MANAGING ADVERSE SELECTION: UNDERINSURANCE VS. UNDERENROLLMENT

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Adverse selection in insurance markets may lead some consumers to underinsure or too few consumers to purchase insurance relative to the socially optimal level. I study whether government intervention can simultaneously mitigate underinsurance and underenrollment due to adverse selection. I show there is a tradeoff in addressing underinsurance and underenrollment that has important welfare implications. I then estimate a model of the California ACA insurance exchange using consumer-level data to quantify the welfare impact of risk adjustment and the individual mandate. I find (1) risk adjustment reduces underinsurance, but reduces enrollment and (2) the mandate increases enrollment, but increases underinsurance.

Keywords: Adverse selection, individual mandate, risk adjustment, health insurance, ACA.

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Governments have increasingly intervened in insurance markets to address inefficiencies resulting from asymmetric information. A common model for government intervention is managed competition, in which insurers compete for consumers in regulated markets called exchanges and must comply with rules that govern pricing and design of insurance contracts (Enthoven, 1978). The insurance exchanges established under the Affordable Care Act (ACA) are a prominent example of managed competition.

One of the principal regulatory decisions in the managed competition model is the degree to which insurers are permitted to price discriminate. Rules limiting insurer price discrimination, often referred to as "community rating," are pervasive in insurance markets, including Medicare Advantage and the ACA exchanges. Adverse selection may occur if insurers cannot use information on consumer risk such as health status to price discriminate. Prior work finds empirical evidence of adverse selection in both Medicare Advantage (Brown et al., 2014; Newhouse et al., 2015) and the ACA exchanges (Panhans, 2017).

Adverse selection may cause some consumers to buy too little insurance coverage (Rothschild and Stiglitz, 1976) or not insure at all (Akerlof, 1970), relative to the socially optimal level. To illustrate, suppose consumers can either (1) purchase plan L, which has a low premium and limited benefits; (2) purchase plan H, which has a high premium and comprehensive benefits; or (3) forgo insurance. Underinsurance, an intensive margin effect, arises when low-risk consumers are attracted to plan L because of the high relative premium for plan H. Underenrollment, an extensive margin effect, may occur if there is an influx of high-risk consumers into plan L, raising its premium and causing low-risk consumers to forgo insurance.

Given the ubiquity of community rating in health insurance markets, a particularly relevant question concerns whether it is possible to mitigate both underinsurance and underenrollment. Risk adjustment is an example of a policy that addresses underinsurance due to adverse selection. In the ACA exchanges, risk adjustment requires that plans with lower-than-average risk consumers make transfer payments to plans with higher-than-average risk consumers. If plan L has lower-than-average risk consumers, risk adjustment imposes additional cost on plan L and provides cost relief to plan H, likely increasing plan L's premium and decreasing plan H's premium. Some enrollees in plan L may substitute to plan H, reducing underinsurance, but others may opt to forgo insurance, reducing enrollment and increasing the average risk of those remaining in the pool. A prominent example of a policy that addresses underenrollment due to adverse selection is the individual mandate. Under the ACA, the individual mandate incentivizes enrollment by requiring consumers to purchase insurance or pay a tax penalty. In markets with adverse selection, the mandate motivates low-risk consumers to enroll, improving the risk pool. Low-risk entrants are likely to select plan L, increasing the difference between the plan premiums and potentially leading to a reduction or even unraveling in demand for plan H.

In this paper, I study whether government intervention in insurance markets can simultaneously mitigate underinsurance and underenrollment due to adverse selection. I first develop a two-plan model to illustrate the tradeoff in addressing underinsurance and underenrollment. I show that the occurrence and extent of the tradeoff depends primarily on the Jacobian of the plans' average claims functions, which I refer to as the "claim slope matrix." The claim slope matrix captures both the intensive and extensive margin effects of adverse selection. I show that the underinsurance-underenrollment tradeoff occurs if average claims are more responsive to changes in plan L's premium than changes in plan H's premium. Insurance markets where the premiums of cheap, limited benefit plans drive the risk level of consumers in the market and between plans are consistent with insurance markets likely to be observed in practice.

In the second part of the paper, I study whether the tradeoff between underinsurance and underenrollment is present in the ACA exchanges. The ACA setting is particularly appealing because (1) there is evidence of both underinsurance and underenrollment and (2) several policies targeting adverse selection are in place, including premium subsidies, risk adjustment, and the individual mandate. I extend the basic two-plan model to a differentiated products model of the ACA exchanges that I take to the data. I estimate the model using consumer-level administrative data from the California ACA exchange. My data contain about 2.5 million records and account for approximately 15 percent of nationwide enrollment in the ACA exchanges (Department of Health and Human Services, 2015). Detailed demographic information enables me to precisely calculate the premium that consumers face for each plan in their choice sets, the consumer-specific subsidy received for each plan, and the consumer-specific penalty imposed for forgoing coverage.

With these data, I estimate consumer-level demand using a nested logit discrete choice model. I address potential endogeneity of the premium by exploiting consumer-level variation in premiums created by exogenous ACA regulations. I estimate average claims and the claim slope matrix by combining my demand estimates with non-parametric estimates of marginal claims from the firms' first-order conditions for profit maximization. I relate these estimates to premiums to measure how marginal claims vary with premiums. My claims estimates provide statistically significant evidence of adverse selection.

I use the estimated model to simulate the impact of ACA risk adjustment. This policy counterfactual is particularly relevant given recent litigation challenging the ACA risk adjustment program and the Trump Administration's subsequent decision to temporarily suspend the program.[1] I find that risk adjustment compresses equilibrium premiums; plans in the least expensive and comprehensive tier (known as bronze) become more expensive, while plans in the most expensive and comprehensive tier (known as platinum) become less expensive. Exchange enrollment shifts from bronze to platinum plans, but total enrollment

[1] The decision in *New Mexico Health Connections v. U.S. Department of Health and Human Services* case challenged the ACA's risk adjustment transfer formula. On July 7, 2018, the Trump Administration responded by suspending risk adjustment transfers for the 2017 plan year totaling $\$10.4$ billion. The Trump Administration announced on July 24, 2018 that it would restore the risk adjustment program.

remains about the same because ACA subsidies are linked to the premium of the one of the cheaper exchange plans. I also simulate the impact of converting the ACA's price-linked subsidies to fixed subsidies or vouchers that do not adjust to premiums. Under vouchers, risk adjustment decreases total exchange enrollment and consumer surplus because consumers are exposed to the higher bronze plan premiums.

I then simulate the impact of the ACA's individual mandate penalty, which was set to zero starting in 2019 according to the Tax Cuts and Jobs Act of 2017. I find that the individual mandate decreases bronze plan premiums, but slightly increases platinum plan premiums. Total exchange enrollment increases, but enrollment in platinum plans declines. Consumer surplus falls because platinum enrollment is reduced and consumers do not benefit from the lower bronze plan premiums (i.e., the ACA's price-linked subsidies are reduced). I simulate an alternative scenario where I convert the ACA's price-linked subsidies to vouchers and find the mandate (1) increases exchange enrollment and (2) increases consumer surplus because consumers benefit from the lower bronze plan premiums.

The primary contribution of this paper is to illustrate the tradeoff in mitigating the intensive and extensive margin effects of adverse selection. Most prior work that studies the effects of adverse selection in insurance markets considers either the intensive or extensive margin, but not both simultaneously. The closest paper to mine is concurrent work by Geruso et al. (2018), who construct a novel graphical framework to illustrate the underinsurance-underenrollment tradeoff in the spirit of Einav, Finkelstein, and Cullen (2010). I show the tradeoff analytically and its dependence on the claim slope matrix. I develop an empirical strategy for estimating the claim slope matrix. The approach can be implemented in markets with a large number of products such as the California exchange, where about 75 different plans offered by 11 different firms are available and the claim slope matrix is therefore 75×75.

This paper also augments the extensive literature on risk adjustment (see Ellis (2008) and

Breyer, Bundorf, and Pauly (2012) for thorough reviews) and the individual mandate. Considerable research examines how well risk adjustment programs equalize firm risk (Brown et al., 2014; Newhouse et al., 2015; Geruso et al., 2016), but comparatively less work has studied its impact on coverage and social welfare. Handel, Hendel, and Whinston (2015) and Layton (2017) find that risk adjustment can yield welfare gains by reducing underinsurance. Mahoney and Weyl (2017) develop a theoretical framework showing that risk adjustment can reduce total enrollment. Previous work has considered how the individual mandate affects the extensive margin. These studies have generally found that the mandate has a beneficial, but small impact on enrollment and welfare (Hackmann, Kolstad, and Kowalski, 2015; Frean, Gruber, and Sommers, 2017; Sacks, 2017). I build on these studies by considering how risk adjustment and the mandate affect both underinsurance and underenrollment in a single framework.

I also contribute to the broader economic literature on health insurance. Recent work has considered the economic tradeoffs between "price-linked" subsidies that adjust to premium changes and "fixed" subsidies or vouchers that are set independently of premiums (Jaffe and Shepard, 2017; Tebaldi, 2017). I extend this literature by studying the interaction of the subsidy design with the individual mandate and risk adjustment. My analysis links to the empirical literature that examines the welfare impact of adverse selection in health insurance markets (Cutler and Reber, 1998; Pauly and Herring, 2000; Cardon and Hendel, 2001; Einav et al., 2013; Handel, 2013; Hackmann et al., 2015). This study also adds to the economic literature studying the early experience of the ACA exchanges (Frean et al., 2017; Tebaldi, 2017; Abraham et al., 2017; Sacks, 2017; Domurat, 2017; Drake, 2018).

The remainder of this paper is organized as follows. Section 1 presents a theoretical model illustrating the tradeoff between underinsurance and underenrollment. Section 2 adapts the model to the ACA setting. Section 3 describes the data I use to estimate the model. Section 4 details how I estimate the model. Section 5 uses the model to simulate the impact of risk adjustment and the individual mandate in the ACA exchanges. Section 6 concludes.

1 Basic Model

In this section, I develop an analytically tractable model to illustrate the tradeoff in addressing underinsurance and underenrollment due to adverse selection. The objective is to establish realistic sufficient conditions on the claim slope matrix for the tradeoff to occur.[2] Consider a competitive market with two firms L and H that each sell one plan with premiums p_L and p_H, respectively. Let $q_f \equiv q_f(p_L, p_H)$ be firm f's demand for $f \in \{L, H\}$ with negative own-price partial derivatives $\frac{\partial q_L}{\partial p_L}, \frac{\partial q_H}{\partial p_H} < 0$ and positive cross-price partial derivatives $\frac{\partial q_L}{\partial p_H}, \frac{\partial q_H}{\partial p_L} > 0$. Denote $c_f \equiv c_f(p_L, p_H)$ as average claims, where $c_L \leq c_H$, and $D(\mathbf{c})$ as the corresponding claim slope matrix

$$D(\mathbf{c}) = \begin{bmatrix} \frac{\partial c_L}{\partial p_L} & \frac{\partial c_L}{\partial p_H} \\ \frac{\partial c_H}{\partial p_L} & \frac{\partial c_H}{\partial p_H} \end{bmatrix}$$

Assume that adverse selection is present such that the own-price partial derivatives satisfy $0 < \frac{\partial c_L}{\partial p_L}, \frac{\partial c_H}{\partial p_H} < 1$ and the cross-price partial derivatives satisfy $-1 < \frac{\partial c_L}{\partial p_H}, \frac{\partial c_H}{\partial p_L} < 0$. Further assume that higher total enrollment $q \equiv q_L + q_H$ reduces market average claims $c \equiv (q_L c_L + q_H c_H)/(q_L + q_H)$. That is, $q(p'_L, p'_H) < q(p''_L, p''_H)$ if and only if $c(p'_L, p'_H) > c(p''_L, p''_H)$ for any premium vectors $p' = (p'_L, p'_H)$ and $p'' = (p''_L, p''_H)$. Individual consumers make the same claims regardless of which plan they choose (i.e., there is no moral hazard). Firm profit $\pi_f(p_L, p_H) = [p_f - c_f]q_f$. In equilibrium, the firms earn zero profit such that $p_L = c_L$ and $p_H = c_H$. Below I illustrate how risk adjustment and the individual mandate affect this competitive equilibrium.

[2] To this end, I make several assumptions that I relax in the next section, where I allow for more than two firms selling heterogeneous products, imperfect competition, imperfect risk adjustment, the divergence of average claims and risk, and moral hazard.

1.1 Risk Adjustment

Risk adjustment transfers money from the firm with lower-than-average risk (firm L) to the firm with higher-than-average risk (firm H) such that each firm is exposed to the same risk. Assume each firm's average claims perfectly represents its risk exposure. Under risk adjustment, each firm is exposed to market average claims c, so the risk adjustment transfer per consumer paid by firm L is $t_L \equiv c - c_L$ and the transfer per consumer received by firm H is $t_H \equiv c_H - c$. The equilibrium conditions are

$$\begin{aligned} p_L &= c_L' \equiv c_L + \psi t_L = (1-\psi)c_L + \psi c \\ p_H &= c_H' \equiv c_H - \psi t_H = (1-\psi)c_H + \psi c \end{aligned} \tag{1}$$

where $\psi \in [0,1]$ is the level of risk adjustment. Without risk adjustment, $\psi = 0$ and the firms set premiums equal to their average claims in equilibrium (i.e., $p_L = c_L$ and $p_H = c_H$). Full risk adjustment corresponds to $\psi = 1$ and the firms set premiums equal to the market average claims in equilibrium (i.e., $p_L = p_H = c$). Partial risk adjustment occurs when $0 < \psi < 1$.

In Appendix A, I show that differentiating equilibrium conditions (1) with respect to the level of risk adjustment ψ yields

$$\begin{aligned} \frac{\partial p_L}{\partial \psi} &= \frac{t_L\left(1-\frac{\partial c_H'}{\partial p_H}\right) - t_H\frac{\partial c_L'}{\partial p_H}}{\left(1-\frac{\partial c_L'}{\partial p_L}\right)\left(1-\frac{\partial c_H'}{\partial p_H}\right) - \frac{\partial c_H'}{\partial p_L}\frac{\partial c_L'}{\partial p_H}} \\ \frac{\partial p_H}{\partial \psi} &= \frac{-t_H\left(1-\frac{\partial c_L'}{\partial p_L}\right) + t_L\frac{\partial c_H'}{\partial p_L}}{\left(1-\frac{\partial c_L'}{\partial p_L}\right)\left(1-\frac{\partial c_H'}{\partial p_H}\right) - \frac{\partial c_H'}{\partial p_L}\frac{\partial c_L'}{\partial p_H}} \end{aligned} \tag{2}$$

Appendix A establishes that risk adjustment increases firm L's premium ($\frac{\partial p_L}{\partial \psi} > 0$) and decreases firm H's premium ($\frac{\partial p_H}{\partial \psi} < 0$). Risk adjustment therefore compresses equilibrium premiums. These premium changes are likely to reduce underinsurance if some of firm L's consumers shift to firm H, but could also reduce enrollment if firm L's marginal buyers choose to forgo insurance. Proposition 1.1 gives sufficient conditions on the claim slope matrix for this tradeoff between underinsurance and underenrollment to occur.

Proposition 1.1. *Suppose (i)* $\frac{\partial c'_L}{\partial p_L} > \frac{\partial c'_H}{\partial p_H}$*; (ii)* $\frac{\partial c'_L}{\partial p_L} > |\frac{\partial c'_L}{\partial p_H}|$*; (iii)* $|\frac{\partial c'_H}{\partial p_L}| > \frac{\partial c'_H}{\partial p_H}$*; (iv)* $|\frac{\partial c}{\partial p_L}| > |\frac{\partial c}{\partial p_H}|$*; and (v)* $\frac{t_L \partial c}{\partial p_L} > t_H \frac{\partial c}{\partial p_H}$*.*[3] *Then risk adjustment*

1. *Decreases total enrollment (*$\frac{\partial q}{\partial \psi} < 0$*)*

2. *Decreases underinsurance (*$\frac{\partial q_H}{\partial \psi} > 0$*)*

Proof. See Appendix A. □

The sufficient conditions in Proposition 1.1 are consistent with insurance markets likely to be observed in practice. Taken together, they imply that changes in firm L's premium have a greater impact on average claims in the market and between plans than changes in firm H's premium. The cheaper plan's premium is the key driver of both extensive and intensive margin selection. The first condition means that firm L faces greater own-price effects than firm H. The second condition indicates that firm L's average claims are more responsive to its own premium than its competitor's premium. The third condition indicates that firm H's average claims are more responsive to firm L's premium than its own premium. The fourth condition means that changes in firm L's premium have a bigger impact on market average claims than changes in firm H's premium. The final condition indicates that firm L's premium, scaled by the average transfer t_L, has a greater effect on market average claims than firm H's premium, scaled by the average transfer t_H.

1.2 Individual Mandate

The individual mandate assesses a penalty ρ on consumers who do not purchase a plan. The penalty can be interpreted as the premium for choosing not to purchase insurance. Assume

[3] I could replace the assumptions on c and c' with analogous assumptions on the more primitive c_L and c_H, but instead make assumptions on c and c' for expositional clarity.

that average claims are decreasing in the penalty such that $\frac{\partial c_L}{\partial \rho}, \frac{\partial c_H}{\partial \rho} < 0$ for a given price vector (p_L, p_H). The equilibrium conditions are

$$\begin{aligned} p_L &= c_L(p_L, p_H, \rho) \\ p_H &= c_H(p_L, p_H, \rho) \end{aligned} \tag{3}$$

In Appendix A, I show that differentiating equilibrium conditions (3) with respect to the penalty yields

$$\begin{aligned} \frac{\partial p_L}{\partial \rho} &= \frac{\frac{\partial c_L}{\partial \rho}\left(1 - \frac{\partial c_H}{\partial p_H}\right) + \frac{\partial c_H}{\partial \rho}\frac{\partial c_L}{\partial p_H}}{\left(1 - \frac{\partial c_L}{\partial p_L}\right)\left(1 - \frac{\partial c_H}{\partial p_H}\right) - \frac{\partial c_H}{\partial p_L}\frac{\partial c_L}{\partial p_H}} \\ \frac{\partial p_H}{\partial \rho} &= \frac{\frac{\partial c_H}{\partial \rho}\left(1 - \frac{\partial c_L}{\partial p_L}\right) + \frac{\partial c_L}{\partial \rho}\frac{\partial c_H}{\partial p_L}}{\left(1 - \frac{\partial c_L}{\partial p_L}\right)\left(1 - \frac{\partial c_H}{\partial p_H}\right) - \frac{\partial c_H}{\partial p_L}\frac{\partial c_L}{\partial p_H}} \end{aligned} \tag{4}$$

In general, these partial derivatives cannot be signed. If there exists a tradeoff between underinsurance and underenrollment, the penalty is likely to decrease firm L's premium ($\frac{\partial p_L}{\partial \rho} < 0$) and increase firm H's premium ($\frac{\partial p_H}{\partial \rho} > 0$). Proposition 1.2 gives sufficient conditions on the claim slope matrix for the tradeoff to occur.

Proposition 1.2. *Suppose (i)* $\frac{\partial c_L}{\partial p_L} > \frac{\partial c_H}{\partial p_H}$*; (ii)* $|\frac{\partial c_H}{\partial p_L}| > |\frac{\partial c_L}{\partial p_H}|$*; (iii)* $\frac{\partial c}{\partial p_L} > \frac{\partial c}{\partial p_H}$*; (iv)* $|\frac{\partial c_L}{\partial \rho}| > |\frac{\partial c_H}{\partial \rho}|$*; (v)* $\frac{\partial c_L}{\partial p_L} + |\frac{\partial c_H}{\partial p_L}| > 1$ *and* $\frac{\partial c_H}{\partial p_H} + |\frac{\partial c_L}{\partial p_H}| < 1$*. Then the individual mandate*

1. *Increases total enrollment ($dq/d\rho > 0$)*

2. *Increases underinsurance ($dq_H/d\rho < 0$)*

Proof. See Appendix A. □

As I establish in the proof of Proposition 1.2, the mandate reduces firm L's premium and increases firm H's premium. These premium changes occur because (1) low-risk consumers motivated to enroll by the mandate disproportionately choose the cheaper plan L and reduce its premium relative to firm H's plan and (2) marginal buyers of firm H's plan shift to firm

L's plan, increasing firm H's premium. Consequently, firm L's enrollment increases and firm H's enrollment decreases. The sufficient conditions in Proposition 1.2 are consistent with insurance markets observed in practice and are similar to those in Proposition 1.1 for risk adjustment. Taken together, they imply that changes in firm L's premium have a greater impact on consumer risk in the market and between plans than changes in firm H's premiums.

The model developed in this section shows that the tradeoff between underinsurance and underenrollment can occur in markets likely to be observed in practice. I now turn to the ACA setting to examine whether the tradeoff does occur in practice.

2 ACA Exchange Model

I extend the basic model of the last section to study the tradeoff between underinsurance and underenrollment in the ACA setting. The objective is to develop a model that captures the important market features of the ACA exchanges and can be estimated empirically. I consider a two-stage model where (1) insurers set the premiums of their plans simultaneously to maximize their expected profit and (2) consumers then select a plan to maximize their expected utility. Below I detail how I model household plan choice and then discuss how I model firm premium-setting. I conclude this section by discussing key aspects of the ACA exchanges that are not modeled and how their omission may bias my empirical results.

2.1 Household Plan Choice

Exchange consumers can select from a diverse set of plans. Plans sold on the exchange are classified by their actuarial value (AV), i.e., the expected percentage of health care costs that the insurance plan will cover. The four actuarial value or "metal" tiers are bronze (60 percent AV), silver (70 percent AV), gold (80 percent AV), and platinum (90 percent AV). Individuals under age 30 can buy a more basic catastrophic plan. Silver is the most common choice because eligible consumers must choose silver in order to receive cost sharing reductions (CSRs) that reduce deductibles, copays, etc. Funded by the federal government through 2017, CSRs have the effect of increasing the actuarial value of silver plans as described in Appendix D. In California, plans within a metal tier are standardized to have the same cost sharing parameters (e.g., deductibles, coinsurance rates, copays, etc.).

In the model, households choose the plan that maximizes their utility function

$$U_{ij} \equiv \alpha_i p_{ij}(\mathbf{p}) + x_j'\beta + d_i'\varphi + \xi_j + \epsilon_{ij} \tag{5}$$

where $\mathbf{p}$ is the vector of insurer base premiums, $p_{ij}(\mathbf{p})$ is household i's premium for plan j, d_i is a vector of demographic characteristics, x_j is a vector of observed product characteristics including the plan AV, ξ_j is a vector of unobserved product characteristics, ϵ_{ij} is an error term with cumulative distribution function $G(\cdot)$, and the household i's premium parameter α_i equals

$$\alpha_i = \alpha + d_i'\gamma$$

CSRs enter equation (5) through the plan AV and premium subsidies reduce the household's premium $p_{ij}(\mathbf{p})$. The household's premium is calculated as

$$p_{ij}(\mathbf{p}) = \max\left\{ \underbrace{r_{ij}p_j}_{\substack{\text{full}\\ \text{premium}}} - \underbrace{\max\{r_{ij}p_b - c_i, 0\}}_{\text{premium subsidy}}, 0 \right\} \tag{6}$$

where r_{ij} is the household's rating factor, p_j is the base premium of plan j, p_b is the base premium of the benchmark plan, and c_i is the household's income contribution cap. The product of the rating factor and the insurer's base premium equals the household's full, unsubsidized premium. The ACA limits variation in the rating factor to the age, smoking status, and geographic residence of the household's members. Insurers can charge a 64-

year-old up to 3 times as much as a 21-year-old. Smokers can be charged 50 percent more than non-smokers, but some states including California prohibit tobacco rating. Each state also defines geographic rating areas, usually composed of counties, in which an insurer's premiums must be the same for consumers of the same age and smoking status. Insurers can vary premiums across rating areas, but not within rating areas. The rating area partition for California is shown in Figure 1.

Under the ACA, the household's premium subsidy equals the difference between what the household pays for the benchmark plan ($r_{ij}p_b$) and the household's income contribution cap c_i ($c_i = \infty$ for households ineligible for premium subsidies). The benchmark plan is the second-cheapest silver plan available to the consumer and varies between consumers because of heterogeneous entry into geographic markets. The income contribution cap ranged from 2 percent of annual income for consumers earning 100 percent of the federal poverty level (FPL) and 9.5 percent of annual income for consumers earning 400 percent of FPL in the 2014 plan year. Consumers can apply the premium subsidy towards the premium of any plan except a catastrophic plan. Premium subsidies are available to consumers who (1) have income between 100 and 400 percent of FPL; (2) are citizens or legal residents; (3) are ineligible for public insurance such as Medicare or Medicaid[4]; and (4) lack an "affordable plan offer" through employer-sponsored insurance either as an employee or as a dependent.[5]

The utility of the outside option $U_{i0} = \alpha_i \rho_i + \epsilon_{i0}$, where ρ_i is the household's individual mandate penalty for choosing to forgo insurance. The penalty was phased in between 2014 and 2016. For the 2016 through 2018 plan years, the penalty for a single individual was the greater of $\$695$ and 2.5 percent of income exceeding the filing threshold. The Tax Cuts and Jobs Act of 2017 set the individual penalty to zero starting in 2019. Exemptions from

[4] In states that expanded Medicaid such as California, most households with income below 138 percent of FPL are eligible for Medicaid. Recent immigrants with income below 138 percent of FPL may be ineligible for Medicaid, but eligible to receive exchange subsidies.

[5] A plan is defined as affordable if the employee's contribution to the employer's single coverage plan is less than 9.5 percent of the employee's household income in 2014 and 9.56 percent of income in 2015.

the ACA's individual mandate are made for certain groups, including (1) those with income below the tax filing threshold and (2) individuals who lack access to a health insurance plan that is less than 8 percent of their income in 2014 and 8.05 percent of their income in 2015.

The utility equations yield the household demand function $q_{ij}(\mathbf{p})$ (i.e., the probability household i chooses plan j). The distribution of the error term ϵ_{ij} determines the form of the household demand function. The effect of a change in the insurer's base premium on a subsidized consumer's demand is given by

$$\frac{\partial q_{ik}(\mathbf{p})}{\partial p_j} = \sum_{l \in J} \frac{\partial q_{ik}(\mathbf{p})}{\partial p_{il}(\mathbf{p})} \frac{\partial p_{il}(\mathbf{p})}{\partial p_j}$$

for all plans j, k in the set of available plans J. Assuming a positive subsidy that does not exceed the full, unsubsidized premium, it follows from equation (6) that

$$\frac{\partial p_{il}(\mathbf{p})}{\partial p_j} = \begin{cases} 0 & l = j, j = b \\ r_{ij} & l = j, j \neq b \\ -r_{ib} & l \neq j, j = b \\ 0 & l \neq j, j \neq b \end{cases} \tag{7}$$

For a non-benchmark plan, an infinitesimal premium increase results in consumers paying more for that plan only. However, an infinitesimal increase in the benchmark premium does not affect what subsidized consumers pay for the benchmark plan, but rather reduces what consumers pay for all other plans because of the larger subsidy. The complex relationship between insurer and consumer premiums, endogenous determination of the benchmark premium, and variation in the benchmark plan across consumers due to heterogeneous firm entry create significant computational challenges. Because of the critical role premium subsidies play in addressing adverse selection, I model the ACA's endogenous subsidy design despite the high computational cost.

2.2 Firm Premium-Setting

In the first stage, a risk-neutral profit-maximizing firm sets the base premium for each plan that it sells to maximize its expected profit

$$\pi_f(\mathbf{p}) \quad = \quad R_f(\mathbf{p}) - C_f(\mathbf{p}) + RA_f(\mathbf{p}) + RI_f(\mathbf{p}) - V_f - FC_f \tag{8}$$

where $R_f(\mathbf{p})$ is total premium revenue, $C_f(\mathbf{p})$ is total claims, $RA_f(\mathbf{p})$ is risk adjustment received, $RI_f(\mathbf{p})$ is reinsurance received, V_f is variable administrative cost (e.g., commissions or fees), and FC_f is fixed cost. Firm premium revenue equals

$$R_f(\mathbf{p}) = \sum_{i \in I, j \in J_f} r_{ij} p_j q_{ij}(\mathbf{p})$$

where I is the set of consumers and J_f is the set of plans sold by firm f. Firm claims equal

$$C_f(\mathbf{p}) = c_f(\mathbf{p}) \sum_{i \in I, j \in J_f} q_{ij}(\mathbf{p})$$

where $c_f(\mathbf{p})$ is average claims.

Defining the risk adjustment transfer is somewhat more involved than in the basic model of the last section. As before, firms with lower-than-average risk make risk adjustment transfer payments to firms with higher-than-average risk such that net payments sum to zero (i.e., $\sum_f RA_f = 0$) . The ACA's zero-sum transfer design contrasts with the design used in Medicare Advantage, where risk adjustment payments are benchmarked to the risk of those choosing the outside option (i.e., traditional Medicare) and do not necessarily sum to zero. ACA risk adjustment occurs at the state level for all firms participating in the individual market, including firms offering individual plans off the exchanges. Risk adjustment therefore reduces firm incentives to market in favorable geographic regions of the state or off the exchanges.

In the basic model, I ignored differences in plan actuarial values and discrepancies between claims and risk when calculating the risk adjustment transfer. These two assumptions allowed me to set the per-consumer transfer equal to $c_f(\mathbf{p}) - c(\mathbf{p})$ (i.e., the difference between the firm's average claims and the market average claims). The first assumption is invalid in the ACA setting because plans with lower cost sharing have higher expected claims than plans with higher cost sharing, even if consumers enrolled in the plans have the same risk. Claims are also unlikely to be a precise measure of risk because some firms are more efficient, have greater bargaining power with providers, or have superior ability to exploit the risk adjustment formula. I relax these assumptions by defining the risk adjustment transfer as

$$RA_f(\mathbf{p}) \quad = \quad \phi_f \left(\sum_{i \in I, j \in J_f} q_{ij}(\mathbf{p}) \right) c_f(\mathbf{p}) - rs_f(\mathbf{p}) \left(\sum_{i \in I, j \in J} q_{ij}(\mathbf{p}) \right) c(\mathbf{p}) \tag{9}$$

where ϕ_f is the firm's efficiency score and $rs_f(\mathbf{p})$ is the firm's risk-adjusted share.[6] The firm's efficiency score accounts for all *unobserved* factors that may cause a firm's claims to deviate from its risk. Firms with higher-than-average efficiency scores have $\phi_f > 1$ and firms with lower-than-average efficiency scores have $\phi_f < 1$. Firms for which claims are a precise measure risk have $\phi_f = 1$. I define the firm's risk-adjusted market share $rs_f(\mathbf{p})$ as

$$rs_f(\mathbf{p}) = \frac{\sum_{i \in I, j \in J_f} h_j q_{ij}(\mathbf{p})}{\sum_{i \in I, j \in J} h_j q_{ij}(\mathbf{p})}$$

where h_j is an exogenous utilization factor that accounts for the plan actuarial value and expected moral hazard that results from choosing a more generous plan.

Reinsurance was a temporary program in effect between 2014 and 2016 that helped to offset the realized claims of high-utilization consumers. In total, the ACA reinsurance program made $\$10$ billion, $\$6$ billion, and $\$4$ billion available for reinsurance in the 2014, 2015, and 2016 plan years, respectively. I include reinsurance in the model by defining the actuarial value τ_f of the reinsurance contract (i.e., the expected percentage of claims that

[6] The risk adjustment formula used in the ACA setting differs slightly from formula (9). Appendix C derives the ACA risk adjustment transfer formula and price equilibrium.

the reinsurer will pay). Reinsurance received equals

$$RI_f(\mathbf{p}) = \tau_f C_f(\mathbf{p}) = \tau_f c_f(\mathbf{p}) \sum_{i \in I, j \in J_f} q_{ij}(\mathbf{p})$$

Substituting the risk adjustment and reinsurance formulas into equation (8) yields

$$\pi_f(\mathbf{p}) \quad = \quad R_f(\mathbf{p}) - rs_f(\mathbf{p})C(\mathbf{p}) - (1 - \phi_f - \tau_f)C_f(\mathbf{p}) - V_f - FC_f \tag{10}$$

where $C(\mathbf{p}) = \sum_f C_f(\mathbf{p})$ is total market claims. The firm's corresponding first-order conditions are

$$MR_j(\mathbf{p}) \quad = \quad \overline{MC}_j(\mathbf{p}) + (1 - \phi_f - \tau_f)MC_j(\mathbf{p}) + v_f \frac{\partial q_f(\mathbf{p})/\partial p_j}{\partial q_j(\mathbf{p})/\partial p_j} \tag{11}$$

for all plans offered by the firm, where $q_j(\mathbf{p})$ is plan demand, $q_f(\mathbf{p})$ is total firm demand, v_f is per-consumer variable administrative cost, and formulas for marginal revenue $MR_j(\mathbf{p}) \equiv \frac{\partial R_f(\mathbf{p})}{\partial q_j}$, marginal claims $MC_j(\mathbf{p}) \equiv \frac{\partial C_f(\mathbf{p})}{\partial q_j(\mathbf{p})}$, and "average" marginal claims $\overline{MC}_j(\mathbf{p}) \equiv \frac{\partial (rs_f(\mathbf{p})C(\mathbf{p}))}{\partial q_j(\mathbf{p})}$ are given in Appendix B. Average marginal claims vary by plan and represent what plan j's marginal claims would have been if its enrollees had average risk (they are not an average of marginal claims across plans). Given $\phi_f = 1$ and $\tau_f = v_f = 0$, risk adjustment replaces the firm's own marginal claims with average marginal claims. Risk adjustment therefore raises marginal cost for firms that draw enrollees with lower-than-average risk and reduces marginal cost for firms with higher-than-average risk.

Appendix B shows how every variable in equation (11) can be written in terms of four variables that I can estimate, including: (1) the household choice probabilities $q_{ij}(\mathbf{p})$; (2) the $J \times J$ household demand sensitivity matrix $D_i(\mathbf{q})$; (3) the firm's average claims function $c_f(\mathbf{p})$; and (4) the $J \times J$ claim slope matrix $D(\mathbf{c})$. The (k, j)-element of household i's demand sensitivity matrix equals the partial derivative $\frac{\partial q_{ik}(\mathbf{p})}{\partial p_{ij}(\mathbf{p})}$. The (k, j)-element of the claim slope matrix equals the partial derivative $\frac{\partial c_f(\mathbf{p})}{\partial p_j}$, where firm f sells plan k (but not necessarily plan j).

2.3 Model Limitations

Although I model many of the key features of the ACA exchanges, I am unable to model some policy details. In particular, I lack demand data on individual plans sold outside the ACA exchanges. Only unsubsidized consumers are likely to consider off-exchange plans because consumers cannot receive subsidies for off-exchange plans. Off-exchange plans have to comply with ACA regulations and are rated together with exchange plans as part of a "single risk pool" (i.e., insurers cannot charge lower premiums to off-exchange consumers for the same plan). On average, California exchange plans paid a per-consumer risk adjustment transfer to off-exchange plans of only \$0.80 in 2014 (compared to average claims of \$314) and \$1.10 in 2015 (compared to average claims of \$338) (Department of Managed Health Care, 2016). Hence, selection between exchange and off-exchange plans is negligible.

Data on claims, risk adjustment, and reinsurance are not available at the rating area level. Consequently, I am unable to model how insurers adjust their geographic rating factors (i.e., ratio of premium in a rating area to the plan base premium) when computing equilibrium base premiums in alternative scenarios. Assuming the geographic rating factors are exogenous could downward bias my estimates of risk adjustment's impact if insurers risk select across rating areas. In practice, geographic rating factors are closely reviewed by California regulators and must be supported with cost data in rate filings.

Because modeling the ACA's endogenous subsidy imposes significant computational challenges, I make compromises elsewhere. I do not permit insurer entry and exit in the model. Although elimination of policies targeting adverse selection could prompt some insurers to exit, no California insurers exited any rating areas in 2019 when the mandate penalty was set to zero. I also assume that products sets and characteristics are exogenous.

This assumption is not particularly onerous because of the ACA's metal tier structure and strict regulations on minimum essential benefits. California has standardized cost sharing parameters and requires insurers to offer exactly one plan in each metal tier. However, firms could use narrow provider networks and restrictive formularies to attract low-risk consumers in the absence of risk adjustment. Ignoring provider networks and formularies could bias the magnitude of my estimates, but is unlikely to have a bearing on my central research question of whether there is tradeoff between underinsurance and underenrollment.

3 Data

To estimate the model, I obtain demand and cost data from several sources. One of the distinguishing features of my empirical analysis is the use of detailed consumer-level enrollment data from Covered California, the ACA exchange in California. There are approximately 2.5 million records in my data, which cover the 2014 and 2015 plan years. Table I summarizes the demand data by firm market share. The California exchange has robust firm participation. Four firms – Anthem, Blue Shield, Centene, and Kaiser – have 95 percent of the market share. The California exchange enrollment data indicate every exchange enrollee's selected plan and key demographic information, such as age, county of residence, income, gender, and subsidy eligibility. These demographic characteristics and rating factors from insurer rate filings (Department of Managed Health Care, 2016) enable me to (1) define the household's complete menu of plan choices and (2) precisely calculate the household-specific premium from the plan base premium.

I use the American Community Survey (ACS) to obtain data on uninsured consumers (Ruggles et al., 2016). I exclude undocumented immigrants and any consumers enrolled in or eligible for another source of insurance coverage. Records from the exchange enrollment data and the ACS form the universe of potential exchange consumers. Table II presents summary statistics on exchange enrollees and the uninsured. Silver is the most commonly selected option because consumers eligible for CSRs must choose a silver plan to receive CSRs. The meager enrollment in gold and platinum plans suggests that underinsurance may be an issue in the exchanges. The large number that choose to forgo exchange coverage may indicate that underenrollment is also a problem.

Data on firm costs come from the medical loss ratio (MLR) reports (Centers for Medicare and Medicaid Services, 2017) and other CMS reports (Centers for Medicare and Medicaid Services, 2015, 2016). These data provide state-level information on risk adjustment, reinsurance, firm claims, variable administrative cost, and fixed administrative cost for each firm. Table III summarizes average claims, risk adjustment transfers, and reinsurance recoveries. Although I do not directly observe the efficiency scores, I can solve for them in the ACA risk adjustment transfer formula (28) using data on realized firm risk adjustment transfers, claims, premiums, and risk-adjusted shares. The utilization factors used in calculating the risk-adjusted share come directly from the formula used by CMS (Pope et al., 2014).

4 Estimation

In this section, I explain how I use the data to estimate the model. Every variable in the model is defined in terms of four variables: (1) the household choice probabilities $q_{ij}(\mathbf{p})$; (2) the household demand sensitivity matrix $D_i(\mathbf{q})$; (3) the firm's average claims function $c_f(\mathbf{p})$; and (4) the claim slope matrix $D(\mathbf{c})$. I discuss how I estimate demand and then explain how I use the demand estimates to estimate claims.

4.1 Estimating Demand

To calculate the household choice probabilities and household demand sensitivity matrix, I model equation (5) as a nested logit at the consumer level, where the vector of error terms ϵ_i has the generalized extreme value distribution. I create two nests: 1) a nest containing all exchange plans and 2) a nest containing only the outside option. I use this two-nest structure because the key observed substitution pattern is between the silver tier and the outside option due to the ACA's linkage of CSRs to the purchase of silver plans. The household choice probabilities are computed as

$$q_{ij}(\mathbf{p};\boldsymbol{\theta}) \quad = \quad \frac{e^{V_{ij}/\lambda}\left(\sum_j e^{V_{ij}/\lambda}\right)^{\lambda-1}}{1+\left(\sum_j e^{V_{ij}/\lambda}\right)^{\lambda}} \tag{12}$$

where $\boldsymbol{\theta}$ is the vector of parameters in equation (5), $V_{ij} \equiv \alpha_i p_{ij}(\mathbf{p}) + x_j'\beta + d_i'\varphi + \xi_j$, and λ is the nesting parameter for the exchange nest. The (k, j) element of the demand sensitivity matrix is given by

$$\frac{\partial q_{ik}(\mathbf{p},\boldsymbol{\theta})}{\partial p_{ij}} = \begin{cases} \alpha q_{ij}(\mathbf{p})\left[\frac{1}{\lambda} + \frac{\lambda-1}{\lambda} q_{ij}'(\mathbf{p}) - q_{ij}(\mathbf{p})\right] & k = j \\ \alpha q_{ij}(\mathbf{p})\left[\frac{\lambda-1}{\lambda} q_{ij}'(\mathbf{p}) - q_{ij}(\mathbf{p})\right] & k \neq j \end{cases} \tag{13}$$

where $q_{ij}'(\mathbf{p})$ is the probability of choosing j, conditional on choosing a plan. I use the estimates of parameter vector $\boldsymbol{\theta}$ from Saltzman (2019). Table IV shows the implied elasticities and semi-elasticities. My estimates are consistent with other estimates of premium sensitivity in the California exchange (Tebaldi, 2017; Domurat, 2017; Drake, 2018).

The main challenge with estimating $\boldsymbol{\theta}$ is identifying the effect of premiums on household choices. In Saltzman (2019), I exploit several sources of variation in absolute premiums (i.e., relative to the outside option) and relative premiums (i.e., between plans). Sources of plausibly exogenous variation in absolute premiums include the increase in mandate penalty assessments between 2014 and 2015 and the 57 percent increase in the government's age rating curve that creates a discontinuity in premiums between ages 20 and 21. Sharp income-based thresholds such as the mandate exemptions and premium subsidy eligibility threshold at 400 percent of FPL create variation in absolute premiums, although consumers may be able to manipulate their incomes. Subsidies are also endogenous because they depend on the benchmark premium. The age 30 threshold for purchasing a catastrophic plan creates exogenous within-market variation in choice sets. Consumers face different relative premiums for catastrophic plans because subsidies cannot be used to purchase a catastrophic plan. There is also significant variation in choice sets and relative premiums across the 19 California rating areas. Unobservables such as provider networks and formularies may be correlated with premiums across insurers and markets. I address this concern by estimating equation (5) with insurer-market fixed effects. Ho and Pakes (2014) and Tebaldi (2017) follow a similar approach. My estimates are very similar when including insurer-market fixed effects. As a final robustness check, I estimate $\boldsymbol{\theta}$ with the control function approach of Petrin and Train (2010) using the insurers' geographic cost factors as instruments. The magnitude of the premium parameter is only slightly larger using the control function approach.

4.2 Estimating Claims

To estimate each firm's average claims function and the claim slope matrix, I combine my demand estimates with firm-level cost data from several sources. I specify the average claims function

$$c_f(\mathbf{p}) = \sum_{k \in J_f} [b_1 \log(q_k(\mathbf{p})) + b_2 x_k q_k(\mathbf{p})] + d_f \tag{14}$$

where b_1, b_2, and d_f are parameters to be estimated. Each firm's claims are a function of its own premiums and the premiums of its competitors. Firms therefore perceive how their premiums affect their claims relative to the outside option and relative to their competitors.

The logarithmic form of equation (14) captures the idea that the marginal consumer will have a greater impact on average claims at low levels of demand than at high levels of demand. The total differential of equation (14) equals

$$dc_f(\mathbf{p}) = \sum_{k \in J_f} \frac{\partial c_f(\mathbf{p})}{\partial q_k(\mathbf{p})} dq_k(\mathbf{p}) = \sum_{k \in J_f} \left[b_1 [q_k(\mathbf{p})]^{-1} + b_2 x_k \right] dq_k(\mathbf{p}) \tag{15}$$

where $\frac{\partial c_f(\mathbf{p})}{\partial q_k(\mathbf{p})} = b_1[q_k(\mathbf{p})]^{-1} + b_2 x_k$ is linear in inverse demand $[q_k(\mathbf{p})]^{-1}$ and product characteristics x_k. I can estimate the claims function parameters b_1 and b_2 by regressing the partial derivative $\frac{\partial c_f(\mathbf{p})}{\partial q_k(\mathbf{p})}$ on inverse demand and product characteristics. I recover the claims function intercept d_f for each firm using the observed averaged claims and the predicted partial derivatives $\frac{\partial c_f(\mathbf{p})}{\partial q_k(\mathbf{p})}$ for all $k \in J_f$ as the initial condition.

There are two important empirical challenges with this approach. First, I do not directly observe the partial derivative $\frac{\partial c_f(\mathbf{p})}{\partial q_k(\mathbf{p})}$. To estimate $\frac{\partial c_f(\mathbf{p})}{\partial q_k(\mathbf{p})}$, I assume that the exchanges are in equilibrium, allowing me to invert first-order conditions (30) to obtain non-parametric estimates of average marginal claims. I then solve for $\frac{\partial c_f(\mathbf{p})}{\partial q_k(\mathbf{p})}$ in (30). Inversion of the first-order conditions is possible because I have written the model such that the system of first-order conditions is full rank. Assuming that the exchanges are in equilibrium, particularly when the exchanges were established in 2014, could be dubious. To determine how this assumption biases my estimates, I compare data on the insurers' predicted and realized average claims from the insurers' rate filings. I find a Pearson correlation coefficient of -0.39 between the insurers' prediction error (predicted minus realized average claims) and the estimated partial derivatives $\frac{\partial c_f(\mathbf{p})}{\partial q_k(\mathbf{p})}$ from inverting the first-order conditions. This negative correlation indicates that if the insurers' predictions had been accurate, there would be more variance in my estimates of $\frac{\partial c_f(\mathbf{p})}{\partial q_k(\mathbf{p})}$ according to marginal claims formula (26) (i.e., larger values of $\frac{\partial c_f(\mathbf{p})}{\partial q_k(\mathbf{p})}$ become larger, while smaller values become smaller),. Hence, the estimated magnitude of parameter b_1 would be larger. The likely effect of assuming the exchanges are in equilibrium, therefore, is to underestimate the impact of policy changes and reduce the likelihood of observing a tradeoff between underinsurance and underenrollment.

The second challenge is that the base premiums (and hence demand) may be endogenous in equation (15), potentially biasing the estimate of parameter b_1. Because I lack consumer-level claims data, I cannot exploit exogenous consumer-level variation in premiums created by ACA regulations as I did to estimate demand. Premiums vary across insurers and between plans offered by the same insurer. I include insurer fixed effects in equation (15) to control for unobserved product characteristics that vary across insurers, such as customer service, provider networks, and formularies. I argue that variation in premiums between plans offered by the same insurer is either exogenous (e.g., the regulated metal tier structure) or observable (e.g., the plan network type and whether the plan is compatible with a health savings account). The magnitude of parameter b_1 is likely to have a standard downward bias if my identification argument fails. Consequently, I would underestimate the impact of policy changes and be less likely to observe a tradeoff between underinsurance and underenrollment.

Table V presents the estimated parameters. The negative value of b_1 is consistent with a market where adverse selection is present; increases in demand reduce average claims, given the plan actuarial value and any associated moral hazard. Conversely, the positive coefficient on the actuarial value variable indicates that more generous plans increase average claims. In the specification with insurer fixed effects, the Health Maintenance Organization (HMO) parameter is negative and statistically significant, consistent with the idea that restricting network access reduces average claims. Adding insurer fixed effects has minimal effect; the magnitudes of the inverse demand and actuarial value parameters slightly increase.

I can calculate all elements of the $J \times J$ claim slope matrix by combining my estimates of the demand sensitivity matrix with estimates of $\frac{\partial c_f(\mathbf{p})}{\partial q_k(\mathbf{p})}$. The (k, j)-element of the claim slope matrix is calculated as

$$\frac{\partial c_f(\mathbf{p})}{\partial p_j} = \frac{\partial c_f(\mathbf{p})}{\partial q_k(\mathbf{p})} \frac{\partial q_k(\mathbf{p})}{\partial p_j} \tag{16}$$

where firm f sells plan k (and may or may not sell plan j). I use formula (16) to calculate how a firm's average claims respond to changes in its own premiums, as well as changes in its competitors' premiums.

5 Simulations

5.1 Simulation Design

I use the estimated model to simulate the impact of risk adjustment and the individual mandate in the ACA exchanges. To estimate the model, I assumed that the observed ACA premiums define a Nash equilibrium that satisfies the firms' first order conditions defined in (30). This Nash equilibrium occurs in the ACA policy environment where risk adjustment, the individual mandate, and ACA price-linked subsidies are in place. I simulate four changes to the ACA policy environment: (1) eliminate risk adjustment; (2) replace ACA subsidies with vouchers; (3) eliminate the mandate; and (4) eliminate the mandate and replace ACA subsidies with vouchers. I simulate the elimination of risk adjustment by solving for the vector of premiums that satisfy the first-order conditions

$$MR_j(\mathbf{p}) \quad = \quad (1 - \tau_f) MC_j(\mathbf{p}) + v_f \frac{\partial q_f(\mathbf{p})/\partial p_j}{\partial q_j(\mathbf{p})/\partial p_j} \tag{17}$$

for all plans j. I replace ACA subsidies with vouchers by making the benchmark premium p_b in the consumer premium formula (6) a constant equal to the benchmark premium in the first counterfactual scenario; I then resolve equation (30) for the Nash equilibrium. Fixing the benchmark premium has the effect of replacing formula (7) with

$$\frac{\partial p_{il}(\mathbf{p})}{\partial p_j} = \begin{cases} r_{ij} & l = j \\ 0 & l \neq j \end{cases} \tag{18}$$

I simulate repeal of the mandate by setting the penalty to zero and then resolving equation (30) for the new Nash equilibrium. In the final scenario, I resolve equation (30) after setting the penalty to zero and making the benchmark premium in the formula (6) a constant equal to the observed ACA benchmark premium.

For each simulation, I compute several measures. Coverage is calculated using equation (12). I compute firm profit in the first scenario as $\pi_f(\mathbf{p}) = R_f(\mathbf{p}) - C_f(\mathbf{p}) + RI_f(\mathbf{p}) - V_f - FC_f$ and use equation (8) to compute profit in the second, third, and fourth scenarios. I also compute consumer surplus $CS_i = (\lambda/\alpha_i) \ln \left(\sum_{j \in J} \exp\left(U_{ij}/\lambda\right) \right)$. Government spending on premium subsidies equals the sum of subsidies received by each consumer in formula (6). Spending on CSRs is computed using formula (31) in Appendix D. I calculate government spending on uncompensated care by multiplying the number of uninsured that I estimate in each scenario by (1) the per-capita amount of medical costs that are paid on behalf of the nonelderly uninsured as estimated by Coughlin et al. (2014) and (2) an inflation factor using data from the National Health Expenditure Accounts to adjust the estimates to the timeframe of this study (Centers for Medicare and Medicaid Services, 2018). Total social welfare equals the sum of consumer surplus, firm profit, and government spending.

5.2 Results

Consider the impact of risk adjustment. Table VI compares average ACA premiums to average premiums in scenario 1 where risk adjustment is eliminated. Risk adjustment leads to reductions in (unsubsidized) platinum and gold premiums by 25 and 15 percent, respectively, and increases in (unsubsidized) bronze and silver premiums by 11 and 2 percent, respectively. Table VI indicates that risk adjustment reduces silver premiums for insurers such as Sharp and Western that have the highest premiums in the absence of risk adjustment. Conversely, premiums rise for insurers such as L.A. Care and Molina that have the lowest premiums without risk adjustment. Table VII shows how risk adjustment affects insurance coverage. The total number of consumers who purchase insurance remains about the same. Enrollment in bronze and silver plans declines under risk adjustment, while enrollment in platinum plans is more than doubled.

Consumers receive larger subsidies under the ACA than in scenario 1 because higher silver plan premiums increase the subsidies that consumers receive. The third column of Tables VI and VII shows the impact of risk adjustment when subsidies are fixed at the level in scenario 1. Premiums and the enrollment distribution across the metal tiers are similar under the ACA and scenario 2, but total coverage is lower in scenario 2. The reason is that the ACA's subsidy design shields consumers from the higher bronze and silver plan premiums that result from risk adjustment. Controlling for subsidy levels, risk adjustment addresses underinsurance, but exacerbates underenrollment.

In Table VIII, I report the impact of risk adjustment on per-capita social welfare. To calculate per-capita amounts, I divide all total dollar amounts by the number of consumers in the market, including those choosing the outside option. ACA risk adjustment increases annual consumer surplus by about \$200 per consumer compared to scenario 1 because average premiums for gold and platinum plans are lower and higher subsidies limit consumer exposure to higher bronze and silver plan premiums. Increased spending on premium subsidies largely offsets the gains in consumer surplus. In contrast, risk adjustment in scenario 2 decreases consumer surplus by about \$200 per year compared to scenario 1. Taxpayer outlays are largely unchanged. Importantly, consumer surplus falls by more than the government saves in premium subsidy outlays, explaining most of the decrease in total social welfare. The loss of highly-profitable low-risk consumers reduces firm profit. Per-capita social welfare declines by about $460 per year.

Now consider the impact of the individual mandate. Table IX compares average ACA premiums to average premiums in scenario 3 where the mandate is repealed. The mandate reduces (unsubsidized) bronze plan premiums by about 4 percent, while (unsubsidized) platinum plan premiums increase by 1.7 percent. Silver and gold plan premiums also decrease modestly. Although the unsubsidized premium impacts may seem small, many consumers face substantially larger percentage changes in premiums after accounting for subsidies.[7] Table X indicates that the mandate increases total exchange enrollment by 24 percent, but shifts enrollment from platinum plans to bronze and silver plans. The individual mandate therefore addresses underenrollment, but exacerbates underinsurance. Table XI indicates that the mandate decreases consumer surplus by about $150 per consumer per year because (1) platinum plan premiums are higher; (2) some consumers are compelled to purchase insurance against their will; and (3) subsidies are lower, limiting the extent to which consumers benefit from lower bronze, silver, and gold premiums. Although subsidy spending increases because of higher exchange enrollment, the government generates revenue from the individual mandate penalty and has reduced uncompensated care costs. Overall, the mandate has minimal net impact on social welfare.

The third columns of Tables IX and X show the impact of the mandate when consumer subsidies are fixed at ACA levels. The effect of the mandate on premiums is not particularly sensitive to the subsidy design, but total exchange enrollment is lower in scenario 4 than in scenario 3. The mandate increases annual per-capita consumer surplus by about $150 per consumer vouchers because consumers benefit from the lower bronze, silver, and gold

[7]For example, suppose a hypothetical consumer is eligible for a $200 subsidy. On average, the consumer would pay $115 for a gold plan and $153 for a platinum plan (i.e., 33 percent more for platinum). Eliminating the mandate roughly increases the consumer's subsidy by $3 to $203 because of the increase in silver premiums. Consumers would now pay $123 for a gold plan and $144 for a platinum plan (i.e., 17 percent more for platinum).

plan premiums (i.e., subsidies are not reduced). The gains in consumer surplus, however, are offset by higher subsidy spending due to higher exchange enrollment. The overall social welfare impact is not particularly sensitive to the subsidy design.

6 Conclusion

Mitigating underinsurance and underenrollment due to adverse selection is a key challenge in the design of efficient insurance markets. In this paper, I study whether it is possible to address both underinsurance and underenrollment simultaneously. I show that there is a tradeoff in addressing the intensive and extensive margin effects of adverse selection which could have important implications for social welfare. I illustrate the tradeoff by studying the impact of risk adjustment and the individual mandate both theoretically and empirically in the ACA exchanges. I find that risk adjustment addresses underinsurance, but reduces enrollment. Conversely, the mandate increases enrollment, but also increases underinsurance.

There are several dimensions along which the analysis in this paper could be extended. It would be particularly valuable to study how market structure affects the nature of the tradeoff between underinsurance and underenrollment. Adding a network formation stage to the exchange model where providers and insurers bargain over inclusion in the network would partially address the assumption that product characteristics are exogenous. A dynamic framework that models how insurers learn over time could improve the accuracy of the welfare estimates. Studying markets without community rating is another fruitful area for future research. High-risk pools or guaranteed renewable insurance policies with longer time horizons that are not subject to community rating regulation (Pauly et al., 1995; Herring and Pauly, 2006) are alternatives that may avoid the underinsurance-underenrollment tradeoff examined in this paper.

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Appendix A: Proofs for the Basic Model

Finding $\frac{\partial p_L}{\partial \psi}$ and $\frac{\partial p_H}{\partial \psi}$

Differentiating price equations (1) with respect to ψ yields

$$\begin{aligned}\frac{\partial p_L}{\partial \psi} &= \frac{\partial c_L'}{\partial \psi} = t_L + (1-\psi)\frac{\partial c_L}{\partial \psi} + \psi\frac{\partial c}{\partial \psi} \\ &= t_L + (1-\psi)\left(\frac{\partial c_L}{\partial p_L}\frac{\partial p_L}{\partial \psi} + \frac{\partial c_L}{\partial p_H}\frac{\partial p_H}{\partial \psi}\right) + \psi\left(\frac{\partial c}{\partial p_L}\frac{\partial p_L}{\partial \psi} + \frac{\partial c}{\partial p_H}\frac{\partial p_H}{\partial \psi}\right) \qquad (19)\end{aligned}$$

$$\begin{aligned}\frac{\partial p_H}{\partial \psi} &= \frac{\partial c_H'}{\partial \psi} = -t_H + (1-\psi)\frac{\partial c_H}{\partial \psi} + \psi\frac{\partial c}{\partial \psi} \\ &= -t_H + (1-\psi)\left(\frac{\partial c_H}{\partial p_L}\frac{\partial p_L}{\partial \psi} + \frac{\partial c_H}{\partial p_H}\frac{\partial p_H}{\partial \psi}\right) + \psi\left(\frac{\partial c}{\partial p_L}\frac{\partial p_L}{\partial \psi} + \frac{\partial c}{\partial p_H}\frac{\partial p_H}{\partial \psi}\right) \qquad (20)\end{aligned}$$

Solving equation (20) for $\frac{\partial p_H}{\partial \psi}$ yields

$$\frac{\partial p_H}{\partial \psi} = \frac{-t_H + (1-\psi)\frac{\partial c_H}{\partial p_L}\frac{\partial p_L}{\partial \psi} + \psi\frac{\partial c}{\partial p_L}\frac{\partial p_L}{\partial \psi}}{1-(1-\psi)\frac{\partial c_H}{\partial p_H} - \psi\frac{\partial c}{\partial p_H}} \qquad (21)$$

Substituting the right-hand side of equation (21) into equation (19) and solving for $\frac{\partial p_L}{\partial \psi}$ yields

$$\frac{\partial p_L}{\partial \psi} = \frac{t_L\left(1-\frac{\partial c_H'}{\partial p_H}\right) - t_H\frac{\partial c_L'}{\partial p_H}}{\left(1-\frac{\partial c_L'}{\partial p_L}\right)\left(1-\frac{\partial c_H'}{\partial p_H}\right) - \frac{\partial c_H'}{\partial p_L}\frac{\partial c_L'}{\partial p_H}}$$

Substituting for $\frac{\partial p_L}{\partial \psi}$ in equation (20) and solving for $\frac{\partial p_H}{\partial \psi}$ yields

$$\frac{\partial p_H}{\partial \psi} = \frac{-t_H\left(1-\frac{\partial c_L'}{\partial p_L}\right) + t_L\frac{\partial c_H'}{\partial p_L}}{\left(1-\frac{\partial c_L'}{\partial p_L}\right)\left(1-\frac{\partial c_H'}{\partial p_H}\right) - \frac{\partial c_H'}{\partial p_L}\frac{\partial c_L'}{\partial p_H}}$$

Proof of Proposition 1.1

The first step is show that the partial derivative $\frac{\partial p_L}{\partial \psi}$ is positive and the partial derivative $\frac{\partial p_H}{\partial \psi}$ is negative. Observe that the numerator of the partial derivative $\frac{\partial p_L}{\partial \psi}$ is positive and the numerator of the partial derivative $\frac{\partial p_H}{\partial \psi}$ is negative because the average transfers t_L and t_H are positive, the own-price partial derivatives satisfy $0 < \frac{\partial c_L'}{\partial p_L}, \frac{\partial c_H'}{\partial p_H} < 1$, and the cross-price partial derivatives satisfy $-1 < \frac{\partial c_L'}{\partial p_H}, \frac{\partial c_H'}{\partial p_L} < 0$. The common denominator $\left(1-\frac{\partial c_L'}{\partial p_L}\right)\left(1-\frac{\partial c_H'}{\partial p_H}\right) - \frac{\partial c_H'}{\partial p_L}\frac{\partial c_L'}{\partial p_H}$ must be strictly positive for the partial derivatives in (2) to be economically meaningful. If the common denominator were negative, higher average transfers would imply larger premium reductions for firm L's plan (i.e., $\frac{\partial p_L}{\partial \psi}$ becomes more negative) and larger premium increases for the firm H's plan (i.e., $\frac{\partial p_H}{\partial \psi}$ becomes more positive). It follows that the partial derivative $\frac{\partial p_L}{\partial \psi}$ is positive and the partial derivative $\frac{\partial p_H}{\partial \psi}$ is negative. Risk adjustment therefore compresses equilibrium premiums such that firm L's premium is increased and the firm H's premium is reduced.

Now consider the effect of risk adjustment on enrollment in firm H's plan. Observe that

$$\frac{\partial q_H}{\partial \psi} = \frac{\partial q_H}{\partial p_L}\frac{\partial p_L}{\partial \psi} + \frac{\partial q_H}{\partial p_H}\frac{\partial p_H}{\partial \psi} > 0$$

because $\frac{\partial q_H}{\partial p_L} > 0$, $\frac{\partial p_L}{\partial \psi} > 0$, $\frac{\partial q_H}{\partial p_H} < 0$, and $\frac{\partial p_H}{\partial \psi} < 0$. Hence, risk adjustment reduces underinsurance.

Now consider the effect of risk adjustment on total enrollment. The effect of risk adjustment on average market claims is given by

$$\begin{aligned}
\frac{\partial c}{\partial \psi} &= \frac{\partial c}{\partial p_L}\frac{\partial p_L}{\partial \psi} + \frac{\partial c}{\partial p_H}\frac{\partial p_H}{\partial \psi} \\
&= \frac{\frac{\partial c}{\partial p_L}\left[t_L\left(1 - \frac{\partial c'_H}{\partial p_H}\right) - t_H\frac{\partial c'_L}{\partial p_H}\right] - \frac{\partial c}{\partial p_H}\left[t_H\left(1 - \frac{\partial c'_L}{\partial p_L}\right) - t_L\frac{\partial c'_H}{\partial p_L}\right]}{\left(1 - \frac{\partial c'_L}{\partial p_L}\right)\left(1 - \frac{\partial c'_H}{\partial p_H}\right) - \frac{\partial c'_H}{\partial p_L}\frac{\partial c'_L}{\partial p_H}}
\end{aligned} \tag{22}$$

Observe that the numerator of equation (22) is positive because

$$\begin{aligned}
&\frac{\partial c}{\partial p_L}\left[t_L\left(1 - \frac{\partial c'_H}{\partial p_H}\right) - t_H\frac{\partial c'_L}{\partial p_H}\right] - \frac{\partial c}{\partial p_H}\left[t_H\left(1 - \frac{\partial c'_L}{\partial p_L}\right) - t_L\frac{\partial c'_H}{\partial p_L}\right] \\
= \;& t_L\frac{\partial c}{\partial p_L}\left[1 - \frac{\partial c'_H}{\partial p_H} + \frac{\partial c'_H}{\partial p_L}\right] - t_H\frac{\partial c}{\partial p_H}\left[1 - \frac{\partial c'_L}{\partial p_L} + \frac{\partial c'_L}{\partial p_H}\right] \\
&- \left(\frac{\partial c}{\partial p_L} - \frac{\partial c}{\partial p_H}\right)\left(t_H\frac{\partial c'_L}{\partial p_H} + t_L\frac{\partial c'_H}{\partial p_L}\right) \\
> \;& t_L\frac{\partial c}{\partial p_L}\left[1 - \frac{\partial c'_H}{\partial p_H} + \frac{\partial c'_H}{\partial p_L}\right] - t_H\frac{\partial c}{\partial p_H}\left[1 - \frac{\partial c'_L}{\partial p_L} + \frac{\partial c'_L}{\partial p_H}\right] \\
> \;& t_L\frac{\partial c}{\partial p_L} - t_H\frac{\partial c}{\partial p_H} \; > \; 0
\end{aligned}$$

where the first inequality follows because $|\frac{\partial c}{\partial p_L}| > |\frac{\partial c}{\partial p_H}|$, the second inequality follows because $|\frac{\partial c'_L}{\partial p_L}| > |\frac{\partial c'_L}{\partial p_H}|$ and $|\frac{\partial c'_H}{\partial p_L}| > |\frac{\partial c'_H}{\partial p_H}|$, and the third inequality follows because $t_L \frac{\partial c}{\partial p_L} > t_H \frac{\partial c}{\partial p_H}$. Because the denominator of equation (22) is also positive, risk adjustment must increase average market claims (i.e., $\frac{\partial c}{\partial \psi} > 0$). Because $q(p'_L, p'_H) < q(p''_L, p''_H)$ if and only if $c(p'_L, p'_H) > c(p''_L, p''_H)$ for any premium vectors $p' = (p'_L, p'_H)$ and $p'' = (p''_L, p''_H)$, it follows that risk adjustment must decrease total enrollment (i.e., $\partial q / \partial \psi < 0$).

Finding $\frac{\partial p_L}{\partial \rho}$ and $\frac{\partial p_H}{\partial \rho}$

Differentiating equilibrium equations (3) with respect to ρ yields

$$\frac{\partial p_L}{\partial \rho} = \frac{\partial c_L}{\partial p_L}\frac{\partial p_L}{\partial \rho} + \frac{\partial c_L}{\partial p_H}\frac{\partial p_H}{\partial \rho} + \frac{\partial c_L}{\partial \rho} \tag{23}$$

$$\frac{\partial p_H}{\partial \rho} = \frac{\partial c_H}{\partial p_L}\frac{\partial p_L}{\partial \rho} + \frac{\partial c_H}{\partial p_H}\frac{\partial p_H}{\partial \rho} + \frac{\partial c_H}{\partial \rho} \tag{24}$$

Solving equation (24) for $\frac{\partial p_H}{\partial \rho}$ yields

$$\frac{\partial p_H}{\partial \rho} = \frac{\frac{\partial c_H}{\partial p_L}\frac{\partial p_L}{\partial \rho} + \frac{\partial c_H}{\partial \rho}}{1 - \frac{\partial c_H}{\partial p_H}} \tag{25}$$

Substituting the right-hand side of equation (25) into equation (23) and solving for $\frac{\partial p_L}{\partial \rho}$ yields

$$\frac{\partial p_L}{\partial \rho} = \frac{\frac{\partial c_L}{\partial \rho}\left(1 - \frac{\partial c_H}{\partial p_H}\right) + \frac{\partial c_H}{\partial \rho}\frac{\partial c_L}{\partial p_H}}{\left(1 - \frac{\partial c_L}{\partial p_L}\right)\left(1 - \frac{\partial c_H}{\partial p_H}\right) - \frac{\partial c_H}{\partial p_L}\frac{\partial c_L}{\partial p_H}}$$

Substituting for $\frac{\partial p_L}{\partial \rho}$ in equation (24) and solving for $\frac{\partial p_H}{\partial \rho}$ yields

$$\frac{\partial p_H}{\partial \rho} = \frac{\frac{\partial c_H}{\partial \rho}\left(1 - \frac{\partial c_L}{\partial p_L}\right) + \frac{\partial c_L}{\partial \rho}\frac{\partial c_H}{\partial p_L}}{\left(1 - \frac{\partial c_L}{\partial p_L}\right)\left(1 - \frac{\partial c_H}{\partial p_H}\right) - \frac{\partial c_H}{\partial p_L}\frac{\partial c_L}{\partial p_H}}$$

Proof of Proposition 1.2

The first step is to establish that the partial derivative $\frac{\partial p_L}{\partial \rho}$ is negative and the partial derivative $\frac{\partial p_H}{\partial \rho}$ is positive. The numerator of the partial derivative $\frac{\partial p_L}{\partial \rho}$ is negative because (1) its first term is negative and (2) the magnitude of its first term exceeds the magnitude of its second term under the assumptions $|\frac{\partial c_L}{\partial \rho}| > |\frac{\partial c_H}{\partial \rho}|$ and $|\frac{\partial c_L}{\partial p_H}| + \frac{\partial c_H}{\partial p_H} < 1$. The numerator of the partial derivative $\frac{\partial p_H}{\partial \rho}$ is positive because (1) its second term is positive and (2) the magnitude of its second term exceeds the magnitude of its first term under the assumptions $|\frac{\partial c_L}{\partial \rho}| > |\frac{\partial c_H}{\partial \rho}|$ and $|\frac{\partial c_H}{\partial p_L}| + \frac{\partial c_L}{\partial p_L} > 1$. The common denominator $\left(1 - \frac{\partial c_L}{\partial p'_L}\right)\left(1 - \frac{\partial c_H}{\partial p'_H}\right) - \frac{\partial c_H}{\partial p'_L}\frac{\partial c_L}{\partial p'_H}$ must be strictly positive for the partial derivatives in (4) to be economically meaningful. If the common denominator were negative, a reduction in the responsiveness of the low plan's average claims to the high plan's premium ($\frac{\partial c_L}{\partial p_H}$) would imply larger premium increases for firm L's plan (i.e. $\frac{\partial p_L}{\partial \rho}$ becomes more positive). Hence, the common denominator is positive, which implies the mandate penalty decreases the premium of firm L's plan ($\frac{\partial p_L}{\partial \rho} < 0$) and increases the premium of firm H's plan ($\frac{\partial p_H}{\partial \rho} > 0$).

Consider the impact of the mandate on underinsurance. Because the right-hand side of equation (24) equals the full derivative $\frac{dc_H}{d\rho}$, it follows that $\frac{dc_H}{d\rho}$ is positive. The derivative $\frac{dq_H}{d\rho}$ is therefore negative because $\frac{dc_H}{d\rho} = \frac{dc_H}{dq_H}\frac{dq_H}{d\rho}$ and $\frac{dc_H}{dq_H} < 0$. Hence, the mandate penalty increases underinsurance.

Now consider the impact of the mandate on total enrollment. By assumption, $\frac{\partial c}{\partial p_L} > \frac{\partial c}{\partial p_H}$. Furthermore,

$$\left|\frac{\partial p_L}{\partial \rho}\right| - \frac{\partial p_H}{\partial \rho} = \frac{\left[-\frac{\partial c_L}{\partial \rho}\left(1 - \frac{\partial c_H}{\partial p_H}\right) + \frac{\partial c_H}{\partial \rho}\left(1 - \frac{\partial c_L}{\partial p_L}\right)\right] + \left[-\frac{\partial c_H}{\partial \rho}\frac{\partial c_L}{\partial p_H} + \frac{\partial c_L}{\partial \rho}\frac{\partial c_H}{\partial p_L}\right]}{\left(1 - \frac{\partial c_L}{\partial p_L}\right)\left(1 - \frac{\partial c_H}{\partial p_H}\right) - \frac{\partial c_H}{\partial p_L}\frac{\partial c_L}{\partial p_H}} > 0$$

because $|\frac{\partial c_L}{\partial \rho}| > |\frac{\partial c_H}{\partial \rho}|$, $\frac{\partial c_L}{\partial p_L} > \frac{\partial c_H}{\partial p_H}$, and $|\frac{\partial c_H}{\partial p_L}| > |\frac{\partial c_L}{\partial p_H}|$. The penalty therefore reduces firm L's premium more than it increases firm H's premium. It follows that

$$\frac{dc}{d\rho} = \frac{\partial c}{\partial p_L}\frac{\partial p_L}{\partial \rho} + \frac{\partial c}{\partial p_H}\frac{\partial p_H}{\partial \rho} + \frac{\partial c}{\partial \rho} < 0$$

Because $q(p'_L, p'_H) < q(p''_L, p''_H)$ if and only if $c(p'_L, p'_H) > c(p''_L, p''_H)$ for any premium vectors $p' = (p'_L, p'_H)$ and $p'' = (p''_L, p''_H)$, it follows that the mandate must increase total enrollment (i.e., $\frac{dq}{d\rho}$ is positive).

Appendix B: Mathematical Formulas in ACA Exchange Model

In this appendix, I write the variables in equation (11) in terms of four variables: (1) the household choice probabilities $q_{ij}(\mathbf{p})$; (2) the household demand sensitivity matrix $D_i(\mathbf{q})$; (3) the firm's average claims function $c_f(\mathbf{p})$; and (4) the claim slope matrix $D(\mathbf{c})$.

Demand Variables

Formulas for plan demand $q_j(\mathbf{p})$ and firm demand $q_f(\mathbf{p})$ are given by

$$q_j(\mathbf{p}) = \sum_{i \in I} q_{ij}(\mathbf{p})$$

$$q_f(\mathbf{p}) = \sum_{k \in J_f} q_k(\mathbf{p}) = \sum_{i \in I, k \in J_f} q_{ik}(\mathbf{p})$$

The partial derivatives of plan demand, firm demand, and the risk-adjusted share with respect to the plan base premium can be written as

$$\frac{\partial q_j(\mathbf{p})}{\partial p_j} = \sum_{i \in I} \frac{\partial q_{ij}(\mathbf{p})}{\partial p_j} = \sum_{i \in I, l \in J} \frac{\partial q_{ij}(\mathbf{p})}{\partial p_{il}(\mathbf{p})} \frac{\partial p_{il}(\mathbf{p})}{\partial p_j}$$

$$\frac{\partial q_f(\mathbf{p})}{\partial p_j} = \sum_{i \in I, k \in J_f} \frac{\partial q_{ik}(\mathbf{p})}{\partial p_j} = \sum_{i \in I, k \in J_f, l \in J} \frac{\partial q_{ik}(\mathbf{p})}{\partial p_{il}(\mathbf{p})} \frac{\partial p_{il}(\mathbf{p})}{\partial p_j}$$

$$\frac{\partial rs_f(\mathbf{p})}{\partial p_j} = \frac{\sum_{i \in I, l \in J} h_l q_{il}(\mathbf{p}) \sum_{i \in I, k \in J_f} h_k \frac{\partial q_{ik}(\mathbf{p})}{\partial p_j} - \sum_{i \in I, k \in J_f} h_k q_{ik}(\mathbf{p}) \sum_{i \in I, l \in J} h_l \frac{\partial q_{il}(\mathbf{p})}{\partial p_j}}{\left(\sum_{i \in I, l \in J} h_l q_{il}(\mathbf{p})\right)^2}$$

Marginal Revenue, Marginal Claims, and Average Marginal Claims

Marginal revenue $MR_j(\mathbf{p})$, marginal claims $MC_j(\mathbf{p})$, and average marginal claims $\overline{MC}_j(\mathbf{p})$ can be expressed as

$$MR_j(\mathbf{p}) = \frac{\partial R_f(\mathbf{p})}{\partial q_j(\mathbf{p})} = \left(\frac{\partial q_j(\mathbf{p})}{\partial p_j}\right)^{-1} \sum_{i \in I} \left(r_{ij} q_{ij}(\mathbf{p}) + \sum_{k \in J_f} r_{ik} p_k \frac{\partial q_{ik}(\mathbf{p})}{\partial p_j} \right)$$

$$MC_j(\mathbf{p}) = \frac{\partial C_f(\mathbf{p})}{\partial q_j(\mathbf{p})} = c_f(\mathbf{p}) \left(\frac{\partial q_j(\mathbf{p})}{\partial p_j}\right)^{-1} \frac{\partial q_f(\mathbf{p})}{\partial p_j} + q_f(\mathbf{p}) \frac{\partial c_f(\mathbf{p})}{\partial q_j(\mathbf{p})} \tag{26}$$

$$\overline{MC}_j(\mathbf{p}) = \frac{\partial (rs_f(\mathbf{p}) C(\mathbf{p}))}{\partial q_j(\mathbf{p})} = \left(\frac{\partial q_j(\mathbf{p})}{\partial p_j}\right)^{-1} \left[C(\mathbf{p}) \frac{\partial rs_f(\mathbf{p})}{\partial p_j} + rs_f(\mathbf{p}) \frac{\partial C(\mathbf{p})}{\partial p_j} \right] \tag{27}$$

where the partial derivative of total claims incurred by all firms with respect to the base premium equals

$$\frac{\partial C(\mathbf{p})}{\partial p_j} = \sum_{f' \in F} \sum_{k' \in J_{f'}} \frac{\partial C_{f'}(\mathbf{p})}{\partial q_{k'}(\mathbf{p})} \frac{\partial q_{k'}(\mathbf{p})}{\partial p_j} = \sum_{f' \in F} \sum_{k' \in J_{f'}} MC_{k'}(\mathbf{p}) \frac{\partial q_{k'}(\mathbf{p})}{\partial p_j}$$

Appendix C: Risk Adjustment Under the ACA

In this appendix, I derive the ACA risk adjustment formula and price equilibrium in the ACA setting. The ACA transfer formula assumes that firms price at average claims and benchmarks transfers to the market average premium, instead of market average claims as in formula (9). The firms' first-order conditions using the ACA formula are similar, but less intuitive and hard to interpret. I use the Nash price equilibrium developed in this appendix in my estimation of the firm's average claims functions and the claim slope matrix.

I start with Pope et al. (2014)'s transfer formula as derived in their first appendix, which allows plans to vary only by their actuarial values (and not by differences in firm efficiency, geographic costs, allowable rating factors, or moral hazard).[8] Pope et al. (2014) show that

[8] I start with this formula because I want to capture all differences in expected risk, except for cost sharing and any associated moral hazard, in the plan's risk score (i.e., cost sharing and moral hazard are addressed through the risk-adjusted share $rs_f(\mathbf{p})$). In contrast, the plan liability risk score $PLRS_j$ as defined in Pope

the per-member per-month risk adjustment transfer can be calculated according to formula $(A14)$:

$$T_j = PLRS_j \times \overline{p} - \frac{AV_j}{\sum_l AV_l s_l}\overline{p}$$

where T_j is the PMPM transfer received by plan j, $PLRS_j$ is plan j's plan liability risk score, $\overline{p}$ is the share-weighted average statewide premium, AV_l is the actuarial value of plan l, and s_l is plan l's market share. Pope et al. (2014) define the plan liability risk score as the ratio of the plan's average liability to the weighted-average liability across firms, which in my notation is $c_j(\mathbf{p})/c(\mathbf{p})$. Denote $R(\mathbf{p})$ as total market revenue. The per-member per-month risk adjustment transfer $ra_j(\mathbf{p})$ of plan j in my notation equals

$$\begin{aligned} ra_j(\mathbf{p}) &= \frac{C_j(\mathbf{p})/q_j(\mathbf{p})}{C(\mathbf{p})/q(\mathbf{p})}\frac{R(\mathbf{p})}{q(\mathbf{p})} - \frac{h_j q(\mathbf{p})}{\sum_{l\in J} h_l q_l(\mathbf{p})}\frac{R(\mathbf{p})}{q(\mathbf{p})} \\ &= \frac{C_j(\mathbf{p})R(\mathbf{p})}{q_j(\mathbf{p})C(\mathbf{p})} - \frac{h_j}{\sum_{l\in J} h_l q_l(\mathbf{p})}R(\mathbf{p}) \end{aligned}$$

where I have replaced the actuarial value factors with the total utilization factors h_j to account for moral hazard. The total risk adjustment transfer $RA_j(\mathbf{p})$ for plan j is given by

$$RA_j(\mathbf{p}) = ra_j(\mathbf{p})q_j(\mathbf{p}) = \frac{C_j(\mathbf{p})R(\mathbf{p})}{C(\mathbf{p})} - s_j(\mathbf{p})R(\mathbf{p})$$

Summing across all plans k offered by firm f yields

$$RA_f(\mathbf{p}) = \frac{C_f(\mathbf{p})R(\mathbf{p})}{C(\mathbf{p})} - rs_f(\mathbf{p})R(\mathbf{p})$$

To allow for variation in the firm bargaining power and ability to exploit risk adjustment, I multiply the first term by the efficiency score ϕ_f to yield the ACA risk adjustment transfer

$$RA_f(\mathbf{p}) = \frac{\phi_f C_f(\mathbf{p})R(\mathbf{p})}{C(\mathbf{p})} - rs_f(\mathbf{p})R(\mathbf{p}) \tag{28}$$

et al. (2014)'s second appendix does not account for certain differences such as variation in geographic cost. Instead, Pope et al. (2014) account for these differences by applying factors in the transfer formula.

Adding the ACA transfer (28) to firm f's profit function yields

$$\pi_f(\mathbf{p}) \quad = \quad (1 - rs_f(\mathbf{p}))R(\mathbf{p}) + \phi_f C_f(\mathbf{p})R(\mathbf{p})/C(\mathbf{p}) - (1-\tau_f)C_f(\mathbf{p}) - V_f - FC_f \tag{29}$$

Firm f's corresponding first-order conditions are given by

$$MR_j(\mathbf{p}) \quad = \quad \overline{MR}_j(\mathbf{p}) - \phi_f MC'_j(\mathbf{p}) + (1-\tau_f)MC_j(\mathbf{p}) + v_f \frac{\partial q_f(\mathbf{p})/\partial p_j}{\partial q_j(\mathbf{p})/\partial p_j} \tag{30}$$

for $j \in J_f$, where $\overline{MR}_j(\mathbf{p}) \equiv \partial[rs_f(\mathbf{p})R(\mathbf{p})]/\partial q_j(\mathbf{p})$ and $MC'_j(\mathbf{p}) = \partial[C_f(\mathbf{p})R(\mathbf{p})/C(\mathbf{p})]/\partial q_j(\mathbf{p})$. Formulas for $\overline{MR}_j(\mathbf{p})$ and $MC'_j(\mathbf{p})$ are given by

$$\overline{MR}_j(\mathbf{p}) \quad = \quad \frac{\partial(rs_f(\mathbf{p})R(\mathbf{p}))}{\partial q_j(\mathbf{p})} = \left(\frac{\partial q_j(\mathbf{p})}{\partial p_j}\right)^{-1}\left[R(\mathbf{p})\frac{\partial rs_f(\mathbf{p})}{\partial p_j} + rs_f(\mathbf{p})\frac{\partial R(\mathbf{p})}{\partial p_j}\right]$$

$$\begin{aligned}
MC'_j(\mathbf{p}) \quad &= \quad \frac{\partial}{\partial q_j(\mathbf{p})}\left(\frac{C_f(\mathbf{p})R(\mathbf{p})}{C(\mathbf{p})}\right) \\
&= \quad \frac{C(\mathbf{p})\left[\frac{\partial C_f(\mathbf{p})}{\partial p_j}R(\mathbf{p}) + C_f(\mathbf{p})\frac{\partial R(\mathbf{p})}{\partial p_j}\right] - C_f(\mathbf{p})R(\mathbf{p})\frac{\partial C(\mathbf{p})}{\partial p_j}}{\frac{\partial q_j(\mathbf{p})}{\partial p_j}[C(\mathbf{p})]^2} \\
&= \quad MC_j(\mathbf{p})\frac{R(\mathbf{p})}{C(\mathbf{p})} + \\
&\quad\quad \frac{C_f(\mathbf{p})\sum_{f' \in F}\sum_{k' \in J_{f'}}\left(C(\mathbf{p})MR_{k'}(\mathbf{p}) - R(\mathbf{p})MC_{k'}(\mathbf{p})\right)\frac{\partial q_{k'}(\mathbf{p})}{\partial p_j}}{[C(\mathbf{p})]^2}
\end{aligned}$$

where

$$\frac{\partial R(\mathbf{p})}{\partial p_j} \quad = \quad \sum_{f' \in F}\sum_{k' \in J_{f'}} \frac{\partial P_{f'}(\mathbf{p})}{\partial q_{k'}(\mathbf{p})}\frac{\partial q_{k'}(\mathbf{p})}{\partial p_j} = \sum_{f' \in F}\sum_{k' \in J_{f'}} MR_{k'}(\mathbf{p})\frac{\partial q_{k'}(\mathbf{p})}{\partial p_j}$$

$$\frac{\partial C(\mathbf{p})}{\partial p_j} \quad = \quad \sum_{f' \in F}\sum_{k' \in J_{f'}} \frac{\partial C_{f'}(\mathbf{p})}{\partial q_{k'}(\mathbf{p})}\frac{\partial q_{k'}(\mathbf{p})}{\partial p_j} = \sum_{f' \in F}\sum_{k' \in J_{f'}} MC_{k'}(\mathbf{p})\frac{\partial q_{k'}(\mathbf{p})}{\partial p_j}$$

Appendix D: Cost Sharing Reductions

In this appendix, I discuss how the ACA provides CSRs to consumers and construct a formula for computing government spending on CSRs. CSRs were funded by the federal government through 2017 until the Trump Administration terminated the government's payment of CSRs. Starting in 2018, insurers are required to fund CSRs. To receive CSRs, eligible consumers with income below 250 percent of poverty must purchase a silver plan. CSRs increase the actuarial value of the silver plan from 70 percent to 94 percent for consumers with income below 150 percent of poverty (group 1), to 87 percent for consumers with income between 150 and 200 percent of poverty (group 2), and to 73 percent of poverty for consumers with income between 200 and 250 percent of poverty (group 3). Ignoring moral hazard, the government's expected outlay is 24 percent of claims for group 1, 17 percent for group 2, and 3 percent for group 3. To account for moral hazard, I follow Pope et al. (2014) and assume there is no moral hazard for consumers in the 73-percent plan, while consumers in the 87- and 94-percent plans increase consumption by 12 percent. Including moral hazard, the government's expected outlay is 26.88 percent of claims for group 1, 19.04 percent for group 2, and 3 percent for group 3. Government spending on cost sharing reductions equals

$$CSR = \sum_{i \in I, j \in J} s_i^g q_{ij}(\mathbf{p})(r_{ij}^c c_j'(\mathbf{p})) \tag{31}$$

where s_i^g is the government's expected share for consumer i as defined above, $q_{ij}(\mathbf{p})$ is the household choice probability, r_{ij}^c is a cost factor accounting for the plan and the household members' ages and geographic residence, and $c_j'(\mathbf{p})$ is plan base claims. The cost factors come from insurer rate filings (Department of Managed Health Care, 2016). Plan base claims are computed from the estimated household choice probabilities and data on firm average claims and cost factors.

Figure 1: Premium Rating Regions in California

Notes: Figure shows the premium rating regions in the California exchange (Department of Managed Health Care, 2016). California's 58 counties are divided into 19 rating areas.

Table I: Insurer Market Share in the California Exchange

	2014	2015
Anthem	29.0%	27.8%
Blue Shield	28.3%	26.4%
Chinese Community	1.1%	0.8%
Contra Costa	0.1%	
Health Net	19.7%	16.4%
Kaiser	17.4%	24.2%
LA Care	2.3%	1.1%
Molina	0.7%	1.5%
Sharp	1.0%	1.2%
Valley	0.1%	0.1%
Western Health	0.3%	0.4%

Table II: Choice and Demographic Distribution

	Exchange	Uninsured
Metals		
Catastrophic	0.7%	
Bronze	24.0%	
Silver	64.9%	
Gold	5.5%	
Platinum	4.8%	
Network Type		
HMO	45.7%	
PPO	45.1%	
EPO	9.2%	
Income		
0% to 138% of FPL	2.9%	2.8%
138% to 150% of FPL	15.0%	5.4%
150% to 200% of FPL	33.8%	20.5%
200% to 250% of FPL	17.4%	16.2%
250% to 400% of FPL	22.7%	29.6%
400%+ of FPL	8.2%	25.4%
Subsidy Eligibility		
Premium tax credits	90.7%	74.6%
Cost sharing reductions	68.5%	44.9%
Penalty Status		
Exempt	3.8%	6.3%
Subject	96.2%	93.7%
Age		
0-17	4.8%	3.2%
18-25	10.4%	20.9%
26-34	15.7%	25.5%
35-44	15.6%	17.0%
45-54	24.4%	17.8%
55-64	29.0%	15.4%
Gender		
Female	52.3%	43.1%
Male	47.7%	56.9%
Year		
2014	48.9%	58.9%
2015	51.1%	41.1%
Average Annual Population	1,239,268	1,407,430

NOTES: Table provides summary statistics on consumers in the California exchange market for the 2014 and 2015 plan years. Data on marketplace consumers come from Covered California. Data on the uninsured come from the ACS.

Table III: Summary Financial Data by Year

	Average Claims		Risk Adj. Received		Reinsurance Received	
	2014	2015	2014	2015	2014	2015
Anthem	$294	$349	-$26	-$4	$58	$44
Blue Shield	$338	$378	$24	$26	$63	$40
Chinese Community	$212	$160	-$119	-$185	$13	$17
Contra Costa	$912		$179		$234	
Health Net	$306	$365	-$17	-$23	$54	$43
Kaiser	$344	$336	$17	-$11	$40	$26
LA Care	$196	$177	-$132	-$126	$1	$1
Molina	$114	$141	-$126	-$130	$13	$6
Sharp	$515	$458	$85	$42	$90	$42
Valley	$430	$391	-$21	-$5	$29	$22
Western Health	$569	$425	$63	-$21	$143	$74

NOTES: Table provides insurer financial data for the 2014 and 2015 plan years on per-member per-month claims, risk adjustment received, and reinsurance received. Claims data are from the MLR reports. Risk adjustment and reinsurance data are from CMS reports (Centers for Medicare and Medicaid Services, 2015, 2016).

Table IV: Estimated Mean Elasticities and Semi-Elasticities

	Own-Premium		Exchange Coverage	
	Elasticity	Semi-Elasticity	Elasticity	Semi-Elasticity
Overall	-9.1	-21.8	-1.2	-3.3
Income (% of FPL)				
0-138	-8.8	-21.3	-1.2	-3.3
138-250	-9.7	-23.1	-1.3	-3.5
250-400	-8.2	-20.0	-1.1	-3.1
400+	-7.8	-19.1	-1.0	-2.9
Gender				
Female	-8.8	-21.0	-1.1	-3.2
Male	-9.5	-22.6	-1.2	-3.4
Age				
18-34	-13.1	-27.9	-1.6	-4.1
35-54	-9.3	-19.9	-1.1	-2.9
55+	-5.6	-12.0	-0.7	-1.7

Notes: Table shows mean premium elasticities and semi-elasticities of demand by demographic group. The first column reports the mean own-premium elasticity of demand. The second column reports the mean own-premium semi-elasticity of demand, which is the the percentage change in a plan's enrollment associated with a \$100 increase in its annual premium. The third column reports the mean own-premium elasticity for exchange coverage (i.e., the percentage change in exchange enrollment associated with a one percent increase in the base premium of all exchange plans). The fourth column reports the mean own-premium semi-elasticity for exchange coverage, which is the percentage change in exchange enrollment associated with a \$100 annual increase in all exchange premiums. I use the plan market shares as weights to compute the mean elasticities and semi-elasticities.

Table V: Predicting the Partial Derivative $\partial c_f(\mathbf{p})/\partial q_j(\mathbf{p})$

	Base	Adding Insurer Fixed Effects
Inverse Demand	-4.993^{***}	-5.108^{***}
	(1.177)	(1.101)
Actuarial Value	20.728^{***}	21.911^{***}
	(7.200)	(7.030)
HMO	1.212	-3.521^{***}
	(1.205)	(1.277)
HSA	-0.381	0.282
	(1.312)	(1.328)
Observations	149	149
R^2	0.588	0.609
Adjusted R^2	0.576	0.575

Notes: Robust standard errors are in parentheses (*** indicates statistical significance at the 1% level). Table shows parameter estimates for the linear regression of the partial derivative $\frac{\partial c_f(\mathbf{p})}{\partial q_j(\mathbf{p})}$ on inverse demand and plan characteristics. In the second column, I add insurer fixed effects to equation (15). Each observation is a plan-year combination.

Table VI: Effect of Risk Adjustment on (Pre-Subsidy) Premiums

	ACA	Scenario 1: Eliminate Risk Adjustment	Scenario 2: Replace ACA Subsidies w/ Vouchers
Metal			
Bronze	$221	$198	$218
Silver	$273	$267	$269
Gold	$315	$367	$310
Platinum	$353	$474	$346
Insurer (Silver Premium)			
Anthem BC	$291	$271	$284
Blue Shield	$262	$279	$261
Chinese Community	$342	$268	$354
Contra Costa	$355	$334	$367
Centene/Health Net	$233	$222	$229
Kaiser	$292	$286	$288
L.A. Care	$259	$238	$247
Molina	$261	$247	$262
Sharp	$324	$380	$332
Valley	$353	$286	$350
Western	$396	$412	$391

Notes: Table shows the impact of risk adjustment on weighted-average premiums by metal tier and by insurer for a 40-year-old. Average premiums for any other age are proportional to the premiums reported in Table VI according to the ACA's age rating curve (Centers for Medicare and Medicaid Services, 2013). Plan premiums are weighted by the realized ACA plan market share for all scenarios.

Table VII: Effect of Risk Adjustment on Insurance Coverage

	ACA	Scenario 1: Eliminate Risk Adjustment	Scenario 2: Replace ACA Subsidies w/ Vouchers
Catastrophic	9,174	26,319	9,075
Bronze	314,528	322,483	304,852
Silver	850,537	870,704	818,946
Gold	72,079	70,420	75,964
Platinum	64,216	26,331	71,757
Total Coverage	1,310,535	1,316,258	1,280,594

Table VIII: Change in Annual Per-Capita Social Welfare Relative to ACA

	Scenario 1: Eliminate Risk Adjustment	Scenario 2: Replace ACA Subsidies w/ Vouchers
Consumer Surplus	-$196	-$405
Profit	$92	-$140
Government Spending		
Premium Subsidies	$223	$234
CSRs	$9	$1
Mandate Revenue	-$4	$3
Uncompensated Care	$4	-$25
Social Welfare	$129	-$332

Table IX: Effect of the Individual Mandate on (Pre-Subsidy) Premiums

	ACA	Scenario 3: Eliminate Individual Mandate	Scenario 4: Vouchers and Eliminate Mandate
Catastrophic	\$195	\$192	\$194
Bronze	\$221	\$229	\$226
Silver	\$273	\$276	\$278
Gold	\$315	\$326	\$322
Platinum	\$353	\$347	\$354

Notes: Table shows the impact of the individual mandate on weighted-average premiums by metal tier for a 40-year-old. Plan premiums are weighted by the realized ACA plan market share for all scenarios.

Table X: Effect of the Individual Mandate on Insurance Coverage

	ACA	Scenario 3: Eliminate Individual Mandate	Scenario 4: Vouchers and Eliminate Mandate
Catastrophic	9,174	5,381	5,725
Bronze	314,528	119,282	154,294
Silver	850,537	767,822	715,213
Gold	72,079	66,661	62,844
Platinum	64,216	97,583	86,695
Total	1,310,535	1,056,729	1,024,772

Table XI: Change in Annual Per-Capita Social Welfare Relative to ACA

	Scenario 3: Eliminate Individual Mandate	Scenario 4: Vouchers and Eliminate Mandate
Consumer Surplus	$142	-$322
Profit	-$37	$134
Government Spending		
Premium Subsidies	$260	$423
CSRs	$10	$28
Mandate Revenue	-$192	-$192
Uncompensated Care	-$196	-$224
Social Welfare	-$13	-$153