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Losses and Economic Capital under Climate Change Dependence in Taiwan: The Case of Crop

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***Abstract*—This research will first examine the impact of climate change, tail loss and economic capital on major crops losses due to single-peril in crop insurance program based on panel data using copula-simulation method for 10 major crops over the 1971-2012. The purpose of this research will build the copula of temperature, precipitation and sunshine duration are copula to be the major climate variables and to assess the tail value at risk (TVaR) loss and economic capital models under climate changes copula estimated. The findings will be important in providing useful knowledge to future help examining risk measures that measure TVaR loss that can be used for determining provisions and capital requirements in order to avoid insolvency on government agricultural budgeting or insurer's coverage and to discovering effective regulations of crop insurance design and to enhance the efficiency of agricultural markets in future.**

Keywords—climate change copulaed, COPULA-AR-GARCH loss models, economic capital

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I. Introduction

Climate change has both biophysical as well as socio-economic effects that influence agricultural production (Antonio and Beirlant, 2007; Kalisch et al., 2011). The crop production is largely concentrated in Asia (Luo et al., 1998; Chang, 2002; Chatrath et al., 2002; Yun, 2003). In all the phenomena of climate change, the effect can result in losses of the type that are the most catastrophic, not only their fierceness but also frequency of occurrence. Climate change has always been a source of single-peril risk or combined-peril risk for many crops and relieved facilities (Kalisch et al. 2011). The occurrence of weather episodes such as extreme perils characterized by maximum or minimum temperature, sequences of precipitation days, and sunshine duration during occurrence of typhoon, flood, frost damage, drought, hailstone, storm damage, front, tornado and disease may significantly affect crop yield loss.

Climate change has always been a source of single-peril risk or combined-peril risk for many crops and relieved facilities (Kalisch et al., 2011). Single-risk insurances are the main lines available which is well develop with a long history in EU, such as UK and Germany hail insurance. Some pretention of crop insurance become controversial or even unavailable such as adverse selection, multiple-peril coverage, yield loss-based pricing, loss ratio-based rating, participation in US. (Skees and Reed, 1986; Goodwin, 1993, 1994; Barry and Skees, 1994; Babcock et al., 2004; Glauber 2004; Carriquiry et al., 2008; Rejesus, et al., 2010; Woodard et al., 2011). However, experience with agricultural yield insurance applications has shown that the aggregation of crop yields causes errors in the risk assessment for farm-level analysis (Rudstrom et al., 2002; Cooper et al., 2009).

Risk measures of insurance price, VaR and TVaR are meant to provide a degree of magnitude of the severity of a potential loss in a coverage portfolio and are therefore meaningful amounts to hold to cover for the risk exposure in agricultural loss. Premium principles are clear examples of risk measures, and these have been extensively explored (Goovaerts et al., 1984; Kaas et al., 2001). In some countries is less develop in the private crop, but there is public crop compensation scheme provided to compensate yield losses after natural disasters. Combined-risk is two or more of perils in an insurance coverage in US (as multiple-peril crop insurance, MPCI) and Sweden. Note that the combined-risk differs from that of MPCI which the yield losses by plagues and diseases and damages are calculated simply as the difference between guaranteed and actual in US. A widely recognized feature of crop yield loss data are high levels of both temperature and precipitation dependence in region.

According to statistics of Taiwan's Agriculture Yearbook, significant financial losses in agricultural sector in Taiwan are commonly caused from various natural events (Chang, 2002; Chen and Chang, 2005; Chang et al., 2012; Lai, 2015) such as typhoons, floods, droughts, insects, earthquakes, hails, and so on. Changes in temperature and precipitation truly have combined to render the remotest corners of the region accessible (Chang, 2002; Chen and Chang, 2005; Chang et al., 2012) in Taiwan. Characteristics of disasters in Taiwan are similar to those of global disasters, such as the annual mean temperature in Taiwan increased by 1.1~1.6°C/century. Regions where at least 75% of all models agree on the precipitation response direction are highlighted in orange to show decreasing precipitation, but the number of torrential rain days (daily rainfall $\geqslant$ 200 mm) has increased. These result carries the possibility of crop yield loss, not only for the individual framer, but also

for its customers. Since 1971-2014, total losses due to natural peril have been over US$ 7428 million in crops (including facilities). An agricultural exposure unit is, roughly, crop exposed to the possibility of loss, for example, fruit (53%), vegetable (14%), rice (13%), special crops (7%), mixed grain (6%) cut flowers (1.76), and facility (0.69%). Major natural perils include single-peril event such as typhoons (73%), floods (16%), frost damage (4%), drought (2%) and/or combined-perils in crops damaged (Lai, 2010, 2015; Lai and Wu, 2013). Here that depending on the temperature, precipitation days, sunshine duration and prospective crops-specific-peril damages may vary considerably

This paper follow part of the risk-peril event on the Copula-AR-GARCH Loss model (Lai, 2017), and display on the copula of temperature, precipitation and sunshine duration are copula to be the major climate variables and to assess the tail value at risk TVaR based economic capital (Calem, P.S. and LaCour-Little, 2001, 2004; Lai 2017), which can also give us the level of unexpected loss in crop losses under climate changes copula estimated. The findings will be important in providing useful knowledge to future help examining risk measures that measure TVaR loss that can be used for determining provisions and capital requirements in order to avoid insolvency on government agricultural budgeting or insurer's coverage and to discovering effective regulations of crop insurance design and to enhance the efficiency of agricultural markets in future.

II. Model and methodology

In collective risk model, the number of losses and are a random variable and is associated with the frequency of crop or facility loss (c) due to the single-peril ($\psi = x1$) or combined-peril ($\psi = x12$) in county-level given time period (t). The individual losses $l_1, l_2, \ldots$ are also random variables and are said to measure the severity of crop or facility losses. In an insurance contract, it will cover the crop-facility loss due to combined-peril y. In risk models, the random sum (Bowers et al., 1997; Boland, 2007) represents the aggregate losses generated by the portfolio for the period under studies (Lai, 2015, 2017) and AR(1)-GJR(1,1) - GARCH(1,1) loss model with climate changes copula estimated (Lai, 2016, 2017). This paper choose to work with the tail value at risk of L_Ω under extreme clime typhoon-flood perils in major insurance coverage at level η, for $\eta \in (0,1)$. Its definition is

$$TVaR_{\kappa}[\mathrm{L}_\Omega] = \frac{1}{1-\eta}\int_{\eta}^{1} VaR[\mathrm{L}_\Omega]d\kappa \qquad (1)$$

or

$$TVaR_{k}[\mathrm{L}_\Omega] = \mathrm{E}[\mathrm{L}_\Omega \mid \mathrm{L}_\Omega > VaR_{\eta}[\mathrm{L}_\eta]] = \mathrm{CTE}[\mathrm{L}_\eta] \qquad (2)$$

In general, when *L* is continuous, $\Pr(\mathrm{L}_\Omega \le VaR_{\eta}[\mathrm{L}_\Omega]) = \eta$ which implies that is exactly the conditional tail expectation (CTE) meaning in specified-peril coverage. Let the aggregate budget or insurance premium equal to aggregate premium for this study, for a holding level ϕ, the TVaR-based economic capital is thus defined as

$$\mathrm{EC}[\mathrm{S}_\Omega, \phi] = \mathrm{TVaR}[\mathrm{S}_\Omega, \phi] - \mathrm{E}[\mathrm{S}_\Omega] \qquad (3)$$

In general, setting the amount of additional capital equal to $\mathrm{TVaR}[\mathrm{S}, \phi]$ -premium, we can define bad time which the aggregate losses of crop insurance excess the threshold , but do not use up all available capital. This value will be used to determine the risk transfer arrangement to be selected for catastrophe cover. However, the TVaR-based economic capital which can also give us the level of unexpected loss in crop losses. Finally, this study will examine risk measures that measure upper tails of distribution functions that can be used for determining provisions and capital requirements in order to avoid insolvency on government agricultural budgeting or insurer's coverage.:.

III. Results of the TVaR and economic capital under climate change dependence

A. *The data*

This paper investigate the crop damage caused by typhoons and floods effect of the conditional copula-GARCH methodology for the period between January, 1971 and December, 2012. This paper focuses on 8 crop types (including 52 sub-items) in Taiwan and is available at http://www.coa.gov.tw. The descriptive statistics chosen include: Mean, Median, Maximum, Minimum, Standard Deviation, Skewness, Kurtosis, Jarque-Bera, Sum and Sum Square Deviation in 1971-2012. For one month, the typhoons and floods loss ranged from 0 to 0.5631 billion and from 0 to 0.1163 billion respectively. Typhoon loss has a mean of 0.0102 billion and a standard deviation of 0.0437. Flood loss has a mean of 0.0022 billion and a standard deviation of 0.0094. We can find that typhoon and flood variables exhibit the characteristic features of loss time series like excess kurtosis and positive skewness (right tail). The normality hypothesis is rejected for all cases, at every confidence level, according to the Jarque Bera test and robust skewness and kurtosis measured that is significant when higher than 3. It means that the empirical observations of returns display fatter tails than the normal distribution.

B. *The results*

Table 1 presents the TVaR and economic capital (EC) under climate change dependences of the crop loss due to typhoons and floods are calculated in the Taiwan in 1971-2012. It is effective to best fitted the series using AR(1)-GJR(1,1) - GARCH(1,1) model which the minimum values of AIC or BIC and maximum values of LL in all models. We can thus observe that the different models can capture different results of value of TVaR and economic capital on crop loss due to 9 cases of large typhoon and 6 cases of lager flood losses. In this case, we see that the Herb typhoon and June flood need to be protected by the catastrophe (Cat) insurance. The findings will be important in providing useful knowledge to future help examining risk measures that measure TVaR loss that can be used for determining

provisions and capital requirements in order to avoid insolvency on government agricultural budgeting or insurer's coverage and to discovering effective regulations of crop insurance design and to enhance the efficiency of agricultural markets.

TABLE I. TVAR AND ECONOMIC CAPITAL (EC) UNDER CLIMATE CHANGE DEPENDENCE IN TAIWAN

			Copula			
Typhoon						
Typhoon name	year	moth	Loss amount	Tail VaR (TVaR)	Economic capital(EC)	Should government provide Cat insurance for crops?
Herb	1996	8	0.5343	0.5202	0.5100	Must
Morakot	2009	8	0.3074			May be
Korsa	2007	10	0.2328			May be
Haitang	2005	7	0.2092			May be
Fanapi	2010	9	0.2059			May be
Zeb	1998	10	0.1868			May be
Jangmi	2008	9	0.1980			May be
Bilis	2000	8	0.1840			May be
Midulle	2004	6	0.1019			May be
Flood						
Flood name	2005	6	0.1163	0.1149	0.1127	Must
June Flood	2011	11	0.0783			May be
Apr. Flood	2012	4	0.0781			May be
May Flood	2006	5	0.0694			May be
June Flood	1998	6	0.0547			May be
June Flood	1997	6	0.0375			May be

IV. Discussion

This paper used mean AR(1)-GJR-GARCH(1,1) model and out-of-sample large loss cases reruns to test the accuracy of the expected loss, TVaR and economic capital (EC) estimates. It will show an alternative way to model joint distribution of random variables with greater flexibility both in terms of marginal distributions and the dependence structure. Herein, this research will present an application of these models to the coverage of crop insurance contracts for all counties/cities on coverage of the large losses by insured associated with the current agricultural programs. This research provide a summary and implications of the models for weather systemic risk in Taiwan's crop insurance program and results for the viability of private crop insurance contracts and concomitant arguments for government support through subsidized premiums and reinsurance argument program in future.

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