures or an option are good examples for hedging those risks, whose values depend on their "underlying assets" – like collaterals in real estate mortgages. For instance, an investor buys an option with a stock as an underlying. The option, "call" or "put", gives the investor a right to buy or sell that stock given that the stock price breaches certain levels. When the investor expectations against the risks are correct, he/she is entitled to a certain amount of financial gains; which sometimes can be unlimited. The price of options themselves is determined by various models, among which Black and Scholes (1973) is most famous.

Secondly, regarding weather derivatives, according to Zhiliang, Peng, Lingyong, Chunyan & Min, 2015, "weather derivatives is a new risk management tool which can be widely used in the financial market to avoid the impact of bad weather effects and control the weather risks". The underlying assets of weather derivatives can be temperature, precipitation, or humidity. These underlyings give weather derivatives even more effective risk-hedging characteristics, since they are almost non-correlated with financial markets, which expose to human expectations or even manipulations. The most commonly used underlying is temperature, which give rise to a branch of weather derivative: temperature-based derivatives.

Valuation models of temperature-based derivatives are much in development processes, with different methods and approaches. However, the ones that most closely model the patterns of annual temperature are most reliable, since they can accompany farmers' experiences over past temperature patterns. This research paper will test the indices approach, from which Alaton (2002) develops a pricing process for temperature-based options for cities in the US. The Alaton pricing model will be used to produce options prices for main rice-growing provinces in Vietnam to see to which extent such options can be used as hedging devices for farmers.

To the author's best knowledge: 1) there is not a real trading market for weather derivatives in general, 2) there are not any previous researches regarding temperature-based derivatives in Vietnam. Therefore, this paper is intended to give readers an overall understanding of temperature-based derivatives through literature review; results regarding the loss-hedging merits of temperature-based options in Vietnam agriculture cities; and implications for actual development and promote of nationwide or Southeast Asian-wide use of temperature-based derivatives. The paper, after background introduction, will explain points regarding limitations and methodologies. Then, a throughout literature review is discussed to act as a framework for the result discussion of a simulated Alaton model (2002) over five cities in Vietnam. The research paper concludes with implications for farmers, non-agricultural players as well as regulators, hoping to create a reference for future researches and policies to bridge the financial market with the agriculture industry and in protection for farmers and gainers for investors.

2. Research Design

a. Purpose – Research Question

The purpose of this paper is to test a temperature-based pricing model of Alaton (2002) over main rice-growing cities in Vietnam; which includes An Giang, Thái Bình, Nam Định, Ninh Bình and Hải Dương. The results of the test in each city are the option price for that city for two main harvest in a year: The Winter-Spring harvest and the Summer-Fall harvest. The options price then serves as a base to answer the research question as follow:

"**To which extent temperature-based options help farmers hedge against losses and attract investors for potential upside gains**?"

b. Methodology

i. Data collection and mining

The main, secondary in their nature, data in this research report is temperature. Temperature data points are collected from General Statistics Office of Vietnam, and Vietnam Meteorological and Hydrological Administration, with a reference to daily temperature data from acuweather.com. Collected temperatures are normalized and clusters first into panel data with marked time t_1 to the respective t_n. Then, by using extension packages from Excel and Matlab; panel data are bonded into matrix vectors for later use in Ornstien-Unlenbeck process. Distributions of temperature and thus vectorized data assume normal distributions.

In addition, to facilitate result discussion and implications, statistics regarding: 1) Vietnam equity market, 2) Vietnam labor statistics, and 3) GDP, general and rice export value are retrieved primarily from General Statistics Office of Vietnam and State Securities Commission of Vietnam, with further sources cited in reference list. These numbers, used along with obtained options price from the model, are used to provide readers with ease to understand the relationships between weather derivatives and financial market in a practical sense.

ii. Modelling and testing

Treated data are input to find the necessary variables in the Alaton model (2002); among which the most important element is temperature volatility estimator in the form of mean-reversing process's standard deviation. The model runs for five cities in Vietnam, each produce respective options price. Particularly in this report, only call options are considered. Resulted call option premium (price) are effectively maximum losses (as max loss later in tables) for long positions – farmers; while abnormal changing temperature basis points are gains for investors. These secondary results are then weighted and compared with real 2017 rice export value to find the probable percentage over total production value that farmers can hedge using temperature-based options. This ultimately answers the research question raised in “Purpose – Research question” part.

c. Research limitations

The author, in data collection and mining process, at best effort tried to minimized any potential biases, anomalies or skewness in data, but still acknowledge the presence of such elements might make mining process less reliable. Thus, the results only assume the normal distribution reliable range of 95%.

Findings are limited by the limited temperature data in Vietnam, and the lack of comparable market prices. Furthermore, the pricing model itself assumes normal distribution, which might not fully capture the evolution of daily and seasonal temperature. In this perspective, it is strongly recommendable for later researches to either qualify the appropriateness of normal distribution; or adopt better distributions for better modelling of real temperature. This will be discussed more in the “Literature review” section.

3. Literature Review

a. The use of financial derivatives in risk management

Derivatives are special financial instruments. This is because the values of derivatives do not normally appear from the derivatives themselves, but from the "underlying asset" values/prices. The underlying assets can be physical like steel, corn, oil, and so on; while increasingly the more popular branches are stocks, bonds, and commercial mortgage-backed securities (CMBS). To create a derivative (like signing a contract), we normally need two parties to the contract: the buyer, often known as the "long position"; and the one to sell, or the "short position". More specifically, the long position will usually come to the possession of the underlying asset. Derivatives can come in various types, from forwards, futures to options, which will serve the speculative intentions of either the long position or the short position accordingly.

Forwards and futures oblige parties to exercise them once they reach expiration date, while options give parties the right of exercising or not. Using these characteristics, manufacturers or investors alike can make gains on their predictions of the directions to which the underlying assets is heading, and also hedge against unfavorable conditions. For instance, in speculating that the price of a crude oil barrel with exceed $70; a refinery enters a forward contract with an exporter to buy such barrel at a price of $65 – this price is also called the "strike". If, the market goes as the refinery predicted, and one barrel costs $70 (or more); the refinery will save itself at least $5. However, there is still a 50-50 chance that the price will crash below $65; in which the refinery will lose an amount that will be a respective gain for the exporter. In this sense, forwards/futures would produce mostly a Win/Lose case; while, since options are rightful; they can often limit losses to both positions; producing Win/Win case.

The study of Mallin, Kean and Reynolds (2001) shows the following

> The survey results show companies are exposed to low degrees of equity and commodity risks*,* with derivatives being used predominately to hedge contractual obligations that result in currency and interest rate risk. OTC forwards is the most used instrument to hedge currency risk and swaps the most popular derivative instrument for hedging interest rate risk. (p.85).

Indeed, the study elaborates the simple example above by showing that, apart from price risk, financial derivatives are crucial to not only manufacturing companies – those with high exposure to price and commodity risks; but also to non-manufacturing firms, export firms with daily exposures to changes in currency or interest rate highs and lows.

Furthermore, Bailly et.al (2003) in “UK corporate use of derivatives” stated that “The evidence suggests that their use is limited in view of the perceived potential benefits that can be derived from their use in risk management”. With their perception of business risks, management is able to choose the right derivative products to hedge risk. Currently, there are many active trading markets for derivatives, namely the Chicago Board of Exchange (CBOE); the Tokyo Exchange, and many other developed and emerging markets that together revolutionize derivatives' usage and turn them into powerful hedging tools in many economy sectors, such as manufacture, service. In this research report, the author also argues for extended use of derivatives for less financial-knowledgeable labor force – like farmers; which, weather derivatives are good choices.

b. Weather derivatives approaches and previous studies

Weather derivatives, unlike financial derivatives, take underlying assets that are mostly untradeable. These are temperature, humidity, precipitation/annual rain amounts, winds, or even the probabilities of natural disasters like floods, tornadoes; all of which are weather elements. Weather derivatives are not too new, and has been used widely in the US and European markets. In 2002, Dutton concluded from his study that nearly 4 trillion USD (approximately 20% of USA's 2017 GDP) is subjected to weather risks. Therefore, weather derivatives with weather as underlying assets are great sources of hedging against fatal losses from uncontrollable nature. Generally, there are three different approaches in pricing of weather derivatives:

1) *Burn analysis* uses historical index to arrive at each derivative's fair value; plus, a risk

premium to produce its price. This approach requires an active trading market for comparable and historical prices; thus applicable for markets where the use of weather derivatives is common already.

2) *Index Modelling* enlarges the burn analysis when adding the historical index distribution; thus yielding more reliable results than that of burn analysis. However, since it is based on *Burn analysis, Index Modelling* is too useful only for developed markets.

3) *Daily simulation* is a relatively new, highly mathematical approach in which stochastic process (unlike straight-line, deterministic assumptions of weather used in Burn analysis and Index Modelling) is used to model temperature patterns on daily to annually basis.

From 2000, there have been many studies based on the Daily simulation approach. Hull and White (2000) modeled future interest rates on Ornstein – Uhlenbeck stochastic process (OU process) – a continuous type. Alaton et.al (2002) produced temperature-based derivatives using similar OU process, but enhanced it by describing temperature evolution with a sine function. Benth and Saliyte (2005) used Norwegian temperature data and hyperbolic Levy process to create a model with variable depends on timing periods – thus volatility between days also evolves compare to the static monthly volatility parameter assume by Alaton model (2002).

On the other hand; Cao and Mei (2000) configures seasonality of historical data (temperature) and proposed a discrete AR process. Recently, the CAR model by Benth (2007) combined the approached used in researches above to form a model for cities in Sweden; whose results fit well and thus make the pricing process computational complex but most accurate.

c. Insuring Vietnam farmers with weather derivatives

Although the country is moving towards modernization with more focus on the service sector, Vietnam still have agriculture sector to account for 15.34% of GDP in 2017 (General Statistics Office of Vietnam, 2018). Vietnam is home to diverse agriculture, among which the water rice is the most important crop for national food security and export. Fruits, vegetables and other crops are planted within the rice harvest seasons. Under the effect of: 1) global warming, and 2) constructions of damns in the Mekong River, the normal rice harvest seasons are seeing increasing volatile in temperatures and precipitation which results in heavier draughts or floods, hurting the agriculture sector billions of dollars in losses. Therefore, it is a growing concern for farmers and agriculture co-ops to manage weather related risks. Bergfjord (2009) proposed: “One might hypothesize that, as firms grow larger and more internationally diversified, self-insurance will become more attractive as opposed to regular insurance services."

Besides the current 10% price subsidiaries, weather derivatives can also act as insurance for farmers, as argued by Heim farth and Musshoff (2011). The market for weather derivatives in the US grew by 20% Year-over-Year in 2011 to $11.8 billion (CME Group, 2011); signify the potential of their use. However, in developing market like China or Vietnam, there has not been an active trading market for weather derivatives. Liu (2006) studied the market for weather derivatives in China and acknowledged the lack of real trading data as the greatest barrier to develop a sound market.

To address this issue, the author finds the pricing model for temperature-based derivatives of Alaton (2002) extremely useful. Utilized the Ornstien-Unlenbeck process (OU process) to model temperature pattern; the Alaton model prices option contracts with temperature as underlying asset. Kermiche and Vuillermet (2016) applied the Alaton model (2002) and concluded that "the temperature derivatives contracts created in this study proved to be efficient tools for hedging climatic risk and decreasing volatility in production revenues for farmers". Lu and Ender (2014) tested Alaton model (2002) and Benth (2007) on the China cities. In addition, Schiller (2012) proposed an extension from the Alaton model by measuring intra-day seasonality, through the testing of Alaton model and other models.

Taken into account of: 1) the emerging nature of Vietnam financial market, 2) the imminent widespread usage thanks to simplicity, the author applied the Alaton model to price temperature-based options for five main rice-growing cities in Vietnam. The author tries to extend the scope of the studies of Lu and Ender (2014), by not only testing the model, but also giving practical implications he see feasible for Vietnam and (hopefully) other nearby South East Asian markets.

d. *Linking weather with insurance*

As mentioned, this paper utilizes the work of Alaton, P. (2002) in building: 1) a stochastic process that describes temperature's seasonal pattern and evolution, 2) pricing model based on market price of risk, since temperature is a non-tradable equity. After modeled derivatives contracts are priced, we will use them in risk-hedging for scenario analyses. Such results will be used to refer to propose necessary of creating a market for temperature-based contracts in agricultural regions of Vietnam as means for: 1) farmers to hedge against climate change, 2) outside investors to earn return on short positions, and 3) regulators to create a weather derivatives market.

The cooling-degree-day (CDD) and the heating degree-day (HDD) are the most common underlyings of temperature-based derivative contracts under these formulas: Alaton, P. (2002):

HDD_i = max {18 – Ti, 0} (1)

CDD_i = max {T_i – 18m 0}(2)

The number of HDDs or CDDs are the deviation of daily average temperatures (DATs) from certain reference levels; which is 18^0 degrees – a US industry standard.

4. Model creation

Compared with the CAR model by Benth (2007); Alaton (2002) used a more specific range of time to try to figure out the patterns of temperature; both of which improved the index modeling method by various means. The Alaton model assumed a constant monthly volatility estimator under a continuous time Ornstein-Uhlenbeck (OU) process; which by itself describes the day-to-day difference in temperature accordingly to the regional/local temperature it follows.

In order to build the model that predicts temperature evolution and changes; first, we use historical daily temperature in 2017 for 5 cities in the northern region of Vietnam; where agricultural harvest seasons are similar to one another. The raw data is then clustered into monthly group vectors for later utilization in finding out volatility estimator.

To model temperature, the Alaton et al. model (2002) fitted the DATs with: 1) a part that describes the annual seasonality of the model; 2) a random, driving-noise and mean-reversion process. The first part is able to structure annual temperature into a sine function:

$$T_m^t = A + Bt + C\sin(\omega t + \varphi) \quad (3)$$

where t stands for measured daily temperature and $\omega = 2\pi/365$; where "A denotes the mean temperature; B is the parameter that represents the global warming; C and φ are, in order, the scale parameter and the coordination parameter of the since function". (see Lu Zong, et.al (2007)).

The second part, which is a random process of temperature is modeled with a Brownian motion with an OU process; which is given by:

$$T_t = (x - T_s^m)e^{-a(t-s)} + T_t^m + \int_s^t e^{-a(t-\tau)}\sigma_\tau dW\tau \quad (4);$$

where T_t^m is given by equation (3) and $W\tau$ is a Brownian motion. α(a) is the mean-reverting parameter of the OU process. Alaton et. al (2002) states that the volatility parameter σ is measured constantly; which describes the relative differences in daily temperature within a month (typically 30 days). The estimated values are arithmetic average of the quadratic variation of T_t:

$$\hat{\sigma}_{\mu}^{2} = \frac{1}{N_{\mu}} \sum_{j=0}^{N_{\mu}-1} (T_{j+1} - \quad T_{j}) \quad (5)$$

And the value comes from the regression method (Alaton et.al 2002):

$$\sigma_{p}^{2} = \frac{1}{N_{\mu}-2} \sum_{j=1}^{N_{\mu}} (\widetilde{T_{j} - \quad \hat{a}} \, T_{j-1}^{m} - (1 - \hat{a}) T_{j-1})\text{^}2 \quad (6)$$

Where the mean-reversion a is estimated by:

$$\widehat{a_{n}} = \quad -log\left(\frac{\sum_{i=1}^{n} Y_{i-1}\{T_{i} - \ T_{i}^{m}\}}{\sum_{i=1}^{n} Y_{i-1}\{T_{i-1} - T_{i-1}^{m}\}}\right) \quad (7)$$

In which

$$Y_{i-1} \quad = \frac{T_{i-1}^{m} - T_{i-1}}{\sigma_{i-1}^{2}} \quad i = 1,2,\ldots n \ (8)$$

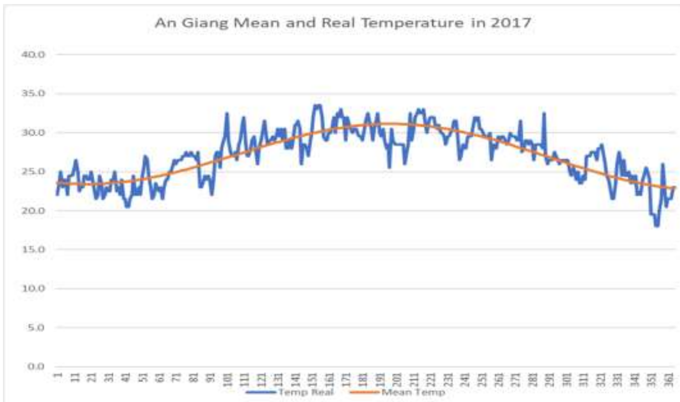
The table below presents the results of the estimated monthly volatilities for the Vietnamese cities in scope of this research.

Table 1. Estimated values of monthly volatilities for the Alaton et.al model (2002) for cities in Vietnam

City	January	February	March	April	May	June	July	August	September	October	November	December
Thái Bình	2.54	5.09	5.03	3.53	2.22	1.74	1.00	1.82	1.46	2.32	3.17	1.32
An Giang	1.51	1.79	1.08	2.44	1.74	1.47	2.53	1.08	0.94	2.20	1.39	2.35
Nam Định	3.32	5.27	4.84	3.22	2.01	1.97	1.00	1.75	1.43	2.32	3.22	1.29
Hải Dương	2.01	3.05	4.94	2.67	2.21	2.31	1.00	1.69	1.96	2.33	2.21	1.32
Ninh Bình	2.04	3.04	4.96	2.43	2.26	2.58	1.14	1.72	1.96	2.31	1.95	1.33

Source: Author's calculation

Figure 1. below shows the Alaton et.al (2002) model's curve of An Giang in 2017 (365-day year). Since the model assumes constant monthly volatilities estimators, the curve is quite smooth; which fits into real temperature:



**Mean temperature: modeled temperatures

Source: Author's calculation

Given adjusted R^2 of 0.9273, it shows that although year to year and day-to-day temperature values might change variably, their monthly volatilities are stable – thus create a climate pattern. From this we can see that the Alaton model (2002) does give reliable prediction for temperature revolution in Vietnam; and thus could its HDDs and CDDs could be used for pricing temperature-based contracts.

5. Temperature-based derivatives pricing and scenario analysis

a. Temperature-based derivatives pricing

Since temperatures, and in addition, its indexes like HDDs and CDDs are non-tradable underlying assets. pricing directly from risk-neutral method and market prices like the Black-Scholes model is difficult. Therefore, a market price of risk is necessary to relates the process of the underlying with the real payoff in existing capital and derivatives market. Canbrera (2009) uses Berlin traded futures to as means to calculate the market price of risk. However, since there has not been a real market for weather derivatives in Vietnam, inference of market price of risk is impossible. Yet, Goncu (2011) suggested that the effect of market price of risk is insignificant for weather derivatives.

Therefore, for this paper, we set the market price of risk accordingly to Vietnam's 2017 equity risk premium at 6.8%, and assuming once the market for agricultural derivatives is established, the risk aversion of investors in such market will be as same as traditional stock market. In the end, there is only one Vietnamese race. Furthermore; taking into account that: 1) Vietnam is still a frontier market, 2) market players' financial knowledge is limited, and 3) simplicity for further practical implementation, in this paper, we will: 1) price only call options – since longing a call would likely equal to shorting a put in a bull market, and 2) assume that farmers/manufacturers will always be long positions to hedge their risks.

In addition, the working mechanisms of these call options would also be dependent on the following assumptions:

+ In cooling harvest, if temperature raise by 2 degrees from Maximum temperature (which will damage the crop), it's worth exercising the option to act as insurance mechanism.

+ Strike point is a degree point.

+ In heating harvest, if temperature drop from Minimum temperature by 2 degrees (which will damage the crop), it's worth exercising the option to act as insurance mechanism.

+ The crops best grow accordingly to the temperature of each harvest. In this sense, farmers would only grow, harvest, and sell their products under two main harvest: Winter-Spring harvest and Summer – Fall harvest; which would translate into two 3-month type of call option contracts accordingly.

+ Insurance coverage (IC) is in term of max loss (%) over the change in crop price per mt for long-positions; therefore, it will be 0 < IC < 1

Here are call option prices of Vietnam cities under research scope:

Option price is in thousand VND (1 usd = 23 255 VND)

Table 2. Call Option Prices

	City	Strike Temp	Option Price	Insurance Coverage
Winter-Spring Harvest	Thái Bình	28	4,867	48.67%
	Nam Định	27	4,758	47.58%
	An Giang	35	6,213	62.13%
	Hải Dương	33	4113	41.12%

	City	Strike Temp	Option Price	Insurance Coverage
	Ninh Bình	30	5525	55.25%
Summer- Fall Harvest	City	Strike Temp	Option Price	Insurance Coverage
	Thái Bình	24	3,616	32.88%
	Nam Định	25	2,891	26.29%
	An Giang	28	5,738	52.16%
	Hải Dương	24	6183.5	56.21%
	Ninh Bình	28	7282.5	66.2%

In combination with Table 1., the listing call option prices could be interpreted in several aspects. First, the temperature, at which each city' contract is exercised, fits into each city's seasonal climate. Since exercise of options depends on anomalies of temperature – which in this case of research +/- 2-3 degrees above max/min temperatures that the crop themselves is prone to, the farmers by their experience could easily time their choice of contracts.

Second, the pricing process of Alaton et.al model produces higher option prices in cool months (HDDs) and cheaper option prices in hot months (CDDs) as it expects a great concentration to the mean temperatures (Gaussian distribution). As a result, farmers can also vary in their choice of period in choosing options to sign. For instance, if farmers in An Giang expects to grow more crops in Summer-Fall harvest season, a tendency in Mekong delta, they can long call options for May-August, which is relatively, as Table 2 has shown to be cheaper to cover at least 52% of their production value. On the other hand, short positions can take chances against long positions. When An Giang farmers buy long positions, investors can already create and short call options for Winter-Harvest harvest in the same or different cities, where the gain often is the call option price itself.

Winter-Spring harvest, as shown in Table 1, depicts a much greater volatile nature than Summer-Fall harvest. This characteristic is a reality for Vietnam northern agricultural areas: when winter brings – most of the time highly unexpected coldness or heat – and irrigations fall short because of retreating Hong river. In this sense, given the hedging merits of option contracts, in cities like Thái Bình or Ninh Bình, 40-60% of the production value could be insured, in absence of necessary protection means.

b. City-case Scenario Analysis

To arrive at Table 3, the following steps are taken:

+ Applying built models' function to project 3-year-ahead temperatures according to each harvest period.

+ Using striking temperature +/- 1-2 degrees as thresholds for the likelihoods of irregular temperatures taking place.

+ The resulting likelihood is the number of periods meet or exceed the thresholds above / total number of periods.

Table 3. 3-year projection

Winter – Spring Harvest		**Summer – Fall Harvest**
Cities	Irregular temperature probability	Irregular temperature probability
Thái Bình	3.65%	5.13%
Ninh Bình	7.03%	5.86%
Nam Định	5.11%	2.56%
Hải Dương	6.57%	5.13%
An Giang	5.47%	6.59%

Source: Author's calculation

The table indicates signs of relief for agriculture industries, which show that irregular temperature probabilities are still quite unlikely to take place. Assume a normal distribution, all normal temperature days are still within 90% level of confidence.

Nevertheless, this result does not reduce the risk-reducing importance of call options. For instance, taking the example of Hải Dương where 18 days over 3-year periods, the model indicate weather increases above normal weather. Then the farmers might, expect a week of abnormal temperature, though the unusual daily temperature is not consecutive; thus increase the chance that a crop's harvest could be reduced – which is when farmers can enter option contracts.

To further illustrate the extent of hedging amounts, we take into accounts of Vietnam 2017 rice export value. The rice export value is measured in USD per metric ton (mt). Exchange rate USD/VND is 23100 as of 14/07/2018.

Table 4. Vietnam Rice Export Value 2009-2017

Vietnam Rice Export Value 2009-2017									
Year	2009	2010	2011	2012	2013	2014	2015	2016	2017
Export value per mt	$407	$420	$514	$440	$446	$464	$408	$435	$450

Source: Vietnam Ministry of Agriculture and Rural Development, 2018.

In recent years, from 2013 onward, export rice price improved, according to the Vietnam Ministry of Agriculture and Rural Development (MARD, 2018), largely due to the improved quality of the planted rice. This improvement is largely distributed to the ongoing effort of farmers and manufacturers in choosing seeds and growing techniques. However, the quality and hence the rice export value is still subject to soil and weather factors: 2015 heavy heat and drought reduced production quantity and quality by the heaviest amount. Therefore, the use of derivatives like call options will aid in reducing in loss value if unfavorable conditions are presented in the scenario analysis. Scenario 1 is for Winter-Summer harvest contracts; Scenario 2 is for Summer-Fall harvest contracts

The following scenarios does the following:

+ Input of export quantity and value per mt for 2017

+ Present 3 cases in which rice price per mt drops or rises by 1, 2 and 3 standard deviation from the mean export price per mt of the 2009-2017. Standard deviation(s) from the mean is denoted by k(s).

+ Identify the currency value of amount hedged by the call options presented in section B.

+ Present how such amount can be used to enhance production and how it is valuable to farmers and investors

Table 5. Simulated hedged values over 2017 Vietnam Rice export value

		2017 Total Vietnam export value			**$2,700,000,000**		
	Cases			**Export (mt)**	**Value hedged**		
	1k	2k	3k		1k	2k	3k
Thái Bình	$16.01	$32.03	$48.04	6,000,000	$96,089,668	$192,179,336	$288,269,004
Nam Định	$15.66	$31.31	$46.97		$93,937,670	$187,875,340	$281,813,010
Hải Dương	$13.53	$27.06	$40.59		$81,183,627	$162,367,255	$243,550,882
Ninh Bình	$18.18	$36.36	$54.54		$109,080,628	$218,161,256	$327,241,884
An Giang	$17.16	$34.33	$51.49		$102,980,010	$205,960,020	$308,940,030

Source: Author's calculation

Since a long position when price is dropping is similar to that of a short position when price is rising, here for this scenario we are taking the long position – who will mostly farmers and rice manufacturers against a possible drop in price; which is 1k, 2k and 3k, accordingly. These changes in price is assumed and thus can be different in reality. The rise or drop in price, under the scope of this research, is mainly due to irregular temperature patterns.

I. Thái Bình case

Taking the case of Thái Bình city, a farmer who longs a 3-month call option before export will experience these possibilities:

1. Export price per mt drops 1k, 2k and 3k. The farmer is entitled to a max loss of $16.01, $32.03 and 48.04$ per mt, respectively. This translated, if a call option bought in Thái Bình is representative for the whole country: max losses are $96mn, $192mn and $288mn, respectively. Because 2017 total rice export value (MARD, 2018) was nearly $3bn, call options hedged losses for nearly 10% of total export value. On the other hand, the short positions in these cases – who and how will be discussed at the next section; earned respectively the hedged losses valued. In other words, if long and short positions are parties of the same country, we can expect a net cash outflow from the country owing to changes in price of 0.

2. If, the case is reverse, and export price increase greatly (and in reality they did from 2014-2017), the farmers can choose: 1) not to exercise the call options while only earned money from the rice, or 2) exercise the contracts and earn the spread. The spread here is the difference between a favorable temperature and the call option's strike temperature (see Table 2.) multiply by the option price per mt. We will also discuss the social economic implications of this high gain scenario in the next section.

Other cities' results would have the same interpretation as Thái Bình as follow:

II. Nam Định case

Export price per mt drops 1k, 2k and 3k. The farmer is entitled to a max loss of $15.66, $31.31 and $46.97 per mt, respectively. This translated, if a call option bought in Thái Bình is representative for the whole country: max losses are about $81mn, $162mn and $243mn, respectively. Because 2017 total rice export value (MARD, 2018) was nearly $3bn; call options hedged losses for nearly 9.2% of total export value. If, the case is reverse, and export price increase greatly (and in reality they did from 2014-2017); the farmers can choose: 1) not to exercise the call options while only earned money from the rice, or 2) exercise the contracts and earn the spread.

III. Hải Dương case

Export price per mt drops 1k, 2k and 3k. The farmer is entitled to a max loss of $13.53,

$27.06 and $40.59 per mt, respectively. This translated, if a call option bought in Thái Bình is representative for the whole country: max losses are about $93mn, $188mn and $281mn, respectively. Because 2017 total rice export value (MARD, 2018) was nearly $3bn, call options hedged losses for nearly 8.8% of total export value. If, the case is reverse, and export price increase greatly (and in reality they did from 2014-2017); the farmers can choose: 1) not to exercise the call options while only earned money from the rice, or 2) exercise the contracts and earn the spread.

IV. Ninh Bình case

Export price per mt drops 1k, 2k and 3k. The farmer is entitled to a max loss of $18.18, $36.36 and $54.54 per mt, respectively. This translated, if a call option bought in Thái Bình is representative for the whole country, max losses are about $109mn, $218mn and $327mn, respectively. Because 2017 total rice export value (MARD, 2018) was nearly $3bn, call options hedged losses for nearly 11% of total export value. If, the case is reverse, and export price increase greatly (and in reality they did from 2014-2017), the farmers can choose: 1) not to exercise the call options while only earned money from the rice, or 2) exercise the contracts and earn the spread.

V. An Giang case:

Export price per mt drops 1k, 2k and 3k. The farmer is entitled to a max loss of $17.16,

$34.33 and $51.49 per mt, respectively. This translated, if a call option bought in Thái Bình is representative for the whole country: max losses are about $103mn, $205mn and $308mn, respectively. Because 2017 total rice export value (MARD, 2018) was nearly $3bn, call options hedged losses for nearly 10% of total export value. If, the case is reverse; and export price increase greatly (and in reality they did from 2014-2017); the farmers can choose: 1) not to exercise the call options while only earned money from the rice, or 2) exercise the contracts and earn the spread.

c. Section summary:

This section has presented: 1) mathematical and statistical formulas of the Alaton model, 2) testing of the Alaton model over northern Vietnam main rice-growing cites to model and project their annual temperature patterns, 3) pricing of call options for Winter-Spring harvest and Summer-Fall harvest, and 4) scenario analysis toward the hedging power of temperature-based call options for 2017 rice export value. The Alaton model utilized a random OU process with mean-reversion for modelling temperatures. Results show that:

+ In case irregular temperature patterns are presented, giving that farmers have proper derivative markets and enter 3-month (1 harvest period) call option on time; serious amount of losses could be hedged against.

+ In favorable temperature and price conditions, farmers as long positions also gain what could be call a non-operation profit.

These hedging mechanisms and earnings have important implications for farmers, manufacturers, securities commission, investors of Vietnam, which will be discusses shortly.

6. Practical Implications and Recommendations

This section considers practical implications, firstly for farmers and manufacturers of rice and other crop in Vietnam, who will be direct customers and receive hedging benefits from this Alaton et. al model temperature-based options. Next, we will look at uses for non-industry players, such as investors and regulators on exchange market. Finally, we want to see what are the necessary factors are for a viable option trading market in Vietnam and other emerging markets: the market price of risk, clearing houses, investment banks and insurance companies, and cross-product derivatives.

a. For farmers and manufacturers

Table 6. After-hedge value

After-hedge value			Seed Quantity at $63.8 per mt (ton)		
1k	2k	3k	1k	2k	3k

$16.9	$33.8	$50.7	0.265	0.529	0.794
$17.2	$34.5	$51.7	0.270	0.541	0.811
$19.4	$38.7	$58.1	0.304	0.607	0.911
$14.7	$29.5	$44.2	0.231	0.462	0.692
$15.7	$31.5	$47.2	0.247	0.493	0.740

To continue the discussion from Section 2, Table 6 above presents one of the many uses besides hedging of the temperature-based call options. Schiller, et.al (2012) stated: "Since weather variables are mostly uncorrelated with the classical financial market, weather derivatives form the only possibility on the financial market of insuring against unfavorable weather. The development of the weather derivatives market assumes that an increasing number of corporations take advantage of these new opportunities".

In addition to the impeded insurance mechanisms, the value once hedge provides quite good back up cash for next-season or future production. Taking the second line of Table 6, as a Thái Bình example: when export price drops 1k, the remain value after the losses is $16.9 per mt. This much money can be effectively used to buy 0.265 mt of high quality type seeds; which then can be stored for use in the future. For this concern, we argue that since there has not been a trading market for agricultural derivatives in Vietnam, their many uses are often overlooked. Table 6 has shown that, in this case a call option, not only helps farmers avoid taking the full-size losses; but free up cash from such losses in price, which provide backup capital for use, like buying seeds for next harvest.

b. Market price of risk and implications for non-agricultural players

The market price of risk, or the extra return an investor wants for any kind of investments usually reflects their hope for beating non-systematic factors such as inflation (described by inflation premium in the CAPM model), or business risk premium. In a vastly similar sense, a temperature-based option offers premium above irregularities in temperature, and extendedly speaking, other climate elements like humidity or rain amount. While farmers are expected to effectively hedge against losses using the proposed product, other non-agricultural earnings can be various. Given that there is an actively traded market for temperature-based derivatives and a derivative contract is in effective period, one initial option contract can change hand multiple times, through which secondary sellers and buyers bet their lucks.

For instance, with Nam Định options priced at VND4758 per metric ton, the primary short-position can bid and sold the contract in secondary market at par. Under the Alaton model valuation, Nam Định option is priced at VND4758 at interest rate of 6.5%, and VND7425 at interest rate of 6%. A speculative secondary investor, having expected this

0.5% drop in interest rate, can ask for the contract at VND5000, and later sold it at VND6000 to make non-exercise profit at VND1000. When this process continues with or without the initial contractors exercising it, layers of profit can grow more. The options can even be bundled into pools, on which a commercial backed type securities could be issued. However, investors should be always careful against too risky speculations and complex structured financial products, given a still-developing Vietnam market.

Furthermore, temperature-based contracts can be included into portfolio. Singal (2017) wrote "commodity futures provide the diversification benefit in combination with equity and bond in the portfolio" and "they can be used as an excellent hedging tools against inflation". In the portfolio context, temperature-based options provide more freedom than futures, since exercising the option is optional, and they bring somewhat a "temperature related risk premium" in the traditional portfolio of equity and bonds. Although there is a need a real market to certify this attribute of Alaton model temperature-based derivatives, we believe that the results should be similar to existing price-underlying or interest-underlying futures or options.

c. Implications for market regulator

The greatest limit of temperature-based derivatives is there has not been a real market. The lack of an official trading platform poses obstacle for potential market players to determine the suitable price ranges, even if the applied Alaton model in this research paper can provide certain grounds for pricing. In addition, as discussed earlier, the benefits of temperature-based to farmers and non-agricultural players are explicit: the derivatives are not only easy to understand, use and monitor; but also suitable to act as a bridge between farmers towards capital and insurance market. Therefore, we propose that the Vietnam government, especially the State Securities Commission, create a market for agricultural, temperature-based derivatives, through these steps:

Step 1: **Towards the emerging market**

We acknowledge that the Vietnam equity market are still in the process of development in terms of regulations. By 2017, Morgan Stanley Capital International still categorized Vietnam as a frontier market. This is mainly due the restricted foreign investors room into listed Vietnam companies, and also the lack of complex financial products, such as commercial back securities, or derivatives. However, since 2016, both the Ho Chi Minh stock exchange (HOSE) and Hanoi stock exchange (HNX) – the only two stock exchange in the country, has taken effort to launch futures and warrants. These derivatives, though quite new to the market and are stock-underlying, received huge investment. According to the State Securities Commission (2018), by July, 2018, there are 35,725 active transaction accounts whose trading amounts are up to VND4.7 trillion (+50%YoY).

Among these accounts, domestic investors account for over 98%, signifying the curiosity of domestic investors towards more complex investment tools.

In this sense, given a still agricultural-based economy, we believe that the market acceptance of temperature-based options will be promising. As with any financial product to be introduced, we suggest the State Securities Commission to work closely with the Ministry of Agriculture and Rural Development and the Ministry of Finance to collaborate in terms of harvest timing data, temperature data, rice and related main crops data, export value data, and insurance policies. We expect such cooperation to result in a concrete and real-time data base for temperature-based derivatives (in our case, the Alaton model options). Although we recommend the simple Alaton model to be used as the based algorithm for pricing, the State Securities Commission has options to use more sophisticated model, like the CAR model of Benth (2007).

Step 2: Create a market, options and involve players

Once chosen an acceptable pricing model, say our Alaton temperature-based model, we propose Agribank, which is one of the four largest banks in the country to support the creation of the clearing house and investment banking of the temperature-based market. Since Agribank, a state-owned, commercial banks, created by the Vietnam government to infuse credit for agriculture production, it will be, at first, the most suitable candidate to back the creation of temperature-based derivatives. The bank will provide the capital needed to facilitate the underwriting of new options, asking and biding, provisions for long-short party gains and losses.

Next, we recommend the bank work closely with securities and brokerage firms to market the option contracts to farmers and non-agricultural investors. The marketing process might involve workshops, simulated trading platforms and discounts for first-time users. According to General Statistics Office of Vietnam (GSO), in Quarter 1, 2018, labor in agriculture is 20.9 million; accounted for nearly 39% of total 15-year-and-above labor force. It would be unrealistic to have all agriculture workforce buying the contracts; but we expect at least 100,000 accounts joining the market (~0.5% of agriculture labor force) once the market is established, already about three times the accounts joining stock-underlying futures. The more bids there are in the market, the more reliable the pricing process will be, up to a point the State Securities Commission (SSC) can combined temperature-based with market price-based models for optimal contract prices.

Step 3: Extend and Evaluate

Our proposed temperature-based option contract can be extended in several ways. Instead of using temperature as the underlying, Agribank and brokerage firms can create other options whose underlyings are humidity, average sun-light hour, and so on. Similar to temperature, those are climate elements which are encompassed in the agricultural production and can be easily monitored by farmers. Farmers, having diverse base of underlying, will have more freedom in choosing the right hedging tool specifically for their crops. In addition, it will be easier for outside investors to follow, for example, investors who like rice might sell and buy temperature-based and rain amount-based options.

On the other hand, options, just like stocks or mortgage, can be pooled together as collateral for commercial-back securities (CBS). We expect the introduction of CBS will elevate the complexity scale of Vietnam market and make it more attractive to foreign investors. As a result, thanks to temperature-based derivatives, Vietnam might be able to see its market upgraded to emerging market, or even developed one.

Lastly, since derivatives themselves are hedging and insurance tools, we suggest insurance companies in Vietnam to involve in the agricultural derivatives market. Insurance companies can create insurance package which consists of several temperature-based options, for example, and sell it for farmers and agricultural firms. The buyers of such insurance packages will be entitled to greater protection against losses, while insurance firms might enjoy higher premium thanks to potential up/downside in options price. In short, we see agricultural temperature-based options as a great bridge that links the agriculture sector more closely with the financial sector, a relationship from which will fuel Vietnam economy to a more in-depth growth.

7. Conclusion

Despite the fact that there has not been a real market for weather derivatives, the author sees great potential for them, especially temperature-based options, as discussed. Schille (2012) proposed the distinctive characteristic of weather derivatives: "Since weather variables are mostly uncorrelated with the classical financial market, weather derivatives form the only possibility on the financial market of insuring against unfavorable weather". This argument can be extended further by noting that, while weather elements are uncorrelated with the equity market, they can be easily monitored by farmers in the production process.

The author expects that, by this ease-of-use, even low-financial knowledgeable farmers will find weather derivatives like Thái Bình options attractive enough to long them as insurance methods. Thus, as mentioned in section 5), the author hopes the introduction of weather derivatives into Vietnam market will engage more agricultural players with the equity market, from which both sector can see great upside potential.

In addition, results showed that the pricing results vary among the provinces. This is a province-specific use of temperature-based derivatives, in which every city in Vietnam can create option contracts suitable for their climate and agricultural production pattern. This suits greatly to the country of greater climate diversity from north to south. As the author wrote in section 3., the State Securities Commission and related parties can create markets and complex financial products from our proposed temperature-based options; which will act as an elevator to improve the health of Vietnam financial system

Ideally, further research can extend the depth of the study by applying more complex model than Alaton model. For instance, Spline model by Schiller (2012) "separate the daily temperature data T_t into a trend and seasonality component in the mean", thereby captures daily temperature variations. In addition, as simple as it is, the used Alaton model (2002) can be applied to countries neighboring Vietnam which are too agricultural intensive, such as Thailand or Myanmar; where we believe the utility of weather options can too be widespread.

Lastly, for further studies that look into Vietnam or other Southeast Asian countries; it is recommendable to extend the number of cities for more data. Beside creating city-specific options like this research paper has done, future researchers can group cities together to form region-wide options. The covered derivative in this report is call options, thus forwards/futures or put options can also be used to testify the insuring power of weather derivatives; however, researchers should always be careful when choosing the types of derivatives, since, not all of them will be suitable for agriculture.

-End-

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Appendix

Abbreviation Chart

Names	Abbreviations
Metric ton	mt
Million	mn
Heating-day degrees	HDDs
Cooling-day degrees	CDDs
Ministry of Agriculture and Rural Development	MARD
The author	Tran Do Thinh Hoang