Estimation of Insurance Deductible Demand under Endogenous Premium Rates

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Abstract

Government subsidized insurance is ubiquitous, yet estimation of demand in such markets remains challenging. Premium charged for a given deductible is determined by actuarial construction, thus observed choice-pairs are endogenous leading to biased estimation under standard econometric approaches. A theoretical model and simulation study are developed, and a new identification strategy proposed. An empirical application using Federal Crop Insurance Program--a $100 billion/year program--data reveals that demand is quite elastic after accounting for this endogeneity. Mistreatment of such endogeneity is likely partly responsible for pervasive faulty findings of inelastic insurance demand in related applications. Policy implications are discussed.

Government subsidization of insurance is commonplace in many insurance markets, including health, flood, terrorism, deposit, agriculture, among others (Ziebarth, 2010; Aron-Dine, Einav, and Finkelstein, 2013; Dickstein et al., 2015; Woodard et al., 2012; Michel-Kerjan and Kunreuther, 2011; Brown, Kroszner, and Jenn, 2002; Brown et al., 2004; Jaspersen and Richter, 2015), and comes in both supply and demand enhancing forms including explicit premium subsidies, mandatory coverage, and favorable government reinsurance. The analysis of consumer responses to subsidization is central to evaluating, budgeting, and designing these programs. Such interventions are often argued on the premise that they either complete a missing market and/or reduce some externality to society, though there are many arguments against such interventions as well (e.g., Priest, 1996). Often, the large administrative databases maintained by the government on actual purchases are the primary source of data for evaluating and predicting market responses to changes in policy or subsidy rates. Understanding how to answer such questions using transactional data is thus of great importance, but presents challenges related to endogeneity and complexity of product and program structures.

In the United States, the Federal Crop Insurance Program (FCIP) is a foundational agricultural support program, with around $100 billion in liabilities annually. In fact, the FCIP is the largest direct agricultural subsidy program in the U.S., and the single largest agricultural insurance program globally and historically. Internationally, subsidized agricultural insurance has also gained a foothold as a preferred mode of intervention to complete missing risk management markets in the presence of systemic risk, including large programs in China, India, and in many African countries (Mahul and Stutley, 2010; Takahashi, 2016; Woodard, Shee, and Mude, *forthcoming*).

Having sound demand elasticity estimates is of upmost policy importance. For example, the United States Government Accountability Office (GAO) recently released a report which concluded--based on elasticity estimates in the literature--that demand for crop insurance in the U.S. is inelastic, and then subsequently inferred that subsidization could be cut, and insured paid rates increased substantially without significantly affecting program participation (GAO, 2014). However, the findings in the literature cited in that report are somewhat puzzling *prima facie* given the large uptake in the last decades observed in the FCIP in response to increased subsidization. The *price* of insurance (premium rate) for a given deductible (*quantity*) or coverage level chosen by the insured is determined according to a convex actuarial premium menu (typically referred to as the "rate curve"). Insurance coverage quantities and prices in observed data are ultimately generated from such actuarial schedules, and thus observed data are endogenously determined. We show that when multiple deductible (i.e., coverage) levels are available, the near universal approach of estimating demand elasticities with observed coverage on premium rates via OLS will thus result in severely biased demand elasticities. This fundamental specification aspect regarding the endogeneity of the premium schedule in deductible level has received no treatment in the economic literature on insurance demand.

To our knowledge no cohesive strategy has been developed, nor theoretical or econometric basis articulated to address this despite the broad appeal in a wide universe of insurance markets. Premium rate endogeneity considerations have been found to be important in related contexts though. For example, Weiss, Tennyson, and Regan (2010), find that accounting for rate endogeneity resulting from regulations can have profound empirical impacts when evaluating incentive distortions in insurance markets, but do not deal with the more fundamental issue at stake related to the fact that fair premium rates vary in response systematically to the deductible purchased as a matter of actuarial construction.

The purpose of this study is to investigate the estimation of insurance deductible demand, with an eye towards identification issues arising from the simultaneous determination of observed rates/deductibles. Existing literature is extended in several ways. First, we derive a theoretical model of insurance deductible demand under an endogenous rate curve which departs from the standard full insurance result. An estimable model of insurance demand is then derived under an endogenous actuarial rate curve and evaluated from an econometric perspective. An estimation strategy is proposed and investigated which involves instrumenting with specific information inferred from the premium rate curve. A simulation study is conducted to investigate the econometric properties of this estimation phenomenon and confirm the performance of the proposed approach. An empirical application is then investigated using program insurance data from the FCIP for a major market to estimate the magnitude of this effect in actual data.

Consistent with the large growth in insurance uptake in response to increased subsidization through time in the FCIP, the theoretical, numerical, and empirical findings uncovered here suggest that demand for this insurance may in fact be orders of magnitude more elastic than previously thought once properly accounting for this endogeneity. Several models and measures are investigated which consistently find that insurance coverage demand is elastic to premium rate, as is the total liability per insured acre. The results indicate that accounting for this effect typically leads to demand elasticities which are consistently 3-5 times greater than under the standard approach. Treatment of this endogeneity may be responsible for much of the longstanding conventional wisdom regarding inelastic insurance demand in many related markets and applications.

Brief Overview of Recent Relevant Literature

Questions related to the performance of government intervention in insurance markets, and estimation issues for insurance demand more generally, have received much attention in the recent literature in a variety of domains. For example, Cohen and Einav (2007) develop a structural model from data on deductible choices to estimate risk preferences for Israeli auto insurance, taking into account adverse selection by modeling claim rates and risk aversion. They uncover several important findings regarding heterogeneity in risk aversion and risk attitudes, and show that it has important implications for pricing. In the health insurance economics literature, several recent studies highlight the difficulties in estimating various classes of elasticities in similarly complex insurance markets. Aron-Dine, Einav, and Finkelstein (2013) conduct a reexamination of the core findings of the RAND health insurance experiments, including a reevaluation of how out-of-pocket expenses affect medical spending. Their work highlights that caution should be taken when attempting to summarize behavior in the presence of nonlinear insurance contracts using a single elasticity.

Using administrative transactional data, Curto et al. (2015) highlight the importance of considering policy structure, provider competition, and subsidies when estimating demand elasticities in the specific case of Medicare Part C. Decarolis, Polyakova, and Ryan investigate impacts of subsidies from the supply side for Medicare Part D, focusing on estimation of welfare effects to account for the estimated $9 billion in government costs which are distributed via returns in that program. Abaluck and Gruber (2011) find that insureds in Medicare Part D exhibit inconsistent behavior by placing more weight on plan premiums than expected out-of-pocket costs (realizations of which are also impacted by deductible) when valuing plan financial incentives. They argue that insureds also undervalue risk-reducing aspects of different plans.

Others have also recognized the challenge in linking correlation between changes in rates and participation to causality (not the least of which is because of the endogeneity of observed rates to the rate curve). For example, Gruber and Poterba (1994) conduct an analysis of tax subsidies on insurance demand by self-employed individuals. They highlight the challenge in connecting changes in tax rates to health insurance participation because of the simultaneous changes in many other factors that affect demand for health insurance coverage, such as a large shift from industrial to service employment in the 1980s, rising real health care costs, and a widening income distribution.

Of fundamental interest from a policy evaluation perspective is the role that producer-paid premium rates have on demand in the FCIP given that the articulated policy goal has consistently been that of maximizing participation (Glauber, 2004). Yet, the literature on crop insurance demand in the FCIP in recent years since the advent of revenue insurance (which is now the vast majority of volume) is scarce. The studies that do exist tend to find that demand is fairly inelastic (see e.g., Goodwin, 1993; Goodwin, Vandeveer, and Deal, 1994; Coble et al., 1996; Du, Feng, and Hennessy, 2014), although with some limited exceptions (see e.g., Richards, 2000).

There are no generally accepted sets of measures nor modeling approaches in the literature for modeling insurance demand, although research in this area in recent decades has revealed a variety of approaches and suggestive findings regarding the various dimensions and dynamics of demand. While fairly fundamental, recognition of the endogeneity between the degree of per unit coverage/liability (or conversely, deductible) to the premium rate observed in transactional data has surprisingly not been discussed extensively in the context of insurance demand estimation. However, some methods have been employed in the literature in which the continuum of coverage choices is discretized into *K* different equations, and then individual choice models for each such discrete coverage level option are estimated.

For example, Richards (2000) investigates a system of discrete choice models in this manner using ordered probit. Du, Feng, and Hennessy (2014) pursue the problem along a similar line by employing a mixed logit approach, and find that coverage demand elasticities vary from positive to negative depending on coverage level, product, and unit structure. While these efforts present a methodological improvements over standard approaches, their implementation does present some problems in practice. Such systems essentially require fitting a minimum of K^2 own- and cross-price elasticities (instead of one elasticity), which are often inefficient and difficult to interpret. For example, the standard FCIP product with 8 coverage level choices (50% to 85% in 5% increments) would mean that such approaches require estimating a total of 64 rate elasticity parameters. Typically, the data needed to fit such a system would render its estimation non-operational; it is also likely to be quite inefficient compared to a single equation model. Placing realistic restrictions on such a system to reflect the mutually exclusive coverage level choice, while also imposing appropriate constraints to reflect the rich underlying mathematical relationships (beyond simple ordinality) between coverage levels, may also be infeasible. This inefficiency may be responsible for some of the unstable findings in the literature such as mixed signs and puzzling cross coverage elasticities.

Richards (2000), using data for California grape insurance for an 11 county area over a 10 year period, partitions the data into 3 coverage level equations, and finds that insurance demand estimated with this method is found to be somewhat elastic. Du, Feng, and Hennessy (2014) also find that demand is elastic for a small subset of coverage levels and products, although the plethora of demand elasticities from their models reveal mixed results (in fact some are found to have positive demand elasticities). Building on this line of work, a more parsimonious and cohesive framework for estimating coverage level choice using an instrumental variables approach is proposed, which can be scaled up reliably to the larger core volume insurance markets regardless of the number of coverage level choices.

While the intent here is not to conduct an extensive literature review, it is worth noting that these and other studies also investigate covariates such education, cropping practice, historical framing information, exogenous fertilizer prices, county average yields, and many others. While previous studies uncover some important aspects and dimensions of the demand decision which are interesting in their own rite, the focus of this study is on the far more basic aspect of estimation related to the econometric properties which arise when estimating coverage choice under an endogenous rate curve.

There are other studies that exist--primarily in the health insurance literature--which investigate various endogenous aspects of demand related to other tangential dimensions of insurance. Again, to our knowledge there are none that focus on estimating deductible demand using information from the rate curve as instruments as we propose below. For example, Schellhorn (2001) evaluates the impact of deductible choice on demand for number of hospitals visits. Like many studies in health, auto, and other fields, the investigation of endogeneity is geared towards to demand for other services from having insurance (i.e., due to informational asymmetries such as moral hazard). That is, focus tends to be on investigating how *having* insurance impacts demand for some the insured service (see e.g., Aron-Dine, Einav, and Finkelstein, 2013; Aron-Dine et al., 2015), or how deductible choice can be used to infer other characteristics of buyers such as risk preferences (see e.g., Cohen and Einav, 2007).

There is also a re-emerging strand of literature that asks the normative question of whether the government *should* subsidize risk management activities, such as agricultural or health insurance, and to what extent these programs can achieve welfare gains (see e.g., Jaffee, 2006; Einav, Finkelstein and Schrimpf, 2010; Einav, Finkelstein, and Cullen, 2010; Coble and Barnett, 2013). While this is an important question in and of itself, here rather, investigation is pursued to determine how demand by agricultural producers is affected by changes in rates, and to what degree these rate curve endogeneity considerations are important from a modeling and policy perspective.

A Simple Theoretical Model of Insurance Demand under Endogenous Rate Curve

It is well known that the standard model of deductible demand under actuarially fair premiums results in full insurance. When premium rates are not actuarially fair, however, then optimal coverage at less than full insurance can result, and indeed this is commonly observed in actual data. Consider the standard expected utility model in the context of deductible demand,

$$EU = \int_{cG}^{\infty} U\left(y - Gc\,r\left(c\right)\right) f\left(y\right) dy + \int_{0}^{cG} U\left(Gc - Gc\,r\left(c\right)\right) f\left(y\right) dy \qquad (1),$$

where $U' > 0, U'' < 0$, $c \in [0,1]$ is the coverage level (1 minus the deductible percent), G is the expected asset value (e.g., expectation of revenue)[1], Gc is the insured liability, $r\left(c\right)$ is the rate curve (i.e., the premium rate conditional on the coverage level, an increasing convex function of *c*), $r'\left(c\right) > 0$, $r''\left(c\right) > 0$ and $r\left(c\right) > 0 \;\forall\; c > 0$,and y is the realized asset value (e.g., actual end of season yield or revenue), and $f\left(y\right)$ is the density of the underlying of interest being insured (e.g., revenue). The term $Gc\,r\left(c\right)$ equals the total premium (i.e., the *liability* times the *premium rate*). The first term is expected utility in cases in which no liability would be due, and the second is the expected utility for cases in which a liability is paid. Note that in cases in which an indemnity is due, y plus the indemnity equals Gc , since the indemnity equals $Max[0, Gc - y]$. Applying Liebniz's integral rule and taking the derivative of EU *wrt c* and equating to zero yields the FOC,

$$\begin{aligned}\frac{\partial EU}{\partial c} &= \left(-c^* r'\left(c^*\right) - r\left(c^*\right)\right) G \int_{c^*G}^{\infty} f\left(y\right) U'\left(y - c^* r\left(c^*\right) G\right) dy \\ &\qquad + \left(-c^* r'\left(c^*\right) - r\left(c^*\right) + 1\right) G\, F\left(c^* G\right) U'\left(\left(c^* - c^* r\left(c^*\right)\right) G\right) = 0,\end{aligned} \qquad (2)$$

and thus *c** is the solution to,

$$g(c) = c^* - \frac{r\left(c^*\right)\int_{c^*G}^{\infty} f\left(y\right)U'\left(y - c^* r\left(c^*\right)G\right)dy + \left(r\left(c^*\right) - 1\right)F\left(c^*G\right)U'\left(\left(c^* - c^* r\left(c^*\right)\right)G\right)}{r'\left(c^*\right)\int_{c^*G}^{\infty} f\left(y\right)U'\left(y - c^* r\left(c^*\right)G\right)dy + r'\left(c^*\right)F\left(c^*G\right)U'\left(\left(c^* - c^* r\left(c^*\right)\right)G\right)} = 0 \qquad (3).$$

Letting $a = \int_{cG}^{\infty} U'\left(y - c\,r\left(c\right)G\right) f\left(y\right) dy$ and $b = F\left(cG\right)U'\left(\left(c - c\,r\left(c\right)\right)G\right)$, yields,

$$c = -\frac{r\left(c\right)a + \left(r\left(c\right) - 1\right)b}{r'\left(c\right)a + r'\left(c\right)b} = \frac{b - \mathrm{r}\left(c\right)(a+b)}{r'\left(c\right)(a+b)} = h(c) \qquad (4),$$

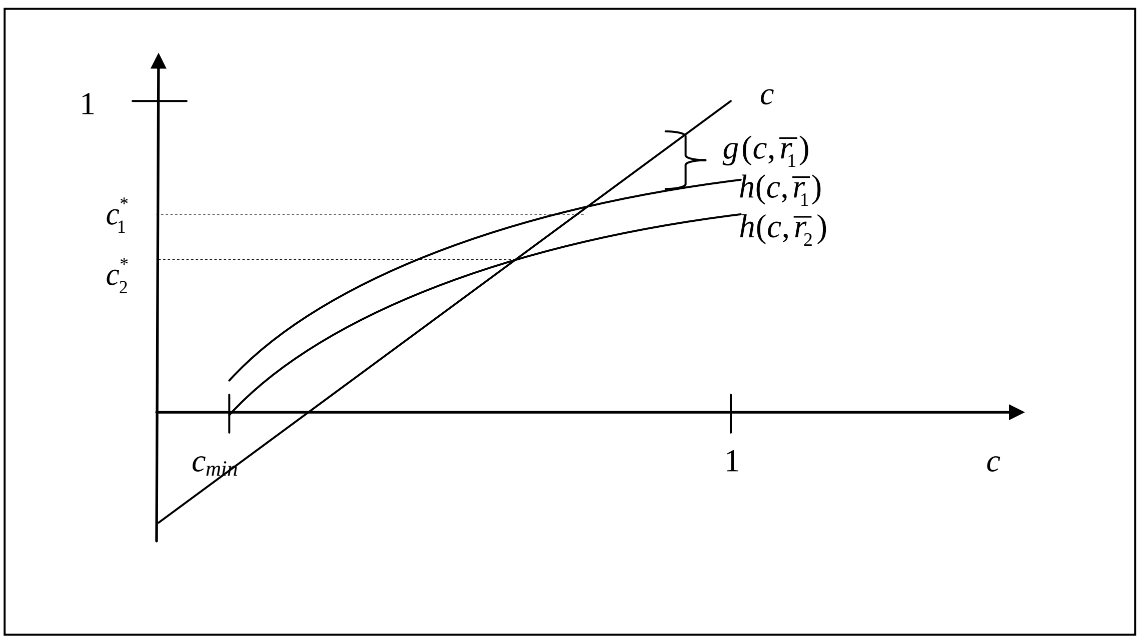
[1] In the federal crop insurance program, for yield insurance this would be equal to the Actual Production History (APH, a proxy for expected yield) which is an average of the previous 4 to 10 years of yields, and for revenue insurance would be equal to the projected preseason price times the APH, where the projected price is usually discovered as the monthly average of some reference exchange traded futures price.

if an interior solution exists.[2] The SOC requires $\frac{\partial^2 EU}{\partial c^2} = \frac{\partial\left(-c + h(c)\right)}{\partial c} = -1 + \frac{\partial h(c)}{\partial c} < 0,$ and thus $\frac{\partial h(c)}{\partial c} < 1$ is necessary for an interior solution.

The terms *a* and *b* in Equation 4 are the limited expected values of marginal utility under insurance over the range of the probability distribution for outcomes above *a* , and below *b*, where *b* is the point below which indemnities would be due relative to the guarantee, *Gc*. To evaluate the change in the optimal coverage level (i.e., 1 - deductible percent) with respect to a shift in the rate curve holding risk and all other variables constant (e.g. as a result in across-the-board subsidy schedule or rate curve shifts), let the rate curve be parameterized with respect to a shifter as, $r(c) = \bar{r} + \gamma(c)$ where $\gamma(c)$ is a non-linear function of *c* and not a function of $\bar{r}$.[3] Note that, $g(c^*, \bar{r}) = c^* \text{-} h(c^*, \bar{r}) = 0$. By the implicit function theorem, $\frac{\partial c}{\partial \bar{r}} = -\frac{\partial g / \partial \bar{r}}{\partial g / \partial c} = \frac{\partial h / \partial \bar{r}}{1 - \partial h / \partial c}$.

The problem is depicted in the Figure 1 below.

Figure 1 - Depiction of the Solution of Optimal Deductible Problem, *c = *h*(*c**)**



[2] We drop the *'s for notational convenience henceforth unless it is unclear the use.
[3] Here, we ignore discounting. The results do not depend critically on such and could be recast similarly.

A necessary condition for an expected utility maximizing interior solution to exist is that $\left.\frac{\partial h}{\partial c}\right|_{c=c^*} < 1$.[4] The figure above depicts the solution for the optimal coverage level as well as for a shift in $\bar{r}$, assuming $\partial h/\partial\bar{r} < 0$. By the IFT, it is sufficient to show that $\partial h/\partial\bar{r} < 0$ to substantiate $\frac{\partial c^*}{\partial\bar{r}} < 0$, as shown above.

Differentiating h *wrt* $\bar{r}$ yields,[5]

$$\begin{aligned}
&\partial h/\partial\bar{r} = \\
&GcF(Gc)U'(Gc - Gcr(c))\int_{cG}^{\infty} U''(y - Gcr(c))\,f(y)\,dy && (-) \\
&-2F(cG)U'(Gc - Gcr(c))\int_{cG}^{\infty} U'(y - Gcr(c))\,f(y)\,dy && (-) \\
&-\left[\int_{cG}^{\infty} U'(y - Gcr(c))\,f(y)dy\right]^2 && (-) \qquad (5), \\
&-Gc\,F(Gc)U''(Gc - Gcr(c))\int_{cG}^{\infty} U'(y - Gcr(c))\,f(y)\,dy && (+) \\
&-F(Gc)^2\,U'(Gc - Gcr(c))^2 && (-)
\end{aligned}$$

where (+) or (-) is the sign of each term. By itself, it is difficult to assess the sign of the derivative in eqn. (5); however, if we note that, $h(c,\bar{r}) = \frac{1}{r'(c)}\left(\frac{b}{(a+b)} - \mathrm{r}(c,\bar{r})\right)$, it is then sufficient to show that the derivative of c with respect to $\bar{r}$ will be negative if $\frac{\partial[b/(a+b)]}{\partial\bar{r}} < \frac{\partial\mathrm{r}(c)}{\partial\bar{r}}$. Clearly, $\frac{\partial\mathrm{r}(c)}{\partial\bar{r}} = 1$. Since $U'' < 0$, then $\frac{\partial b}{\partial\bar{r}} = -F(cG)U''((c - c\,r(c))G)Gc > 0$, and similarly, $\frac{\partial a}{\partial\bar{r}} > 0$. We cannot assess whether or not $\frac{\partial a}{\partial\bar{r}} > \frac{\partial b}{\partial\bar{r}}$ or if $a > b$ without further information as to any empirical particular case and solution for *c*. However, since *a* and *b*, and their derivatives *wrt* $\bar{r}$, are all positive, it must be the

[4] Note that the derivative of *h wrt c* may be negative, and in fact could be if the rate curve were say very steep in coverage (e.g., which could occur if the subsidy rate were higher at lower coverage levels). The fact that it must be less than one in order to satisfy the SOC is due to concavity of the utility function and convexity of the rate curve. Of course, there could be cases in which the utility functions, distribution, and rate curve may not allow for any interior solution. We do not focus on this case and rule it out in our application due to the fact that we do in fact observe purchases in reality which are interior.

[5] Direct calculation of the derivative via the IFT is precluded here due to the complexity of function. While it can be calculated, it cannot be reasonably interpreted, thus we argue by deduction based on components.

case that $\frac{\partial[b/(a+b)]}{\partial \bar{r}} < 1$. Thus, $\frac{\partial[b/(a+b)]}{\partial \bar{r}} < \frac{\partial \mathrm{r}(c)}{\partial \bar{r}}$ and $\partial c^*/\partial \bar{r} < 0$. The same results can be shown similarly for changes in the slope of the rate curve (i.e., that the optimal coverage level is decreasing in the slope of the rate curve).

Note that the above case assumes that the underlying risk did not change, only the rate curve itself (e.g., as a result of additional loadings or changes in subsidy, and not actuarially driven by actuarially fair rate changes). Next, suppose that there is change in risk, holding all else constant. Let θ be a risk parameter, so that $F(cG\,|\,\theta)$. Assuming the presence of an interior solution, and that the guarantee is less than the mean of the underlying, then $\frac{\partial F(cG\,|\,\theta)}{\partial \theta} > 0$, and $\frac{\partial \int_{cG}^{\infty} f(y\,|\,\theta)\,dy}{\partial \theta} < 0$. Thus, $\frac{\partial[b/(a+b)]}{\partial \theta} > 0$, and so $\frac{\partial c}{\partial \theta} > 0$, provided we do not allow $\mathrm{r}(c)$ to depend on risk.

In the previous case, the optimal coverage decision was deduced under a fixed rate curve/function. However, if the insurer also observes information about the change in risk and modifies the actuarial function correspondingly, then whether the increase in the rate will offset the size of risk reduction effect will be an empirical question generally, and depend on the specific utility function and rating method (i.e., generator for the rate curve). However, in the case of actuarially fair insurance and perfect information, the expected income effect resulting from a change in risk will be zero (i.e., the expected income of insured will not change), but the risk reduction effect will be positive. Thus, $\frac{dc}{d\theta} > 0$. If insurers are risk neutral and can borrow and lend at the risk free rate, then the rate curve is akin to the supply curve for intensity of coverage, and insurers will offer as many units of coverage that the market demands at prices along the rate curve.

As a last point, suppose one sought to evaluate the implications of liquidity or other budgeting constraints. This type of analysis could accommodate by modifying the above expected utility function to include some penalty function for premium Gcr, say $EU = \int_{cG}^{\infty} U\left(y - Gcr(c) - \varphi\left(Gcr(c)\right)\right) f(y)\,dy + \int_{0}^{cG} U\left(Gc - Gcr(c) - \varphi\left(Gcr(c)\right)\right) f(y)\,dy$ and then derive in a straightforward and similar manner. Increasing the severity of such a penalty function will induce downward shifts in optimal coverage. In this case, there could exist cases--even in the actuarially fair ratemaking scenario--such that changes in actuarially fair premium rates could result in a net reduction in coverage choice.

In the case of a rate change only, with no accompanying changes in risk, then the result is still unequivocally that an across-the-board increase/decrease in the rate curve (or conversely, across-the-board decrease/increase in subsidy) will lead to an accompanying decrease/increase in optimal coverage. For example, if there is a decrease in the premium rate, then such decrease will both lessen the liquidity penalty (leading to higher coverage) and lead to an increase in optimal coverage via the fact that $\frac{\partial c}{\partial \theta} > 0$, derived above. The liquidity effects may or may not be symmetric in these two cases though, as it penalizes based on a *certain* amount paid now in premium, but does not similarly compensate expected utility through uncertain/risky recoveries later as a result of indemnity payments.

The above analysis points out several salient points.[6] The first is that, how producers respond to changes in the rate depends inherently on the source or cause of the rate change. If it is due to across-the-board subsidy cuts, say, then the impact on demand is unequivocally negative. If it is due to drifting risk through time (and accompanying increases in actuarially fair premium rates) then the effect could be positive or negative, depending on the actuarial methodology/function that generates the rate curve and any features of the utility function (e.g., with respect to liquidity constraints). The second is that what is observed empirically are actual purchase decisions, and associated rates that correspond to such decisions.

In reality, changes in the menu (producer paid) insurance rates we observe arise from several sources. The implication is that simply running a regression of menu rate actually charged on some measure of insurance quantity actually observed will not result in very comprehensive measures of demand elasticities, necessarily. To make matters worse, if a dummy variable is included for different policy regimes (precisely across which different subsidy regimes exist), then not surprisingly, regression results of the menu rate on quantity (liability, acreage, etc.) can be absorbed by those fixed effects resulting in "elasticities" which are small or zero.

[6] Code is available from the authors upon request for all derivations.

With this in mind, we suggest an alternative approach to operationalize such estimation using information inferred from the rate curve.

Estimable Model of Insurance Deductible Demand under Endogenous Pricing

An important consideration from an empirical standpoint is the potential for endogeneity between the premium rate observed, and the quantity of coverage purchased. In the FCIP, the supply for any given product is essentially perfectly inelastic given mandatory offer requirements. However as noted, higher coverage level products will have higher premium rates as a matter of actuarial construction.

The issue of rate/coverage endogeneity is an important consideration in the FCIP, as since the late 90's there has been a large movement in the market towards higher coverage levels, as well as revenue products (which have higher expected loss costs per unit of liability than do yield policies). The government determines rates by first estimating base rates for the county. The government's rating systems uses the 65% coverage level (i.e., 35% deductible) product premium rate is used as the base rate. Then "coverage level differentials" are applied to construct rates at different coverages. Thus, the rate curve tends to shift up and down from year to year in roughly parallel in response to any changes in base methodology or new experience data.

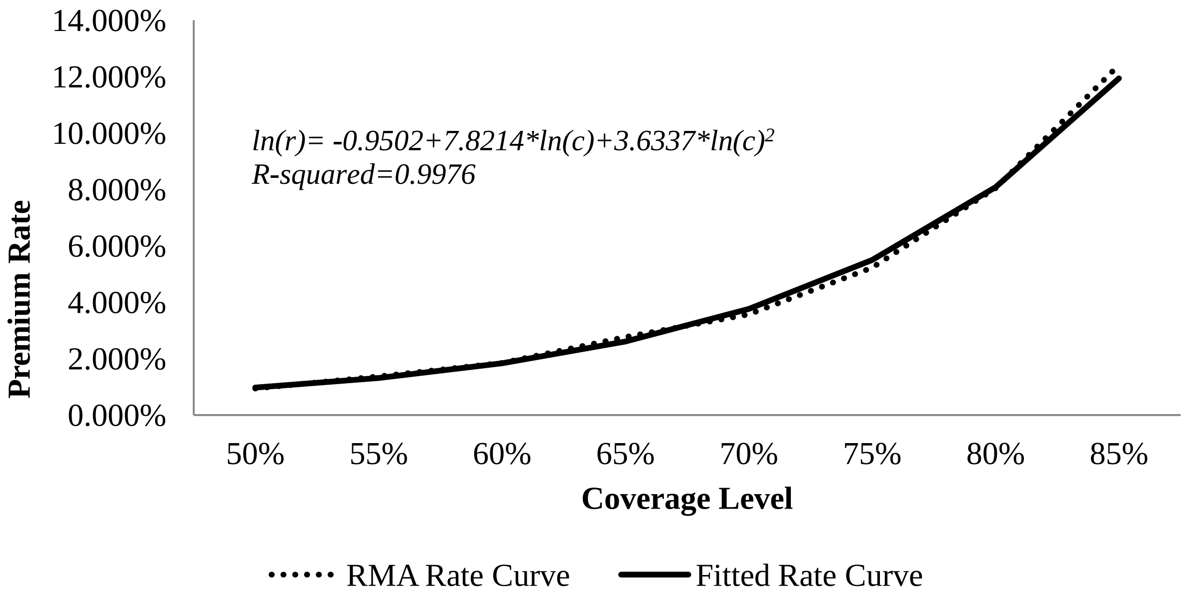
Consider the double-log demand model with *quantity* defined by the coverage level percent (which equals one minus the percent deductible), and *price* by the insurance premium rate,

$\ln(c) = \beta_0 + \beta_1 \ln(r) + \beta_2 x + \varepsilon$, where c is coverage level demanded, r is the premium rate, β_1 is the rate elasticity, x are demand shifters, and ε is a random innovation. In the insurance case, r is not fixed, but rather is a function of the coverage level elected. The standard insurance contract is structured as a put option on the underlying random variable to be insured (e.g., yield, or revenue). Thus, the payoff (or *indemnity*) payable under any given outcome of the underlying insured variable is $I(y \mid G, c) = Max(0, G \times c - y)$, where G is the expected value of the underlying (e.g., expected yield or revenue), $G \times c$ is the maximum possible indemnity (known as the *liability),* and, y is the underlying. The indemnity divided by the liability is known as the *loss cost ratio*, and conceptually is the loss (or indemnity) expressed as a percent of the liability.

The function which represents premium rate as a function of coverage level is commonly referred to as the "rate curve", and is typically convex and upward sloping in coverage, since higher coverage levels have a higher frequency and severity of payoffs under any distribution of the underlying risk. The actuarially fair rate curve can then be expressed as the expected value of the loss cost ratio, $r(c)=\int_0^{Gc}\frac{Max(0,Gc-y)}{Gc}dF(y)$, where $F(y)$ is the distribution of y. In practice the rate at each coverage level is then loaded for expenses, or in the case of many government programs is subsidized. As a matter of actuarial construction, the rate curve is often approximated by some other function based on historical data. Let the rate curve be expressed as an exponential function which is polynomial in the log coverage level $r(c)=\exp\left(\sum_i \alpha_i \ln(c)^i\right)$.

For example, Figure 2 below displays the actual rate curve for crop year 2015 for McLean county Illinois (the largest county by volume) for corn revenue protection insurance, and the fitted rate curve using this approximation above (*R-squared* = 0.9976). Corn accounts for nearly half of all FCIP premiums, with the vast majority being for revenue insurance in the Central Corn Belt.

Figure 2 - Actual and Fitted Rate Curve, McLean County Illinois Revenue Insurance



Note: Figure displays actual rate curve for McLean County, IL, as published by USDA-Risk Management Agency (RMA) for Revenue Protection Insurance during crop year 2015, using an expected yield of 150 bu./acre (Basic Units), and the fitted rate curve using the approximated exponential polynomial in log coverage.

For a given rate curve and demand function, the equilibrium premium rate and coverage level can be found as the solution to a system of equations consisting of the demand equations and the rate curve equation above. For analytical tractability and exposition, consider a second order rate curve approximation. The equilibrium rate can then be obtained by solving,

$$r^* = \exp\left(\alpha_0 + \alpha_1 \ln(c^*) + \alpha_2 \ln(c^*)^2 + \beta_2 x + \varepsilon\right)$$
$$= \exp\left(\alpha_0 + \alpha_1\left(\beta_0 + \beta_1 \ln(r^*) + \beta_2 x + \varepsilon\right) + \alpha_2\left(\beta_0 + \beta_1 \ln(r^*) + \beta_2 x + \varepsilon\right)^2\right)$$

Note that this case is slightly different than the standard approach to solving simultaneous supply and demand equations since the rate curve is not a supply curve strictly speaking, but rather shows the schedule of the *total* amount of premium rate that the insurer demands for accepting commensurate levels of coverage. Also, while the supply curve is typically expressed as quantity supplied as a function of price, the rate curve rather expresses price (i.e., premium rate) as a function of quantity (i.e., coverage level). Taking logs and solving with respect to $\ln(r)$ yields,

$$\ln(r^*) = \alpha_0 + \alpha_1\left(\beta_0 + \beta_1\ln(r^*) + \beta_2 x + \varepsilon\right) + \alpha_2\left(\beta_0 + \beta_1\ln(r^*) + \beta_2 x + \varepsilon\right)^2$$
$$= -\frac{\sqrt{-4\alpha_2\,\beta_1\beta_2\,x - 4\alpha_2\,\beta_1\,\varepsilon + \left(\alpha_1^{\,2} - 4\alpha_0\,\alpha_1\right)\beta_1^{\,2} + \left(-4\alpha_2\,\beta_0 - 2\alpha_1\right)\beta_1 + 1} + 2\alpha_2\left(\beta_1\,\beta_2\,x + \beta_1\,\varepsilon + \left(\beta_0 + \alpha_1\right)\beta_1\right) - 1}{2\,\alpha_2\,\beta_1^{\,2}}$$

The equilibrium coverage level, c^*, can then be derived by inserting the solution for $\ln(r^*)$ into the original equation. Similarly, one can solve for coverage directly by inserting the rate curve into the demand equation and solving for $\ln(c)$ to obtain,

$$\ln(c^*) = -\frac{\sqrt{-4\alpha_2\,\beta_1\beta_2\,x - 4\alpha_2\,\beta_1\,\varepsilon + \left(\alpha_1^{\,2} - 4\alpha_0\,\alpha_1\right)\beta_1^{\,2} + \left(-4\alpha_2\,\beta_0 - 2\alpha_1\right)\beta_1 + 1} + \alpha_1\,\beta_1 - 1}{2\alpha_2\,\beta_1}$$

As is clear from the equations above, the coverage level elected and rate paid by the insurer in observed data are clearly endogenously determined. These implications are discussed below.

Implications for Empirical Specification

In standard supply and demand estimation, it is well known that demand parameters estimated via simple OLS regression of quantity on price will be biased since price is endogenous. The standard identification approach is to instrument the demand equation using the supply shifters. While this case is slightly different given that the rate curve is not technically a supply curve, similar logic reveals that in order to identify the insurance deductible demand equation, information about the rate curve must be used to instrument the demand equation. As the above derivations elucidate, it is clear that the premium rate observed (i.e., analogous to "price" in the standard demand model) is a function of the error term in the demand equation, and is thus endogenous. One candidate method is to utilize instrumental variables approaches, where the instruments are exogenous information about the rate curve itself (i.e., the parameters of the rate curve associated with each observation). If the rate curve applicable to each observation can be parameterized parsimoniously, then parameters related to shifters, slope, and/or curvature of the rate curve can be employed as instruments. Note that these rate curve parameters are analogous to supply shifters in standard supply and demand systems.

In the FCIP, these rate schedules are published prior to the sales period, and thus are exogenous to the actual choice of coverage level in a given year. One can also predict with fairly high certainty what the impact would be of failing to pursue a proper instrumentation strategy. Since the rate curve is strictly upward sloping in coverage, failure to pursue a proper instrumentation strategy would be expected to attenuate recovered elasticity estimates towards a positive number (i.e., towards zero). This effect may be largely responsible for the findings of inelastic insurance demand estimates typically found in the literature.

To our knowledge, this is the first study to propose using such information from the rate curve in order to control for this endogeneity. There is one study which we are aware that mentions this endogeneity in passing in considering deductible demand estimation, that of Michel-Kerjan, Raschk, and Kunreuther (2015). While the application is different than that here, there are some parallels that are instructive. They estimate demand for corporate property and terrorism insurance, and employ an instrument using the policy writing company's liquidity and operating revenue. While this instrument may capture information for shifts in the supply curve across writing companies, it would not identify endogeneity arising from movements along the rate curve by coverage elected as is the case here. For example, consider the case in which two buying companies have bought different deductibles in the same time period from the same writing company. They would both be charged different premiums commensurate with the deductible bought, but simply instrumenting with information from the writing company would not identify this. We build on those approaches by developing the underlying theory and an estimation strategy for the same. In the case of the FCIP, while there are several Approved Insurance Providers (19 at the time of this writing), the rates for all products are set by the government. Companies must sell at the same price, and must sell to anyone. Therefore, in this case, company information is irrelevant. Rather, it is information about the actual slope of the rate curve which is relevant.

An alternative approach would be to discretize the product offerings by coverage level and treat each coverage level as a different product with its own demand equation. The analyst would then estimate demand equations for each coverage level as if separate substitutable "goods". This approach may present some difficulties generally, however, in at least two ways. The first is that the offering at each coverage level is not independent functionally of others, but rather are in a sense systematically mathematically related in a manner similar to how options at different strike prices are related. Thus, ignoring this structure and treating them as different goods could result in loss of information.

Second, and more importantly, it may render the number of estimable parameters to be infeasibly large in many cases. This can lead to both interpretation and estimation efficiency issues and inconsistent signs, and furthermore is arguably not a reasonable representation of the decision process across the spectrum of coverage choice. The prospect of defining a proper set of restrictions to place on such a system in order to reflect the holistic decision (and operationalizing the same), would likely be a tenuous one. Moreover, the estimated elasticities are likely to depend critically on the calibration of such restrictions, and substantiating any particular implementation of the same may be impossible or inconclusive. The method proposed here though, is very simple to implement, interpret, and also has a sound theoretical basis. Next, a representative simulation study is conducted to investigate these impacts.

Simulation Study

Simulations are conducted using the rate curve, demand equation, and equilibrium solutions derived above. For tractability, the rate equation was parameterized as $r(c) = \exp\left(\alpha_0 + \alpha_2 \ln(c)^2\right)$, where $\alpha_0 = 1$, and the rate curve slope parameter $\alpha_2 \sim N(-30,5)$. Note that the simulated rate curve parameter α_2 will be used as the instrument. The demand equation was parameterized as $\ln(c) = \beta_0 + \beta_1 \ln(r) + \varepsilon$, where $\beta_0 = -4$, and the demand elasticity was evaluated over several different values, $\beta_1 = \{-0.5, -1.0, -1.5\}$. Simulations are conducted over sample sizes of N ={500, 750, 1000}. Each trial is run for 1,000 iterations.

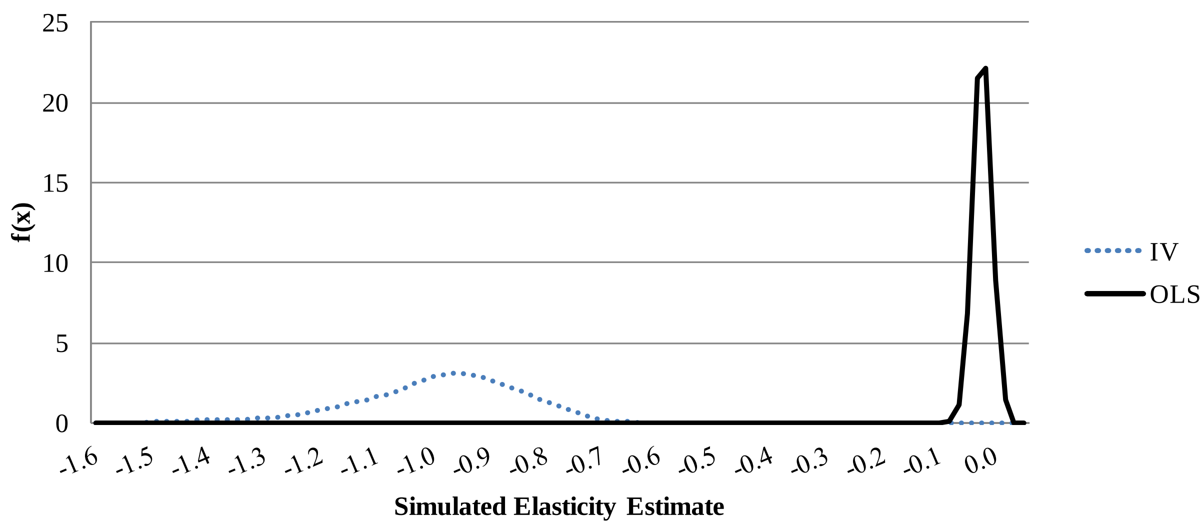
Table 1 presents the simulation results summarized over all trials. Not surprisingly, the demand elasticities recovered via OLS are biased and inconsistent, and are severely attenuated toward zero relative to true values. For example, for a simulated sample size of *N=1,000* and true elasticity equal to -1, the mean recovered elasticity under OLS is -0.07, while the proposed instrumental variables (IV) approach yields approximately -1.00. This is consistent with all elasticity levels and trial sample sizes. Figure 3 displays simulated kernel densities of recovered demand elasticities for the case when *N*=500 and the true elasticity equals -1.

Table 1 - Mean and Standard Deviation of Simulated Demand Elasticities

N	*Demand Elasticity (True)*	*OLS*		*IV*	
		μ	*σ*	*μ*	*σ*
500	-0.5	-0.061	0.010	-0.506	0.054
500	-1	-0.070	0.016	-1.028	0.148
500	-1.5	-0.079	0.020	-1.546	0.254
750	-0.5	-0.061	0.007	-0.503	0.043
750	-1	-0.072	0.014	-1.004	0.114
750	-1.5	-0.082	0.016	-1.517	0.195
1000	-0.5	-0.060	0.007	-0.505	0.038
1000	-1	-0.072	0.011	-1.004	0.103
1000	-1.5	-0.081	0.015	-1.515	0.174

Note: Table presents simulated mean and standard deviation of parameter estimates under OLS and IV estimation over different simulated sample sizes and elasticity parameters.

Figure 3 - Simulated Demand Elasticity Densities, OLS vs. IV (*True Elasticity =-1, N=500*)



Data and Empirical Approach

Insurance records from the United States Department of Agriculture (USDA) Risk Management Agency (RMA) were collected from the Summary of Business (SOB) dataset from 1999-2014. The SOB data contain county level annual summaries by crop, insurance product, and coverage level, and include data on number of policies sold, acreage insured, premiums, subsidies, losses, and liabilities. In the U.S. crop insurance program, base prices at which the insured may guarantee their expected crop are scaled by a projected futures price. The relationship between premium, liability, average yield insured, and coverage level in general is $Prem = G \times c \times P \times r$,where P is projected price, G is a measure of expected yield (known as Actual Production History, or APH, in the FCIP program), and *Prem* is premium. Liability is then $Liab = G \times c \times P$.

Projected crop prices for corn insurance in this region are determined annually using the average of the Chicago Mercantile Exchange (CME) December Corn Futures price during the month of February; this is not a producer choice but rather is dictated by the government. CME Corn Futures Option implied volatilities during the last five days of February are also employed by the USDA for calibrating rates. This study focuses on data for "buy up" coverage (coverage above the 100% subsidized level) for all counties in Illinois for corn revenue insurance policies. Premiums are also subsidized under the FCIP. Producer paid premium rates as faced by the insured were employed for estimation, whereby for each coverage level, the premium rate is calculated by dividing premium minus subsidy by liability. Note that this results in a "projected crop price" normalized measure and is valid for comparisons across regions and years. In order to calculate the rate curve parameters for each county/year, models are fit for each, of the form $r(c) = \exp\left(\hat{\alpha}_0 + \hat{\alpha}_2 \ln(c)^2 + \hat{\phi}\right)$, where $\hat{\phi}$ is a normally distributed error term; $\hat{\alpha}_0$ can be interpreted as a rate curve shifter, and $\hat{\alpha}_2$ a measure of curvature.[7] Counties which do not have at least one thousand acres in each of at least three coverage levels are omitted. The average *R-sq* across all rate curve models was 0.93, and resulted in 928 county/annual observations.

In the estimation below, focus is placed on how demand for coverage level relates to average premium rate observed. Thus, an acreage weighted coverage level measure is constructed as a candidate measure for insurance quantity. In addition to outright coverage as a measure of insurance quantity, a measure of liability/acre is also investigated. In this case, since projected prices vary widely from year to year, a price normalized measure of liability/acre is calculated by dividing total liability for each county by total acres insured, and then dividing by the projected price. Note that the liability/acre measure will also embody within it trends in yields through time; since these trends are universally positive in this region, one would expect

[7] I also investigated using a model with a linear log rate term, but found this was not necessary in order to provide sufficient fit for the rate curves and so opted for the more parsimonious model. Additional analyses using that model did not change the nature of the results. The parameters Ire also very highly correlated and thus including both as instruments in the estimation below was unnecessary.

that the elasticity with respect to the liability/acre quantity measure would be greater than those recovered from the coverage level quantity measure if trend yields drift with rate changes through time (but that the relation between instrumented and non-instrumented models would be similar).

The impact of coverage level scaling is also investigated by constructing a buy-up adjusted coverage level, whereby the "free" coverage level product (50% coverage) is subtracted from the coverage level measure above. This is arguably a better measure of coverage quantity, since 50% coverage is equivalent of paying zero and receiving zero buy up coverage. As a practical matter, the 100% subsidized, 50% deductible Catastrophic insurance (CAT) only provides an arguably modicum of protection which is fairly negligible to most farmers, and in the grand scheme of the FCIP. Thus the adjusted measure is more appropriate for analyzing important program performance decisions. Note that this rescaling should not affect any policy analysis which follows from the models if premium impacts are reconstituted properly; it would be expected to have scaling effects on the magnitude of the elasticity parameter in double log elasticity models, since these models fundamentally measure *percent* change in quantity demanded per *percent* change in premium rate. Thus the rescaling provides a more reasonable elasticity for comparison and interpretation. We estimate the models using standard OLS as well as IV models using two stage least squares with the recovered rate curve parameter as an instrument.

Results

Tables 2 and 3 present results for endogeneity tests using the Augmented Durbin-Wu-Hausman test (Davidson and MacKinnon, 1993), for the coverage level and liability/acre models, respectively, using the estimated rate curve parameter as an instrument. Tests are conducted with and without fixed effects and policy dummies. Not surprisingly, the results unanimously indicate the presence of endogeneity. Farm policy dummies and the individual rate intercepts are also investigated for candidacy as exclusive instruments (instead of also as exogenous variables). Validity tests of the over-identification restrictions using the Sargan test ($\chi^2 = 272.5$) rejected their inclusion, and the recovered rate curve parameter is thus employed as the only instrument. This is not an issue since the system is just identified.

Table 2 - Augmented DWH Endogeneity Test, Coverage Level Model

t-stat	22.8741	13.3495	21.7532	12.0086
p-value		0	0	0
Dep. Var	Coverage	Coverage	Coverage	Coverage
Fixed Effects	No	Yes	No	Yes
Policy Dummies	No	No	Yes	Yes

Table 3- Augmented DWH Endogeneity Test, Liability/Acre Model

t-stat	20.6608	12.4364	19.4194	10.817
p-value	0	0	0	0
Dep. Var	Liability/Acre	Liability/Acre	Liability/Acre	Liability/Acre
Fixed Effects	No	Yes	No	Yes
Policy Dummies	No	No	Yes	Yes

Table 4- Instrument Relevance Tests, Coverage Level Model

F -stat	51.595	35.265	79.283	71.035
p-value	0.000	0.000	0.000	0.000
Partial *R-sq.*	0.056	0.042	0.086	0.085
Dep. Var	Coverage	Coverage	Coverage	Coverage
Fixed Effects	No	Yes	No	Yes
Policy Dummies	No	No	Yes	Yes

Table 5- Instrument Relevance Tests, Liability/Acre Model

F -stat	444.759	35.265	446.5162	71.0354
p-value	6.16E-81	4.22E-09	3.52E-81	1.53E-16
Partial *R-sq.*	0.4803	0.0422	0.4827	0.0851
Dep. Var	Liability/Acre	Liability/Acre	Liability/Acre	Liability/Acre
Fixed Effects	No	Yes	No	Yes
Policy Dummies	No	No	Yes	Yes

Tables 4 and 5 report instrument relevance tests using the partial *F*-test and also report partial *R-squared*, for the coverage level (Table 4) and liability/acre (Table 5) models, respectively. All tests for all models indicate strong evidence of instrument relevance.

Table 6 presents OLS regression results for all coverage and liability/acre models. The different horizontal panels display results with and without policy dummies and fixed effects. Similar to the simulations, demand for all measures are quite inelastic under the standard approach of regressing coverage level or liability per acre on premium rate observed. The OLS coverage level model reveals an elasticity of -0.102 in the pooled model, and -0.076 in the fixed effects model. The comparable adjusted coverage level elasticity (which is perhaps a more relevant elasticity for interpretation) for those models is -0.297 and -0.210. The liability/acre model elasticities under standard OLS under all specifications are likewise inelastic, consistent with the bulk of the previous literature.

Turning attention to Table 7, which presents results for the IV regressions under the proposed approach of instrumenting with parameters of the latent rate curve, reveals that elasticities are consistently orders of magnitude higher than their counter parts under OLS. For example, the adjusted coverage level model elasticities are -1.89 and -1.176 in the models without and with fixed effects, respectively. The adjusted coverage level models (*CovAdj*), not surprisingly, consistently stated elasticities as levels greater than for the unadjusted level (*Cov*). The liability per acre model (*Liab)* rate elasticities where typically the most elastic, but the effect from OLS to IV was consistent with the other models. For example, the liability model with fixed effect in Table 7, panel 2, reveals a rate elasticity for liability of -1.130. The comparable OLS elasticity in Table 6 was -0.353. All estimated elasticities were significant at the 1% level.

These results leave little doubt to whether a) there is endogeneity, b) the instrumentation strategy proposed is addresses the fundamental endogeneity and is well founded, c) that the impact on elasticities recovered are economically and statistically significant, and consistent and robust across approaches, and finally d) that demand for insurance intensity (coverage or liability per acre) are elastic or at least unit elastic. Regardless of the merits of any one of the specific models, the most important takeaway is that the impact of this endogeneity across any specification is robust. In all cases, and under all quantity measures (with or without policy dummies and fixed effects), the recovered elasticities were typically around 3 to 5 times greater in magnitude under IV than under OLS.

Table 6 - OLS Insurance Demand Regression Results

Model	Cov	CovAdj	Liab	Cov	CovAdj	Liab	Cov	CovAdj	Liab	Cov	CovAdj	Liab
Rate Elasticity	**-0.102** **	**-0.297** **	**-0.464** **	**-0.076** **	**-0.210** **	**-0.353** **	**-0.122** **	**-0.358** **	**-0.531** **	**-0.098** **	**-0.277** **	**-0.420** **
std. err.	*0.007*	*0.021*	*0.019*	*0.006*	*0.017*	*0.014*	*0.007*	*0.022*	*0.019*	*0.006*	*0.019*	*0.015*
Constant	-0.596 **	-2.290 **	3.250 **				-0.670 **	-2.526 **	2.994 **			
std. err.	*0.023*	*0.069*	*0.062*				*0.024*	*0.073*	*0.064*			
D2002							0.029 **	0.092 **	0.100 **	0.022 **	0.067 **	0.066 **
std. err.							*0.004*	*0.011*	*0.010*	*0.003*	*0.008*	*0.007*
Fixed Effects	*No*	*No*	*No*	*Yes*	*Yes*	*Yes*	*No*	*No*	*No*	*Yes*	*Yes*	*Yes*

*Note: Tables presents OLS insurance demand results for the coverage level, adjusted coverage level, and liability per acre models (Cov, CovAdj, and Liab) for Illinois corn revenue insurance (1999-2014, N=928) with and without fixed effects and policy dummies (D2002). * = 5% significance, **= 1% significance*

Table 7 - Instrumental Variables (IV) Insurance Demand Regression Results

Model	Cov	CovAdj	Liab	Cov	CovAdj	Liab	Cov	CovAdj	Liab	Cov	CovAdj	Liab
Rate Elasticity	**-0.638** **	**-1.890** **	**-1.829** **	**-0.412** **	**-1.176** **	**-1.130** **	**-0.552** **	**-1.632** **	**-1.593** **	**-0.333** **	**-0.946** **	**-0.936** **
std. err.	*0.082*	*0.246*	*0.212*	*0.064*	*0.187*	*0.151*	*0.056*	*0.168*	*0.142*	*0.036*	*0.106*	*0.083*
Constant	-2.359 **	-7.533 **	-1.238				-2.114 **	-6.796 **	-0.569			
std. err.	*0.271*	*0.808*	*0.697*				*0.189*	*0.562*	*0.475*			
D2002							0.105 **	0.316 **	0.287 **	0.070 **	0.205 **	0.172 **
std. err.							*0.013*	*0.037*	*0.031*	*0.009*	*0.025*	*0.020*
Fixed Effects	*No*	*No*	*No*	*Yes*	*Yes*	*Yes*	*No*	*No*	*No*	*Yes*	*Yes*	*Yes*

*Note: Table presents proposed IV insurance demand results for the coverage level, adjusted coverage level, and liability per acre models (Cov, CovAdj, and Liab) for Illinois corn revenue insurance (1999-2014, N=928) with and without fixed effects and policy dummies (D2002). Instrumental variable is the estimated rate curve parameter for each county/year. * = 5% significance, **= 1% significance*

Conclusion

The premium rate charged for insurance depends on the coverage level (deductible) elected, which is derived from a convex actuarial menu, and as such is endogenous. While an extensive literature exists evaluating insurance demand elasticities generally, very little (if any) focus has been placed on accounting for this fundamental aspect of insurance demand estimation. These core considerations are outlined, and a more comprehensive but still operationally feasible method developed using an instrumental variables approach. Failure to account for the simultaneity of observed rates to coverage level choice in demand models is found to attenuate widely employed demand elasticities recovered under non-IV settings towards zero. The findings suggest that failure to properly account for this phenomenon when estimating demand elasticities induces large bias towards finding inelastic demand.

This has important policy implications. As noted, a recent GAO report suggested that premium subsidies could be cut and premium rates raised significantly without causing much of a demand response in the program (GAO, 2014). Recent publications from the Economic Research Service of the USDA (O'Donahue, 2014) as well as many other studies are cited which support GAO conclusions. The policy implications of our findings are thus fairly important to informing that debate, in that they suggest that actually the program would likely respond fairly abruptly to large cuts in subsidization. It is not the intent of this study to argue for or against subsidization, but simply to investigate the econometric properties of such estimation. This is also not to criticize the GAO by any means for citing the peer reviewed literature. That notwithstanding, policy makers should be properly informed by the most applicable and relevant research when seeking to estimate the impacts of policy changes on demand.

This study focuses on estimating demand for quantity/intensity of coverage for *land that is insured*. These elasticities do not include multiplicative effects of acreage moving into and out of the program due to changes in overall rate levels. Thus, the total market demand elasticity for coverage (i.e., total program liability, or total premium) must be strictly greater than what is uncovered here. Future research evaluating aggregate policy analyses which take into account the combined elasticities of both acreage responses and coverage intensity in a cohesive framework is thus of value. Nevertheless, while we only investigate one region/crop here, the direction of error arising from ignoring this endogeneity is unambiguous and undeniable, and thus fairly generalizable.

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