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The Tangled Web of Agricultural Insurance: Evaluating the Impacts of Government Policy

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This paper examines how changes in major elements of the U.S. federal crop insurance program affect the structure of the agricultural insurance industry. We model interactions between farmers, insurance agents and insurance companies. Marginal changes in government policy (premium subsidy rate, A&O subsidy rate, and loading factor) affect the insurance premium rate, agent compensation rates, agent effort levels, and market demand for crop insurance. Farmers prefer a marginal increase in the premium subsidy rate, but the insurance companies' most preferred policy is a marginal increase in the A&O subsidy rate. We also evaluate the consequences of changes in crop prices.

Key words: agriculture subsidy, crop insurance, vertical restraints

Introduction

Subsidized crop insurance programs in general, and the U.S. subsidized crop insurance program in particular, have received considerable attention from researchers and policymakers since the 1990s.[1] Most of these studies have focused on moral hazard, impacts on farm income and risk, environmental effects, adverse selection, determinants of the demand for crop insurance, and alternative methods for estimating actuarially fair premium rates (Glauber, 2013; Goodwin and Smith, 2013b). Little attention has been given to the supply side of the federal crop insurance program and the economic implications of the Standard Reinsurance Agreement (SRA) between private insurance companies who deliver federally subsidized crop insurance products to farmers and the U.S. government.[2] The lack of focus on the supply side of the U.S. subsidized crop insurance program is to some extent surprising. Over the past six years, crop insurance companies received between $2 billion and $3 billion annually from the federal government to deliver heavily subsidized crop insurance products to the farm sector (Glauber, 2013), about 15 % of total federal spending on all farm subsidy programs since 2007.

To provide an understanding of the supply side of the U.S. federal crop insurance program and the economic effects of the different subsidies embedded in this program, we present a new model of the crop insurance industry. Our model is structured to examine the tradeoffs between two different government objectives: adequate participation in the program and minimizing the taxpayer/net social

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[1] See, for example, recent surveys and reviews of crop insurance issues by Coble and Barnett (2013), Goodwin and Smith (2013a), Goodwin and Smith (2013b), Glauber (2013), Miranda and Farrin (2012), Smith and Glauber (2012).

[2] Exceptions include Babcock and Hart (2006); Ker (2001); Glauber (2004); Smith, Glauber, and Dismukes (2012); and Smith and Glauber (2012), most of whom have raised concerns about the transfer efficiency of providing subsidies to farmers through a program delivered by private insurance companies.

costs of the program (Goodwin and Smith, 1995; Gardner and Kramer, 1986). The model is used to evaluate the effects of marginal changes in crop insurance policy variables and crop prices on payments to insurance agents and those agent marketing efforts while considering different types of competition between insurance companies. We also evaluate the effects of marginal changes in crop insurance policy variables on overall participation by farmers, subsidies to farmers, crop insurance companies' revenues, and net social cost.

The policy variables include subsidy rates on the premiums paid directly by farmers, direct subsidies to the crop insurance companies for administration and operating (A&O) costs, and catastrophic risk loading factors on premium rates mandated by legislation. We also examine the effects of increases in crop prices like those that have occurred for corn, wheat, oilseeds, and other heavily insured commodities over the period 2006 to 2012 on agent compensation rates and effort levels.[3] Indirectly, the model also provides insights regarding the consequences of the methods used by the USDA Risk Management Agency (RMA) to establish policy premium rates, which have been criticized as overestimating actuarially fair rates (Coble et al., 2010).[4]

The model takes the form of a sequential game involving crop insurance companies and independent insurance agents. Insurance agents market crop insurance policies to farmers and then supply those policies to insurance companies. The model allows for the endogenous entry/exit of insurance agents. Insurance companies demand policies from insurance agents and either compete with other companies for agent services or form a monopsony cartel. Symmetric equilibria are determined for each type of insurance company market.

The analysis presented here is most closely related to the literature regarding commission sales and vertical restraints. Hart et al. (1990) and Ordover, Saloner, and Salop (1990) develop vertical restraint models where upstream firms compete in prices and downstream firms compete in quantities. In our model, upstream insurance companies compete in prices, which are the compensation rates set for insurance agents, and downstream insurance agents compete in quantities of effort. Recent studies on commission sales include Armstrong and Zhou (2011) and Inderst and Ottaviani (2012a; 2012b; 2012c). In these models, firms set prices for consumers and commissions for intermediaries. As in the model presented here, firms' (insurance companies') products are only sold to consumers (farmers) through an intermediary (insurance agents) providing advice to consumers. However, this literature focuses on how consumer heterogeneity leads to different equilibrium outcomes and possible policies to address consumer- protection issues. Consumers may differ due to different levels of knowledge about prices (Armstrong and Zhou, 2011), different levels of knowledge about an advisor's incentives (Inderst and Ottaviani, 2012c), or differentiated products (Inderst and Ottaviani, 2012a).

In contrast to the commission sales literature, here insurance companies offer homogeneous, federally subsidized crop insurance products, and in the model we abstract from farmer heterogeneity. As discussed below, the SRA among the government, insurance companies, and insurance agents codifies vertical restraints and limits the possible behavior of upstream insurance companies and downstream insurance agents. The government sets premium rates so that there is no strategic pricing, and insurance companies are forced to accept any conforming contract so that vertical integration is not relevant. Since insurance products and premium rates are standardized, consumer protection issues relevant for other industries are not applicable. Another difference in this paper is that we consider competition between intermediaries (agents) for a consumer's (farmer's)

[3] Several economists have argued that these increases in prices for crops such as corn, soybeans, and wheat have had important impacts on agricultural insurance companies' profits and the size of the U.S. crop insurance industry (for example, Babcock, 2011; Glauber, 2013; Goodwin and Smith, 2013a).

[4] This issue is discussed in Appendix B.

business. Most of the literature on commission sales abstracts from the decision by a buyer to choose an intermediary.[5]

We find that a marginal increase in the A&O subsidy rate paid to insurance companies does not change the premium rate for farmers, but increases agent compensation rates and agent effort levels. A marginal increase in the premium subsidy rate benefits farmers by reducing their out-of-pocket costs for crop insurance. The increase in the premium subsidy rate also has an added effect of reducing the returns to effort on the part of insurance agents, leading those agents to expend less effort per farmer (for sufficiently low compensation rates). On a per policy basis, raising the premium subsidy rate has no effect on insurance company revenues, as the increase in the premium subsidy is exactly offset by the reduction in farmer-paid premiums. However, government expenditures on subsidies increase both on a per policy basis and because the amount of insurance demanded by farmers increases as the price they pay for coverage declines.

Inflating actuarially fair premium rates through a marginal increase in the catastrophic loading factor has the following effects. On a per policy basis, government premium subsidy payments and A&O subsidy payments increase, as do insurance company revenues. The overall effect on quantity is ambiguous as farmers demand less insurance with higher premium rates, and—for sufficiently low compensation rates—insurance agents respond to the rate increase with an increase in effort. The increase in agent effort increases the quantity of insurance purchased by farmers, but—depending on the parameterization of the model—the increase in effort may or may not offset the decrease in quantity due to the increase in the premium rate.

Comparing the net social costs of marginal policy changes is more complex, and we evaluate changes in policy parameters using a convenient baseline of no prior government policy. In this context, an increase in the premium subsidy rate is the marginal change most preferred by farmers, least preferred by insurance companies, and has the lowest associated net cost. A marginal increase in the A&O subsidy rate yields the highest benefit for insurance companies but has the highest taxpayer cost, provides no benefits to farmers, and has the highest net social cost.

We also investigate the impacts of changing crop prices on equilibrium outcomes. Holding agent compensation rates constant, a marginal increase in crop prices increases agents' effort. If the market for agents' services is competitive, then a change in crop prices does not change agent compensation rates. Instead, if insurance companies collude, then agent compensation rates are likely to decrease as crop prices increase. This result suggests an empirical test regarding insurance company market performance.

The U.S. Crop Insurance Program

The U.S. federal crop insurance program was established in 1938 and is overseen by the Federal Crop Insurance Corporation (FCIC). Until 1980, Congress for the most part required the FCIC to establish and charge farmers actuarially fair premium rates that would cover expected indemnities, while the federal government covered the A&O expenses of the program (Gardner and Kramer, 1986; Kramer, 1983). Prior to 1983, the FCIC relied on independent agents to sell federal yield insurance products and hired independent crop loss adjusters to assess losses (Goodwin and Smith, 1995; Kramer, 1983).

The 1980 Crop Insurance Act mandated a major change in the delivery system, requiring the FCIC to allow private insurance companies to sell and service federally developed and subsidized crop insurance products. The 1980 Act also explicitly introduced subsidies that lowered farmer-paid premium rates below actuarially fair levels. In addition, insurance companies received a direct

[5] Our analysis is also related to the literature examining revenue-sharing contracts (Dana and Spier, 2001). In our model, insurance companies choose agent compensation rates where these rates determine the amount of revenue shared with insurance agents. The type of competition between insurance companies influences the agent compensation rates chosen. In this paper we only consider linear agent compensation rates as nonlinear pricing is not allowed under the current SRA. We leave the evaluation of nonlinear agent compensation and nonlinear subsides for future consideration.

subsidy to cover their A&O costs and were able to keep a substantial proportion of any underwriting gains associated with policies for which they retained some risk of loss. Through stop loss provisions (Ker, 2001) and the creation of insurance pools into which companies were able to dispose of policies they perceived to involve atypically high risks of loss, the federal government also accepted responsibility for a disproportionate share of expected indemnity payments.

The disproportionate allocation of risk between the companies and the government is related to two crucial elements of the program. First, companies operating in any given state are required to accept all insurance policies purchased by farmers and offered to them by independent insurance agents, regardless of the potential risk of loss. Second, premium rates are established by the government, largely on the basis of the average per acre expected insurable loss ratio in the county in which the farm purchasing the insurance is located, and companies are prohibited from making any adjustments to those premium rates.

Since 1983, the relationship between the government and the companies and agents selling and servicing federally subsidized crop insurance contracts has been codified in a series of SRAs. The SRA is periodically modified through negotiations between the private companies and the FCIC, and is altered by Congressional legislation. The specific terms of the SRA and the levels of premium rate and A&O subsidies have changed over time as a result of the 1994 Crop Insurance Reform Act, the 2000 Agricultural Risk Protection Act, and various farm bills (for example, the 2008 farm bill reduced A&O subsidy rates). However, the basic structure of the program (A&O subsidies, premium rate subsidies, a mandated catastrophic loading factor, and risk sharing between the companies and the federal government) has not been altered substantively by legislation since 1994.[6]

While the FCIC oversees the U.S. federal crop insurance program, the RMA manages the program. The RMA is responsible for developing and maintaining all federally subsidized insurance products, including all premium rates. Crop insurance companies and insurance agents are not allowed to adjust those premium rates for any individual farmer. If they do so, they face severe penalties and can be banned from selling and servicing federal crop insurance products in the future. Under the provisions of the 1994 Crop Insurance Reform Act, the RMA is required to estimate the actuarially fair premium rate for each policy (on a county-by-county basis).[7] As discussed above, the RMA increases the premium rate by a legislatively mandated catastrophic risk loading factor of 13.64%. The rationale for the loading factor is that extreme adverse events may not be included in the historical data typically used to estimate the actuarially fair premium rates for each county.[8]

Farmers are required to pay only a portion of the total premium for their insurance coverage. The government subsidizes a substantial proportion of that total premium, paying its share directly into the insurance pool from which any indemnities for losses will be paid. The government's share of the total premium depends on the amount of coverage purchased by the farmer. As a result of the 2000 Agricultural Risk Protection Act, which substantially increased such subsidies, the government's share in recent years has averaged 62% (Glauber, 2013).

The government also pays a separate direct A&O subsidy to the insurance companies. The A&O subsidy is defined as a proportion of the total premium paid into the insurance pool by both the farmer and the government. That subsidy is currently 18% and is substantially lower than before 2008, when the A&O subsidy rate was reduced under the provisions of the 2008 farm bill. In the 2010 SRA negotiations, the companies claimed that the reduction in the A&O subsidy would create severe financial difficulties for them and were successful in negotiating a cap on insurance agent compensation rates. The agent-compensation rate cap is equal to approximately 15% of total

[6] For example, the 2014 farm bill introduced a new area (county) revenue- and yield-based product called the supplementary coverage option and mandated the development of some new products (for example, a margin insurance program for rice). However, this bill did not change the underlying structure of the major subsidy related components of the federal crop insurance program.

[7] In Appendix B we discuss how some of the methods used by the RMA to estimate premium rates may overestimate the actuarially fair rate.

[8] For most crops, the USDA National Agricultural Statistical Service only has data on county yields beginning in or after 1948.

premiums, limiting an insurance company's costs, and is enforced by the RMA, with severe penalties for companies who attempt to exceed it.

Typically, independent insurance agents market crop insurance policies to farmers in any given state and are then free to allocate them to any insurance company operating in that state. The companies therefore compete for those policies and, in effect, insurance agent services. Historically, in states in which underwriting gains are large, insurance companies have competed vigorously and offered relatively high payments (compensation rates) to insurance agents for their services and policies (Smith, Glauber, and Dismukes, 2012).

Model

We present a model of agricultural insurance with four types of economic agents: the federal government, farmers, insurance agents, and insurance companies. The government determines the premium rate and reduces the farmer-paid share of that premium rate through additional subsidies. The government also provides direct subsidies to insurance companies, offsetting their A&O costs, and may establish the maximum compensation rate that insurance companies can use to pay insurance agents for their services. Farmers buy insurance through insurance agents. Insurance agents exert effort to sell policies to farmers and then choose the insurance company through which each policy is issued. Insurance companies set the wage/compensation rate for insurance agents. Companies and agents are assumed to maximize profits. The government's policy actions are assumed to be exogenous to the model, but the costs of these actions are endogenously determined.

Two different types of symmetric equilibria are examined through a sequential game of complete information. In the game, crop insurance companies simultaneously determine their compensation rates for insurance agents. Subsequently, insurance agents choose their effort levels in response to the compensation rates they are offered. The model also accounts for endogenous entry and exit of insurance agents, where agents enter and exit until agent profits are zero. With this framework it is possible to determine the equilibrium number of insurance agents, but we leave this for future work.

Each symmetric equilibrium in the model is characterized by an equilibrium level of effort that all insurance agents exert in relation to their clients and an equilibrium compensation rate that is offered by all insurance companies. In the competitive equilibrium, each insurance company sets its compensation rate so that all insurance companies make zero economic profit. In the collusive equilibrium, insurance companies coordinate their actions to obtain a monopsony solution in relation to compensation rates for insurance agents.

Government

Farmers pay a premium rate, p, for each unit (dollar) of insurance coverage they purchase. Two distinct government policies affect that premium rate, causing it to differ from the actuarially fair premium rate, f, which generates premium payments that would equal expected losses/expected indemnity payments.[9] Under the terms of the 1994 Crop Insurance Reform Act, the USDA RMA is first required to identify the actuarially fair premium rate for a policy using all available data. The RMA is then required to add a loading factor to account for the possibility that the historical data used to calculate the actuarially fair premium rate do not include sufficient extreme events that cause losses to be exceptionally high. In practice, RMA accomplishes this goal by dividing every estimated actuarially fair rate by a proportion, $1-\alpha$, that is less than 1, legislatively defined as 0.88.

Thus, if this were the only adjustment to the farmer-paid premium rate, then farmers would pay g, where $g = f/(1-\alpha)$ and $\alpha \in (0,1)$. However, the legislation (as currently defined by the 2000 Agricultural Risk Protection Act) also requires the federal government to pay a share, s, of the estimated total premium, g. Thus, the actual farmer-paid premium rate is therefore

[9] Since f is the actuarially fair premium rate for one dollar of insurance coverage, $f \in [0,1]$.

$p = (1-s)g = \frac{(1-s)}{(1-\alpha)} f$. The cost of this subsidy to the government is $sgQ = \frac{sf}{(1-\alpha)} Q$, where Q is the total expected crop revenue insured. The subsidy cost of sgQ is paid directly to the insurance pool established by the insurance companies. In addition, the government also pays an independent direct subsidy to the insurance companies totaling $s_d Q$, where s_d is the direct subsidy rate for administration and operations.

Throughout the paper, we make the following assumption.

ASSUMPTION 1. *The premium rate set by the government is g where $g < 1$, and the direct subsidy rate set by the government is s_d, where $s_d < f$.*

Assumption 1 ensures that the government does not charge more than one dollar for one dollar of insurance coverage ($g > 1$). Requiring $s_d < f$ ensures that the direct subsidy paid to insurance companies ($s_d Q$) does not exceed the basic cost of insurance provision (fQ).[10] In fact, since 1981—when private companies began to deliver subsidized crop insurance in the United States—the A&O subsidy rate has not exceeded 35% of the actuarially fair premium rate.

Farmers

Farmers demand agricultural insurance. They are potentially differentiated by many factors, including risk preferences, the probability of a loss occurring, and transaction costs associated with purchasing agricultural insurance. We abstract from potential heterogeneity among farmers by using general demand functions that do not identify the sources of such variation.

A farmer's demand for insurance is a function of the premium rate she pays for coverage, p, and the effort level of insurance agents. Each farmer observes the price at which she is offered insurance and the effort level of each agent. The farmer then chooses an insurance agent and how much insurance to purchase. Each farmer is assumed to purchase insurance from only one agent. Some farmers might not purchase agricultural insurance if the premium rate of agricultural insurance is too high compared to their probability of a loss or if their transaction costs are too large. Insurance agents are able to reduce these transaction costs by expending effort.

There are K farmers, where $k = 1, \ldots K$ indexes each farmer. The demand function for farmer k is $D_k(p, \mathbf{e}_k)$, where p is the premium per unit of insurance and $\mathbf{e}_k$ is a vector of effort levels expended by insurance agents on farmer k. A farmer's coverage level is D_k: the expected yield a farmer insures. The expected price for the insured crop is Θ, so that $q_k = \Theta D_k(p, \mathbf{e}_k)$ is the expected revenue from production that farmer k insures and pq_k is the amount that farmer k pays for insurance. The market demand for insurance is $Q = \sum_{k=1}^{K} q_k$, where Q is the total amount of insurance purchased by farmers. Throughout most of the paper we implicitly assume that the prices of agricultural crops do not change so that it does not matter if farmers insure revenue or quantity. In the Analysis Section, we consider the case in which prices of agricultural prices change over time causing a shift in the demand for insurance as measured by the dollar amount of coverage (liability). This sort of shift occurs because the farmer's insurance coverage is tied to the value of the crop. When crop prices increased substantially in real terms, as between 2002 and 2013, the result is an increase in the real dollar amount of insurance coverage.

Each farmer's demand function, D_k, depends on her characteristics and her preferences. Hence, D_k is unspecified, but we assume that the quantity demanded of insurance is nonincreasing in the premium rate. We also assume that the quantity demanded is nondecreasing in agents' effort at a decreasing rate, but only for the agent from who insurance is purchased. The implications of these assumptions are as follows.

ASSUMPTION 2. *If a farmer purchases insurance, she does so from only one agent. Her demand function $D_k(p, \mathbf{e}_k)$, is concave, differentiable twice in the premium rate and three times in effort*

[10] Note that fQ is the expected loss associated with insurance provision.

levels. If farmer k purchases insurance from agent a

$$\frac{\partial D_k}{\partial p} \leq 0 \qquad \frac{\partial D_k}{\partial e_{ak}} \geq 0 \qquad \frac{\partial^2 D_k}{\partial e_{ak}^2} \leq 0 \qquad \frac{\partial^2 D_k}{\partial e_{ak} \partial p} \geq 0 \qquad \frac{\partial D_k}{\partial e_{a'k}} = 0$$

where e_{ak} is the effort level agent a exerts for farmer k and $a' \neq a$.

We assume that $\frac{\partial^2 D_k}{\partial e_{ak} \partial p} \geq 0$ which implies that agent effort becomes relatively more effective as the premium rate paid by the farmer increases; that is, if the premium rate is high (low) relative to expected indemnities, then farmers choose a lower (higher) coverage rate and the marginal effect of an increase in agent effort will be relatively large (small). This assumption ensures that a tradeoff exists between premium rates and agent effort levels for insurance agents.[11] Note that we also assume $\frac{\partial D_k}{\partial e_{a'k}} = 0$, which implies that if farmer k purchases insurance from agent a, then other agents' efforts do not influence the farmer's purchase decision.

Insurance Agents

There are A insurance agents indexed by a. Each agent chooses her effort level for each farmer, e_{ak}, to maximize profits. Agent effort is required to sell insurance policies to farmers. Thus $e_{ak} \geq 0$ and $\mathbf{e}_a$ is a K-element vector indicating the effort level that agent a expends on each farmer. In addition to choosing effort levels for each farmer, agents also choose the insurance company through which each policy is sold. If an agent sells a policy through insurance company i, the agent receives a share, w_i, of the total premium associated with the policy.

Let q_a^i be the quantity of insurance issued by agent a through insurance company i, where $q_a^i = \sum_{k \in (a,i)} q_k$ and is a function of p and $\mathbf{e}$, the A by K matrix of insurance agents' effort levels.[12] An insurance agent's profit-maximization problem is

$$(1) \qquad \max_{\mathbf{e}_a \geq 0} \pi_a = \sum_{i=1}^{I} w_i g q_a^i - C_a(\mathbf{e}_a) - F_a$$

where $C_a(\mathbf{e}_a)$ is the joint variable cost of effort and F_a is agent a's fixed cost. An agent's total quantity of insurance is $q_a = \sum_{i=1}^{I} q_a^i$, the sum of all policies issued by that agent through all the companies.

In practice, the variable costs, C_a, and fixed costs, F_a, incurred by individual agents may differ amongst agents. Since the focus here is on symmetric equilibria, we leave any potential agent heterogeneity unspecified and make the following assumptions.

ASSUMPTION 3. *$C_a(\mathbf{e}_a)$ is a three times differentiable, increasing, convex, and symmetric function where* $\left.\frac{\partial C_a(\mathbf{e}_a)}{\partial e_{ak}}\right|_{e_{ak}=0} = 0$.

The assumption that $\left.\frac{\partial C_a(\mathbf{e}_a)}{\partial e_{ak}}\right|_{e_{ak}=0} = 0$ indicates that if agent a exerts no effort for farmer k ($e_{ak} = 0$), then the marginal cost associated with an increase in effort for farmer k is zero. The symmetry of C_a implies that the elements of $\mathbf{e}_a$ can be rearranged without changing the value of C_a.

[11] See equations (A2) and (A3) in Appendix A. By assuming $\frac{\partial^2 D_k}{\partial e_{ak} \partial p} \geq 0$, this ensures agents increase their effort when a policy change increases the premium rate.

[12] In equilibrium there is a set of ordered pairs (k,a,i) where each element of the set indicates that farmer k bought insurance from agent a issued through insurance company i. $k \in i$ is the set of farmers whose insurance is issued through company i and $k \in a$ is the set of farmers who bought insurance from agent a. $k \in (a,i)$ is the set of farmers who bought insurance from agent a issued through company i.

Insurance Companies

There are I insurance companies indexed by i. Each insurance company offers a compensation rate, w_i, to insurance agents to maximize the company's expected profits. The compensation rate is the share of total premiums from any policies given to an agent, where $w_i \in [0, \bar{w}]$ as the government may cap the agent's share at $\bar{w} < 1$. Let q^i be the quantity insured through insurance company i, where $q^i = \sum_{a=1}^{A} q_a^i$ as the insurance company's quantity of insurance is the sum of all the policies issued through that company by each agent. Hence q^i is a function of p, the premium rate per unit of insurance, and **e**, a matrix of insurance agents' effort levels. Total market wide purchases of crop insurance equal the sum of all insurance companies' quantities, $Q = \sum_{i=1}^{I} q^i$.

Company i collects premium payments of pq^i from farmers and receives premium and A&O subsidy payments of $(sg + s_d)q^i$ from the government. Insurance company i pays its insurance agents $w_i g q^i$, and has an expected loss of $\sum_{k \in i} c_k q_k$.[13] The expected loss from farmer k is the probability of a loss, c_k, multiplied by the amount of insurance purchased, and may vary across farmers. The profit-maximization problem for insurance company i is

$$\max_{w_i \in [0, \bar{w}]} \pi_i = \left(\frac{(1 - w_i)}{(1 - \alpha)} f + s_d \right) q^i - \sum_{k \in i} c_k q_k. \tag{2}$$

In equation (2), f is the actuarial fair premium rate for the market wide portfolio of insurance contracts and, by definition, equals the expected loss among firms where

$$fQ - \sum_{k=1}^{K} c_k q_k = 0. \tag{3}$$

If the actuarially fair premium rate f is the premium rate to be subsidized, then insurance revenues from farmer-paid premiums and the government premium subsidy will equal expected losses. Instead, the full premium rate is $g = \frac{f}{(1-\alpha)}$ and the expected loss ratio is the ratio of expected losses to total insurance premiums, $\frac{\sum_{k=1}^{K} c_k q_k}{gQ} = 1 - \alpha$. Since $\alpha \in (0,1)$, the expected loss ratio is between 1 and 0, and is decreasing in α.

Government Policy

Throughout the paper, there are three different types of government policies we consider: the premium subsidy rate (s), the direct A&O subsidy rate (s_d), and the loading factor (α). In general, the government chooses these policy parameters to balance two different policy objectives: adequate participation in the crop insurance program and minimizing the taxpayer/net social costs of the program (Goodwin and Smith, 1995; Gardner and Kramer, 1986). The following corollary considers marginal changes in s, α, and s_d on the premium rate farmers pay for insurance (p).

COROLLARY 1. *1(a). An increase in the subsidy rate, s, decreases the premium rate farmers pay for insurance* ($\frac{\partial p}{\partial s} < 0$). *1(b). An increase in the adjustment to the actuarial fair premium rate (an increase in* α*) increases the premium rate farmers pay for insurance* ($\frac{\partial p}{\partial \alpha} > 0$). *1(c). An increase in the administration and operations subsidy rate* (s_d) *does not change the premium rate farmers pay for insurance* ($\frac{\partial p}{\partial s_d} = 0$).

Note that Corollary 1 just considers changes in the premium rate paid by farmers. Any changes in s, α, or s_d have other effects on the equilibrium of the model. For instance, a marginal change in α also affects agent effort levels and agent compensation rates. This in turn affects overall demand for insurance and the cost and benefits for each type of agent. The Symmetric Equilibrium Section

[13] We assume that insurance companies have no fixed costs to ensure the existence of a competitive equilibrium.

examines the equilibrium effects associated with changes in effort, and the Competitive Symmetric Equilibrium and Collusive Monopsony Symmetric Equilibrium Sections examine the equilibrium effects associated with changes in the agent compensation rate.

Symmetric Equilibrium

We focus on two different symmetric equilibria using the model outlined in the Model Section. A sequential game of complete information is considered in which all insurance companies simultaneously determine their compensation rates for insurance agents and then all insurance agents simultaneously determine their effort levels. Insurance agents compete with one another in the quantity of effort and insurance companies compete with each other in agent compensation rate levels.

The first equilibrium is a competitive equilibrium for insurance companies characterized by each insurance company increasing its compensation rate until it achieves zero economic profit. The second equilibrium allows insurance companies to collude to achieve a monopsony solution. The two equilibria are differentiated only by the type of competition occurring among insurance companies. Competition among insurance agents remains the same in each case. While both of these scenarios are abstractions, they serve as useful benchmarks regarding how the nature of competition in the agricultural insurance market and government policies affect equilibrium outcomes.

Backwards induction of the sequential game starts with the insurance agent's problem. The best response of an insurance agent is a function of the equilibrium compensation rate set by the insurance companies. Since competition between insurance agents remains the same for the different equilibria we consider, the best response of an insurance agent to any given compensation rate is the same for the insurance company competitive and collusive monopsony equilibria. The Insurance Agent Effort Subsection focuses on the equilibrium effort level from an insurance agent's best response function. Endogenous entry, where agents enter and exit the market until each agent earns zero economic profit, is allowed.

To obtain a symmetric equilibrium and avoid issues associated with the assignment of heterogenous farmers to heterogeneous insurance agents, we eliminate heterogeneity among farmers and insurance agents using the following assumptions.

ASSUMPTION 4. *4(a). The probability of a loss is the same for all farmers ($c_k = c$ for all k) and all farmers have the same demand function for insurance. 4(b). For any pair of values for p and $\mathbf{e}_k$, $D_k(p, \mathbf{e}_k) = D(p, \mathbf{e}_k)$ for all k. 4(c). The fixed cost for all insurance agents is the same ($F_a = F_A$ for all a) and the joint variable cost function is the same for all agents. For a particular $\mathbf{e}_a$, $C_a(\mathbf{e}_a) = C_A(\mathbf{e}_a)$ for all a.*

In a symmetric equilibrium, all insurance companies set the same compensation rate and all insurance agents exert the same amount of effort for their clients. The symmetric equilibria we find serve as a useful benchmarks for the analysis.

One immediate result of Assumption 4 and equation (3) is that the actuarially fair premium rate is equal to the probability of a loss. This standard result in the insurance literature is expressed by the following lemma.

LEMMA 1. *$f = c$ and $0 \leq f \leq 1$, since c is a probability.*

The proof of this lemma and most of the propositions that follow are included in Appendix A.

Insurance Agent Effort

Backwards induction in the sequential game starts with the insurance agent's profit-maximization problem as expressed in equation (1). Incorporating Assumption 4 and Lemma 1 into equation (1), the representative insurance agent's problem is

$$\max_{\mathbf{e}_a \geq 0} \pi_a = \sum_{i=1}^{I} \frac{w_i f}{(1-\alpha)} q_a^i - C_A(\mathbf{e}_a) - F_A. \tag{4}$$

The insurance agent's problem is used to determine the symmetric equilibrium effort level described in the following proposition.

PROPOSITION 1. *In a symmetric equilibrium, an insurance agent's effort is $e_{ak} = 0$ if $I_{k\in a} = 0$ and $e_{ak} = e^*$ if $I_{k\in a} = 1$, where e^* is implicitly determined from*

$$\frac{f w_i \Theta}{(1-\alpha)} \frac{\partial D}{\partial e^*} = \frac{\partial C_A}{\partial e^*}. \tag{5}$$

In Proposition 1, $I_{k\in a}$ is an indicator function indicating when farmer k buys insurance through agent a. In a symmetric equilibrium, if farmer k buys insurance through agent a, then agent a expends an effort level of e^* for farmer k. If farmer k does not purchase insurance through agent a, then agent a exerts no effort towards farmer k. The equilibrium effort level, e^*, is determined from the first-order condition of the insurance agent's problem, as defined in equation (4).[14] The equilibrium level of effort expended on the farmer who is a client of an agent, e^*, is a function of w_i, f, Θ, α, and s.

In equation (5), D is a function of $p = \frac{(1-s)}{(1-\alpha)} f$ and e^*, as implied by Assumption 4. In any symmetric equilibrium however, $\mathbf{e}_k$ is a vector of all zeros except for one element that takes on the value e^*. Thus in what follows, we express $D(p, \mathbf{e}_k)$ simply as $D(p, e^*)$.

Comparative static effects of w_i, s, α, and s_d in e^* are summarized by the following proposition.

PROPOSITION 2. *In a symmetric equilibrium,*

$$\frac{\partial e^*}{\partial w_i} \geq 0 \qquad \frac{\partial e^*}{\partial s} \leq 0 \qquad \frac{\partial e^*}{\partial \alpha} \geq 0 \qquad \frac{\partial e^*}{\partial s_d} = 0.$$

Proposition 2 indicates that insurance agents increase their equilibrium effort for their clients if their share of total premiums increases. The other comparative statics concern the policy variables set by the government: s, α, and s_d. Here we only consider the initial or direct effect of these variables on the equilibrium level of effort, which is determined by holding the agent compensation rate, w, constant. In the Competitive Symmetric Equilibrium and the Collusive Monopsony Symmetric Equilibrium Sections, we determine the total effect which includes the direct effect and any indirect effects through changes in the agent compensation rate.

In this context, an increase in the subsidy rate, s, decreases the premium rate farmers pay, p, and farmers buy more insurance. The increase in insurance sales increases insurance agent profits. Insurance agents respond by reducing their effort level, which lowers their cost of effort and further increases agent profits (recall that for Assumption 2, $\frac{\partial^2 D_k}{\partial e_{ak} \partial p} \geq 0$). An increase in the rate adjustment parameter, α, increases average premium revenue, an effect that benefits insurance agents but also decreases the quantity demanded of insurance, an effect that adversely affects insurance agents. Insurance agents respond by increasing their effort levels. The administration and operations subsidy rate, s_d, has no direct effect on agent effort.

Competitive Symmetric Equilibrium

The competitive symmetric equilibrium for insurance companies is characterized by insurance companies competing with one another by adjusting agent compensation rates until insurance

[14] We use superscript $*$ to denote any symmetric equilibrium. Superscript c refers to a competitive equilibrium determined in the Competitive Symmetric Equilibrium, and superscript m refers to a collusive monopsony equilibrium determined in the Collusive Monopsony Symmetric Equilibrium Section.

companies receive zero expected economic profit. The expected profit of each insurance company will be zero because otherwise each insurance company will increase its compensation rate to capture all of the market. The representative insurance company's problem is described by equation (2). Simplifying equation (2) using Assumption 4, Lemma 1, and the condition $q^i = \sum_{k \in i} \Theta D_k$, the insurance company's problem becomes

$$\max_{w_i \in [0,\bar{w}]} \pi_i = \left(\frac{(\alpha - w_i)}{(1-\alpha)} f + s_d \right) q^i \tag{6}$$

where we assume that $\frac{(\alpha - w_i)}{(1-\alpha)} f + s_d \geq 0$ so that insurance company expected profits are nonnegative. Note that q^i is a function of p, e, and K.

A change in w_i has two separate effects on an insurance company's profits. An increase in w_i decreases the return on every unit of insurance, as a larger share of the company's revenues is paid to insurance agents. However, an increase in w_i also increases each agent's effort level and the quantity of insurance purchased by each farmer.

Insurance companies choose compensation rates prior to insurance agents making their choices about the company to which they will allocate policies. Hence, the equilibrium compensation rate will be the same across insurance companies, $w_i = w^c$ for all i. This result occurs due to the perfectly elastic residual supply curve of agent services faced by each insurance company. If any one insurance company offers a compensation rate slightly above the other companies' rates, then all agents will supply their services to that company. Given that insurance companies earn zero expected profits, the competitive equilibrium compensation rate is

$$w^c = \alpha + \frac{(1-\alpha)s_d}{f}. \tag{7}$$

In a symmetric equilibrium, each insurance company obtains the same market share, $\frac{1}{I}$, and issues the same amount of insurance coverage, $\frac{K\Theta D}{I}$.

The competitive equilibrium compensation rate is increasing in α and s_d. Increases in α and s_d increase the revenue per unit of insurance that each insurance company receives without initially increasing its costs. Insurance companies now earn positive economic profits, which are passed on to insurance agents. Note that $\frac{\partial w^c}{\partial \alpha} = 1 - \frac{s_d}{f}$; thus, $\frac{\partial w^c}{\partial \alpha} > 0$ from Assumption 1.

An increase in f decreases the equilibrium compensation rate as an increase in f increases the cost of providing insurance. Note that the subsidy rate, s, does not effect the equilibrium compensation rate. Holding the amount of insurance purchased by farmers constant, a change in s does not affect the amount of revenue an insurance company receives, only the source of that revenue. An increase in s implies that more insurance company revenue comes from the government rather than from farmers.

In a competitive market, insurance companies are likely to support a ceiling, $\bar{w}$, for agent compensation rates. If insurance agent compensation is limited through a binding maximum compensation rate, then insurance companies would be able to make positive profits. Another consequence of a binding maximum compensation rate would be to lower agent effort levels, affecting the market quantity of insurance.[15] Absent a binding compensation rate ceiling, competition among insurance companies drives w up until their profits are zero.

The exogenous policy variables in the model are s, α, and s_d. Proposition 2 above describes how changes in the policy variables affect the equilibrium level of effort, e^c. From equation (7), changes in these variables affect the competitive equilibrium compensation rate. Changes in s, α, and s_d have implications for the level of agent effort. The total change in agent effort is a result of the direct effect on effort, as indicated in Proposition 2, and also the indirect effect through the compensation

[15] Inderst and Ottaviani (2012c) make a similar point in their study, in which they evaluate the effect of capping an intermediary's commission as a policy to promote consumer protection.

rate. For example, it is straightforward to show that an increase in the subsidy rate has a nonpositive effect: that is, $\frac{de^c}{ds} = \frac{\partial e^c}{\partial s} + \frac{\partial e^c}{\partial w^c}\frac{\partial w^c}{\partial s} \leq 0$. This result follows because $\frac{\partial e^c}{\partial s} \leq 0$ from Proposition 2 and, from equation (7), $\frac{\partial w^c}{\partial s} = 0$.

The effects of the exogenous policy variables on the competitive equilibrium compensation rate and effort level are summarized by the following proposition.

PROPOSITION 3. *3(a). An increase in the subsidy rate, s, has no effect on the compensation rate but decreases the effort level of agents (*$\frac{\partial w^c}{\partial s} = 0$ *and* $\frac{de^c}{ds} \leq 0$*). 3(b). An increase in the rate adjustment parameter,* α*, increases both the compensation rate and effort level (*$\frac{\partial w^c}{\partial \alpha} \geq 0$ *and* $\frac{de^c}{d\alpha} \geq 0$*). 3(c). An increase in the A&O subsidy rate,* s_d*, increases the compensation rate and agent effort level (*$\frac{\partial w^c}{\partial s_d} > 0$ *and* $\frac{de^c}{ds_d} \geq 0$*).*

Collusive Monopsony Symmetric Equilibrium

Here, we consider a collusive equilibrium in which the insurance companies coordinate their actions to behave as a monopsonist. We assume that insurance companies split the monopsony profits equally. This symmetric collusive equilibrium provides a useful contrast to the symmetric competitive equilibrium. The representative insurance company's problem is again described by equation (6). However, in the monopsony equilibrium, the "company" supplies the entire market with insurance coverage. Thus the individual company's demand for policies, q^i, is replaced by the market demand to establish the monopsonist's profit-maximization problem. The monopsonist's problem is

$$\max_{w\in[0,\bar{w}]} \pi = \left(\frac{(\alpha - w)}{(1-\alpha)} f + s_d\right) Q \tag{8}$$

where market demand is $Q = K\Theta D(p,e)$. Again we assume that insurance company profits are nonnegative, $\frac{(\alpha-w)}{(1-\alpha)} f + s_d \geq 0$. The symmetric equilibrium agent compensation rate for the monopsony problem is characterized by the following proposition.

PROPOSITION 4. *If* $\frac{\partial^2 e}{\partial w^2} \leq 0$*, the monopsony symmetric equilibrium agent compensation rate,* w^m*, exists and is implicitly determined by the following equation.*

$$\left(\frac{(\alpha - w^m)}{(1-\alpha)} f + s_d\right) \Theta \left(\frac{\partial D}{\partial e^m}\right)^2 = \left(\frac{\partial^2 C_A}{\partial e^{m2}} - \frac{f w^m \Theta}{(1-\alpha)} \frac{\partial^2 D}{\partial e^{m2}}\right) D \tag{9}$$

Note that Proposition 4 depends on $\frac{\partial e^*}{\partial w_i}$ as defined in equation (A1) in Appendix A. The requirement that $\frac{\partial^2 e}{\partial w^2} \leq 0$ in Proposition 4 is sufficient but not necessary for a solution. We opt for this sufficiency condition as it simplifies the analysis and allows for a straightforward interpretation. In Proposition 2, an increase in the equilibrium compensation rate is shown to increase agent effort. The sufficient condition that $\frac{\partial^2 e}{\partial w^2} \leq 0$ implies that the effect of the compensation rate on effort is diminishing.

As in the competitive equilibrium, we are interested in how changes in the exogenous policy variables s, α, and s_d change the monopsony compensation rate and agents' effort levels. The effects of the exogenous policy variables on the monopsony equilibrium compensation rate are summarized in the following proposition.

PROPOSITION 5. *Assume that $\frac{\partial^2 e}{\partial w^2} \leq 0$. An increase in the A&O subsidy rate, s_d, increases the monopsony symmetric equilibrium compensation rate, where*

$$\frac{\partial w^m}{\partial s_d} = -\frac{\Theta\left(\frac{\partial D}{\partial e^m}\right)^2}{BT} \geq 0,$$

$$\textit{where } T \equiv -\frac{2\Theta}{B}\left(\frac{f}{1-\alpha}\right)\left(\frac{\partial D}{\partial e^m}\right)^2 + \frac{R\Theta^2}{B^2}\left(\frac{f}{1-\alpha}\right)\left(\frac{\partial D}{\partial e^m}\right)^2\left(3\frac{\partial^2 D}{\partial e^{m2}} - \frac{1}{B}\frac{\partial D}{\partial e^m}\frac{\partial B}{\partial e^m}\right) \leq 0,$$

$$B \equiv \frac{\partial^2 C_A}{\partial e^{m2}} - \frac{f w^m \Theta}{(1-\alpha)}\frac{\partial^2 D}{\partial e^{m2}} \geq 0, \qquad \textit{and} \qquad R \equiv \frac{(\alpha - w^m)}{(1-\alpha)} f + s_d \geq 0.$$

For sufficiently low compensation rates, $\frac{\partial w^m}{\partial s} \leq 0$ and $\frac{\partial w^m}{\partial \alpha} \geq 0$.

In Proposition 5 the sign of $\frac{\partial w^m}{\partial s_d}$ is determined over the entire space of exogenous policy variables (values of s, α, and s_d) conditional on $\frac{\partial^2 e}{\partial w^2} \leq 0$. The signs of $\frac{\partial w^m}{\partial s}$ and $\frac{\partial w^m}{\partial \alpha}$ potentially change over this space, but we show in the proof of Proposition 5 that for a sufficiently small compensation rate, say $w^m \approx 0$, then it must be that $\frac{\partial w^m}{\partial s} \leq 0$ and $\frac{\partial w^m}{\partial \alpha} \geq 0$.

Note that $0 \leq w^m \leq \alpha + \frac{(1-\alpha)s_d}{f}$, so that insurance company profits are nonnegative for any w^m in this range. If $w^m = \alpha + \frac{(1-\alpha)s_d}{f}$, then the collusive monopsony wage is the same as the competitive wage rate, w^c. As w^m decreases, the compensation rate for insurance agents falls and the returns for insurance companies increase. This argument suggests that insurance companies in competitive markets benefit from binding compensation rate ceilings.

Proposition 5 shows how the exogenous policy variables affect the monopsony compensation rate. We now examine the total effect of s, α, and s_d on agent effort levels in a monopsony setting. The total change in effort level includes both the direct effect and the indirect effect through changes in the compensation rate.

PROPOSITION 6. *Assume that $\frac{\partial^2 e}{\partial w^2} \leq 0$. An increase in the administration and operations subsidy rate, s_d, increases the monopsony symmetric equilibrium agent effort level, where*

$$\frac{de^m}{ds_d} = -\frac{\Theta^2}{BT}\frac{f}{(1-\alpha)}\left(\frac{\partial D}{\partial e^m}\right)^3 \geq 0.$$

For sufficiently low compensation rates, an increase in s lowers the effort level ($\frac{de^m}{ds} \leq 0$) and an increase in α increases the effort level ($\frac{de^m}{d\alpha} \geq 0$).

As with changes in the equilibrium compensation rate, it is possible that $\frac{de^m}{ds}$ and $\frac{de^m}{d\alpha}$ change signs as the compensation rate increases, but we cannot show that this is the case without highly restrictive assumptions about crop insurance demand and insurance agent costs.

We now combine the results of Propositions 5 and 6 to discuss the effects of changes in s and α. An increase in s lowers the premium rate that farmers pay for insurance and increases the quantity demanded of insurance. Since a lower premium rate has the same effect on the quantity demanded as a greater agent effort level, insurance companies respond to the increase in s by lowering the compensation rate ($\frac{\partial w^m}{\partial s} \leq 0$) which lowers an agent's effort level ($\frac{de^m}{ds} \leq 0$). The decrease in agent compensation rates allows insurance companies to increase their profits.

There is a similar story for an increase in α. An increase in α increases the premium rate farmers pay for insurance and decreases the quantity of insurance they demand. Insurance companies respond by increasing the compensation rate ($\frac{\partial w^m}{\partial \alpha} \geq 0$) to increase the effort level of agents ($\frac{\partial e^m}{\partial \alpha} \geq 0$).

Analysis

This section examines the impact of marginal policy changes and changes in crop prices. First, we evaluate marginal changes in policy conditional on no prior government policy. This analysis allows us to evaluate the marginal effects of an increase in s, α, or s_d separately and make direct comparisons between the competitive and collusive models. Next, we consider increases in demand for insurance due to changes in agricultural crop prices. This analysis is relevant as crop prices have increased over time and because as crop prices increase the amount of crop insurance farmers purchase also increases.

Marginal Policy Changes

The model includes three exogenous policy variables: s, α, and s_d. In the Competitive Symmetric Equilibrium and the Collusive Monopsony Symmetric Equilibrium Sections we described how marginal changes in these policy variables change the equilibrium agent compensation rate (w^*) and agent effort level (e^*). The focus there was on the direction of each change. Here the focus is on the magnitude of the changes. The relative magnitudes of these changes are equally as important since while a policy maker may find it useful to know that an increase in s_d will increase equilibrium agent effort, it is also useful to know by how much agent effort will increase.

In addition to changes in agent effort and compensation rate, we extend our analysis to consider changes in the market quantity of crop insurance and the associated changes in the costs/benefits due to a marginal change in policy. This analysis is relevant in a case where policy makers consider a change in policy to increase the quantity of insurance farmers buy but are also interested in the cost/benefit tradeoffs associated with that change. Our analysis also provides a framework to evaluate the choice of policy instruments. While it is important to understand the change in the market quantity of insurance and the change in costs/benefits due to a marginal change in s, α, or s_d, it is also important to be able to evaluate whether a policy goal is more easily achieved with a marginal change in s, α, or s_d.

We consider marginal changes in each policy variable for both the competitive and collusive monopsony symmetric equilibrium. In order to make direct comparisons across policy variables and equilibrium types, we determine the effect associated with a change in s, α, and s_d conditional on the baseline case of no government intervention. With no prior government intervention, $s = \alpha = s_d = 0$, and the equilibrium compensation rate and effort are zero. Additionally, the premium rate is $p = f$, and the symmetric equilibrium quantity of crop insurance is $Q = K\Theta D(f, 0)$.

Conditioning on no prior government intervention allows us to compare the magnitude of the different policy effects as a change in α and a change in s may have different effects conditional on the values of α, s, and s_d. One drawback to this analysis is that our results do not directly apply to the current state of the U.S. federal crop insurance program. Currently there is substantial government intervention in the crop insurance program, and any marginal changes in policy from the current state may be different from marginal policy changes conditional on no prior intervention. Nevertheless, the analysis serves as a useful benchmark for evaluating the impact of changes in s, α, and s_d.

The marginal effects of changes in s, s_d, and α on the competitive equilibrium compensation rate and effort level are as follows in this setting.

PROPOSITION 7. *Conditional on no prior government policy (NP), a marginal change in each of the policy variables has the following effects on the competitive equilibrium.*

$$\left.\frac{\partial w^c}{\partial s_d}\right|_{NP} \geq \left.\frac{\partial w^c}{\partial \alpha}\right|_{NP} > \left.\frac{\partial w^c}{\partial s}\right|_{NP} = 0$$

$$\left.\frac{de^c}{ds_d}\right|_{NP} \geq \left.\frac{de^c}{d\alpha}\right|_{NP} \geq \left.\frac{de^c}{ds}\right|_{NP} = 0$$

In a competitive market, a marginal increase in s_d increases company revenues on a dollar-for-dollar basis, resulting in the largest increase in w^c as companies compete for agents' policies. A marginal increase in α generates a smaller increase in company revenues and a subsequent smaller increase in w^c. A marginal increase in s has no effect on company revenues at the margin because the premium subsidy increase is associated with a corresponding and exactly offsetting decrease in the farmer-paid premium rate. The effects on agent effort flow from the impacts on premium rates and compensation rates.

The marginal effects for the collusive equilibrium are similar to the results from the competitive equilibrium. The largest difference is that the collusive marginal effects are conditional on $\frac{1-f}{f} \geq Z$, where Z depends on the functional form of agents' cost and farmers' demand.

PROPOSITION 8. *Let* $Z \equiv \frac{\frac{-\partial D}{\partial p}\frac{\partial^2 C_A}{\partial e^{m2}}}{\Theta\left(\frac{\partial D}{\partial e^m}\right)^2} \geq 0$. *Conditional on no prior government policy, a marginal change in any one of the policy variables has the following effects on the collusive monopsony symmetric equilibrium. If* $\frac{1-f}{f} \geq Z$, *then*

$$\left.\frac{\partial w^m}{\partial s_d}\right|_{NP} > \left.\frac{\partial w^m}{\partial \alpha}\right|_{NP} \geq \left.\frac{\partial w^m}{\partial s}\right|_{NP} = 0$$

$$\left.\frac{de^m}{ds_d}\right|_{NP} \geq \left.\frac{de^m}{d\alpha}\right|_{NP} \geq \left.\frac{de^m}{ds}\right|_{NP} = 0.$$

If the marginal cost of effort is constant, then $\frac{\partial^2 C_A}{\partial e^{m2}} \approx 0$ and $Z \approx 0$. In this case, $\frac{1-f}{f} \geq Z$ and the results of Proposition 8 are applicable. Instead, if the marginal cost of effort is sufficiently increasing, then $\frac{1-f}{f} < Z$ and the order of the marginal effects in Proposition 8 changes: $\partial\alpha$ has a larger impact than ∂s_d, which is larger than ∂s. A change in s does not change the compensation rate and effort level (as in the competitive case). In the monopsony setting, a marginal increase in s increases the quantity of insurance, as shown below, and the collusive response from insurance companies is to decrease the agent compensation rate. Conditional on no prior government policy, the agent compensation rate is zero and cannot be reduced further, so any change due to a marginal increase in s is zero.

Combining the results of Proposition 7 and 8 we have the following.

COROLLARY 2. *Conditional on no prior government policy, a marginal change in s does not change the equilibrium compensation rate or effort level. If* $\frac{1-f}{f} \geq Z$, *then a marginal change in* s_d *results in a greater increase in the equilibrium compensation rate and effort level than a marginal change in* α. *If* $\frac{1-f}{f} < Z$, *the ranking of the marginal effects for the competitive equilibrium differ from the collusive equilibrium. For the competitive equilibrium, a marginal change in* s_d *results in a greater increase, while a marginal change in* α *results in a greater increase in the equilibrium compensation rate and effort level for the collusive equilibrium.*

The symmetric market demand for insurance is $Q^* = K\Theta D(p, e^*)$. Hence, the effect on Q^* of a marginal increase in policy instrument x is $\frac{\partial Q^*}{\partial x} = K\Theta\left(\frac{\partial D}{\partial p}\frac{\partial p}{\partial x} + \frac{\partial D}{\partial e^*}\frac{de^*}{dx}\right)$ where $x = \{s, \alpha, s_d\}$. The following proposition compares the differences in these effects on the competitive equilibrium.

PROPOSITION 9. *Let* $Z \equiv \frac{\frac{-\partial D}{\partial p}\frac{\partial^2 c_A}{\partial e^{m2}}}{\Theta\left(\frac{\partial D}{\partial e^m}\right)^2} \geq 0$. *Conditional on no prior government policy,*

$$\text{if } \frac{1}{2} \geq Z, \qquad \text{then } \left.\frac{\partial Q^c}{\partial s_d}\right|_{NP} \geq \left.\frac{\partial Q^c}{\partial \alpha}\right|_{NP} \geq \left.\frac{\partial Q^c}{\partial s}\right|_{NP}$$

$$\text{if } \frac{1}{f} \geq Z \geq \frac{1}{2}, \qquad \text{then } \left.\frac{\partial Q^c}{\partial s_d}\right|_{NP} \geq \left.\frac{\partial Q^c}{\partial s}\right|_{NP} \geq \left.\frac{\partial Q^c}{\partial \alpha}\right|_{NP}$$

$$\text{if } Z \geq \frac{1}{f}, \qquad \text{then } \left.\frac{\partial Q^c}{\partial s}\right|_{NP} \geq \left.\frac{\partial Q^c}{\partial s_d}\right|_{NP} \geq \left.\frac{\partial Q^c}{\partial \alpha}\right|_{NP}.$$

A marginal increase in either s or s_d always leads to an increase in the market demand for insurance: $\left.\frac{\partial Q^c}{\partial s}\right|_{NP} \geq 0$ and $\left.\frac{\partial Q^c}{\partial s_d}\right|_{NP} \geq 0$. If $Z \geq 1$, then $\frac{\partial Q^c}{\partial \alpha} \leq 0$ and a marginal increase in α leads to a decrease in the quantity of insurance sold to farmers. An increase in α causes agents to increase their effort, but when $Z \geq 1$ the increase in effort is dominated by the increase in the premium rate, reducing the market demand of insurance. Note that $\frac{1}{f} \geq 1$ so that $Z \geq 1$ in the third case of Proposition 9, and it is possible for $Z \geq 1$ in the second case.

In the monopsony environment, the differences in the effects of changes in s, α, and s_d are described in Proposition 10, which yields results similar to those for the competitive equilibrium.

PROPOSITION 10. *Let* $Z \equiv \frac{\frac{-\partial D}{\partial p}\frac{\partial^2 c_A}{\partial e^{m2}}}{\Theta\left(\frac{\partial D}{\partial e^m}\right)^2} \geq 0$. *Conditional on no prior government policy,*

$$\text{if } \frac{1}{3} \geq Z, \qquad \text{then } \left.\frac{\partial Q^m}{\partial s_d}\right|_{NP} \geq \left.\frac{\partial Q^m}{\partial \alpha}\right|_{NP} \geq \left.\frac{\partial Q^m}{\partial s}\right|_{NP}$$

$$\text{if } \frac{1}{2f} \geq Z \geq \frac{1}{3}, \qquad \text{then } \left.\frac{\partial Q^m}{\partial s_d}\right|_{NP} \geq \left.\frac{\partial Q^m}{\partial s}\right|_{NP} \geq \left.\frac{\partial Q^m}{\partial \alpha}\right|_{NP}$$

$$\text{if } Z \geq \frac{1}{2f}, \qquad \text{then } \left.\frac{\partial Q^m}{\partial s}\right|_{NP} \geq \left.\frac{\partial Q^m}{\partial s_d}\right|_{NP} \geq \left.\frac{\partial Q^m}{\partial \alpha}\right|_{NP}.$$

As in the competitive equilibrium, a marginal increase in either s or s_d always leads to an increase in market demand for insurance: $\left.\frac{\partial Q^m}{\partial s}\right|_{NP} \geq 0$ and $\left.\frac{\partial Q^m}{\partial s_d}\right|_{NP} \geq 0$. Also as before, it is possible for a marginal increase in α to lower the market demand for insurance. In the collusive monopsony environment, if $Z \geq \frac{1}{2}$, then $\frac{\partial Q^m}{\partial \alpha} \leq 0$.

Compare Proposition 9 to Proposition 10. For small values of Z, note that a marginal increase in s_d will result in the largest increase in the market quantity. Connecting back to Corollary 2, for small values of Z, a marginal increase in s_d also generates the largest increase in equilibrium agent effort. For large values of Z, a marginal increase in α results in a reduction in the market quantity but also generates the largest increase in collusive equilibrium effort. Note that in Proposition 9 and Proposition 10 the ordering of the marginal effects are the same but the thresholds based on the value of Z differ. The threshold values for Z are lower in the collusive monopsony case.

We now make a direct comparison between the two symmetric equilibria.

COROLLARY 3. *Comparing the competitive to the collusive equilibrium, we find that*

$$\left.\frac{\partial Q^m}{\partial s}\right|_{NP} = \left.\frac{\partial Q^c}{\partial s}\right|_{NP} \qquad \left.\frac{\partial Q^m}{\partial \alpha}\right|_{NP} = \left(\frac{1}{2}\right)\left.\frac{\partial Q^c}{\partial \alpha}\right|_{NP} \qquad \left.\frac{\partial Q^m}{\partial s_d}\right|_{NP} = \left(\frac{1}{2}\right)\left.\frac{\partial Q^c}{\partial s_d}\right|_{NP}.$$

Note that a marginal change in s is the same regardless of the type of symmetric competition. This is because a marginal change in s does not change equilibrium effort levels and so the change in quantity due to a marginal change in s only occurs due to the change in the premium rate farmers pay, p. For a marginal change in either α or s_d, the marginal policy effects in the collusive monopsony are only half as large. In a competitive equilibrium, any gains for insurance companies due to a marginal change in policy are passed through to insurance agents. In a collusive equilibrium, this is not the case as insurance companies are able to suppress the agent compensation rate and retain some profits. In a competitive equilibrium, a marginal change in policy results in a larger change in the agent's compensation rate (due to the greater pass through) and thus a larger change in the agent's effort level and market quantity.

Now consider the net social costs associated with any policy change conditional on no prior policy intervention. Changes in s, α, or s_d may benefit or disadvantage farmers and insurance companies. Insurance companies only benefit in a noncompetitive market environment as competitive profits are always zero. Likewise, insurance agents do not benefit in economic surplus terms as their profits are zero under either of the two types of symmetric equilibrium we consider.

Farmers benefit from a policy change if the price of insurance is below the actuarially fair price. The total benefit to farmers (FB) is $FB = (f-p)Q$. A marginal change in policy variable x changes FB as follows: $\frac{\partial FB}{\partial x} = (f-p)\frac{\partial Q}{\partial x} - \frac{\partial p}{\partial x}Q$. Conditional on no prior policy intervention, $f = p$ and $\left.\frac{\partial FB}{\partial x}\right|_{NP} = -\frac{\partial p}{\partial x}Q$. The marginal changes in farmer benefits are

$$(10) \qquad \left.\frac{\partial FB}{\partial s}\right|_{NP} = fQ \qquad \left.\frac{\partial FB}{\partial \alpha}\right|_{NP} = -fQ \qquad \left.\frac{\partial FB}{\partial s_d}\right|_{NP} = 0.$$

In a collusive monopsony, insurance companies may also benefit from marginal changes in policy. The total marginal benefit for insurance companies is the marginal increase in industry profits, $\pi = \left(\left(\frac{\alpha - w^m}{1-\alpha}\right) f + s_d\right) Q$. Conditional on no prior policy intervention, the marginal changes in insurance company industry profits are

$$(11) \qquad \left.\frac{\partial \pi^m}{\partial s}\right|_{NP} = 0 \qquad \left.\frac{\partial \pi^m}{\partial \alpha}\right|_{NP} = \frac{fQ}{2}\left(1 - \frac{-\frac{\partial D}{\partial p}\frac{\partial^2 C_A}{\partial e^{m2}}}{\Theta\left(\frac{\partial D}{\partial e^m}\right)^2}\right) \qquad \left.\frac{\partial \pi^m}{\partial s_d}\right|_{NP} = \frac{Q}{2}.$$

Note that the largest benefit to farmers results from an increase in s. An increase in s_d does not benefit farmers at all, and an increase in α increases the costs to farmers of their insurance coverage. If the market is not competitive, then an increase in either s_d or α will create the largest benefit for insurance companies. A change in s does not affect insurance company profits because there is a corresponding offset in the premium rate paid by farmers.

Now consider the costs associated with a policy change. Here we focus only on the cost to the government.[16] The total cost to the government for any agricultural insurance policy is $TC = \frac{fs}{(1-\alpha)}Q + s_d Q$. As before, we examine a marginal change in policy conditional on no prior policy. The marginal increases in total costs are

$$\left.\frac{\partial TC}{\partial s}\right|_{NP} = fQ \qquad \left.\frac{\partial TC}{\partial \alpha}\right|_{NP} = 0 \qquad \left.\frac{\partial TC}{\partial s_d}\right|_{NP} = Q.$$

A marginal increase in s_d has the highest marginal cost for the government.

Comparing the total benefits to the total costs for marginal changes in government policy conditional on no prior government intervention, the following proposition summarizes our results. We define net costs, NC, as total costs minus total benefits. Total benefits equal the farmer benefits plus any insurance company benefits. Total costs are the total costs to the government.

[16] Changes in policy affect the number of agents and total effort level. While agents always make zero profits, they must incur a fixed cost to enter the market and incur higher costs to exert higher levels of effort. Our analysis abstracts from these costs.

PROPOSITION 11. *Let* $Z \equiv \frac{\frac{-\partial D}{\partial p}\frac{\partial^2 C_A}{\partial e^{m2}}}{\Theta\left(\frac{\partial D}{\partial e^m}\right)^2} \geq 0$. *For the competitive symmetric equilibrium*

$$0 = \left.\frac{\partial NC^c}{\partial s}\right|_{NP} \leq \left.\frac{\partial NC^c}{\partial \alpha}\right|_{NP} \leq \left.\frac{\partial NC^c}{\partial s_d}\right|_{NP},$$

and for the collusive monopsony equilibrium if $\frac{1-f}{f} \geq Z$, *then*

$$0 = \left.\frac{\partial NC^m}{\partial s}\right|_{NP} \leq \left.\frac{\partial NC^c}{\partial \alpha}\right|_{NP} \leq \left.\frac{\partial NC^c}{\partial s_d}\right|_{NP}.$$

When comparing competitive and monopsony equilibria

$$\left.\frac{\partial NC^m}{\partial s}\right|_{NP} = \left.\frac{\partial NC^c}{\partial s}\right|_{NP} = 0$$
$$\left.\frac{\partial NC^m}{\partial \alpha}\right|_{NP} = \left(\frac{1+Z}{2}\right)\left.\frac{\partial NC^c}{\partial \alpha}\right|_{NP}$$
$$\left.\frac{\partial NC^m}{\partial s_d}\right|_{NP} = \left(\frac{1}{2}\right)\left.\frac{\partial NC^c}{\partial s_d}\right|_{NP}.$$

In Proposition 11, the ordering of the collusive monopsony net costs is applicable when $\frac{1-f}{f} \geq Z$. As stated before, if the marginal cost of effort is constant, then $Z \approx 0$ and $\frac{1-f}{f} \geq Z$. If the marginal cost of effort is sufficiently increasing, then ∂s_d has the largest associated change in net cost with $\partial \alpha$ in the middle. Note that the comparison of the competitive and monopsony equilibrium is valid for all values of Z.

Conditional on no prior government policy, net costs are always lowest (zero) with a marginal increase in s, and the marginal change in net costs due to a change in s are the same for both types of equilibria. Similar to Corollary 3, the change in net costs due to a marginal change in s_d is only half as large in the collusive monopsony case. The results are slightly different for $\partial \alpha$ as the change in net costs is smaller in the monopsony case only when $Z \leq 1$. These changes are more favorable for the monopsony case as net costs decrease.

Finally, compare the costs/benefits of a marginal change in policy to the corresponding change in the market quantity of insurance, conditional on no prior government policy and a small value of Z. A marginal change in s results in no change in net costs, the largest increase in farmer benefits, and the smallest change in the equilibrium quantity of insurance. A marginal change in s_d results in the largest change in the equilibrium quantity of insurance but has no benefit to farmers, has the highest change in cost for the government and the overall highest net cost. These results suggest a relevant policy tradeoff between changes in the market equilibrium quantity of insurance and the costs/benefits of a marginal change in policy.

Changes in Crop Prices

Crop prices have increased over time, and as crop prices increase farmers purchase more crop insurance to insure their higher expected revenues. In our model, the total amount of crop insurance purchased is $Q = K\Theta D$, where K is the number of farmers, Θ is the expected price of the crop, and D is the expected yield from farming that is insured. As crop prices increase, the total amount of crop insurance purchased increases; equilibrium agent compensation rates and agent effort levels change as a result.

For a symmetric equilibrium, a marginal increase in Θ has the following effect on the effort level.

$$\frac{\partial e^*}{\partial \Theta} = \frac{f w^* \frac{\partial D}{\partial e^*}}{(1-\alpha)\left(\frac{\partial^2 C_A}{\partial e^{*2}} - \frac{f w^* \Theta}{(1-\alpha)} \frac{\partial^2 D}{\partial e^{*2}}\right)} \geq 0 \tag{12}$$

Equation (12) is determined by implicitly differentiating equation (5) and is only the partial effect of a change in Θ on e^*. A marginal change in Θ also changes the equilibrium agent compensation rate, and the total effect of a change in Θ on e^* is $\frac{de^*}{d\Theta} = \frac{\partial e^*}{\partial \Theta} + \frac{\partial e^*}{\partial w^*} \frac{\partial w^*}{\partial \Theta}$. Ignoring for the moment any changes in the compensation rate due to a change in Θ, $\frac{\partial e^*}{\partial \Theta}$ is nonnegative. As Θ increases each farmer spends more on crop insurance, increasing the effort level of agents.

The competitive agent compensation rate is defined in equation (7) and the collusive monopsony compensation rate is implicitly defined in equation (9). In a competitive equilibrium, a marginal change in Θ does not affect the equilibrium compensation rate: $\frac{\partial w^c}{\partial \Theta} = 0$. Insurance companies set the agent compensation rate as high as possible in a competitive equilibrium. Since the compensation rate is the agent's share of total premiums, an increase in Θ does not permit insurance companies to increase the compensation rate; if they did insurance company profits would be negative. An increase in Θ also does not allow competitive insurance companies to decrease the agent compensation rate. This is due to the perfectly elastic residual supply of insurance policies that each insurance company faces. While an increase in Θ does not change the competitive equilibrium compensation rate, agents expend more effort: $\frac{de^c}{d\Theta} \geq 0$.

The change in the collusive monopsony compensation rate due to a marginal change in Θ is more complex. An increase in Θ increases insurance company profits and insurance companies may respond by lowering the compensation rate. The following proposition describes this behavior.

PROPOSITION 12. *If* $w^m \geq \frac{\alpha}{2} + \frac{(1-\alpha)s_d}{2f}$ *and* $\frac{\partial^2 e^m}{\partial w^{m2}} \leq 0$, *then* $\frac{\partial w^m}{\partial \Theta} \leq 0$.

Note that when $w^m \leq \frac{\alpha}{2} + \frac{(1-\alpha)s_d}{2f}$, the sign of $\frac{\partial w^m}{\partial \Theta}$ cannot be determined without additional restrictions and may be either positive or negative. When $w^m \geq \frac{\alpha}{2} + \frac{(1-\alpha)s_d}{2f}$, then a marginal increase in Θ induces insurance companies to decrease the collusive monopsony compensation rate. For insurance company profits to be positive, it is assumed that $\alpha + \frac{(1-\alpha)s_d}{f} \geq w^m$. Combining this condition with the condition from Proposition 12, if $\alpha + \frac{(1-\alpha)s_d}{f} \geq w^m \geq \frac{\alpha}{2} + \frac{(1-\alpha)s_d}{2f}$, then a marginal increase in Θ results in a decrease in the monopsony compensation rate. In the collusive monopsony case, the sign of $\frac{de^m}{d\Theta}$ cannot be determined.

Conclusion

This study develops a model to examine the effects of changes to the U.S. federal crop insurance program on the structure of the agricultural insurance industry. This paper is one of the first to model the supply side of the industry and evaluate the interactions between policy variables and competition in these markets. The industry (and model) consists of insurance agents and crop insurance companies. Agents sell federally subsidized crop insurance policies to farmers, and the insurance companies then buy those policies from the agents by offering them compensation rates per dollar of liability. Symmetric equilibria are solved under two alternative assumptions about competition among insurance companies. In the first environment, insurance companies are competitive; in the second, they form a monopsonistic cartel to obtain insurance policies from independent insurance agents, who sell those policies to farmers. In both environments, agents are competitive suppliers of insurance policies to insurance companies, and agents are operating in a market where entry and exit are relatively easy.

In practice, the federal government subsidizes insurance contracts in two ways: by reducing the premium paid by farmers through a premium subsidy rate and by paying a further direct subsidy

Table 1. List of Variables and Optimization Problems

Variables	Definition
Indexes	
$k = 1 \ldots K$	Farmers
$a = 1 \ldots A$	Agents
$i = 1 \ldots I$	Companies
Policy Variables	
s	Premium subsidy rate, between 0 and 1
α	Loading factor, between 0 and 1
s_d	Direct subsidy rate, between 0 and f
Exogenous Variables	
Θ	Crop price
c_k	Probability of a loss from farmer k (c with symmetry), between 0 and 1
F_a	Fixed cost of agent a (F_A with symmetry)
$C_a(\cdot)$	Joint variable cost function of agent a ($C_A(\cdot)$ with symmetry)
Endogenous Variables	
w_i	Agent compensation rate from company i, between 0 and 1
A	Number of agents
e_{ak}	Agent a's effort level for farmer k
$\mathbf{e}_a$	Agent a's effort level for all farmers (K vector)
$\mathbf{e}_k$	Effort level farmer k receives from all agents (A vector)
Premium Rates	
f	Actuarially fair rate, between 0 and 1
$g = \frac{f}{(1-\alpha)}$	Rate set by the government, between 0 and 1
$p = \frac{(1-s)}{(1-\alpha)} f$	Rate farmers pay, between 0 and g
Insurance Demand	
$D_k(p, \mathbf{e}_k)$	Farmer k's coverage level/expected yield insured, ($D(\cdot)$ with symmetry)
$q_k = \Theta D_k(p, \mathbf{e}_k)$	Farmer k's amount (revenue) insured
$q_a^i = \sum_{k \in (a,i)} q_k$	Amount of insurance issued by agent a through company i
$q^i = \sum_{a=1}^{A} q_a^i$	Amount of insurance issued through company i
$Q = \sum_{k=1}^{K} q_k$	Market demand of insurance
Optimization Problems	
Insurance Agents	$\max_{\mathbf{e}_a \geq 0}\ \pi_a = \sum_{i=1}^{I} w_i g q_a^i - C_a(\mathbf{e}_a) - F_a$
Insurance Companies	$\max_{w_i \in [0,\bar{w}]}\ \pi_i = \left(\frac{(1-w_i)}{(1-\alpha)} f + s_d \right) q^i - \sum_{k \in i} c_k \Theta D_k$

to insurance companies to cover A&O costs. The premium rate subsidy is the proportion of the total premium paid by the government, and the insurance companies' direct subsidy is defined as a proportion of the total premium associated with the policies an insurance company acquires. However, the federal government also enters the market in a third way by determining the premium rate for each policy by estimating the actuarially fair premium rate and then inflating that rate by adding a catastrophic loading factor.

The model evaluates the effects of changes in these three core elements of the federal program. Some of the results are straightforward, but others are somewhat unexpected and provide useful insights about the rent-seeking behavior of private insurance companies and insurance agents. We find that marginal increases in the A&O subsidy rate, s_d, do not change the premium rates for farmers but increase agent compensation rates, agent effort levels, market quantity, insurance company profits, and subsidy payments by the government. Taking into consideration the competition among insurance companies, the direction of these changes is the same, but the magnitude of these effects depends on whether insurance companies collude or are perfectly competitive.

Increasing the premium subsidy rate, s, benefits farmers by reducing their out-of-pocket costs for crop insurance. The increase in the premium subsidy rate also has an added effect of reducing the returns to effort on the part of insurance agents, leading those agents to expend less effort per farmer (for sufficiently low compensation rates). On a per policy basis, increasing the premium subsidy rate has no effect on insurance company revenues, as the increase in the premium subsidy is exactly offset by the reduction in farmer-paid premiums, leaving the overall premium rate (g) unchanged. Government expenditures on subsidies, however, are increased both on a per policy basis and because the amount of insurance demanded by farmers increases.

A major finding concerns the effects of the inflation of premium rates by adjusting the catastrophic loading factor reflected by increases in the value of α in the model. An increase in α generates higher premium rates for farmers and higher levels of subsidy payments on a per policy basis by the government and higher revenues on a per policy basis for the insurance companies. The overall effect on quantity due to a marginal increase in α is ambiguous. A marginal increase in α increases the premium rate and—holding compensation rates constant—insurance agents respond to the rate increase with an increase in effort. The increase in effort increases the quantity of insurance purchased by farmers, but—depending on the parameterization of the model—the increase in effort may or may not offset the decrease in quantity due to the increase in the premium rate. For similar reasons, the overall effect of a marginal change in α on insurance company profits is ambiguous.

The costs and benefits of policy changes are evaluated using a convenient baseline of no prior government policy. Conditional on no prior government policy, farmers prefer a marginal increase in the premium subsidy rate. This change has the lowest associated net cost but is the insurance companies' least preferred policy. The insurance companies' most preferred policy is a marginal increase in the direct subsidy rate. A marginal increase in the direct subsidy rate has the highest associated net cost, the highest cost to the government, and does not benefit farmers.

Lastly, we investigate the impacts of changing crop prices on equilibrium outcomes. Holding compensation rates constant, we find that a marginal increase in crop prices increases agent effort. If the market for insurance companies is competitive, then a change in crop prices does not change the agent compensation rate. If, instead, insurance companies collude, then the agent compensation rate will change and is likely to decrease as crop prices increase. This result suggests an empirical test regarding insurance company market performance.

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Appendix A: Proofs

Proof of Lemma 1

Equation (3) is $fQ - \sum_{k=1}^{K} c_k \Theta D_k = 0$. Assumption 4 states that $c_k = c$ for all k, and equation (3) becomes $fQ = c\sum_{k=1}^{K} \Theta D_k$. The $\sum_{k=1}^{K} \Theta D_k = Q$, and equation (3) further reduces to $f = c$, which is the intended result.

Proof of Proposition 1

Note that a solution to equation (1) exists because the objective function is concave. Assumption 2 states that the demand function is concave and Assumption 3 states that the joint variable cost function is convex.

There are k first-order conditions of equation (1) and each first-order condition is

$$\frac{fw_i\Theta}{(1-\alpha)}\frac{\partial D(p,\mathbf{e}_k)}{\partial e_{ak}} - \frac{\partial C_A(\mathbf{e}_a)}{\partial e_{ak}} = 0.$$

If farmer k does not purchase insurance through agent a, then $\frac{\partial D(p,\mathbf{e}_k)}{\partial e_{ak}} = 0$ by Assumption 2. In this case the first-order condition reduces to $\frac{\partial C_A(\mathbf{e}_a)}{\partial e_{ak}} = 0$ and by Assumption 3 is only satisfied for effort levels of $e_{ak} = 0$. This establishes the result that $e_{ak} = 0$ if $I_{k\in a} = 0$.

If farmer k purchases insurance through agent a, then $\frac{\partial D(p,\mathbf{e}_k)}{\partial e_{ak}} > 0$ by Assumption 2 and $\frac{\partial C_A(\mathbf{e}_a)}{\partial e_{ak}} \geq 0$ by Assumption 3.[17] Now let $e^* > 0$ be a solution to one of the first-order conditions with $I_{k\in a} = 1$. The existence of e^* has already been established. Since demand is homogeneous and C_A is symmetric (Assumption 3), if e^* is a solution to one of the first-order conditions with $I_{k\in a} = 1$, then it is a solution for all the first-order conditions with $I_{k\in a} = 1$. This establishes e^* as the symmetric equilibrium effort level when $I_{k\in a} = 1$. Note that e^* is implicitly determined from the equation in Proposition 1 as this is the first-order condition of the insurance agent.

An alternative equilibrium one might consider is where each agent exerts the same amount of effort for all farmers regardless of whether or not a farmer buys a policy through them. This cannot be an equilibrium because effort is costly. An agent could reduce her effort level for farmers that do not purchase from her and be strictly better off.

Proof of Proposition 2

The four inequalities in Proposition 2 are shown by implicitly differentiating equation (5):

$$\frac{fw_i\Theta}{(1-\alpha)}\frac{\partial D}{\partial e^*} = \frac{\partial C_A}{\partial e^*}.$$

Note that D is a function of p and e^* where $p = \frac{(1-s)}{(1-\alpha)}f$, and C_A is a function of e^*.

Implicitly differentiating equation (5) with respect to e^* yields

$$\partial e^* \left(\frac{\partial^2 C_A}{\partial e^{*2}} - \frac{fw_i\Theta}{(1-\alpha)}\frac{\partial^2 D}{\partial e^{*2}}\right).$$

$\frac{\partial^2 C_A}{\partial e^{*2}} \geq 0$ by the convexity of C_A (Assumption 3) and $\frac{\partial^2 D}{\partial e^{*2}} \leq 0$ by Assumption 2. Let $B \equiv \frac{\partial^2 C_A}{\partial e^{*2}} - \frac{fw_i\Theta}{(1-\alpha)}\frac{\partial^2 D}{\partial e^{*2}}$ where $B \geq 0$.

[17] It is possible that $\frac{\partial D(p,\mathbf{e}_k)}{\partial e_{ak}} = 0$, but this condition results in a degenerate equilibrium where the effort level of all agents is zero. We ignore this trivial case.

Now implicitly differentiate equation (5) with respect to e^* and each of the exogenous variables to get the following.

(A1) $$\frac{\partial e^*}{\partial w_i} = \frac{1}{B}\frac{f\Theta}{(1-\alpha)}\frac{\partial D}{\partial e^*}$$

(A2) $$\frac{\partial e^*}{\partial s} = \frac{1}{B}\frac{fw_i\Theta}{(1-\alpha)}\frac{\partial^2 D}{\partial e \partial p}\frac{\partial p}{\partial s}$$

(A3) $$\frac{\partial e^*}{\partial \alpha} = \frac{1}{B}\left(\frac{fw_i\Theta}{(1-\alpha)^2}\frac{\partial D}{\partial e^*} + \frac{fw_i\Theta}{(1-\alpha)}\frac{\partial^2 D}{\partial e \partial p}\frac{\partial p}{\partial \alpha}\right)$$

(A4) $$\frac{\partial e^*}{\partial s_d} = 0$$

The denominator for each equation is the same and is greater than or equal to 0. Regarding the numerators, we know that $\frac{\partial D}{\partial e^*} > 0$ and $\frac{\partial^2 D}{\partial e \partial p} \geq 0$ from Assumption 2. Since $p = \frac{(1-s)}{(1-\alpha)}f$, $\frac{\partial p}{\partial s} = -\frac{f}{(1-\alpha)} < 0$ and $\frac{\partial p}{\partial \alpha} = \frac{(1-s)}{(1-\alpha)^2}f > 0$. Use the above information to sign each comparative static and what results are the inequalities listed in Proposition 2.

Proof of Poposition 3

The competitive symmetric equilibrium compensation rate is defined in equation (7). From this equation we know that

(A5) $$\frac{\partial w^c}{\partial s} = 0 \qquad \frac{\partial w^c}{\partial \alpha} = 1 - \frac{s_d}{f} \geq 0 \qquad \frac{\partial w^c}{\partial s_d} = \frac{1-\alpha}{f} \geq 0.$$

The total change in the equilibrium effort level due to a change in either s, α, or s_d is

(A6) $$\frac{de^c}{ds} = \frac{\partial e^c}{\partial s} \qquad \frac{de^c}{d\alpha} = \frac{\partial e^c}{\partial \alpha} + \frac{\partial e^c}{\partial w^c}\left(1 - \frac{s_d}{f}\right) \qquad \frac{de^c}{ds_d} = \frac{\partial e^c}{\partial w^c}\frac{(1-\alpha)}{f}$$

where the comparative statics of e^c are defined in equations (A1) through (A4) and signed in Proposition 2.

Proof of Proposition 4

The first-order condition from the monopsonist's problem (equation 8) is

$$-\frac{f}{(1-\alpha)}K\Theta D + \left(\frac{(\alpha - w)}{(1-\alpha)}f + s_d\right)K\Theta\frac{\partial D}{\partial e}\frac{\partial e}{\partial w}.$$

Setting the first-order condition equal to zero, replacing w with w^m, e with e^m, and substituting $\frac{\partial e^*}{\partial w_i}$ from equation (A1) results in equation (9).

The second-order condition of the monopsonist's problem is

$$-2\frac{f}{(1-\alpha)}K\Theta\frac{\partial D}{\partial e}\frac{\partial e}{\partial w} + \left(\frac{(\alpha - w)}{(1-\alpha)}f + s_d\right)K\Theta\left(\left(\frac{\partial e}{\partial w}\right)^2\frac{\partial^2 D}{\partial e^2} + \frac{\partial D}{\partial e}\frac{\partial^2 e}{\partial w^2}\right)$$

and we want to show that the second-order condition is less than or equal to 0 so that w^m is a maximum value of equation (8).

The signs of $\frac{\partial D}{\partial e}$ and $\frac{\partial^2 D}{\partial e^2}$ are nonnegative and nonpositive respectively, as assumed in Assumption 2. The sign of $\frac{\partial e}{\partial w}$ is nonnegative as shown in Proposition 2. $\frac{\partial^2 e}{\partial w^2}$ is the remaining component in the second-order condition to be signed. If $\frac{\partial^2 e}{\partial w^2} \leq 0$, then the second-order condition is less than or equal to 0.

Note that it is possible to determine $\frac{\partial^2 e}{\partial w^2}$ from equation (A1). This would allow us to determine a second order condition that is both necessary and sufficient. This condition would depend on the third derivative of the demand function and the agent cost function. We opt instead for the simpler requirement of $\frac{\partial^2 e}{\partial w^2} \leq 0$ which is just a sufficient condition.

Proof of Proposition 5

As before, let

(A7) $$B \equiv \frac{\partial^2 C_A}{\partial e^{m2}} - \frac{f w^m \Theta}{(1-\alpha)} \frac{\partial^2 D}{\partial e^{m2}}.$$

If follows that

(A8) $$\frac{\partial B}{\partial e^m} = \frac{\partial^3 C_A}{\partial e^{m3}} - \frac{f w^m \Theta}{(1-\alpha)} \frac{\partial^3 D}{\partial e^{m3}},$$

(A9) $$\frac{\partial B}{\partial p} = -\frac{f w^m \Theta}{(1-\alpha)} \frac{\partial^3 D}{\partial e^{m2} \partial p}, \quad \text{and}$$

(A10) $$\frac{dB}{dw^m} = \frac{\partial B}{\partial e^m} \frac{\partial e^m}{\partial w^m} - \frac{f\Theta}{(1-\alpha)} \frac{\partial^2 D}{\partial e^{m2}}.$$

$\frac{\partial e^m}{\partial w^m}$ is defined in equation (A1) and can be represented as $\frac{\partial e^m}{\partial w^m} = \frac{1}{B} \frac{f\Theta}{(1-\alpha)} \frac{\partial D}{\partial e^m}$ and we have that

$$\frac{\partial^2 e^m}{\partial w^{m2}} = \frac{1}{B^2} \left(\frac{f\Theta}{(1-\alpha)} \right)^2 \frac{\partial D}{\partial e^m} \left(2 \frac{\partial^2 D}{\partial e^{m2}} - \frac{1}{B} \frac{\partial D}{\partial e^m} \frac{\partial B}{\partial e^m} \right)$$

If $\frac{\partial^2 e}{\partial w^2} \leq 0$, then it must be that

(A11) $$2 \frac{\partial^2 D}{\partial e^{m2}} - \frac{1}{B} \frac{\partial D}{\partial e^m} \frac{\partial B}{\partial e^m} \leq 0$$

as $\frac{\partial D}{\partial e} \geq 0$ from Assumption 2 and $B \geq 0$ from Assumptions 2 and 3.

Now let

(A12) $$R \equiv \frac{(\alpha - w^m)}{(1-\alpha)} f + s_d$$

where $R \geq 0$ so that the profits of insurance companies are nonnegative. Equation (9) can be represented as $\frac{R\Theta}{B} \left(\frac{\partial D}{\partial e^m} \right)^2 - D = 0$. Implicit differentiation of the above equation yields the comparative statics of w^m with respect to a change in the exogenous policy variables. These are as follows.

$$\frac{\partial w^m}{\partial s} = -\frac{\frac{\Theta}{B}\frac{\partial R}{\partial s}\left(\frac{\partial D}{\partial e^m}\right)^2 + \frac{2R\Theta}{B}\frac{\partial D}{\partial e^m}\left(\frac{\partial^2 D}{\partial e^m \partial p}\frac{\partial p}{\partial s} + \frac{\partial^2 D}{\partial e^{m2}}\frac{\partial e^m}{\partial s}\right) - \frac{R\Theta}{B^2}\left(\frac{\partial D}{\partial e^m}\right)^2\frac{\partial B}{\partial s} - \frac{\partial D}{\partial p}\frac{\partial p}{\partial s} - \frac{\partial D}{\partial e^m}\frac{\partial e^m}{\partial s}}{\frac{\Theta}{B}\frac{\partial R}{\partial w^m}\left(\frac{\partial D}{\partial e^m}\right)^2 + \frac{2R\Theta}{B}\frac{\partial D}{\partial e^m}\frac{\partial^2 D}{\partial e^{m2}}\frac{\partial e^m}{\partial w^m} - \frac{R\Theta}{B^2}\left(\frac{\partial D}{\partial e^m}\right)^2\frac{dB}{dw^m} - \frac{\partial D}{\partial e^m}\frac{\partial e^m}{\partial w^m}}$$

$$\frac{\partial w^m}{\partial \alpha} = -\frac{\frac{\Theta}{B}\frac{\partial R}{\partial \alpha}\left(\frac{\partial D}{\partial e^m}\right)^2 + \frac{2R\Theta}{B}\frac{\partial D}{\partial e^m}\left(\frac{\partial^2 D}{\partial e^m \partial p}\frac{\partial p}{\partial \alpha} + \frac{\partial^2 D}{\partial e^{m2}}\frac{\partial e^m}{\partial \alpha}\right) - \frac{R\Theta}{B^2}\left(\frac{\partial D}{\partial e^m}\right)^2\frac{\partial B}{\partial \alpha} - \frac{\partial D}{\partial p}\frac{\partial p}{\partial \alpha} - \frac{\partial D}{\partial e^m}\frac{\partial e^m}{\partial \alpha}}{\frac{\Theta}{B}\frac{\partial R}{\partial w^m}\left(\frac{\partial D}{\partial e^m}\right)^2 + \frac{2R\Theta}{B}\frac{\partial D}{\partial e^m}\frac{\partial^2 D}{\partial e^{m2}}\frac{\partial e^m}{\partial w^m} - \frac{R\Theta}{B^2}\left(\frac{\partial D}{\partial e^m}\right)^2\frac{dB}{dw^m} - \frac{\partial D}{\partial e^m}\frac{\partial e^m}{\partial w^m}}$$

$$\frac{\partial w^m}{\partial s_d} = -\frac{\frac{\Theta}{B}\frac{\partial R}{\partial s_d}\left(\frac{\partial D}{\partial e^m}\right)^2 + \frac{2R\Theta}{B}\frac{\partial D}{\partial e^m}\left(\frac{\partial^2 D}{\partial e^m \partial p}\frac{\partial p}{\partial s_d} + \frac{\partial^2 D}{\partial e^{m2}}\frac{\partial e^m}{\partial s_d}\right) - \frac{R\Theta}{B^2}\left(\frac{\partial D}{\partial e^m}\right)^2\frac{\partial B}{\partial s_d} - \frac{\partial D}{\partial p}\frac{\partial p}{\partial s_d} - \frac{\partial D}{\partial e^m}\frac{\partial e^m}{\partial s_d}}{\frac{\Theta}{B}\frac{\partial R}{\partial w^m}\left(\frac{\partial D}{\partial e^m}\right)^2 + \frac{2R\Theta}{B}\frac{\partial D}{\partial e^m}\frac{\partial^2 D}{\partial e^{m2}}\frac{\partial e^m}{\partial w^m} - \frac{R\Theta}{B^2}\left(\frac{\partial D}{\partial e^m}\right)^2\frac{dB}{dw^m} - \frac{\partial D}{\partial e^m}\frac{\partial e^m}{\partial w^m}}$$

Now we specify the terms in the above comparative statics. R is defined in equation (A12) and

$$\frac{\partial R}{\partial s} = 0, \qquad \frac{\partial R}{\partial \alpha} = \frac{(1-w^m)}{(1-\alpha)^2}f, \qquad \frac{\partial R}{\partial s_d} = 1, \qquad \frac{\partial R}{\partial w} = -\frac{f}{(1-\alpha)}.$$

$p = \frac{(1-s)}{(1-\alpha)}f$ so that

$$\frac{\partial p}{\partial s} = -\frac{f}{(1-\alpha)}, \qquad \frac{\partial p}{\partial \alpha} = \left(\frac{f}{1-\alpha}\right)\left(\frac{1-s}{1-\alpha}\right), \qquad \frac{\partial p}{\partial s_d} = 0, \qquad \frac{\partial p}{\partial w} = 0.$$

$\frac{\partial e^*}{\partial w}$ is defined in equation (A1) and we already expressed this term as $\frac{\partial e^m}{\partial w^m} = \frac{1}{B}\left(\frac{f\Theta}{1-\alpha}\right)\frac{\partial D}{\partial e^m}$. $\frac{\partial e^m}{\partial s_d} = 0$ from equation (A4). From equations (A2) and (A3) we have

$$\frac{\partial e^m}{\partial s} = -\frac{w^m\Theta}{B}\left(\frac{f}{1-\alpha}\right)^2\frac{\partial^2 D}{\partial e^m \partial p} \quad \text{and} \quad \frac{\partial e^m}{\partial \alpha} = \frac{1}{B}\frac{f w^m \Theta}{(1-\alpha)^2}\left(\frac{\partial D}{\partial e^m} + \frac{(1-s)}{(1-\alpha)}f\frac{\partial^2 D}{\partial e^m \partial p}\right).$$

$\frac{dB}{dw^m}$ is defined in equation (A10) and equation (A8) defines $\frac{\partial B}{\partial e^m}$. The remaining terms are

$$\frac{\partial B}{\partial s} = \frac{\partial B}{\partial e^m}\frac{\partial e^m}{\partial s} + \frac{\partial B}{\partial p}\frac{\partial p}{\partial s}, \quad \frac{\partial B}{\partial \alpha} = \frac{\partial B}{\partial e^m}\frac{\partial e^m}{\partial \alpha} + \frac{\partial B}{\partial p}\frac{\partial p}{\partial \alpha} - \frac{f w^m \Theta}{(1-\alpha)^2}\frac{\partial^2 D}{\partial e^{m2}}, \quad \text{and} \quad \frac{\partial B}{\partial s_d} = 0$$

where $\frac{\partial B}{\partial p}$ is defined in equation (A9).

The denominators of $\frac{\partial w^m}{\partial s}$, $\frac{\partial w^m}{\partial \alpha}$, and $\frac{\partial w^m}{\partial s_d}$ are all the same. Denote the denominator by T where

$$T \equiv \frac{\Theta}{B}\frac{\partial R}{\partial w^m}\left(\frac{\partial D}{\partial e^m}\right)^2 + \frac{2R\Theta}{B}\frac{\partial D}{\partial e^m}\frac{\partial^2 D}{\partial e^{m2}}\frac{\partial e^m}{\partial w^m} - \frac{R\Theta}{B^2}\left(\frac{\partial D}{\partial e^m}\right)^2\frac{dB}{dw^m} - \frac{\partial D}{\partial e^m}\frac{\partial e^m}{\partial w^m}$$

$$T \equiv -\left[\frac{2\Theta}{B}\left(\frac{f}{1-\alpha}\right)\left(\frac{\partial D}{\partial e^m}\right)^2\right] + \left[\frac{R\Theta^2}{B^2}\left(\frac{f}{1-\alpha}\right)\left(\frac{\partial D}{\partial e^m}\right)^2\left(3\frac{\partial^2 D}{\partial e^{m2}} - \frac{1}{B}\frac{\partial D}{\partial e^m}\frac{\partial B}{\partial e^m}\right)\right].$$

$T \leq 0$ by Assumption 2 and equation (A11).

The numerator of $\frac{\partial w^m}{\partial s}$ is

$$U \equiv \frac{\Theta}{B}\frac{\partial R}{\partial s}\left(\frac{\partial D}{\partial e^m}\right)^2 + \frac{2R\Theta}{B}\frac{\partial D}{\partial e^m}\left(\frac{\partial^2 D}{\partial e^m \partial p}\frac{\partial p}{\partial s} + \frac{\partial^2 D}{\partial e^{m2}}\frac{\partial e^m}{\partial s}\right) - \frac{R\Theta}{B^2}\left(\frac{\partial D}{\partial e^m}\right)^2\frac{\partial B}{\partial s} - \frac{\partial D}{\partial p}\frac{\partial p}{\partial s} - \frac{\partial D}{\partial e^m}\frac{\partial e^m}{\partial s}$$

$$U \equiv \left[\frac{w^m R\Theta^2}{B^2}\left(\frac{f}{1-\alpha}\right)^2\frac{\partial^2 D}{\partial e^m \partial p}\left(\frac{1}{B}\left(\frac{\partial D}{\partial e^m}\right)^2\frac{\partial B}{\partial e^m} - 2\frac{\partial^2 D}{\partial e^{m2}}\right)\right] + \left[\left(\frac{f}{1-\alpha}\right)\frac{\partial D}{\partial p}\right]$$
$$+ \left[\frac{\Theta}{B}\left(\frac{f}{1-\alpha}\right)\frac{\partial D}{\partial e^m}\frac{\partial^2 D}{\partial e^m \partial p}\left(\frac{fw^m}{1-\alpha} - 2R\right)\right] - \left[\frac{w^m R\Theta^2}{B^2}\left(\frac{f}{1-\alpha}\right)^2\left(\frac{\partial D}{\partial e^m}\right)^2\frac{\partial^3 D}{\partial e^{m2}\partial p}\right]$$

and cannot be signed without additional assumptions. The first term in U is nonnegative by equation (A11), the second term in U is nonpositive by Assumption 2, the sign of the third term is determined by the sign of $\frac{fw^m}{1-\alpha} - 2R$ which may be positive or negative, and the sign of the fourth term is determined by the sign of $\frac{\partial^3 D}{\partial e^{m2}\partial p}$ which may be positive or negative. The comparative static $\frac{\partial w^m}{\partial s} = -\frac{U}{T}$ and since $T \leq 0$, $\frac{\partial w^m}{\partial s} \geq 0$ if and only if $U \geq 0$.

The numerator of $\frac{\partial w^m}{\partial \alpha}$ is

$$V \equiv \frac{\Theta}{B}\frac{\partial R}{\partial \alpha}\left(\frac{\partial D}{\partial e^m}\right)^2 + \frac{2R\Theta}{B}\frac{\partial D}{\partial e^m}\left(\frac{\partial^2 D}{\partial e^m \partial p}\frac{\partial p}{\partial \alpha} + \frac{\partial^2 D}{\partial e^{m2}}\frac{\partial e^m}{\partial \alpha}\right) - \frac{R\Theta}{B^2}\left(\frac{\partial D}{\partial e^m}\right)^2\frac{\partial B}{\partial \alpha} - \frac{\partial D}{\partial p}\frac{\partial p}{\partial \alpha} - \frac{\partial D}{\partial e^m}\frac{\partial e^m}{\partial \alpha}$$

$$V \equiv \left[\frac{w^m R\Theta^2}{B^2}\frac{f}{(1-\alpha)^2}\frac{\partial D}{\partial e^m}\left(\frac{\partial D}{\partial e^m} + \frac{(1-s)}{(1-\alpha)}f\frac{\partial^2 D}{\partial e^m \partial p}\right)\left(2\frac{\partial^2 D}{\partial e^{m2}} - \frac{1}{B}\frac{\partial D}{\partial e^m}\frac{\partial B}{\partial e^m}\right)\right]$$
$$- \left[\left(\frac{f}{1-\alpha}\right)\left(\frac{1-s}{1-\alpha}\right)\frac{\partial D}{\partial p}\right] - \left[\frac{\Theta}{B}\left(\frac{f}{1-\alpha}\right)\left(\frac{1-s}{1-\alpha}\right)\frac{\partial D}{\partial e^m}\frac{\partial^2 D}{\partial e^m \partial p}\left(\frac{fw^m}{1-\alpha} - 2R\right)\right]$$
$$+ \left[\frac{w^m R\Theta^2}{B^2}\left(\frac{f}{1-\alpha}\right)^2\left(\frac{1-s}{1-\alpha}\right)\left(\frac{\partial D}{\partial e^m}\right)^2\frac{\partial^3 D}{\partial e^{m2}\partial p}\right] + \left[\frac{\Theta}{B}\frac{f}{(1-\alpha)^2}\left(\frac{\partial D}{\partial e^m}\right)^2\left(1 - 2w^m + \frac{w^m R\Theta}{B}\frac{\partial^2 D}{\partial e^{m2}}\right)\right]$$

and cannot be signed without additional assumptions. There are five terms in V. The first term in V is nonpositive by equation (A11); the second term is nonnegative by Assumption 2; the sign of the third term is determined by the sign of $\frac{fw^m}{1-\alpha} - 2R$, which may be positive or negative; and the sign of the fourth term is determined by the sign of $\frac{\partial^3 D}{\partial e^{m2}\partial p}$, which may be positive or negative. These first four terms correspond to the terms in U (the numerator of $\frac{\partial w^m}{\partial s}$), but the last term does not. The sign of the fifth term depends on the sign of $1 - 2w^m + \frac{w^m R\Theta}{B}\frac{\partial^2 D}{\partial e^{m2}}$. The comparative static $\frac{\partial w^m}{\partial \alpha} = -\frac{V}{T}$ and since $T \leq 0$, $\frac{\partial w^m}{\partial \alpha} \geq 0$ if and only if $V \geq 0$.

The numerator of $\frac{\partial w^m}{\partial s_d}$ is

$$\frac{\Theta}{B}\frac{\partial R}{\partial s_d}\left(\frac{\partial D}{\partial e^m}\right)^2 + \frac{2R\Theta}{B}\frac{\partial D}{\partial e^m}\left(\frac{\partial^2 D}{\partial e^m \partial p}\frac{\partial p}{\partial s_d} + \frac{\partial^2 D}{\partial e^{m2}}\frac{\partial e^m}{\partial s_d}\right) - \frac{R\Theta}{B^2}\left(\frac{\partial D}{\partial e^m}\right)^2\frac{\partial B}{\partial s_d} - \frac{\partial D}{\partial p}\frac{\partial p}{\partial s_d} - \frac{\partial D}{\partial e^m}\frac{\partial e^m}{\partial s_d}$$
$$= \frac{\Theta}{B}\left(\frac{\partial D}{\partial e^m}\right)^2.$$

The comparative static $\frac{\partial w^m}{\partial s_d} = -\frac{\Theta\left(\frac{\partial D}{\partial e^m}\right)^2}{BT}$ and since $T \leq 0$, $\frac{\partial w^m}{\partial s_d} \geq 0$. This proves the first result in the proposition.

Next we show that for a sufficiently low compensation rate $\frac{\partial w^m}{\partial s} \leq 0$ and $\frac{\partial w^m}{\partial \alpha} \geq 0$. To prove our intended result, we show that $U \leq 0$ and $V \geq 0$ for a sufficiently small compensation rate. Setting the compensation rate equal to zero, we have

$$U|_{w^m=0} = \left(\frac{f}{1-\alpha}\right)\frac{\partial D}{\partial p} - \frac{2R\Theta}{B}\left(\frac{f}{1-\alpha}\right)\frac{\partial D}{\partial e^m}\frac{\partial^2 D}{\partial e^m \partial p} \leq 0$$

$$V|_{w^m=0} = -\left(\frac{f}{1-\alpha}\right)\left(\frac{1-s}{1-\alpha}\right)\frac{\partial D}{\partial p} + \frac{2R\Theta}{B}\left(\frac{f}{1-\alpha}\right)\left(\frac{1-s}{1-\alpha}\right)\frac{\partial D}{\partial e^m}\frac{\partial^2 D}{\partial e^m \partial p} + \frac{\Theta}{B}\frac{f}{(1-\alpha)^2}\left(\frac{\partial D}{\partial e^m}\right)^2 \geq 0$$

where $R \geq 0$ so that insurance company profits are nonnegative and $B \geq 0$. Assumption 2 provides the signs for the demand terms.

Proof of Proposition 6

$\frac{de^m}{ds_d} = \frac{\partial e^m}{\partial s_d} + \frac{\partial e^m}{\partial w^m}\frac{\partial w^m}{\partial s_d}$ is the total effect of an increase in s_d on the effort level. The total effect contains a direct effect and an indirect effect through the change in the compensation rate. From Proposition 2, we know that $\frac{\partial e^m}{\partial s_d} = 0$ and both $\frac{\partial e^m}{\partial w^m}$ and $\frac{\partial w^m}{\partial s_d}$ are defined in Proposition 5.

The other results for effort levels are that for a sufficiently low compensation rate

$$\frac{de^m}{ds} = \frac{\partial e^m}{\partial s} + \frac{\partial e^m}{\partial w^m}\frac{\partial w^m}{\partial s} \leq 0 \qquad \text{and} \qquad \frac{de^m}{d\alpha} = \frac{\partial e^m}{\partial \alpha} + \frac{\partial e^m}{\partial w^m}\frac{\partial w^m}{\partial \alpha} \geq 0.$$

The sign of these expressions is determined from results in Propositions 2 and 5.

Proof of Proposition 7

Conditional on no prior government policy, $\alpha = 0$, $s = 0$ and $s_d = 0$. When all these policy variables are zero, then $w^c = 0$ (see equation 7) and $e^* = 0$ (see equation 5). The comparative statics of w^c are determined by making the relevant substitutions in equation (A5). Note that $f \leq 1$ as $f = c$ and c is the probability of a loss.

The total effect on e^c is determined from equation (A6). Simplifications from no prior government policy combined with equations (A1) through (A4) are useful.

Proof of Proposition 8

Conditional on no prior government policy, $\alpha = 0$, $s = 0$ and $s_d = 0$. When all these policy variables are zero, then $w^m = 0$ and $e^* = 0$ (see equation 5). Proposition 5 indicates that $\frac{\partial w^m}{\partial s} \leq 0$. Since conditional on no prior government policy, $w^m = 0$ it must be that $\frac{\partial w^m}{\partial s} = 0$. Also from Proposition 5, $\frac{\partial w^m}{\partial s_d} = -\frac{\Theta\left(\frac{\partial D}{\partial e^m}\right)^2}{BT}$ and $\frac{\partial w^m}{\partial \alpha} = -\frac{V}{T}$. Conditional on no prior government policy (NP)

$$V|_{NP} = -f\frac{\partial D}{\partial p} + f\Theta\frac{\left(\frac{\partial D}{\partial e^m}\right)^2}{\frac{\partial^2 C_A}{\partial e^{m2}}} \qquad \text{and} \qquad T|_{NP} = -2f\Theta\frac{\left(\frac{\partial D}{\partial e^m}\right)^2}{\frac{\partial^2 C_A}{\partial e^{m2}}}$$

thus

$$\left.\frac{\partial w^m}{\partial s_d}\right|_{NP} = \frac{1}{2f} \geq 0 \qquad \text{and} \qquad \left.\frac{\partial w^m}{\partial \alpha}\right|_{NP} = \frac{1}{2} + \frac{-\frac{\partial D}{\partial p}\frac{\partial^2 C_A}{\partial e^{m2}}}{2\Theta\left(\frac{\partial D}{\partial e^m}\right)^2} \geq 0.$$

It is straightforward to show that $\frac{\partial w^m}{\partial s_d}\Big|_{NP} \geq \frac{\partial w^m}{\partial \alpha}\Big|_{NP}$ only when $\frac{1-f}{f} \geq \frac{\frac{-\partial D}{\partial p}\frac{\partial^2 C_A}{\partial e^{m2}}}{\Theta\left(\frac{\partial D}{\partial e^m}\right)^2}$.

Equations (A2) through (A4) are all equal to zero since $w^m|_{NP} = 0$. The total effect for a change in e^m conditional on no prior government policy is $\frac{de^m}{dx}\Big|_{NP} = \frac{\partial e^m}{\partial w^m}\frac{\partial w^m}{\partial x}$ where x is either s, α, or s_d. Since $\frac{\partial w^m}{\partial e^m} \geq 0$ the order of the comparative statics for e^m are the same as w^m.

Proof of Proposition 9

$\frac{\partial Q^*}{\partial x} = K\Theta\left(\frac{\partial D}{\partial p}\frac{\partial p}{\partial x} + \frac{\partial D}{\partial e^*}\frac{de^*}{dx}\right)$ where $x = \{s, \alpha, s_d\}$. Note that $\frac{de^c}{dx}$ is the total effect which includes a direct effect and an indirect effect through w. The comparative static effects on effort determined in the proof of Proposition 2 are used to simplify the above changes.

The marginal changes in market demand due to a change in either s, α, or s_d, conditional on no prior government policy (NP) are

(A13) $$\frac{\partial Q^c}{\partial s}\Big|_{NP} = fK\Theta\left(\frac{\Theta}{B}\left(\frac{\partial D}{\partial e^c}\right)^2\frac{\partial w^c}{\partial s} - \frac{\partial D}{\partial p}\right)$$

(A14) $$\frac{\partial Q^c}{\partial \alpha}\Big|_{NP} = fK\Theta\left(\frac{\partial D}{\partial p} + \frac{\Theta}{B}\left(\frac{\partial D}{\partial e^c}\right)^2\frac{\partial w^c}{\partial \alpha}\right)$$

(A15) $$\frac{\partial Q^c}{\partial s_d}\Big|_{NP} = \frac{fK\Theta^2}{B}\left(\frac{\partial D}{\partial e^c}\right)^2\frac{\partial w^c}{\partial s_d}$$

where equation (A7) defines B.

The agent compensation rate for a symmetric competitive equilibrium is w^c (equation 7). Conditional on no prior government policy

$$\frac{\partial w^c}{\partial s}\Big|_{NP} = 0 \qquad \frac{\partial w^c}{\partial \alpha}\Big|_{NP} = 1 \qquad \frac{\partial w^c}{\partial s_d}\Big|_{NP} = \frac{1}{f}$$

and the changes in market demand for the symmetric competitive equilibrium are as follows.

$$\frac{\partial Q^c}{\partial s}\Big|_{NP} = -fK\Theta\frac{\partial D}{\partial p} \qquad \frac{\partial Q^c}{\partial \alpha}\Big|_{NP} = fK\Theta\left(\frac{\partial D}{\partial p} + \frac{\Theta}{B}\left(\frac{\partial D}{\partial e^c}\right)^2\right) \qquad \frac{\partial Q^c}{\partial s_d}\Big|_{NP} = \frac{K\Theta^2}{B}\left(\frac{\partial D}{\partial e^c}\right)^2$$

Note that from our symmetry assumption $f = c$ which is the probability of a loss. Since f is a probability, it is bounded between 0 and 1. Lastly, from equation (A7) and conditional on no prior government intervention, $B|_{NP} = \frac{\partial^2 C_A}{\partial e^{*2}}$.

Proof of Proposition 10

The proof here is similar to the proof of Proposition 9. The marginal changes in market demand due to a change in either s, α, or s_d, conditional on no prior government policy (NP) are

(A16) $$\frac{\partial Q^m}{\partial s}\Big|_{NP} = fK\Theta\left(\frac{\Theta}{B}\left(\frac{\partial D}{\partial e^m}\right)^2\frac{\partial w^m}{\partial s} - \frac{\partial D}{\partial p}\right)$$

(A17) $$\frac{\partial Q^m}{\partial \alpha}\Big|_{NP} = fK\Theta\left(\frac{\partial D}{\partial p} + \frac{\Theta}{B}\left(\frac{\partial D}{\partial e^m}\right)^2\frac{\partial w^m}{\partial \alpha}\right)$$

(A18) $$\frac{\partial Q^m}{\partial s_d}\Big|_{NP} = \frac{fK\Theta^2}{B}\left(\frac{\partial D}{\partial e^m}\right)^2\frac{\partial w^m}{\partial s_d}.$$

The agent compensation rate for a symmetric competitive equilibrium is w^m (equation 7). Conditional on no prior government policy

$$\left.\frac{\partial w^m}{\partial s}\right|_{NP} = 0 \qquad \left.\frac{\partial w^m}{\partial \alpha}\right|_{NP} = \frac{1}{2} + \frac{-\frac{\partial D}{\partial p}\frac{\partial^2 C_A}{\partial e^{m2}}}{2\Theta\left(\frac{\partial D}{\partial e^m}\right)^2} \qquad \left.\frac{\partial w^m}{\partial s_d}\right|_{NP} = \frac{1}{2f}$$

and the changes in market demand for the symmetric competitive equilibrium are as follows.

$$\left.\frac{\partial Q^m}{\partial s}\right|_{NP} = -fK\Theta\frac{\partial D}{\partial p} \quad \left.\frac{\partial Q^m}{\partial \alpha}\right|_{NP} = \frac{fK\Theta}{2}\left(\frac{\partial D}{\partial p} + \frac{1}{B}\left(\frac{\partial D}{\partial e^c}\right)^2\right) \quad \left.\frac{\partial Q^m}{\partial s_d}\right|_{NP} = \frac{K\Theta^2}{2B}\left(\frac{\partial D}{\partial e^c}\right)^2$$

Note that from our symmetry assumption $f = c$ which is the probability of a loss. Since f is a probability, it is bounded between 0 and 1. Lastly, from equation (A7) and conditional on no prior government intervention, $B|_{NP} = \frac{\partial^2 C_A}{\partial e^{*2}}$.

Proof of Proposition 11

The net costs of a competitive symmetric equilibrium are $NC^c = TC - FB$ and the net costs of a collusive monopsony equilibrium are $NC^m = TC - FB - \pi^m$. The results of the proposition are shown by using the benefit and cost measures defined in the paper.

Proof of Proposition 12

Represent equation (9) as $\frac{R\Theta}{B}\left(\frac{\partial D}{\partial e^m}\right)^2 - D = 0$ where $R \equiv \left(\frac{\alpha - w^m}{1-\alpha}\right) f + s_d$ and $B \equiv \frac{\partial^2 C_A}{\partial e^{*2}} - \frac{f w_i \Theta}{(1-\alpha)}\frac{\partial^2 D}{\partial e^{*2}}$. Implicitly differentiate equation (9) with respect to w^m and Θ to get $\frac{\partial w^m}{\partial \Theta} = -\frac{Y}{X}$ where

$$Y = \frac{R}{B}\left(\frac{\partial D}{\partial e^m}\right)^2 - \frac{\partial B}{\partial \Theta}\frac{R\Theta}{B^2}\left(\frac{\partial D}{\partial e^m}\right)^2 + \frac{2R\Theta}{B}\frac{\partial D}{\partial e^m}\frac{\partial^2 D}{\partial e^{m2}}\frac{\partial e^m}{\partial \Theta} - \frac{\partial D}{\partial e^m}\frac{\partial e^m}{\partial \Theta}$$

$$X = \frac{\partial R}{\partial w^m}\frac{\Theta}{B}\left(\frac{\partial D}{\partial e^m}\right)^2 - \frac{\partial B}{\partial w^m}\frac{R\Theta}{B^2}\left(\frac{\partial D}{\partial e^m}\right)^2 + \frac{2R\Theta}{B}\frac{\partial D}{\partial e^m}\frac{\partial^2 D}{\partial e^{m2}}\frac{\partial e^m}{\partial w^m} - \frac{\partial D}{\partial e^m}\frac{\partial e^m}{\partial w^m}.$$

The undefined terms in X and Y are as follows: $\frac{\partial R}{\partial w^m} = -\frac{f}{1-\alpha}$, $\frac{\partial B}{\partial \Theta} = \frac{\partial B}{\partial e^m}\frac{\partial e^m}{\partial \Theta} - \frac{f w^m}{1-\alpha}\frac{\partial^2 D}{\partial e^{m2}}$, and $\frac{\partial e^m}{\partial \Theta} = \frac{f w^m}{(1-\alpha)B}\frac{\partial D}{\partial e^m}$. Note that both $\frac{\partial B}{\partial w^m}$ and $\frac{\partial e^m}{\partial w^m}$ have been defined previously in equations (A10) and (A1) respectively.

Simplify both X and Y to get the following.

$$Y = w^m\frac{R\Theta}{B^2}\left(\frac{f}{1-\alpha}\right)\left(\frac{\partial D}{\partial e^m}\right)^2\left(3\frac{\partial^2 D}{\partial e^{m2}} - \frac{1}{B}\frac{\partial D}{\partial e^m}\frac{\partial B}{\partial e^m}\right) - \frac{1}{B}\left(\frac{\partial D}{\partial e^m}\right)^2\left(\frac{f w^m}{1-\alpha} - R\right)$$

$$X = \Theta\frac{R\Theta}{B^2}\left(\frac{f}{1-\alpha}\right)\left(\frac{\partial D}{\partial e^m}\right)^2\left(3\frac{\partial^2 D}{\partial e^{m2}} - \frac{1}{B}\frac{\partial D}{\partial e^m}\frac{\partial B}{\partial e^m}\right) - \frac{2\Theta}{B}\left(\frac{f}{1-\alpha}\right)\left(\frac{\partial D}{\partial e^m}\right)^2$$

$X \leq 0$ from Assumption 2 and the proof of Proposition 5. Equation (A11) in the proof of Proposition 5 is particularly useful, but the inequality is based on $\frac{\partial^2 e^m}{\partial w^{m2}} \leq 0$. If $Y \leq 0$, then $\frac{\partial w^m}{\partial \Theta} = -\frac{Y}{X} \leq 0$ and is the intended result. If $\frac{f w^m}{1-\alpha} - R \geq 0$, then $w^m \geq \frac{\alpha}{2} + \frac{(1-\alpha)s_d}{2f}$ and $Y \leq 0$.

Appendix B: Premium Rate Estimation

In the model, we allow for the actuarial fair premium rate to be increased by a catastrophic risk loading factor, α , as mandated under the terms of the 1994 Crop Insurance Reform Act and still required by RMA in compliance with the provisions of the 2014 Agricultural Act. Changes in α have been shown to have important effects on insurance company revenues, agent compensation rates, taxpayer costs, the quantity of crop insurance purchased by farmers, and the net social costs of the program.

There are two practical, policy-related reasons to consider the role of α. First, as discussed in the text under the provisions of the 1994 Crop Insurance Reform Act the RMA is required to estimate the actuarially fair premium rate for each policy and then apply a 13.64% catastrophic risk loading factor when setting premium rates. Second, until 2012 the RMA utilized rate-setting practices that ignored underlying long-run upward trends in yields for crops like corn and soybeans (Coble et al., 2010). This practice also effectively added a loading factor to actuarially fair premium rates.

With respect to the catastrophic risk loading factor mandated by the 1994 Crop Insurance Reform Act, the rationale for applying that loading factor was that such loading factors are typically applied by private insurance companies in pricing their products, regardless of the line of business, to account for extreme events that may not have been included in the data used to estimate rates. This practice is widely viewed as consistent with actuarial approaches to rate setting for individual policies as a means of avoiding the risk of underpricing those policies. However, the application of the catastrophic risk loading factor to all crop insurance products in over 3,000 U.S. counties results in total premiums that exceed total expected indemnities if the premium rates to which the loading factor is applied are on average actuarially fair.

The reason for adjusting rates for catastrophic risk is straightforward; it is unlikely that the data used to compute actuarially fair premium rates in every county, for every crop, fail to adequately account for extreme adverse effects (or, equivalently, always includes excessive numbers of observations on favorable events). For example, in most counties in Midwestern states, the data used to compute premium rates in 2012 consist of no more than about forty annual observations on county-wide loss ratios for the insured crop as participation in the federal crop insurance program was relatively limited prior to the 1970s.

For many counties, however, those observations included at least two extreme events: the 1993 floods that devastated corn and soybean crop production in counties in Missouri, Iowa, and other states bordering the Mississippi and Missouri Rivers and the 2012 extreme drought conditions in Iowa, Indiana, Illinois, and parts of other adjacent states. For Great Plains states like North Dakota, Montana, and Texas, the data also include two extreme event yield observations: 1983 and 1988, arguably the two worst drought years in the past 100 years, including yields during the Dust Bowl era. Since these extreme events are included as past observations, it is unclear by how much premiums need to be adjusted to account for catastrophic risk.

In addition, prior to 2013, premium rates were also inflated by using rate-setting procedures that underestimated farmers' expected yields for a crop. Rate-setting procedures failed to account for substantial long-run upward trends in farm-level yields but accounted for them at the county level in establishing expected losses. The result, as Coble et al. (2010) have demonstrated, is to overestimate the frequency of losses at the farm level by systematically underestimating farm yields. This issue has been important in corn-belt states where yields for both corn and soybeans have shown persistent and substantial upward trends since the early 1980s, and Coble et al. (2010) have emphasized this point in their discussion of the use of county-level target yields to determine premium rates for individual farms.

Until 2013, the upward yield trends were not effectively taken into account at the farm level in the rate-setting procedures implemented by the RMA for the individual farm. County-wide average premium rates are established from county target yields, where forecasts of those county target yields are based on yield trends, typically estimated using National Agricultural Statistical Service data.

Farmers with actual production history (APH) yields lower than the target yield for their county are then charged higher premium rates, effectively because RMA assumes that the distribution of losses in absolute terms is similar for all farms in the county.

Prior to 2013, for most farms, a farm's APH yield was computed as the arithmetic average of its realized yields over the previous four to ten years, resulting in expected yield estimates that could be as much as 5% lower than the actual expected yields. The discrepancy between expected yield estimates and actual expected yields occurred because yield trends were ignored in computing the farm-level APH, as discussed by Coble et al. (2010). Therefore, prior to 2013, the RMA's rate-setting approach resulted in premium rates for most farms that exceeded the actuarially fair premium rate for those farms. Since 2013, upward yield trends for some major crops such as corn and soybeans have taken upward trends in farm-level yields into account. This adjustment has resulted in substantial reductions in farm-level premium rates in states like Iowa, Illinois, and Indiana for crops such as corn and soybeans, which account for over half of the total premiums paid into the US crop insurance program (RMA, 2012).