TESTING IMPLIED VOLATILITY DISCOVERY PERIOD LENGTH ASSUMPTIONS IN THE FEDERAL CROP INSURANCE PROGRAM

A Thesis

Presented to the Faculty of the Graduate School

of Cornell University

In Partial Fulfillment of the Requirements for the Degree of

Master of Science

by

Jixuan Yao

August 2016

ABSTRACT

The United States Department of Agriculture - Risk Management Agency (RMA) uses Chicago Mercantile Exchange (CME) corn futures options implied volatilities--averaged during the last five business days of February--to establish the volatility factor for rating corn revenue insurance under the Federal Crop Insurance Program (FCIP) in the Midwest. Following Woodard (2015), a set of tests of implied volatility discovery period length are conducted to assess the actuarial appropriateness of this discovery method in pricing revenue insurance for corn. A significant negative relationship is found between implied volatility (using the current RMA method) and eventual program and region specific loss ratios. As articulated in Woodard (2008) and Woodard et al. (2012), observable information prior to the insurance sales periods should not have power in predicting eventual loss ratios under the program. These results replicate and corroborate those of Woodard (2015) in statistically rejecting the actuarial appropriateness of the RMA's 5-day implied volatility discovery period method. We also conduct tests of alternative discovery periods and fail to reject that some longer periods are actuarially valid.

BIOGRAPHICAL SKETCH

Jixuan Yao was born February 7, 1992 in Zibo, China. She graduated from Shanghai University of Finance and Economics with a Bachelor of Science in Actuarial Science in July, 2014. She is a Master of Science candidate in Applied Economics and Management at the Charles H. Dyson School of Applied Economics and Management, Cornell University, and will pursue her PhD of Agricultural Economics at Purdue University.

ACKNOWLEDGEMENTS

Thank you to my parents Ling Xue and Yongtao Yao, my grandmother Xiuyun Ji, and my late grandfather, Shizhong Xue. Without your support and encouragement, I would not have been able to finish my Master's degree at Cornell University.

I thank Prof. Joshua D. Woodard, my academic advisor, for including me on this project developing the research question, data, and models, teaching me the analysis conducted in the thesis, editing and drafting the vast majority of the text, as well as building the RMA premium calculator API at Ag-Analytics.Org, which were all most critical in enabling this thesis. I have learned a lot from you on how to do research in a right way. Furthermore, I would like to thank the other two committee members, Prof. Calum Turvey and Prof. Jennifer Ifft. Thank you for your patience, suggestions, and incredible help during the process and with my PhD applications.

I wish to acknowledge a few other people in the Dyson school. Thank you Dr. Leslie Verteramo Chiu, it has been a wonderful time doing research with you in the last fall. Your encouragement and suggestions for my PhD application meant a lot to me. Prof. Shanjun Li, thanks for writing me a recommendation letter for my PhD application. I learned a lot in your econometrics class and many thanks for your suggestions on my course studies whilst at Cornell. Linda Sanderson, thanks for your patience and help during my PhD application, and your incredible work for the past two years!

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER I

INTRODUCTION

The primary method through which the United States government subsidizes domestic agriculture is via the Federal Crop Insurance Program (FCIP; Woodard et al., 2012; Woodard, 2015; Woodard, 2013; Woodard, 2016). Since the early 2000's, revenue insurance--which protects against joint yield and price risk--has replaced yield insurance as the predominant product in the market. Today, Revenue Protection (RP) constitutes the vast majority of premium volume in major markets. In 2015, RP was approximately 93% of total premium received for corn insurance nationwide, and over 90% of total liability (Woodard, 2016a; Woodard, 2016b). Whether RP insurance is actuarially fairly priced is of vital importance, as proper pricing of agricultural insurance has been a major focus in the literature given it can have a significant impact on insurance demand, policy evaluation, and product performance (Woodard, Sherrick, and Schnitkey, 2011; Woodard et al., 2011; Woodard and Sherrick, 2011; and Woodard, 2016c).

Under RMA's current methodology, the volatility factor used for pricing revenue insurance is calculated as the simple average of time-adjusted corn futures-options (traded on the Chicago Mercantile Exchange, or CME) implied volatilities (IVs) for the last five business days of February in major corn markets. Despite not providing any valid empirical tests, a primary RMA maintenance contractor and contributing developer to the current legacy rating systems in official use for the U.S. Government--Goodwin, Harri, Rejesus, Coble, and Knight (2014)--defends the current method on primarily conceptual grounds, citing literature on the Efficient Markets Hypothesis. It may be reasonable to use only a few days (or a particular trade in time, for that matter) to establish the volatility factor if the market is *almost perfectly* efficient. However, many agricultural futures-options markets may be thinly traded during such short discovery periods, and

indeed the notional volume traded during this preseason discovery period is small relative to the liabilities it is subsequently employed to price under the FCIP.

To test whether the official IV method used by RMA to bill the nation's agricultural producers is actuarially objectionable or not, we test whether eventual loss ratio outcomes are significantly related with IV (Woodard, 2008; Woodard et al, 2012; Woodard, 2015). Loss ratio--defined as the ratio of total indemnity to total premium--should have an expected value of 1.0 by Law, and if premium rates are actuarially fairly priced. Note, if IV is an appropriate risk signal for this intended use, realized insurance indemnities (i.e. loss payments) should be higher or lower in expectation in correspondence with inter-year changes in IV, but unrelated to loss ratio. If the premium rating methodology and volatility calibration method is appropriate, then premiums should likewise be priced correspondingly higher if IV (and expected losses) are higher. Put simply, preseason implied volatilities for an appropriate discovery period and pricing integration method should be related (should not be related) to indemnities (loss ratios) in expectation. A valid statistical test of this hypothesis should ask the question of whether IVs determined under any such discovery methodology are predictive of eventual loss ratios. If so, then the methodology can be rejected as being actuarially valid. Woodard (2015) develops this conceptual framework, and conducts several such tests which find that IV determination under the RMAs current methods are negatively related to (and predictive of) eventual loss ratios, both globally and with respect to specific markets, in violation of actuarial principles.

Whether crop insurance products are priced appropriately is of vital economic and policy importance, given that billions of dollars in premiums and liabilities are linked to the determination of this single parameter (nearly $50 billion in liabilities annually for corn alone).

The first research objective of this thesis is to replicate earlier results by Woodard (2015), testing whether the current 5-day discovery period used to calibrate premium levels is sufficient to accurately forecast (and equate in expectation) future revenue insurance loss levels. In the seminal work on the topic, Woodard (2015) finds econometric evidence that the RMAs methodology for discovering the price volatility component used for revenue risk pricing is not actuarially valid, since preseason IVs during this 5-day discovery period have predictive power in forecasting future ***loss ratios*** (i.e., losses relative to premium).

The second objective of this thesis is to engage in a minor excursion of the analysis of Woodard (2015) by evaluating whether different discovery period lengths for determining IV are likewise rejected, or not. Using the Ag-Analtyics.Org Open Data/Open Source Platform functionality for restating historical premium rates and losses for different IV levels under the official RMA premium rating methodology (in conjunction with micro-market data on historical FCIP business volumes and losses), we test whether different discovery period lengths likewise result in rejection of the actuarial validity of the current RMA 5-day discovery period methodology using these established testing methodologies.

The thesis is organized as follows. Chapter II provides a brief overview of the literature. Chapter III discusses the data sources, premium rating infrastructure employed, and methods. Results are reported in chapter IV. Chapter V concludes.

CHAPTER II

BRIEF OVERVIEW OF RELEVANT LITERATURE

There is a rich literature on the topic of implied volatility estimation and performance in predicting eventual volatility and consistency with the seminal Black-Sholes Model (BSM; see e.g., Woodard, 2015 for an extensive review). In general, the BSM remains the litmus test for calculating implied volatility in practice due to its ease of use and simplicity, though in some contexts the case for extensions have been made.

As noted above, the FCIP determines projected (base) prices as the average of February closing prices for the December futures contract, and determines volatilities using the average of Black-Scholes implied volatilities for near-the-money futures-options during the last 5 trading days of February. A recent report by Goodwin et al. (2014)--the U.S. Government rating contractor reviewer for RMA who reviewed the current IV methodology--defends the use of current methods and recommends that they be continued. In large part, their conclusions are based on a review of the literature, but with no valid statistical tests within the context of using the parameter for rating the FCIP.

All arguments regarding the Black-Scholes (or more appropriately for futures-options, Black Model) assumptions for use in crop revenue insurance pricing aside, there is a large literature evaluating the performance of implied volatilities for forecasting future realized volatility in commodity markets (see e.g., Garcia and Leuthold, 2004; Egelkraut, Garcia, and Sherrick, 2007; Egelkraut and Garcia, 2006). While results vary, most previous studies tend to argue that market implied volatilities perform somewhat reasonably, or at least that they cannot be easily invalidated or rejected when evaluating univariate historical price series alone.

However, an interesting aspect of most previous studies on the issue of volatility forecasting using IV is that they tend to focus on price time-series analyses almost exclusively, and tend to ignore potentially exogenous determining factors of option prices and implied volatilities, market timing, or time discovery aggregation effects such as those explored in Woodard (2015).

An exception is an overview by Bulut et al. (2014), which argues that arbitrarily short IV discovery periods lack an economic basis when markets are less than perfectly efficient. They also find empirical evidence that IV can vary significantly (5 to 10 basis points in some cases) across very short (5-10 day) periods, with attributions being mostly random. Even RMAs contracted analysis by Sumaria Systems (Goodwin et al., 2014)--despite insisting firmly on a 5 day preseason IV discovery period to predict terminal volatility at harvest 7 months later--strangely argues against a one day discovery period, citing thinly traded future-options on a daily basis. Bulut et al. also find that the elasticity of crop insurance premium rates under the current FCIP method, relative to IV, is very high. Sherrick (2015) also investigates the elasticity of premium rates with respect to IV in the FCIP. In a few stylized examples, he illustrates that the IV elasticity tends to be greater for higher coverage level products.

CHAPTER III

DATA AND METHODS

All data and results from premium rating models under restated IV for the official RMA rating method are obtained from Ag-Analytics.Org (Woodard, 2015; Woodard, 2016a; Woodard, 2016b). Ag-Analytics.Org is an open source/open data system for environmental economic, risk, and agricultural analytics, with real-time data sourced from multiple sources. It also has an automated web API for obtaining crop insurance premiums rates constructed in adherence to the published official RMA premium rating methodology employed for pricing the FCIP.

This study restricts investigation to major corn production states in the US, including Iowa, Illinois, Nebraska, Minnesota, Indiana, South Dakota, Ohio, Kansas, Wisconsin and Missouri (see Table 1), as in Woodard (2015) and Woodard et al. (2012).

Table 1. Top 10 Corn Planted Acres / Production States (2011-2015 in total)

State	***Planted Acres***	***State***	***Production (bushels)***
Iowa	69100000	Iowa	11246500000
Illinois	61000000	Illinois	9688100000
Nebraska	48500000	Nebraska	7736950000
Minnesota	41669500	Minnesota	6461749000
Indiana	29700000	Indiana	4375140000
South Dakota	28670000	South Dakota	3573260000
Kansas	22100000	Ohio	2686120000
Wisconsin	20600000	Kansas	2475010000
Ohio	18450000	Wisconsin	2327110000
Missouri	17000000	Missouri	2096440000

Source: NASS QuickStats, via Ag-Analytics (2016)

Historical indemnity and insurance volume data are obtained from official FCIP Summary of Business (SOB) data, via Ag-Analytics.Org, for the period of 1998-2015 for the primary

(C=607) corn producing counties. The SOB dataset includes figures for total premium, indemnity, reported acres, and liability at the county/crop/coverage level, annually (N=48,760). RMA has rebranded their revenue insurance product set through time; we include all major revenue insurance products in this analysis including the current RP product, as well as its predecessors.

RMA employs daily IV estimates from market traded futures-options data, as published by standard data vendors. Note that historical realized volatility is different that IV as derived from traded futures-options under the BSM assumption.

Overview-Crop Insurance Mechanics

Insurance liability is defined as the maximum possible indemnity that the insurance company may be obligated to pay, and is defined as follows:

$$Liability = Approved\ Yield * Cov * Projected\ Price * Reported\ Acreage$$

where *Cov* is the coverage level (between 50% and 85%, or 100% minus the deductible percent), *Approved Yield* is the average of the farm's previous 4-10 years of crop yields (production/acre), *Projected Price* is the preseason average price, and *Reported Acreage* is the covered acreage. Most revenue insurance sold under the program also has what is known as a "Harvest Price Option", which ultimately establishes the *Projected Price* as the maximum of a) the preseason price in February, or b) the Harvest Price in October. Premium rates are calculated conditional on liability, approved yield, base price, location, and other factors as determined by RMA. Extensive and in depth reviews of the RMA's premium rating methods are covered, for example, in Woodard (2008), Woodard, Sherrick, and Schnitkey (2011), Woodard et al. (2012),and Woodard (2014), as well as high level overviews on the RMA's website. Projected and harvest price determination are as

defined in Commodity Exchange Price Provisions (CEPP) of the Common Crop Insurance Policy Basic Provisions, by crop type, state, and sales closing date.

In addition to the 5-day discovery period employed by RMA, eight alternative scenarios for establishing IV are also evaluated, including averages over the previous 30 days, 90 days, 180 days, 250 days, 325 days, 400 days and 500 days. Four closely related alternative measures of averaging and aggregating volatility are investigated for robustness. The highlighted value in Table 3 is a replicate of the method employed by RMA currently (i.e. where the IV of the contract that expires in December for the crop year is employed).

Table 2. Volatility Factor Construction Methods Evaluated

Implied Volatility (All contracts)	Daily volatility value is calculated using the simple average of all contract types with different expiration month. Volatility value used is implied volatility.
Historical Volatility (All contracts)	Daily volatility value is calculated using the simple average of all contract types with different expiration month. Volatility value used is historical volatility.
Implied Volatility (DEC contracts)	**Use volatility value of December contracts only as daily volatility. Volatility value used is implied volatility.**
Historical Volatility (DEC contracts)	Use volatility value of December contracts only as daily volatility. Volatility value used is historical volatility.

The IV measure investigated which uses *All Contracts* is calculated as the simple average of all contract expirations trading during the period, which for corn includes the April, May, June, July, September and December contracts. We also evaluate the historical futures volatility as published and calculated on that day by CRB. Figures 1-4 below display the annual volatility measures which would have been estimated using the alternative discovery periods described. Figure 5 displays the historical and IV measure for the 5 day discovery period, by historical year. It is not surprising that the historical volatility for the front year December contract is quite low

compared to IV since during the off-season, as few material events that will eventually impact the December realized price occur during that period.

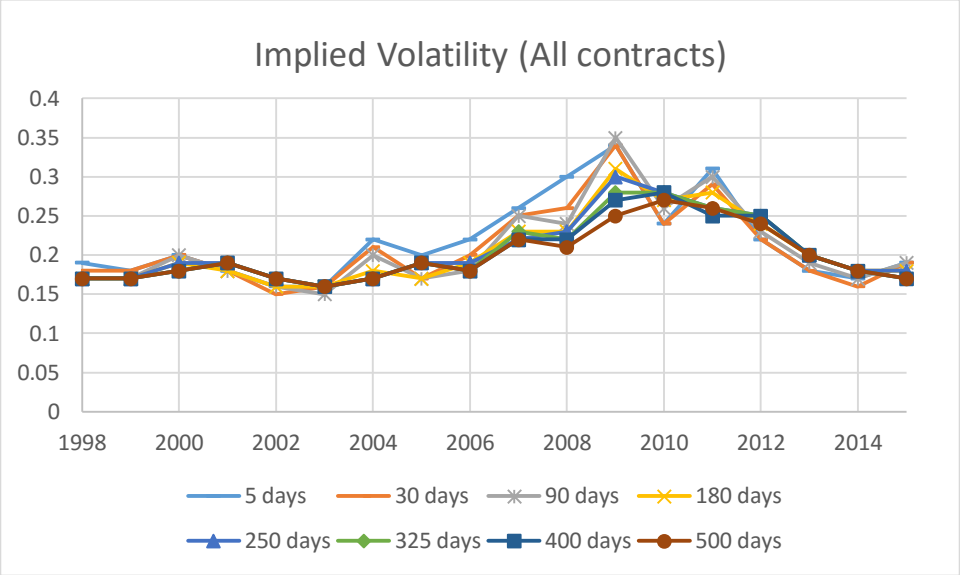

Figure 1. Volatility Factor Calculated Using Different Scenarios for All Contracts with Implied Volatility

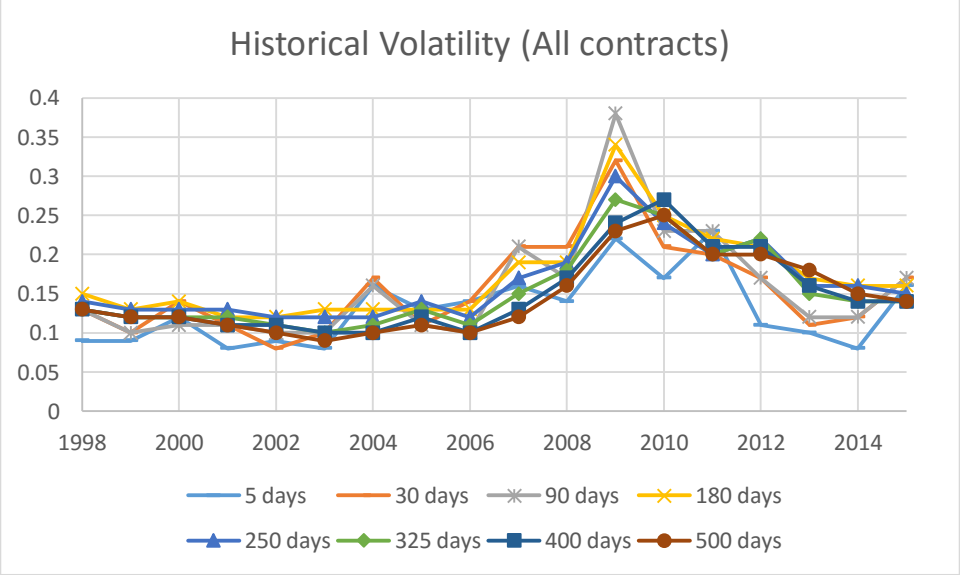

Figure 2. Volatility Factor Calculated Using Different Scenarios for All Contracts with Historical Volatility

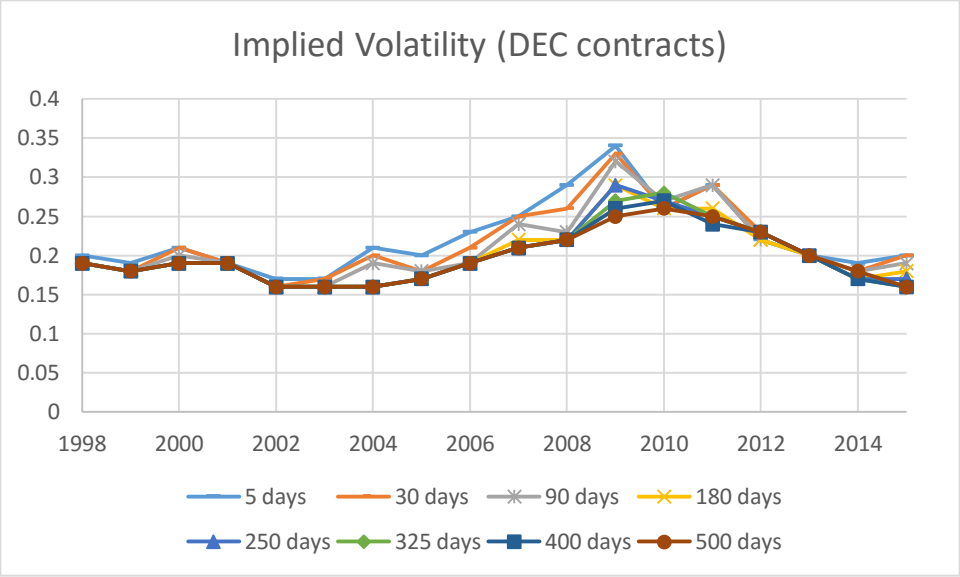

Figure 3. Volatility Factor Calculated Using Different Scenarios for December Contracts with Implied Volatility

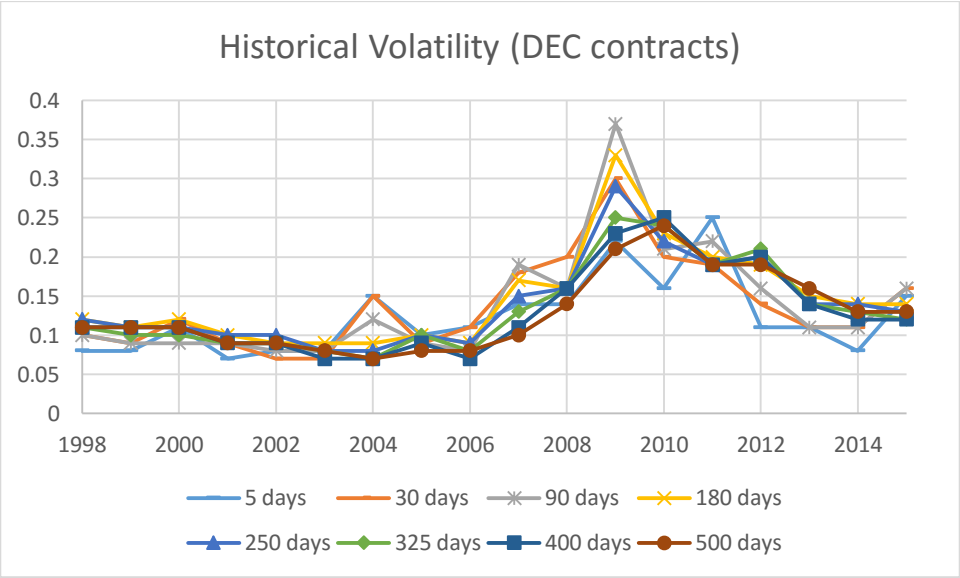

Figure 4. Volatility Factor Calculated using different scenarios for December contracts with historical volatility

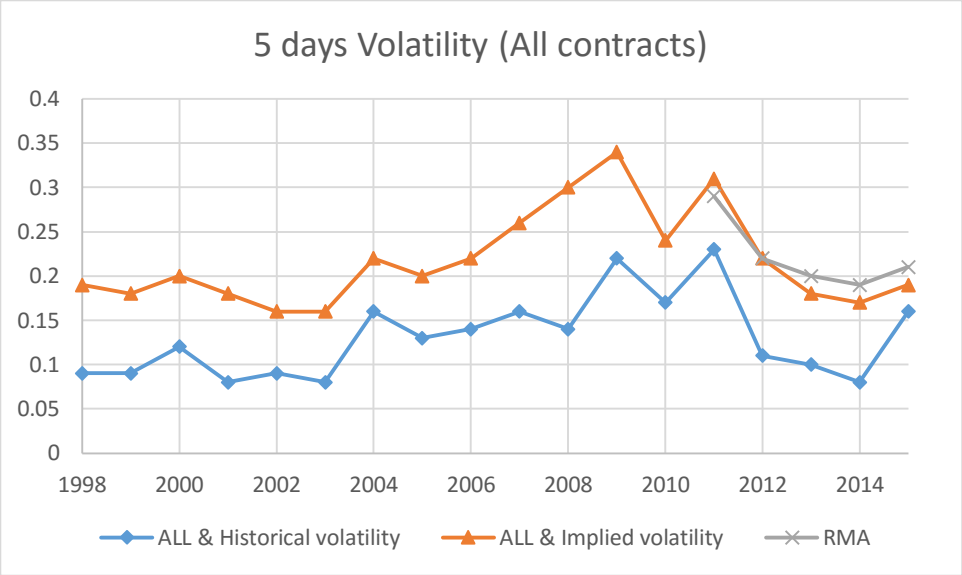

Figure 5. Comparison of 5 Days Volatility Factor Calculated Using the Average of All Contracts with Official Volatility Factor

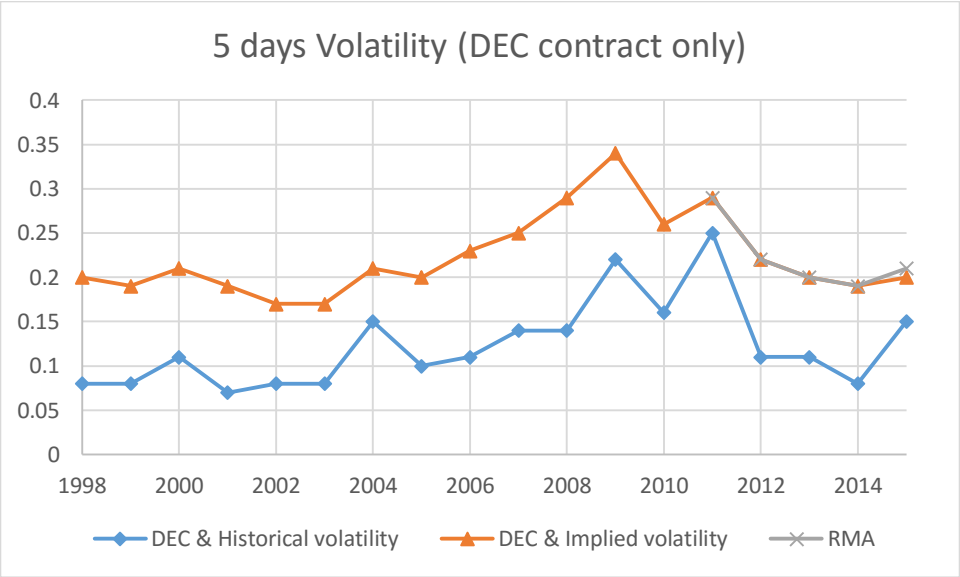

Figure 6. Comparison of 5 days Volatility Factor calculated Using average of December Contracts with Official Volatility Factor

Elasticity of Premium Rate with respect to Volatility Under RMAs Published Methodology

Before the current "Combo" policy was introduced in 2011, revenue insurance came in two major flavors: Crop Revenue Coverage (CRC) and Revenue Assurance (RA). Restating premiums under alternative volatility factors post 2011 can be done directly using the rating parameters published during those years and the current methodology. However, to restate premiums before 2011, in order to estimated what loss ratios would have been under those events given alternative IV levels, rate elasticities must be reverse engineered from the published premium rating system. In order to restate premium rate before 2011, a simplified premium rate calculation model is engineered based on the current methodology.

Premium rate is defined as:

$$Premium\ Rate = \frac{Premium\ (\$\ /\ acre)}{Liability\ (\$\ /\ acre)} = \frac{Premium\ (\$\ /\ acre)}{APH * Coverage\ Level * Base\ Price}$$

Premium ($ / Acre) is the nominal cost established for a given insurance cover. As RMA uses a Continuous Rating System approach with respect to APH, we estimate representative APHs using historical county yield data from NASS to establish reasonable average yield levels to plug into RMAs rating methodology (see Woodard, Sherrick, and Schnitkey, 2011). Two alternative premium restatement models are also evaluated for robustness, including a non-linear log model, and a linear model, as follows:

$$Log\ model: \ln(Premium\ Rate_{it}) = \beta_1 * \ln(IV_i) + \beta_2 * [\ln(IV_i)]^2 + \alpha_t + e_{it}$$

$$Linear\ Model: Premium\ Rate_{it} = \beta_1 * IV_i + \beta_2 * (IV_i)^2 + \alpha_t + e_{it}$$

Both premium rate approximation methods for characterizing premium rate as a function of alternative IVs perform well, with R-squares typically around 0.99.

Figure 7 illustrates displays the reverse engineered premium model fit against the actual premium rates which would have been quoted by RMAs rating system under alternative volatilities for Geary County, Kansas, for a coverage level of 50%.

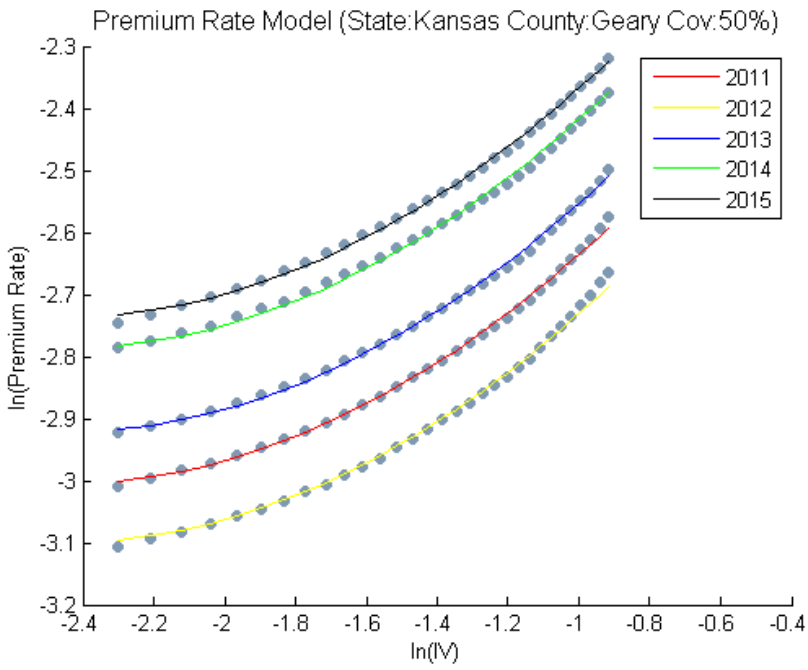

Figure 7. Premium rate: real value and estimated value (State: Kansas, county: Geary, coverage level: 50%)

Regression results for this county are displayed below. A separate set of models were evaluated for each county/year. Regression results for alternative cases are located in the Appendix. Overall, the approximation methods accurately restate premiums under alternative IVs without debate.

Table 3. Ordinary Least-squares Estimates (State: Kansas, county: Geary, coverage level: 50%)

Variable	*Coefficient*	*t-statistic*	*probability*
constant	-1.963081	-258.630942	0.000000
year 2012	-0.095436	-62.602211	0.000000
year 2013	0.082443	54.079122	0.000000
year 2014	0.218180	143.116637	0.000000
year 2015	0.268203	175.929825	0.000000
ln(IV)	0.843228	83.131383	0.000000
ln(IV)^2	0.170486	52.742019	0.000000

R-squared = 0.9990
Rbar-squared = 0.9990

Loss Ratio Restatement

In order to restate what historical loss ratios would have been under different levels of IV, we first restate what premium rate would have been under alternative IVs (as determined by different discovery period methodologies for IV, after inserting into RMA premium rating method), using the models above. Using such restated premiums, we then calculate what the restated loss ratio would have been as follows:

$$.Restated\ Loss\ Ratio\ = \frac{PremRate\ Restated\ under\ IV_1}{Original\ PremRate\ under\ IV_1} * \frac{PremRate\ Restated\ under\ IV_2}{Original\ PremRate\ under\ IV_2}$$

Comparison of Model I and Model II

Restated premium rate and loss ratio under alternative IVs is illustrated below for Adams County Illinois.

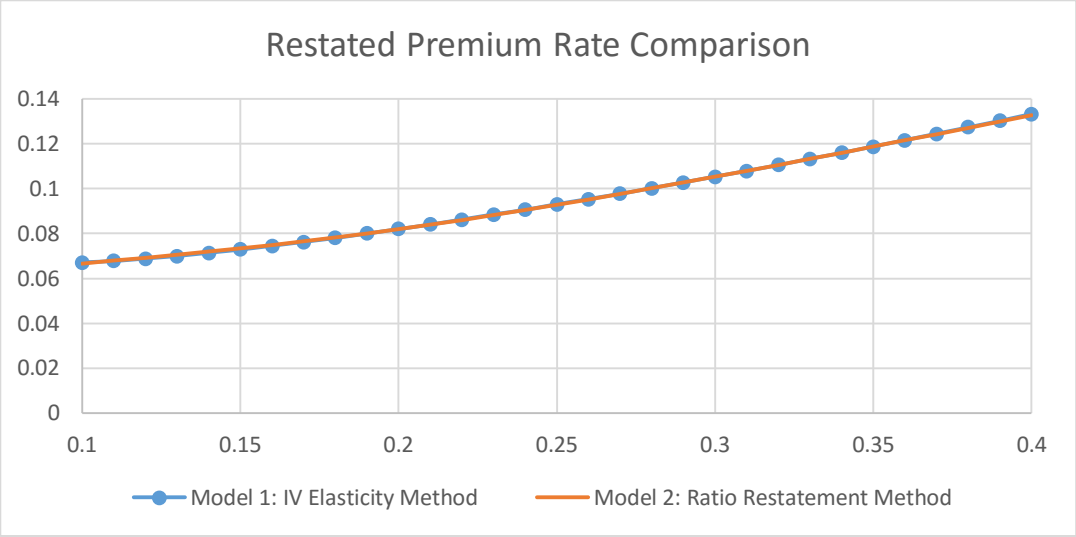

Figure 8. Comparison of Two Models on Restated Premium Rate (State: Illinois County: Adams, Year: 2008, Coverage level: 0.85)

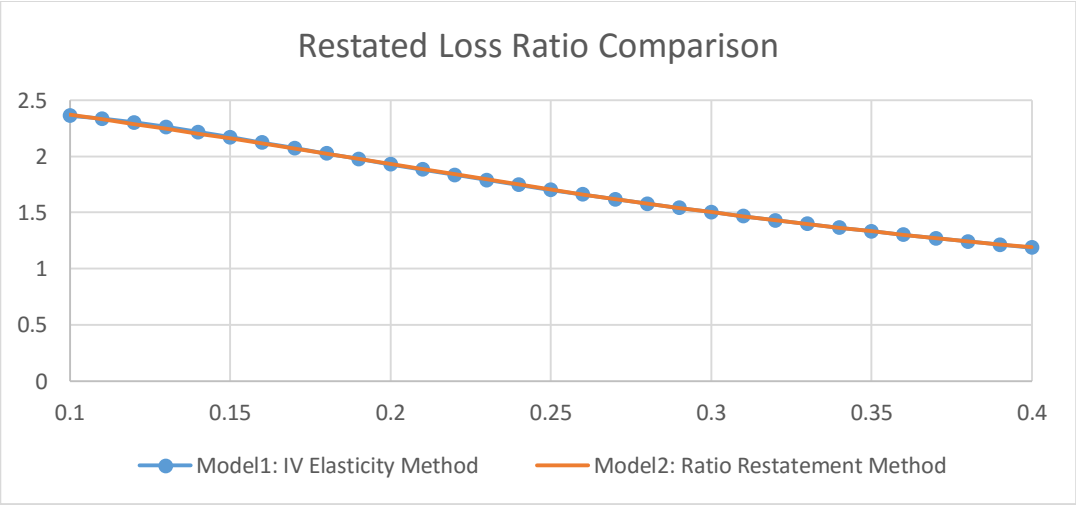

Figure 9. Comparison of Two Models on Restated Loss Ratio (State: Illinois County: Adams, Year: 2008, Coverage level: 0.85)

As illustrated in Figures 8 and 9, the two models perform similarly. More examples are contained in the Appendix. Following Woodard (2008), Woodard et al., (2012) and Woodard (2015), with the restated historical loss ratios under alternative IVs in hand, we test for excluded preseason information content by estimating regressions of realized loss ratios by year and county on preseason implied volatility, controlling for coverage level and other factors, and for different discovery periods, as:

$$Ln(Loss\ Ratio_{it}) = \beta_1 * Coverage\ Level_{it} + \beta_2 * Ln(IV_{it}) + \alpha_i + e_{it}$$

For robustness, we also perform the same exercise using data aggregated by coverage level as:

$$Ln(Loss\ Ratio_{it}) = \beta_1 * Aggregated\ Coverage\ Level_{it} + \beta_2 * Ln(IV_{it}) + \alpha_i + e_{it}$$

Last, we also evaluate robustness using county aggregated data without coverage level regressors:

$$Ln(Loss\ Ratio_{it}) = \beta_1 * Ln(IV_{it}) + \alpha_i + e_{it}$$

CHAPTER IV

RESULTS

A simple loop is written to re-estimate the econometric model in Woodard (2015) over different discovery periods for IV (5 days, 30 days, 90 days, etc.). Primary tests are conducted using Basic Unit premiums. While most of the volume currently is in Enterprise Units, we found according to the RMAs rating methodology that the premium rate elasticity with respect to IV is greater for Enterprise Units; thus, using Basic units results in a conservative assessment which should err toward failing to reject the hypothesis of actuarial appropriateness of a given IV discovery period. Table 8 displays the regression coefficient on the IV variable for the regressions of restated loss ratio on IV. Regardless of the restatement method and econometric model, the 5-day period is summarily rejected.

The numbers in bold represent those cases in which the parameter was insignificantly different from zero (i.e., failure to reject that the discovery period as actuarially appropriate). Table 9 further displays results for RMAs current methodology employing only the 5-day discovery period. The coefficient on IV is statistically negatively related to eventual loss ratio, indicating that higher preseason loss ratios are predictive of lower eventual relative losses under the RMAs premium rating methodology, and vice-a-versa. This is a clear violation of actuarially appropriate ratemaking. Figures 10 and 11 illustrate a graphical depiction of these tables and shows that the discovery period after which the hypothesis of actuarial validity fails to be rejected falls around 325 days. Figures 12 and 13 provide further robustness tests to alternative model set ups, and are universally consistent and robust. Log and linear premium rate models for historical volatility cases are also reported for these tests in the Appendix. Regression results are robust to whether Enterprise Units are used to perform the analysis or Basic Units, as shown in Figure 14.

Table 4. Coefficient of Implied Volatility (Basic Unit, Log Premium Rate Model and Implied Volatility)

IV series		*5 days*	*30 days*	*90 days*	*180 days*	*250 days*	*325 days*	*400 days*	*500 days*
Model I: No coverage level aggregation	All contracts & State fixed effects	-0.7843	-0.8057	-0.6736	-0.3189	-0.0769	***0.0646***	0.2307	0.2146
	All contracts & County fixed effects	-0.8091	-0.8314	-0.7050	-0.3547	-0.1099	***0.0338***	0.2004	0.1811
	December contracts & State fixed effects	-0.9654	-0.8350	-0.8696	-0.4874	-0.1842	***0.0025***	0.1623	0.3069
	December contracts & County fixed effects	-0.9991	-0.8700	-0.9036	-0.5134	-0.2034	***-0.0112***	0.1505	0.2929
Model II: Coverage level aggregation	All contracts & State fixed effects	-0.7539	-0.7896	-0.6238	-0.2173	***0.0103***	0.1864	0.3569	0.3856
	All contracts & County fixed effects	-0.7970	-0.8426	-0.7148	-0.3372	-0.1120	***0.0721***	0.2411	0.2570
	December contracts & State fixed effects	-0.9060	-0.7941	-0.8023	-0.4569	-0.1489	***0.0652***	0.2200	0.4227
	December contracts & County fixed effects	-0.9788	-0.8892	-0.9018	-0.5446	-0.2229	***0.0044***	0.1602	0.3507
Model III: Coverage level aggregation (no coverage level control)	All contracts & State fixed effects	-0.7997	-0.8458	-0.7204	-0.3842	-0.1860	***-0.0178***	0.1301	0.1364
	All contracts & County fixed effects	-0.8046	-0.8503	-0.7263	-0.3918	-0.1948	***-0.0271***	0.1205	0.1261
	December contracts & State fixed effects	-0.9765	-0.8862	-0.8980	-0.5613	-0.2511	***-0.0245***	0.1300	0.3033
	December contracts & County fixed effects	-0.9820	-0.8920	-0.9034	-0.5657	-0.2552	***-0.0282***	0.1263	0.2990

Table 5. Regression Results for 5 Days' Scenario (Official Method)

Regression Parameters		*coefficient*	*t-statistic*	*p value*
Model I:	All contracts & State fixed effects	-0.7843	-23.1750	0.0000
	All contracts & County fixed effects	-0.8091	-24.4502	0.0000
	December contracts & State fixed effects	-0.9654	-24.1758	0.0000
	December contracts & County fixed effects	-0.9991	-25.5840	0.0000
Model II:	All contracts & State fixed effects	-0.7539	-11.8945	0.0000
	All contracts & County fixed effects	-0.7970	-12.7107	0.0000
	December contracts & State fixed effects	-0.9060	-12.0801	0.0000
	December contracts & County fixed effects	-0.9788	-13.1666	0.0000
Model III:	All contracts & State fixed effects	-0.7997	-12.6575	0.0000
	All contracts & County fixed effects	-0.8046	-12.9285	0.0000
	December contracts & State fixed effects	-0.9765	-13.1367	0.0000
	December contracts & County fixed effects	-0.9820	-13.4121	0.0000

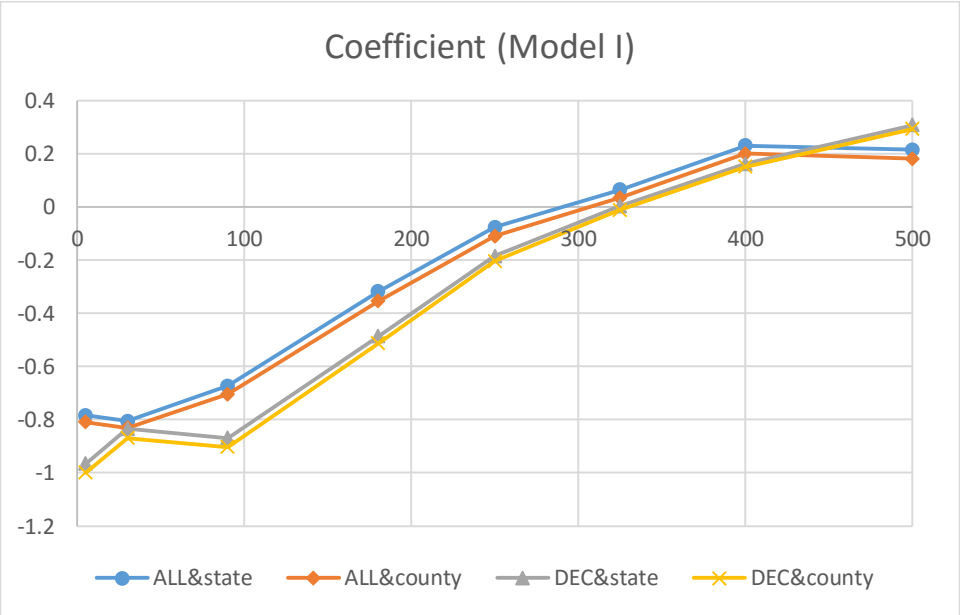

Figure 10. Coefficient of IV of Model 1 (No coverage level aggregation)

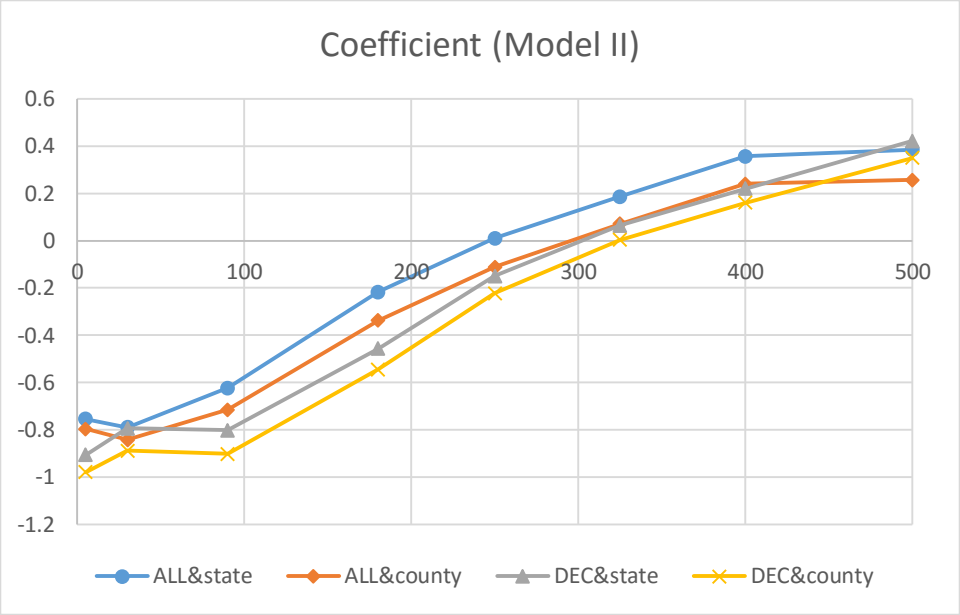

Figure 11. Coefficient of IV of Model 2 (With coverage level aggregation)

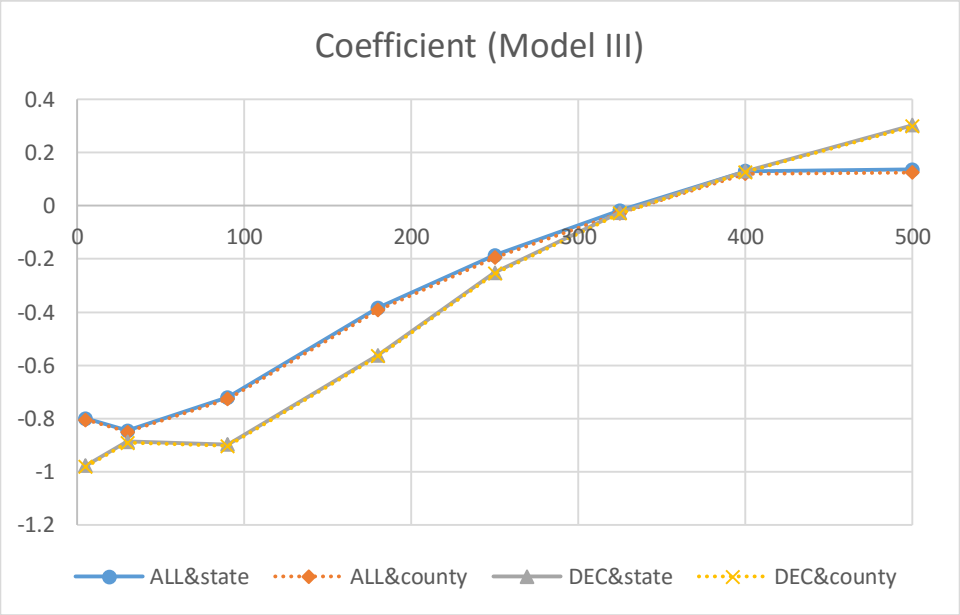

Figure 12. Coefficient of IV of Model 3 (With coverage level aggregation but without coverage level control)

Table 6. Ordinary Least-squares Estimates for Optimal Cases (Basic Unit, Log Premium Rate Model and Implied Volatility)

Cases		*Optimal days*	*coefficient*	*t-statistic*	*p value*
Model I: No coverage level aggregation	All contracts & State fixed effects	325 days	0.0646184	1.5586389	0.119088
	All contracts & County fixed effects	325 days	0.0337789	0.8317974	0.405527
	December contracts & State fixed effects	325 days	0.0025483	0.059937	0.952206
	December contracts & County fixed effects	325 days	-0.0111646	-0.2680423	0.788668
Model II: Coverage level aggregation	All contracts & State fixed effects	250 days	0.0103206	0.1319394	0.895035
	All contracts & County fixed effects	325 days	0.0720646	0.9055641	0.365188
	December contracts & State fixed effects	325 days	0.0651576	0.8176459	0.413578
	December contracts & County fixed effects	325 days	0.0043757	0.0552512	0.955939
Model III: Coverage level aggregation (no coverage level control)	All contracts & State fixed effects	325 days	-0.017765	-0.2329857	0.815777
	All contracts & County fixed effects	325 days	-0.0270781	-0.3599995	0.718855
	December contracts & State fixed effects	325 days	-0.0244842	-0.3095899	0.756879
	December contracts & County fixed effects	325 days	-0.0281538	-0.3606333	0.718381

Table 7. Coefficient of Implied Volatility (Basic Unit, Linear Premium Rate Model and Implied Volatility)

IV series		*5 days*	*30 days*	*90 days*	*180 days*	*250 days*	*325 days*	*400 days*	*500 days*
No coverage level aggregation	All contracts & State fixed effects	-0.7843	-0.8036	-0.6595	-0.3065	***-0.0626***	0.0840	0.2491	0.2303
	All contracts & County fixed effects	-0.8091	-0.8295	-0.6912	-0.3429	-0.0962	***0.0527***	0.2183	0.1961
	December contracts & State fixed effects	-0.9654	-0.8287	-0.8579	-0.4706	-0.1644	***0.0222***	0.1773	0.3213
	December contracts & County fixed effects	-0.9991	-0.8640	-0.8924	-0.4973	-0.1841	***0.0081***	0.1652	0.3068
Coverage level aggregation	All contracts & State fixed effects	-0.7539	-0.7868	-0.6121	-0.2087	***0.0207***	0.2018	0.3713	0.3985
	All contracts & County fixed effects	-0.7970	-0.8409	-0.7066	-0.3347	-0.1075	***0.0815***	0.2490	0.2626
	December contracts & State fixed effects	-0.9060	-0.7887	-0.7923	-0.4383	-0.1288	***0.0845***	0.2365	0.4396
	December contracts & County fixed effects	-0.9788	-0.8859	-0.8950	-0.5299	-0.2064	***0.0207***	0.1738	0.3640
Coverage level aggregation (no coverage level control)	All contracts & State fixed effects	-0.7997	-0.8419	-0.7050	-0.3684	-0.1679	***0.0054***	0.1530	0.1588
	All contracts & County fixed effects	-0.8046	-0.8464	-0.7110	-0.3761	-0.1768	***-0.0040***	0.1433	0.1484
	December contracts & State fixed effects	-0.9765	-0.8785	-0.8849	-0.5388	-0.2276	***-0.0023***	0.1496	0.3238
	December contracts & County fixed effects	-0.9820	-0.8844	-0.8903	-0.5433	-0.2317	***-0.0060***	0.1458	0.3196

Table 8. Ordinary Least-squares Estimates for Optimal Cases (Basic Unit, Linear Premium Rate Model and Implied Volatility)

Cases		*Optimal days*	*coefficient*	*t-statistic*	*p value*
Model I: No coverage level aggregation	All contracts & State fixed effects	250 days	-0.06264	-1.52766	0.12660
	All contracts & County fixed effects	325 days	0.05266	1.29523	0.19525
	December contracts & State fixed effects	325 days	0.02225	0.52211	0.60160
	December contracts & County fixed effects	325 days	0.00813	0.19485	0.84551
Model II: Coverage level aggregation	All contracts & State fixed effects	250 days	0.02066	0.26371	0.79201
	All contracts & County fixed effects	325 days	0.08154	1.02361	0.30605
	December contracts & State fixed effects	325 days	0.08446	1.05684	0.29061
	December contracts & County fixed effects	325 days	0.02071	0.26099	0.79411
Model III: Coverage level aggregation (no coverage level control)	All contracts & State fixed effects	325 days	0.00541	0.07085	0.94352
	All contracts & County fixed effects	325 days	-0.00396	-0.05263	0.95803
	December contracts & State fixed effects	325 days	-0.00227	-0.02862	0.97717
	December contracts & County fixed effects	325 days	-0.00595	-0.07614	0.93931

Table 9. Ordinary Least-squares Estimates for Optimal Cases (Enterprise Unit, Log Premium Rate Model and Implied Volatility)

Cases		*Optimal days*	*Coefficient*	*t-statistic*	*t-probability*
Model I: No coverage level aggregation	All contracts & State fixed effects	325 days	0.06427	1.55240	0.12057
	All contracts & County fixed effects	325 days	0.03368	0.83051	0.40626
	December contracts & State fixed effects	325 days	-0.00301	-0.07090	0.94348
	December contracts & County fixed effects	325 days	-0.01657	-0.39827	0.69043
Model II: Coverage level aggregation	All contracts & State fixed effects	250 days	0.01595	0.20433	0.83810
	All contracts & County fixed effects	325 days	0.07853	0.98867	0.32285
	December contracts & State fixed effects	325 days	0.05642	0.70951	0.47802
	December contracts & County fixed effects	325 days	-0.00293	-0.03701	0.97048
Model III: Coverage level aggregation (no coverage level control)	All contracts & State fixed effects	325 days	-0.01821	-0.23930	0.81088
	All contracts & County fixed effects	325 days	-0.02748	-0.36596	0.71441
	December contracts & State fixed effects	325 days	-0.03106	-0.39369	0.69382
	December contracts & County fixed effects	325 days	-0.03473	-0.44562	0.65588

Table 10. Ordinary Least-squares Estimates for Optimal Cases (Enterprise Unit, Linear Premium Rate Model and Implied Volatility)

Cases		*Optimal days*	*Coefficient*	*t-statistic*	*t-probability*
Model I: No coverage level aggregation	All contracts & State fixed effects	250 days	-0.06264	-1.52768	0.12660
	All contracts & County fixed effects	325 days	0.05266	1.29521	0.19525
	December contracts & State fixed effects	325 days	0.02225	0.52209	0.60161
	December contracts & County fixed effects	325 days	0.00813	0.19483	0.84553
Model II: Coverage level aggregation	All contracts & State fixed effects	250 days	0.02066	0.26371	0.79201
	All contracts & County fixed effects	325 days	0.08154	1.02360	0.30605
	December contracts & State fixed effects	325 days	0.08446	1.05683	0.29061
	December contracts & County fixed effects	325 days	0.02071	0.26098	0.79411
Model III: Coverage level aggregation (no coverage level control)	All contracts & State fixed effects	325 days	0.00541	0.07084	0.94353
	All contracts & County fixed effects	325 days	-0.00396	-0.05264	0.95802
	December contracts & State fixed effects	325 days	-0.00227	-0.02863	0.97716
	December contracts & County fixed effects	325 days	-0.00596	-0.07615	0.93930

CHAPTER V

CONCLUSION

In order to verify the volatility methodology used by RMA for premium rate making in the FCIP, we constructed multiple models to test whether IV calculated using RMA's method for establishing the preseason IV used for revenue volatility calibration is statistically significantly related to eventual end-of-season loss ratios. Corroborating the results of Woodard (2015), we find unequivocal evidence that the 5-day period for IV discovery is predictive of eventual end-of-season loss ratios, and thus is actuarially inappropriate.

Further tests were conducted to restate what historical premium rates and loss ratios would have been under alternative IV discovery periods, using RMAs own published system to estimate restated premiums. The number of days found in which there is failure to reject actuarial appropriateness is greatly in excess of the current 5-day period. This is not surprising given the relative thinness of the futures-options market during the last 5 days of February.

While we do find that extending the discovery period length sufficiently eventually results in failure to reject actuarial appropriateness (specifically, around 325 days), we would caution that this does not necessarily imply that extending the IV averaging period to 325 days prior to the sales opening date is the "best" option. Rather, a multitude of alternative methods could be devised to establish this parameter, and others could also be viable.

From a reinsurers point of view, for example, there is likely more interest in what would have been the constant IV over the period such that the program would have achieved actuarial fairness. Investigation of this and other issues should warrant further research. Simulation analyses of the econometric methodology would also be of great value to further assess the properties of

the testing methodology employed herein. Other systemic factors that affect rating and policy performance within this context, as motivated by related issues in agriculture insurance, also warrant further attention (see e.g.,Turvey and Stokes, 2008; Turvey,Woodard and Liu, 2014; Woodard, 2016d; Sherrick et al, 2014; Sherrick, Schnitkey and Woodard, 2014; Turvey, 1990).

REFERENCES

B. K. Goodwin, A. H., R. M. Rejesus, K. H. Coble, T. O. Knight (2014). "Actuarial Review for Price Volatility Factor Methodology."

Bulut, H., et al. (2011). "Volatility Factor in Concept and Practice." No 160537, NCIS Special Reports from National Crop Insurance Services (NCIS)

Day, T. E. and C. M. Lewis (1993). "Forecasting Futures Market Volatility." The Journal of Derivatives 1(2): 33-50

Egelkraut, T. M., & Garcia, P. (2006). Intermediate Volatility Forecasts Using Implied Forward Volatility: The Performance of Selected Agricultural Commodity Options. *Journal of Agricultural and Resource Economics*, *31*(3), 508-528.

Egelkraut, T. M., Garcia, P., & Sherrick, B. J. (2007). The term structure of implied forward volatility: Recovery and informational content in the corn options market. *American Journal of Agricultural Economics*, *89*(1), 1-11.

Paulson, N.D., Joshua D. Woodard, and Bruce A. Babcock, "Modeling “Shallow Loss” Crop Revenue Programs: Issues and Implications for the 2012 Farm Bill," Agricultural Finance Review (2013).

Sherrick, B. (2015). "Understanding the Implied Volatility (IV) Factor in Crop Insurance." farmdoc daily 5(37): Department of Agricultural and Consumer Economics, University of Illinois at Urbana-Champaign, February 27, 2015.

Sherrick, B.J., Gary D. Schnitkey , Joshua D. Woodard, "Crop insurance loss experience, ratings changes, and impacts on participants" Agricultural Finance Review (2014) 74:4 , 443-463

Sherrick, B.J., Christopher A Lanoue, Joshua Woodard, Gary D. Schnitkey, Nicholas D. Paulson (2014), "Crop Yield Distributions: Fit, Efficiency, and Performance", Agricultural Finance Review, 74: 3

Turvey, C. G. (1990). " Alternative Estimates of Weighted Implied Volatilities from Soybean and Live Cattle Options." The Journal of Futures Markets 10(4): 353-366

Turvey, C. G. and J. R. Stokes (2008). "Market Structure and the Value of Agricultural Contingent Claims." Canadian Journal of Agricultural Economics 56: 79–94

Turvey, C.G., J.D. Woodard, and E. Liu, (2014) "Financial engineering for the farm problem", Agricultural Finance Review, Vol. 74 Iss: 2, pp.271 - 286

Woodard, J.D., B.J. Sherrick, "Estimation of Mixture Models using Cross-Validation Optimization: Implications for Crop Yield Distribution Modeling," American Journal of Agricultural Economics 93-4(2011): 968-982.

Woodard, J.D., N. Paulson, D. Vedenov, and G. Power, "Efficiency in the Modeling of Dependence Structures: An Application of Alternative Copulas to Agricultural Insurance Rating," Agricultural Economics 42-IS1(Nov. 2011): 101-112.

Woodard, J., Schnitkey, G. D., Sherrick, B. J., Lozano-Gracia, N., & Anselin, L. (2012). "A Spatial Econometric Analysis of Loss Experience in the U.S. Crop Insurance Program." Journal of Risk and Insurance. 79:261-186.

Woodard, J.D., A.D. Pavlista, G.D. Schnitkey, K. Ward, P. Burgener, "Government Insurance Program Design, Incentive Effects, and Technology Adoption: The Case of Skip-Row Crop Insurance," American Journal of Agricultural Economics (2012).

Woodard, J.D., "Theme Overview: Current Issues in Risk Management and U.S. Agricultural Policy," Choices (2013).

Woodard, J.D., B.J. Sherrick, G.D. Schnitkey, "Actuarial Impacts of Loss Cost Ratio Ratemaking in U.S. Crop Insurance Programs," Journal of Agricultural and Resource Economics, 36-1(April 2011):211-228.

Woodard, J. (2014). "Impacts of Weather and Time Horizon Selection on Crop Insurance Ratemaking: A Conditional Distribution Approach." North American Actuarial Journal.

Woodard, J.D. (2015). " Identification of Hedging Pressure Effects in Commodity Futures-Options Markets: Implications for Price Discovery." *Working Paper, Cornell University*.

Woodard, J.D. (2016). "Data Science and Management for Large Scale Empirical Applications in Agricultural and Applied Economics Research." *Applied Economic Perspectives and Policy*. 1-16.

Woodard J.D. (2016), "Big Data and Ag-Analytics: An Open Source, Open Data Platform for Agricultural & Environmental Finance, Insurance, and Risk," Agricultural Finance Review (Invited Paper, IARFIC Keynote Address)

Woodard, J.D. (2016), " Estimation of Insurance Deductible Demand under Endogenous Premium Rates." Selected Proceedings Paper 2016 Agricultural & Applied Economics Association Annual Meeting, Boston, Massachusetts, July 31-August 2

Woodard, J.D. (2016), "Ag-Analytics.org Data Warehouse", 2016, Available online at: aganalytics.org (Accessed: March, 2016).

Woodard, J.D. (2016) "Integrating High Resolution Soil Data into Federal Crop Insurance Rates: Actuarial, Policy, and Sustainability Implications," *AGree Working Paper*, Available Online at: http://www.foodandagpolicy.org/sites/default/files/Woodard%20Working%20Paper_SoilCropInsurance_Jan-2016.pdf

APPENDIX

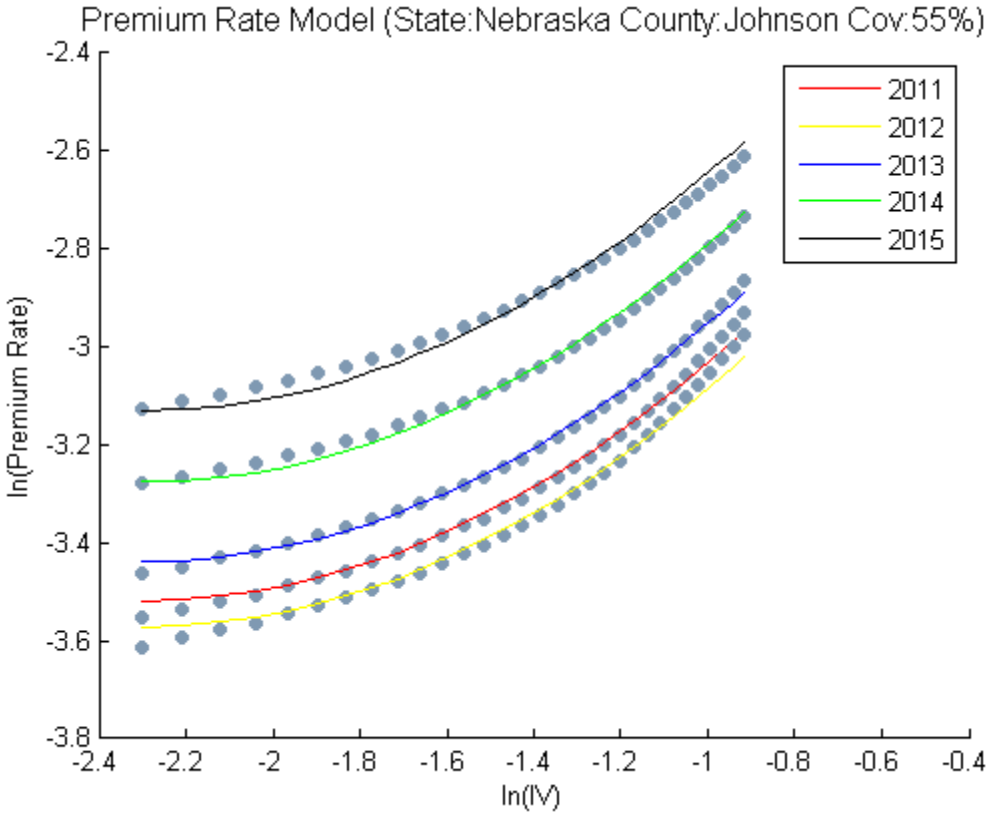

Figure 13. Premium rate: real value and estimated value (State: Nebraska, county: Johnson, coverage level: 55%)

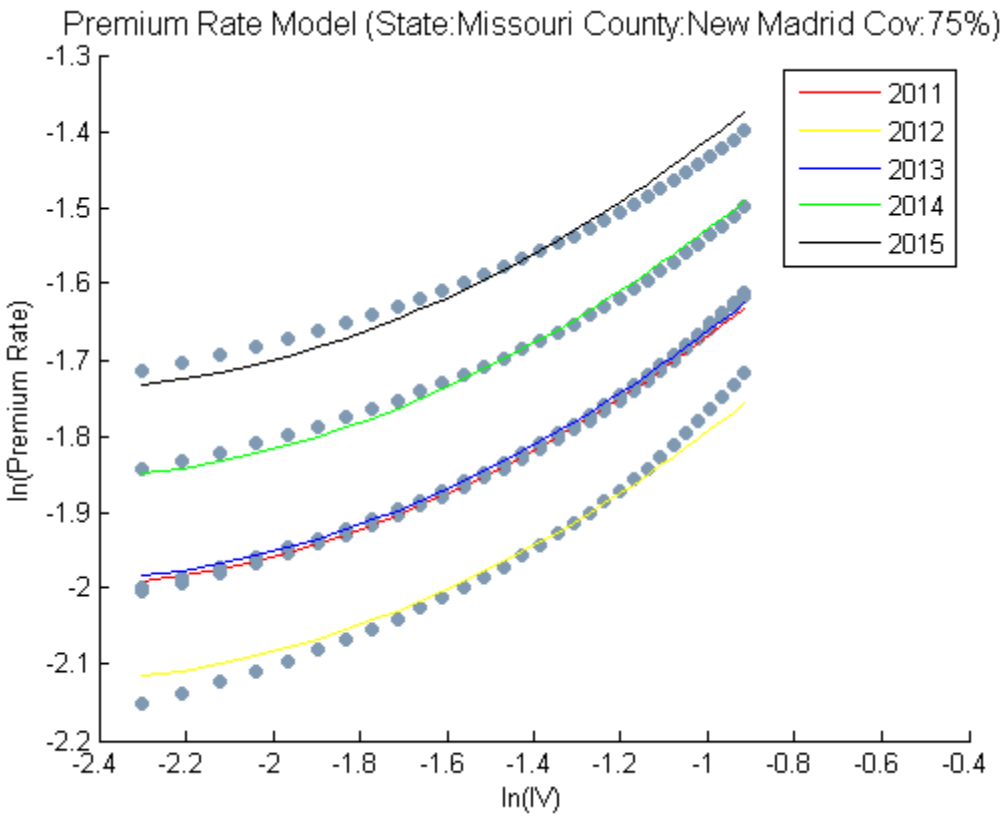

Figure 14. Premium rate: real value and estimated value (State: Missouri, county: New Madrid, coverage level: 75%)

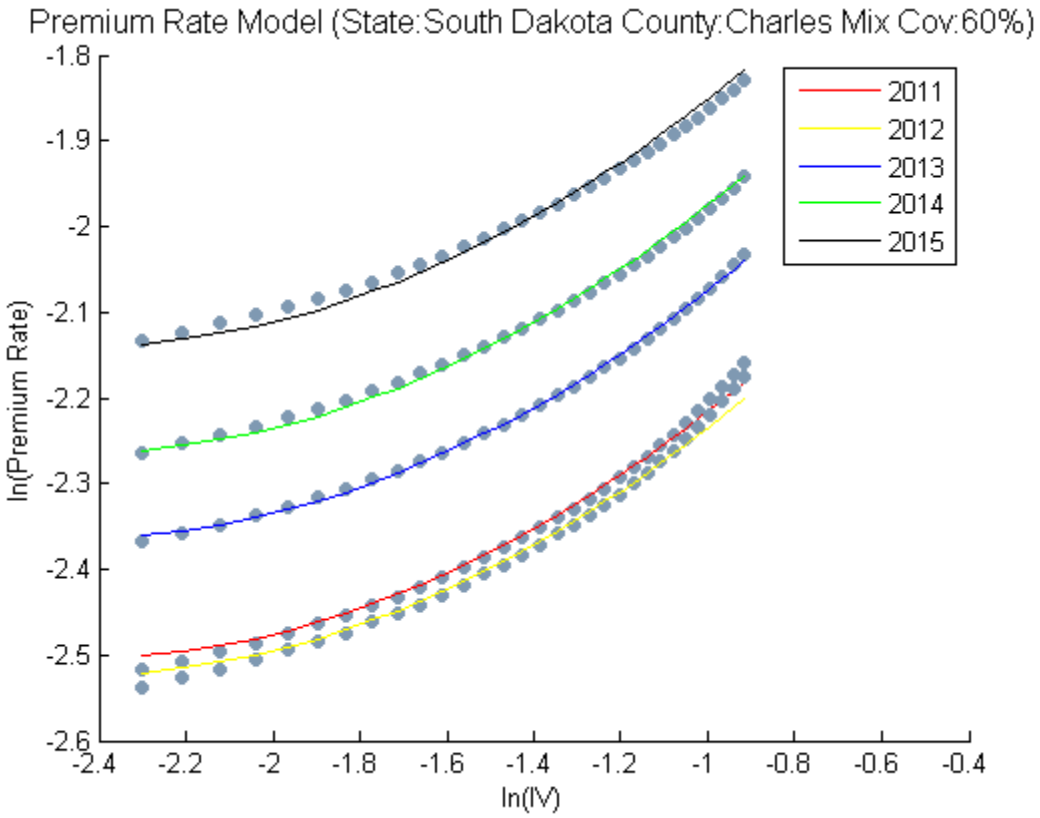

Figure 15. Premium rate: real value and estimated value (State: South Dakota, county: Charles Mix, coverage level: 60%)

Table 11. t-statistic of Implied Volatility (Basic Unit, Linear Premium Rate Model and Implied Volatility)

IV series		*5 days*	*30 days*	*90 days*	*180 days*	*250 days*	*325 days*	*400 days*	*500 days*
No coverage level aggregation	All contracts & State fixed effects	-23.175	-23.277	-20.104	-8.326	-1.877	1.559	5.319	4.603
	All contracts & County fixed effects	-24.450	-24.546	-21.494	-9.455	-2.742	0.832	4.715	3.964
	December contracts & State fixed effects	-24.176	-21.281	-21.970	-11.308	-4.352	0.060	3.587	6.530
	December contracts & County fixed effects	-25.584	-22.660	-23.317	-12.158	-4.907	-0.268	3.395	6.360
Coverage level aggregation	All contracts & State fixed effects	-11.894	-12.174	-9.858	-2.962	0.132	2.358	4.308	4.316
	All contracts & County fixed effects	-12.711	-13.106	-11.310	-4.566	-1.422	0.906	2.889	2.851
	December contracts & State fixed effects	-12.080	-10.720	-10.707	-5.603	-1.867	0.818	2.595	4.777
	December contracts & County fixed effects	-13.167	-12.059	-12.072	-6.702	-2.807	0.055	1.902	3.983
Coverage level aggregation (no coverage level control)	All contracts & State fixed effects	-12.658	-13.123	-11.665	-5.444	-2.472	-0.233	1.629	1.588
	All contracts & County fixed effects	-12.928	-13.383	-11.929	-5.629	-2.625	-0.360	1.529	1.488
	December contracts & State fixed effects	-13.137	-12.181	-12.232	-6.990	-3.186	-0.310	1.544	3.461
	December contracts & County fixed effects	-13.412	-12.441	-12.477	-7.137	-3.280	-0.361	1.518	3.457

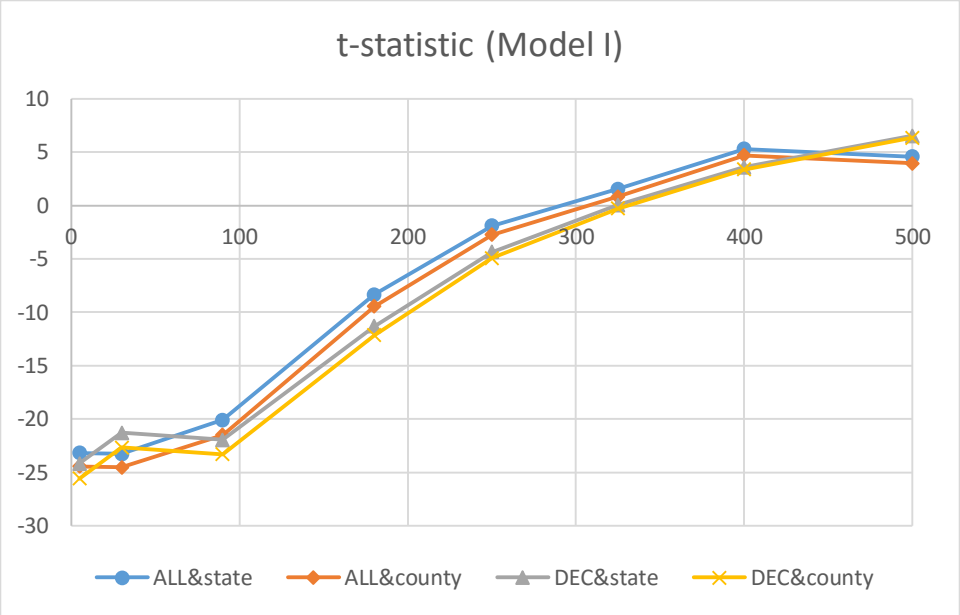

Figure 16. t-statistic of IV of Model 1 (No coverage level aggregation)

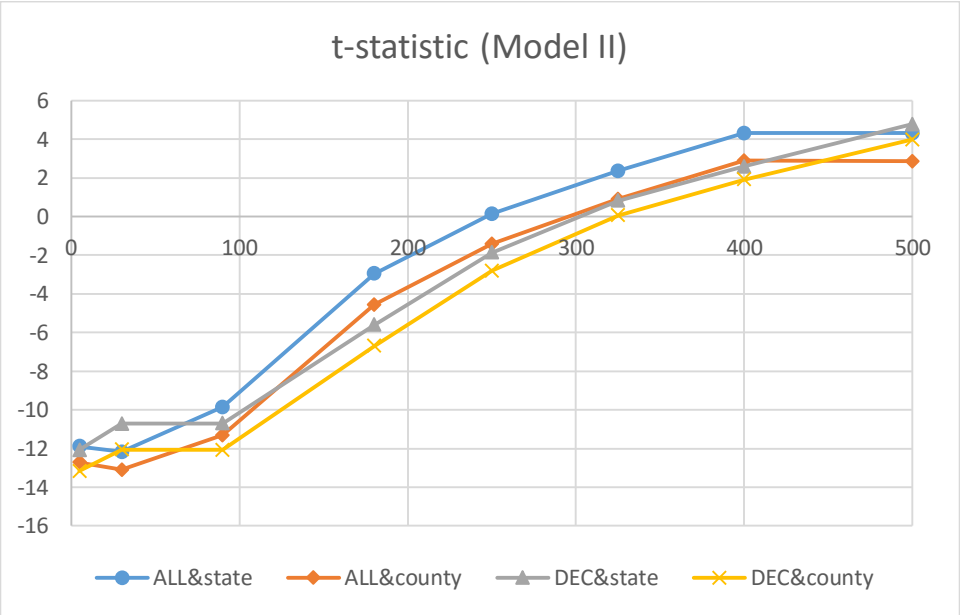

Figure 17. t-statistic of IV of Model 2 (With coverage level aggregation)

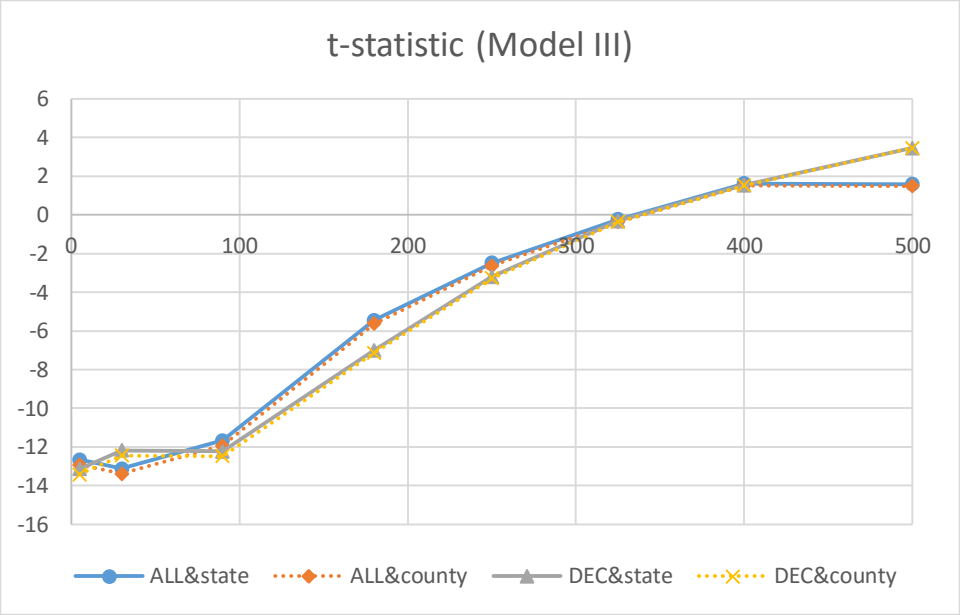

Figure 18. t-statistic of IV of Model 3 (With coverage level aggregation but without coverage level control)

Table 12. Coefficient of Implied Volatility (Basic Unit, Log Premium Rate Model and Historical Volatility)

IV series		*5 days*	*30 days*	*90 days*	*180 days*	*250 days*	*325 days*	*400 days*	*500 days*
No coverage level aggregation	All contracts & State fixed effects	-1.0419	-0.7939	-0.7791	-0.5245	-0.2144	-0.0853	***0.0019***	0.0737
	All contracts & County fixed effects	-1.0730	-0.8190	-0.8079	-0.5578	-0.2438	-0.1083	***-0.0196***	0.0519
	December contracts & State fixed effects	-0.7651	-0.6176	-0.5710	-0.3355	-0.0969	***0.0580***	0.1232	0.1593
	December contracts & County fixed effects	-0.7989	-0.6428	-0.5970	-0.3578	-0.1157	***0.0412***	0.1112	0.1432
Coverage level aggregation	All contracts & State fixed effects	-1.0642	-0.8367	-0.8114	-0.5102	-0.1793	-0.0691	***0.0402***	0.1565
	All contracts & County fixed effects	-1.1434	-0.9024	-0.9006	-0.6382	-0.3026	-0.1693	***-0.0546***	0.0606
	December contracts & State fixed effects	-0.7752	-0.6471	-0.6089	-0.3293	-0.0892	***0.0871***	0.1407	0.2134
	December contracts & County fixed effects	-0.8868	-0.7275	-0.7058	-0.4235	-0.1720	***0.0125***	0.0826	0.1406
Coverage level aggregation (no coverage level control)	All contracts & State fixed effects	-1.0887	-0.8789	-0.8566	-0.6309	-0.3429	-0.2181	-0.1250	***-0.0408***
	All contracts & County fixed effects	-1.0932	-0.8821	-0.8607	-0.6360	-0.3488	-0.2230	-0.1289	***-0.0443***
	December contracts & State fixed effects	-0.8013	-0.6871	-0.6503	-0.4244	-0.2069	-0.0465	***0.0274***	0.0505
	December contracts & County fixed effects	-0.8062	-0.6905	-0.6544	-0.4278	-0.2102	-0.0499	***0.0253***	0.0482

Table 13. Ordinary Least-squares Estimates for Optimal Cases (Basic Unit, Log Premium Rate Model and Historical Volatility)

Cases		*Optimal days*	*Coefficient*	*t-statistic*	*t-probability*
Model I: No coverage level aggregation	All contracts & State fixed effects	400 days	0.00186	0.07621	0.93925
	All contracts & County fixed effects	400 days	-0.01964	-0.82168	0.41127
	December contracts & State fixed effects	325 days	0.05799	2.95020	0.00318*
	December contracts & County fixed effects	325 days	0.04116	2.14040	0.03233*
Model II: Coverage level aggregation	All contracts & State fixed effects	400 days	0.04019	0.83251	0.40514
	All contracts & County fixed effects	400 days	-0.05463	-1.11637	0.26429
	December contracts & State fixed effects	325 days	0.08711	2.23560	0.02540
	December contracts & County fixed effects	325 days	0.01255	0.31727	0.75105
Model III: Coverage level aggregation (no coverage level control)	All contracts & State fixed effects	500 days	-0.04082	-0.90054	0.36785
	All contracts & County fixed effects	500 days	-0.04431	-0.99449	0.32001
	December contracts & State fixed effects	400 days	0.02744	0.76922	0.44178
	December contracts & County fixed effects	400 days	0.02526	0.71971	0.47172

* $p<0.05$

Table 14. Coefficient of Implied Volatility (Basic Unit, Linear Premium Rate Model and Historical Volatility)

IV series		*5 days*	*30 days*	*90 days*	*180 days*	*250 days*	*325 days*	*400 days*	*500 days*
No coverage level aggregation	All contracts & State fixed effects	-1.0419	-0.7242	-0.6925	-0.4207	-0.1175	***-0.0022***	0.0765	0.1329
	All contracts & County fixed effects	-1.0730	-0.7488	-0.7207	-0.4530	-0.1461	***-0.0247***	0.0553	0.1113
	December contracts & State fixed effects	-0.7651	-0.5788	-0.5126	-0.2655	***-0.0456***	0.0929	0.1416	0.1768
	December contracts & County fixed effects	-0.7989	-0.6036	-0.5382	-0.2875	***-0.0643***	0.0762	0.1297	0.1607
Coverage level aggregation	All contracts & State fixed effects	-1.0642	-0.7693	-0.7304	-0.4155	-0.0898	***0.0085***	0.1112	0.2142
	All contracts & County fixed effects	-1.1434	-0.8328	-0.8174	-0.5375	-0.2078	***-0.0891***	0.0179	0.1186
	December contracts & State fixed effects	-0.7752	-0.6069	-0.5521	-0.2638	***-0.0420***	0.1191	0.1565	0.2277
	December contracts & County fixed effects	-0.8868	-0.6863	-0.6480	-0.3578	-0.1257	***0.0433***	0.0966	0.1518
Coverage level aggregation (no coverage level control)	All contracts & State fixed effects	-1.0887	-0.8118	-0.7762	-0.5359	-0.2530	-0.1402	-0.0539	***0.0178***
	All contracts & County fixed effects	-1.0932	-0.8150	-0.7802	-0.5408	-0.2589	-0.1451	-0.0578	***0.0144***
	December contracts & State fixed effects	-0.8013	-0.6459	-0.5933	-0.3552	-0.1551	***-0.0105***	0.0477	0.0709
	December contracts & County fixed effects	-0.8062	-0.6493	-0.5973	-0.3585	-0.1583	***-0.0139***	0.0455	0.0685

Table 15. Ordinary Least-squares Estimates for Optimal Cases (Basic Unit, Linear Premium Rate Model and Historical Volatility)

Cases		*Optimal days*	*Coefficient*	*t-statistic*	*t-probability*
Model I: No coverage level aggregation	All contracts & State fixed effects	325 days	-0.00221	-0.08628	0.93125
	All contracts & County fixed effects	325 days	-0.02472	-0.98699	0.32365
	December contracts & State fixed effects	250 days	-0.04558	-2.14588	0.03189*
	December contracts & County fixed effects	250 days	-0.06426	-3.09137	0.00199*
Model II: Coverage level aggregation	All contracts & State fixed effects	325 days	0.00854	0.17013	0.86491
	All contracts & County fixed effects	325 days	-0.08915	-1.75602	0.07912
	December contracts & State fixed effects	250 days	-0.04204	-1.00699	0.31396
	December contracts & County fixed effects	325 days	0.04332	1.09317	0.27435
Model III: Coverage level aggregation (no coverage level control)	All contracts & State fixed effects	500 days	0.01785	0.39202	0.69505
	All contracts & County fixed effects	500 days	0.01438	0.32117	0.74809
	December contracts & State fixed effects	325 days	-0.01054	-0.28657	0.77445
	December contracts & County fixed effects	325 days	-0.01388	-0.38346	0.70139

* $p<0.05$

Table 16. Coefficient of Implied Volatility (Enterprise Unit, Log Premium Rate Model and Implied Volatility)

IV series		*5 days*	*30 days*	*90 days*	*180 days*	*250 days*	*325 days*	*400 days*	*500 days*
No coverage level aggregation	All contracts & State fixed effects	-0.7843	-0.8041	-0.6812	-0.3172	-0.0750	***0.0643***	0.2326	0.2233
	All contracts & County fixed effects	-0.8091	-0.8297	-0.7124	-0.3528	-0.1078	***0.0337***	0.2025	0.1902
	December contracts & State fixed effects	-0.9654	-0.8378	-0.8748	-0.4861	-0.1876	***-0.0030***	0.1630	0.3114
	December contracts & County fixed effects	-0.9991	-0.8728	-0.9086	-0.5118	-0.2066	***-0.0166***	0.1513	0.2976
Coverage level aggregation	All contracts & State fixed effects	-0.7539	-0.7885	-0.6307	-0.2119	***0.0160***	0.1889	0.3619	0.3981
	All contracts & County fixed effects	-0.7970	-0.8409	-0.7197	-0.3277	-0.1024	***0.0785***	0.2504	0.2749
	December contracts & State fixed effects	-0.9060	-0.7970	-0.8080	-0.4570	-0.1545	***0.0564***	0.2178	0.4248
	December contracts & County fixed effects	-0.9788	-0.8911	-0.9058	-0.5424	-0.2266	***-0.0029***	0.1595	0.3548
Coverage level aggregation (no coverage level control)	All contracts & State fixed effects	-0.7997	-0.8446	-0.7293	-0.3830	-0.1844	***-0.0182***	0.1323	0.1461
	All contracts & County fixed effects	-0.8046	-0.8491	-0.7353	-0.3906	-0.1932	***-0.0275***	0.1228	0.1358
	December contracts & State fixed effects	-0.9765	-0.8896	-0.9038	-0.5598	-0.2548	***-0.0311***	0.1303	0.3079
	December contracts & County fixed effects	-0.9820	-0.8955	-0.9091	-0.5642	-0.2588	***-0.0347***	0.1265	0.3037

Table 17. Coefficient of Implied Volatility (Enterprise Unit, Linear Premium Rate Model and Implied Volatility)

IV series		*5 days*	*30 days*	*90 days*	*180 days*	*250 days*	*325 days*	*400 days*	*500 days*
No coverage level aggregation	All contracts & State fixed effects	-0.7843	-0.8036	-0.6595	-0.3065	***-0.0626***	0.0840	0.2491	0.2303
	All contracts & County fixed effects	-0.8091	-0.8295	-0.6912	-0.3429	-0.0962	***0.0527***	0.2183	0.1961
	December contracts & State fixed effects	-0.9654	-0.8287	-0.8579	-0.4706	-0.1644	***0.0222***	0.1773	0.3213
	December contracts & County fixed effects	-0.9991	-0.8640	-0.8924	-0.4973	-0.1841	***0.0081***	0.1651	0.3068
Coverage level aggregation	All contracts & State fixed effects	-0.7539	-0.7868	-0.6121	-0.2087	***0.0207***	0.2018	0.3713	0.3985
	All contracts & County fixed effects	-0.7970	-0.8409	-0.7066	-0.3347	-0.1075	***0.0815***	0.2490	0.2626
	December contracts & State fixed effects	-0.9060	-0.7887	-0.7923	-0.4383	-0.1288	***0.0845***	0.2365	0.4396
	December contracts & County fixed effects	-0.9788	-0.8859	-0.8950	-0.5299	-0.2064	***0.0207***	0.1738	0.3640
Coverage level aggregation (no coverage level control)	All contracts & State fixed effects	-0.7997	-0.8419	-0.7050	-0.3684	-0.1679	***0.0054***	0.1530	0.1588
	All contracts & County fixed effects	-0.8046	-0.8464	-0.7110	-0.3761	-0.1768	***-0.0040***	0.1433	0.1484
	December contracts & State fixed effects	-0.9765	-0.8785	-0.8849	-0.5388	-0.2276	***-0.0023***	0.1496	0.3238
	December contracts & County fixed effects	-0.9820	-0.8844	-0.8903	-0.5433	-0.2317	***-0.0060***	0.1458	0.3196

Table 18. Coefficient of Implied Volatility (Enterprise Unit, Log Premium Rate Model and Historical Volatility)

IV series		*5 days*	*30 days*	*90 days*	*180 days*	*250 days*	*325 days*	*400 days*	*500 days*
No coverage level aggregation	All contracts & State fixed effects	-1.0419	-0.8180	-0.8131	-0.5576	-0.2497	-0.1218	-0.0402	***0.0303***
	All contracts & County fixed effects	-1.0730	-0.8435	-0.8425	-0.5919	-0.2799	-0.1453	-0.0622	***0.0080***
	December contracts & State fixed effects	-0.7651	-0.6371	-0.6018	-0.3690	-0.1307	***0.0210***	0.0861	0.1233
	December contracts & County fixed effects	-0.7989	-0.6625	-0.6281	-0.3917	-0.1499	***0.0039***	0.0739	0.1069
Coverage level aggregation	All contracts & State fixed effects	-1.0642	-0.8603	-0.8447	-0.5376	-0.2100	-0.1037	***-0.0020***	0.1119
	All contracts & County fixed effects	-1.1434	-0.9279	-0.9359	-0.6710	-0.3388	-0.2072	-0.0997	***0.0135***
	December contracts & State fixed effects	-0.7752	-0.6676	-0.6410	-0.3633	-0.1249	***0.0466***	0.0986	0.1730
	December contracts & County fixed effects	-0.8868	-0.7497	-0.7394	-0.4606	-0.2105	***-0.0299***	0.0391	0.0988
Coverage level aggregation (no coverage level control)	All contracts & State fixed effects	-1.0887	-0.9042	-0.8931	-0.6669	-0.3809	-0.2571	-0.1708	***-0.0890***
	All contracts & County fixed effects	-1.0932	-0.9075	-0.8972	-0.6719	-0.3869	-0.2620	-0.1747	***-0.0925***
	December contracts & State fixed effects	-0.8013	-0.7081	-0.6836	-0.4609	-0.2436	-0.0866	-0.0133	***0.0108***
	December contracts & County fixed effects	-0.8062	-0.7115	-0.6877	-0.4643	-0.2469	-0.0900	-0.0155	***0.0084***

Table 19. Coefficient of Implied Volatility (Enterprise Unit, Linear Premium Rate Model and Historical Volatility)

IV series		*5 days*	*30 days*	*90 days*	*180 days*	*250 days*	*325 days*	*400 days*	*500 days*
No coverage level aggregation	All contracts & State fixed effects	-1.0419	-0.7242	-0.6925	-0.4207	-0.1175	***-0.0022***	0.0765	0.1329
	All contracts & County fixed effects	-1.0730	-0.7488	-0.7207	-0.4530	-0.1461	***-0.0247***	0.0553	0.1113
	December contracts & State fixed effects	-0.7651	-0.5788	-0.5126	-0.2655	***-0.0456***	0.0929	0.1416	0.1768
	December contracts & County fixed effects	-0.7989	-0.6036	-0.5382	-0.2875	***-0.0643***	0.0762	0.1297	0.1607
Coverage level aggregation	All contracts & State fixed effects	-1.0642	-0.7693	-0.7304	-0.4155	-0.0898	***0.0085***	0.1112	0.2142
	All contracts & County fixed effects	-1.1434	-0.8328	-0.8174	-0.5375	-0.2078	-0.0892	***0.0179***	0.1186
	December contracts & State fixed effects	-0.7752	-0.6069	-0.5521	-0.2638	***-0.0420***	0.1191	0.1565	0.2277
	December contracts & County fixed effects	-0.8868	-0.6863	-0.6480	-0.3578	-0.1257	***0.0433***	0.0966	0.1518
Coverage level aggregation (no coverage level control)	All contracts & State fixed effects	-1.0887	-0.8118	-0.7762	-0.5359	-0.2530	-0.1402	-0.0539	***0.0178***
	All contracts & County fixed effects	-1.0932	-0.8150	-0.7802	-0.5408	-0.2589	-0.1451	-0.0578	***0.0144***
	December contracts & State fixed effects	-0.8013	-0.6459	-0.5933	-0.3552	-0.1551	***-0.0105***	0.0477	0.0709
	December contracts & County fixed effects	-0.8062	-0.6493	-0.5973	-0.3585	-0.1583	***-0.0139***	0.0455	0.0685