Managing Adverse Selection in Health Insurance Markets: Underinsurance vs. Underenrollment

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Abstract

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.

Governments have increasingly intervened in health 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. This decision involves an economic tradeoff between reclassification risk and adverse selection (Handel et al., 2015). Reclassification risk may arise when insurers can price a change in a consumer's expected risk by increasing future premiums. Adverse selection could occur if insurers cannot use information on consumer risk such as health status to price discriminate. Limiting insurer ability to price discriminate reduces reclassification risk, but exacerbates adverse selection. Rules limiting insurer price discrimination, often referred to as "community rating," are pervasive in insurance markets, including Medicare Advantage and the ACA insurance exchanges. Prior work finds empirical evidence of adverse selection in these markets (Brown et al., 2014; Newhouse et al., 2015; 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 with community rating can simultaneously mitigate underinsurance and underenrollment due to adverse selection. I show that in realistic scenarios, there is a tradeoff in addressing underinsurance and underenrollment. I also examine whether the underinsurance-underenrollment tradeoff is present in the ACA exchanges. The ACA exchange setting is particularly appealing because price discrimination is limited and several policies targeting adverse selection are in place, including premium subsidies, reinsurance, risk adjustment, and the individual mandate.

I specify a differentiated products model of the ACA exchanges where firms simultaneously set premiums and then consumers choose plans. I estimate the model using consumer-level administrative data from the California ACA exchange (known as Covered California). 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 (1) the premium that consumers face for each plan in their choice sets; (2) the consumer-specific subsidy received for each plan and (3) the consumer-specific penalty imposed for forgoing coverage. I also obtain firm financial data from several sources, including the ACA medical loss ratio (MLR) reports.

Using these data, I estimate consumer-level demand and firm-level cost. I estimate demand for health insurance 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. My estimates indicate that low-income individuals, young adults, and males have more premium-elastic demand. Overall, a $\$100$ annual premium increase would, on average, reduce a plan's demand by 21.8 percent. If the premiums of all exchange plans were to increase by $\$100$ per year, demand for exchange coverage would fall by 3.3 percent. I also obtain non-parametric estimates of plan marginal costs by inverting the firm's first-order conditions for profit maximization. I relate these estimates to premiums to measure how marginal costs vary with premiums. My cost estimates provide statistically significant evidence of adverse selection.

I first use the estimated model to simulate the impact of risk adjustment in the ACA exchanges. 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. Consumers are mostly shielded from the higher bronze plan premiums because the ACA's subsidies are linked to the premium of the one of the cheaper exchange plans. As a result, exchange enrollment shifts from bronze to platinum plans while total exchange enrollment remains about the same. Consumer surplus increases by 4 percent, but social welfare is largely unchanged because higher subsidy spending offsets the gains in consumer surplus. I also simulate the impact of converting the ACA's price-linked subsidies to fixed subsidies or vouchers that do not adjust to premiums. I find that under vouchers, risk adjustment decreases total exchange enrollment by 3 percent and consumer surplus by 4 percent because consumers are exposed to the higher bronze plan premiums.

I then simulate the impact of the ACA's individual mandate penalty, which will

[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.

be set equal 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 by 24 percent, but enrollment in platinum plans declines by 34 percent. Consumer surplus falls by 2.6 percent 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 by 28 percent and (2) increases consumer surplus by 6.6 percent 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. This paper also augments the extensive literature on risk adjustment (see Ellis (2008) and Breyer et al. (2012) for thorough reviews). 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 et al. (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. I build on these studies by considering how risk adjustment affects both underinsurance and underenrollment in a single framework. 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 et al., 2015; Frean et al., 2017; Sacks, 2017). To my knowledge, there are no papers in the literature that study how the mandate affects underinsurance.

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) find that price-linked subsidies can result in higher premiums and lower social welfare relative to vouchers, but price-linked subsidies have advantages when insurance costs are uncertain. Tebaldi (2017) finds that replacing price-linked subsidies with vouchers of the same amount would reduce average markups by 11 percent. I extend this literature by studying the interaction of the subsidy design with the individual mandate and risk adjustment. My analysis also links to recent work considering interactions between adverse selection and market power (Lustig, 2010; Starc, 2014; Ericson and Starc, 2015; Mahoney and Weyl, 2017). I augment 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; Saltzman, 2018).

The remainder of this paper is organized as follows. Section 1 provides background on the ACA exchanges. Section 2 builds a model of the ACA exchanges. Section 3 describes the data I use to estimate the model. Section 4 details how I estimate the model. Section 5 presents estimates of demand and claims. Section 6 simulates the impact of risk adjustment and Section 7 simulates the impact of the individual mandate in the ACA exchanges. Section 8 concludes.

1 Policy Background

One of the key mechanisms for expanding health insurance under the ACA is the creation of regulated state insurance exchanges, where insurers sell insurance plans directly to consumers. 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). Select individuals, mostly those under age 30, can buy a more basic catastrophic plan. The silver tier is the most common choice because eligible consumers must choose silver in order to receive cost sharing subsidies (i.e., subsidies that reduce deductibles, copays, etc.). In California, plans within a metal tier are standardized to have the same cost sharing parameters (e.g., deductibles, coinsurance rates, copays, etc.).

The ACA restricts the ability of insurers to price discriminate to a consumer's age, smoking status, and geographic residence. 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. The rating area partition for California is shown in Figure 1. Insurers can opt to serve only part of a rating area. Below I describe several ACA policies that are designed to limit underinsurance and underenrollment that may result from regulation on price discrimination.

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.

1.1 Policies Targeting Underinsurance

The primary ACA policy targeting underinsurance due to adverse selection is risk adjustment. Under the ACA's risk adjustment program, firms with lower-than-average risk make transfer payments to firms with a higher-than-average risk such that net transfer payments sum to zero. 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. Risk adjustment occurs at the state level for all firms participating in the individual market, including firms offering individual plans in the exchanges and off the exchanges. Risk adjustment therefore reduces the incentives of firms to market in favorable geographic regions of the state or off the exchanges.

1.2 Policies Targeting Underenrollment

Several ACA policies target underenrollment due to adverse selection. The ACA's individual mandate requires most individuals to purchase insurance or pay a penalty. Exemptions from the 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 individual mandate penalty amount was phased in between 2014 and 2016. For the 2016 through 2018 plan years, the penalty for a single individual is the greater of $\$695$ and 2.5 percent of income exceeding the filing threshold. The Tax Cuts and Jobs Act of 2017 sets the individual penalty amount to zero starting in 2019.

The ACA's premium subsidies also target underenrollment. The amount of the subsidy equals the difference between the benchmark plan premium and the consumer's income contribution cap. 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 metal 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; and (4) lack an "affordable plan offer" through employer-sponsored insurance either as an employee or as a dependent.[2]

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.

2 Model

In this section, I develop a framework to study the impact of policies targeting underinsurance and underenrollment due to adverse selection. I first build a model of the ACA exchanges that I take to the data. I then construct a conceptual version of the model to illustrate the tradeoff in addressing underinsurance and underenrollment.

2.1 ACA Exchange Model

Consider a two-stage model where (1) insurers first set the premiums of their plans simultaneously to maximize their expected profit and (2) consumers then select a plan to maximize their expected utility. To ease the computational burden, I do not permit insurer entry and exit in the model. I 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 also 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, particularly in the absence of risk adjustment. Ignoring provider networks and formularies could bias my welfare estimates, but is unlikely to have a bearing on my central research

[2] 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.

question of whether it is possible to simultaneously mitigate underinsurance and underenrollment. Below I detail how I model household plan choice and then discuss how I model firm premium-setting.

2.1.1 Stage 2: Households Choose Plans

In the second stage, households choose the plan that maximizes their utility function

$$U_{ij} \equiv \alpha_i p_{ij} + x_j' \beta + d_i' \varphi + \xi_j + \epsilon_{ij} \tag{1}$$

where p_{ij} 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, 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

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

The household's premium p_{ij} is calculated as

$$p_{ij} = \max \left\{ \underbrace{r_i p_j}_{\substack{\text{full} \\ \text{premium}}} - \underbrace{\max\{r_i p_b - c_i, 0\}}_{\text{subsidy}}, 0 \right\} \tag{2}$$

where r_i is the household's rating factor that accounts for the age, smoking status, and geographic residence of the household's members. The product of the household's rating factor and the insurer's base premium p_j equals the household's full, unsubsidized premium for plan j. Under the ACA, the subsidy is equal to the difference between what the household pays for the benchmark plan ($r_i p_b$) and the household's income contribution cap c_i ($c_i = \infty$ for households ineligible for premium subsidies).

If households are rational economic agents, they should view the penalty ρ_i assessed under the individual mandate as the price of choosing to forgo insurance. The utility of the outside option therefore equals

$$U_{i0} = \alpha_i \rho_i + \epsilon_{i0} \tag{3}$$

In Saltzman (2018), I find that consumers exhibit greater responsiveness to the *existence* of the penalty than the *amount* of the penalty. Consumers might have a taste for complying with the mandate or a distaste for paying a fine. To account for this behavioral response to the mandate, I include in the vector of demographic variables d_i in equation (1) a variable that indicates whether household i is subject to the individual mandate.

The specification of utility equation (1) captures potential heterogeneity in preferences across demographic groups. The demographic parameters φ indicate each demographic's taste for exchange insurance, all else equal, and are identified because they do not appear in equation (3). The interaction term parameters γ indicate how premium sensitivity varies by demographic group.

2.1.2 Stage 1: Firms Set Premiums

Consider the first-stage problem where firms set premiums. Risk adjustment is a key policy that affects firm incentives. Firms with lower-than-average risk make transfer payments to firms with higher-than-average risk so that each firm faces the average risk in the market. Ignoring differences in plan actuarial values and discrepancies between claims and risk, the risk adjustment transfer RA_f is designed to replace the firm's average claims with the average claims in the market. Equivalently, the transfer replaces the firm's total claims $C_f(\mathbf{p})$ with its market share $s_f(\mathbf{p})$ of total market claims $C(\mathbf{p}) = \sum_f C_f(\mathbf{p})$.

The ACA transfer formula must accommodate differences in plan actuarial values. Plans with lower cost sharing (e.g., platinum) have higher expected claims than plans with higher cost sharing (e.g., bronze), even if consumers enrolled in the two plans have the same risk. To address this issue, I define the firm's risk-adjusted market share $rs_f(\mathbf{p})$ of total market claims as

$$rs_f(\mathbf{p}) = \frac{\sum_{k \in J_f} h_k q_k(\mathbf{p})}{\sum_{j \in J} h_j q_j(\mathbf{p})}$$

where $q_j(\mathbf{p})$ is plan j's demand and h_j is a factor that accounts for the plan actuarial value and expected moral hazard that results from choosing a more generous plan. The summation in the numerator is taken over all of firm f's plans J_f, while the summation in the denominator is taken over all exchange plans J.

The transfer formula also needs to account for the imprecision of claims as a measure of risk. This imprecision may arise because some firms are more efficient, have greater bargaining power, or superior ability to exploit the risk adjustment formula. I define the firm's efficiency score ϕ_f to account for all unobserved factors that may cause a firm's cost to deviate from its risk-adjusted market share of total market claims. Firms with higher-than-average efficiency scores have $\phi_f > 1$ and firms with lower-than-average efficiency scores have $\phi_f < 1$. The ACA risk adjustment transfer can be written as[3]

$$RA_f(\mathbf{p}) \quad = \quad \phi_f C_f(\mathbf{p}) - rs_f(\mathbf{p})C(\mathbf{p}) \tag{4}$$

The risk adjustment transfers net to zero such that $\sum_f RA_f(\mathbf{p}) = 0$. A risk-neutral, profit-maximizing firm f sets the premiums of the plans J_f that it offers to maximize its expected profit

$$\begin{aligned} \pi_f(\mathbf{p}) &= R_f(\mathbf{p}) - C_f(\mathbf{p}) + RA_f(\mathbf{p}) \\ &= R_f(\mathbf{p}) - rs_f(\mathbf{p})C(\mathbf{p}) - (1 - \phi_f)C_f(\mathbf{p}) \end{aligned} \tag{5}$$

where $R_f(\mathbf{p})$ is the total premium revenue that the firm collects. If the firm has average efficiency and its risk adjusted share equals its market share, then the transfer $RA = C_f(\mathbf{p}) - s_f(\mathbf{p})C(\mathbf{p})$ and $\pi_f(\mathbf{p}) = R_f(\mathbf{p}) - s_f(\mathbf{p})C(\mathbf{p})$. Hence, this transfer would replace the firm's own claims with its market share of total market claims.

The first-order conditions corresponding to equation (5) are given by

$$MR_j(\mathbf{p}) \quad = \quad \overline{MC}_j(\mathbf{p}) + (1 - \phi_f)MC_j(\mathbf{p}) \tag{6}$$

for all plans j offered by the firm, where "average marginal claims" $\overline{MC}_j(\mathbf{p}) = \partial(s_f(\mathbf{p})C(\mathbf{p}))/\partial q_f(\mathbf{p})$. Average marginal claims are what plan j's marginal claims would have been if its enrollees had average risk. Each firm now faces average marginal claims instead of its own marginal claims. Risk adjustment raises marginal cost for firms that draw enrollees with lower-than-average risk, incentivizing them to increase premiums according to equation (6). Conversely, risk adjustment reduces marginal cost for firms with higher-than-average risk, incentivizing them to decrease premiums.

To complete the model, I need to account for reinsurance and firm administra-

[3] The risk adjustment formula used in the ACA setting differs slightly from formula (4). Appendix B derives the ACA risk adjustment transfer formula and price equilibrium.

tive costs. 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 the reinsurer will pay). Firms may also have variable administrative costs V_f such as commissions and fees and fixed administrative costs FC_f such as overhead. Inclusion of these institutional details results in the expected profit function

$$\pi_f(\mathbf{p}) \;=\; R_f(\mathbf{p}) - rs_f(\mathbf{p})C(\mathbf{p}) - (1-\phi_f-\tau_f)C_f(\mathbf{p}) - V_f - FC_f \tag{7}$$

with corresponding first-order conditions

$$MR_j(\mathbf{p}) \;=\; \overline{MC}_j(\mathbf{p}) + (1-\phi_f-\tau_f)MC_j(\mathbf{p}) + v_f\frac{\partial q_f(\mathbf{p})/\partial p_j}{\partial q_j(\mathbf{p})/\partial p_j} \tag{8}$$

for all plans j offered by the firm, where v_f is per-member variable administrative cost, $q_j(\mathbf{p})$ is plan j's demand, and $q_f(\mathbf{p})$ is firm f's total demand. The fraction $(\partial q_f(\mathbf{p})/\partial p_j)/(\partial q_j(\mathbf{p})/\partial p_j)$ lies in the interval $[0,1]$ and measures the degree to which consumers substitute to plans offered by other firms if firm f increases the premium for plan j. The fraction equals 0 if there is no substitution and 1 if there is complete substitution to plans offered by other firms.

Appendix A shows how every variable in the model can be written in terms of four variables that I can estimate, including: (1) the probability $q_{ij}(\mathbf{p})$ that household i selects plan j; (2) the partial derivative $\partial q_{ik}(\mathbf{p})/\partial p_{ij}$ for all plans j and k; (3) the firm's average claims function $c_f(\mathbf{p})$; and (4) the vector of "claim slopes" with elements $\partial c_f(\mathbf{p})/\partial p_j$ for all plans j that each firm f offers. The claim slope measures how a firm's average claims respond to a plan premium change and plays a key role in determining the combined effect of adverse selection and moral hazard.

After estimating the demand and claims variables, I can use the first-order conditions (14) in Appendix B to compute equilibrium premiums under alternative scenarios. A significant computational challenge with using the first-order conditions is the ACA's endogenous subsidy, as defined in equation (2). The first-order condition for the benchmark plan is different than the first-order conditions for all other plans. For the benchmark plan, an infinitesimal premium increase of $\epsilon > 0$ does not affect what consumers pay for the plan, but rather reduces what consumers pay for all other plans by ϵ. In contrast, a premium increase of ϵ for any other plan increases what consumers pay for that plan by ϵ, but has no bearing on what consumers pay for all other plans. Adding to the computational burden is that the benchmark plan varies across consumers depending on the plans available in their geographic market. Because of the important role premium subsidies play in addressing adverse selection, I include the ACA's endogenous subsidy design in my model despite the high computational cost.

2.2 Conceptual Model

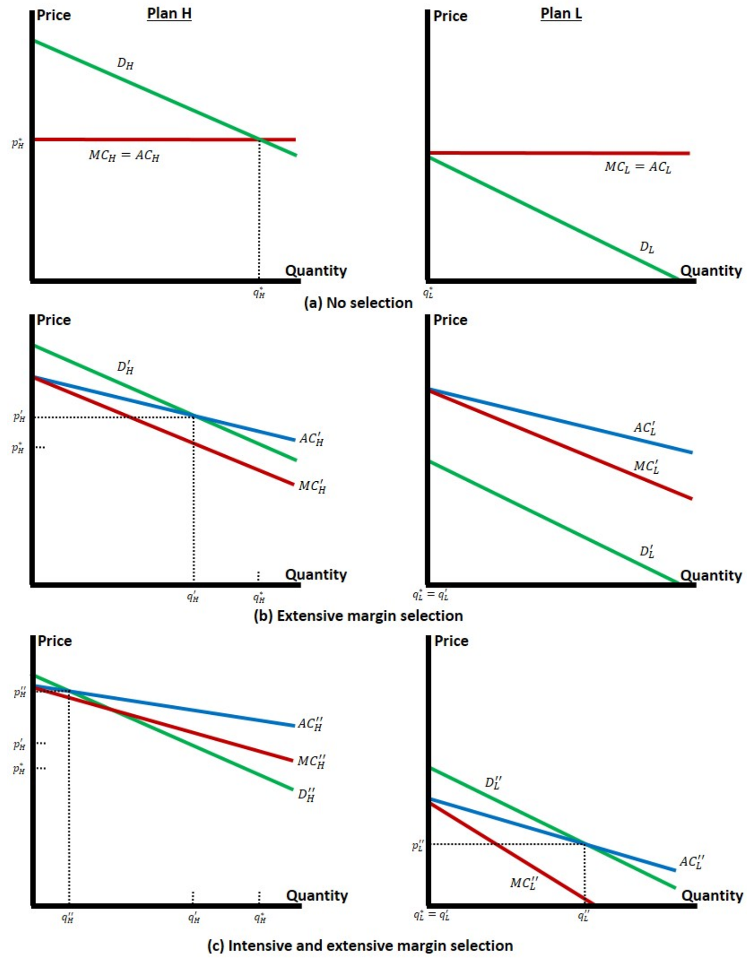
Because of the complex institutional details of the ACA, the tradeoff in addressing underinsurance and underenrollment may be opaque in the model developed above. I now construct a graphical representation in the spirit of Einav and Finkelstein (2011) to show an example of the tradeoff. I assume (1) the market is competitive such that firms price at average cost; (2) cost is directly proportional to risk; and (3) consumers can either purchase plan H with premium p_H that has comprehensive benefits, purchase plan L with premium p_L that has limited benefits, or forgo insurance. Even with only three options, developing an intuitive graphical representation is challenging because of cross-price effects. Define the "best response" function $p_k(p_j)$ as the premium for plan $k \neq j$ that equates price and average cost such that $p_k(p_j) = c_k(p_j, p_k(p_j))$. I write the demand curve $D_j = q_j(p_j, p_k(p_j))$, the average cost curve $AC_j = c_j(p_j, p_k(p_j))$ and the marginal cost curve $MC_j = MC_j(p_j, p_k(p_j))$ for $j = H, L$ and $k \neq j$.

Figure 2 illustrates an example of how adverse selection can lead to underinsurance and underenrollment. Plan H experiences higher costs than plan L because of its more comprehensive benefit package. Neither plan faces adverse selection in panel (a), as the marginal cost and average cost curves coincide for each plan and do not respond to premium changes. The socially optimal number of consumers q_H^* are covered under plan H and no consumers purchase plan L. Panel (b) shows the impact of selection between each plan and the outside option (i.e., extensive margin adverse selection), but not selection between the plans. The marginal cost and average cost curves diverge and are downward-sloping with respect to quantity, indicating the presence of extensive margin adverse selection. There is no selection between plans because the slopes of the plan marginal cost curves are equal. At equilibrium, enrollment in plan H falls to q_H' and plan H's premium increases to p_H'. Plan L remains unprofitable and $q_L' = q_L^* = 0$. Extensive margin adverse selection in this example results in underenrollment relative to the socially optimal level q_H^*, but does not lead any consumers to underinsure. Panel (c) illustrates how adverse selection between plans affects the market equilibrium. The marginal cost curve for plan L is now steeper, indicating that the expected cost of its marginal consumer is more sensitive to premium changes (i.e., plan L faces greater adverse selection). The cost differential between the two plans increases because low-risk consumers have a lower relative willingness-to-pay for plan H. A market for plan L emerges; enrollment in plan L increases from $q_L^* = 0$ to $q_L^{''}$. Conversely, enrollment in plan H declines to $q_H^{''}$. Despite the increase in underinsurance, total enrollment $q_L^{''} + q_H^{''}$ in panel (c) exceeds total enrollment $q_H^{'}$ in panel (b), but is still less than total enrollment q_H^* in panel (a).

Consider the typical market with both underinsurance and underenrollment. Addressing underinsurance requires a policy such as risk adjustment that eliminates the effects of selection between plans H and L, as illustrated in panel (a) of Figure 3. Because plan L faces greater adverse selection, plan L's risk adjustment transfer payment to plan H raises its marginal cost by more than plan H's marginal cost is reduced. Total enrollment therefore declines and enrollment shifts from plan L to plan H, resulting in a new equilibrium that is very similar to the one depicted in panel (b) of Figure 2. Expanding enrollment requires a policy such as the individual mandate that shifts out the demand curves (or alternatively, a policy that shifts the cost curves in). Panel (b) of Figure 3 shows that the mandate shifts the demand curves for both plans, but marginal cost falls more for plan L because it faces greater adverse selection. Total enrollment increases, but plan L attracts a larger share of new enrollees. I ignore cross-price effects, which would likely result in plan L's demand curve shifting further out and plan H's curve shifting inward from D_H'. Hence, underinsurance is likely to be worse than what is depicted in panel (b).

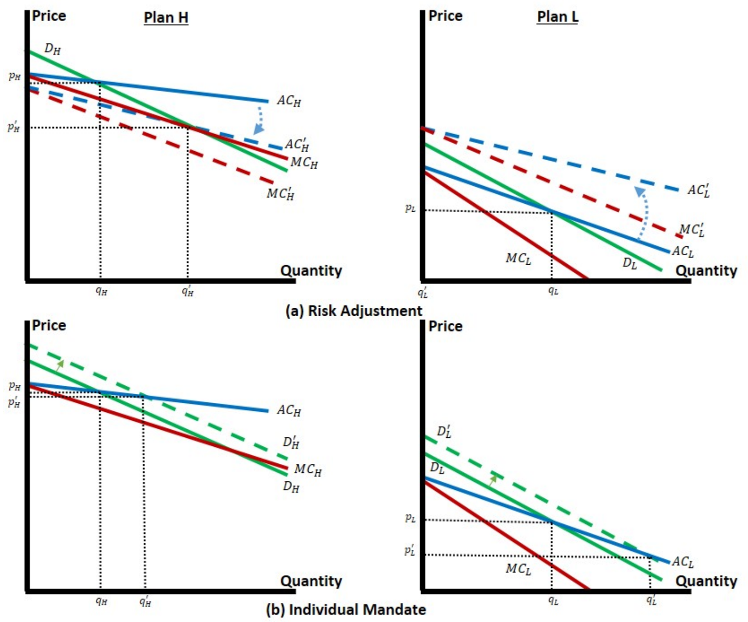
There are some alternative policies that could address both underinsurance and underenrollment, although they have significant caveats. A first-best, but highly impractical policy would be to ban the sale of plan L and mandate that the q_H^* customers with the highest willingness-to-pay purchase plan H. Alternatively, risk adjustment could be coupled with external subsidy funding so that it is no longer revenue neutral and does not result in enrollment declines. Subsidy funding can be explicit as in Medicare Advantage or implicit as in the ACA exchanges (i.e.,

Figure 2: Effect of Adverse Selection on Underinsurance and Underenrollment



Notes: Figure shows an example of how adverse selection can lead to underinsurance and underenrollment. Panel (a) shows the market equilibrium when there is no selection; consumers only choose plan H. Panel (b) shows how selection between each plan and the outside option (but not between plans) affects the market equilibrium; enrollment in plan H is reduced and no one enrolls in plan L. Panel (c) shows how both extensive and intensive margin adverse selection affect the market equilibrium; enrollment shifts from plan H to plan L. Total enrollment in panel (c) is less than in panel (a), but more than in panel (b).

Figure 3: Addressing Underinsurance and Underenrollment



Notes: Figure shows how risk adjustment and the individual mandate affect enrollment and coverage levels. In panel (a), the risk adjustment transfer from plan L to plan H rotates plan L's cost curves up and plan H's cost curves down. Because plan L faces greater adverse selection, plan L's costs go up more than plan H's costs go down. Hence, total enrollment declines and enrollment shifts from plan H to plan L. In panel (b), the individual mandate shifts out the demand curves for both plans, but marginal cost falls more for plan L because it faces greater adverse selection. Total enrollment increases, but plan L attracts a larger share of new enrollees. As discussed in the text, I ignore cross-price effects, which could lead to greater underinsurance than depicted in panel (b).

higher premiums trigger larger, offsetting subsidies). Welfare gains from preventing enrollment declines must be compared to welfare losses from subsidy outlays.

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 1 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 other firms largely serve local markets. 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.

Table 1: Insurer Market Share in the California Exchange

	2014	2015
Anthem Blue Cross	29.0%	27.8%
Blue Shield of California	28.3%	26.4%
Centene/Health Net	19.7%	16.4%
Chinese Community Health Plan	1.1%	0.8%
Contra Costa Health Plan	0.1%	
Kaiser Permanente	17.4%	24.2%
L.A. Care Health Plan	2.3%	1.1%
Molina Healthcare	0.7%	1.5%
Sharp Health Care	1.0%	1.2%
Valley Health Plan	0.1%	0.1%
Western Health Advantage	0.3%	0.4%

Notes: Table reports the market shares for each firm participating in the California exchange.

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 2 presents summary statistics on exchange enrollees and the uninsured. Silver is the most commonly selected option because consumers eligible for cost sharing reductions (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 3 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 (12) 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 probability $q_{ij}(\mathbf{p})$ that household i selects plan j; (2) the partial derivative $\partial q_{ik}(\mathbf{p})/\partial p_{ij}$ for all plans j and k; (3) the firm's average claims function $c_f(\mathbf{p})$; and (4) the vector of claim slopes with elements $\partial c_f(\mathbf{p})/\partial p_j$ for all plans j that each firm f offers. I briefly discuss how I estimate the demand function and its partial derivative with respect to the consumer's premium and then explain how I use the demand estimates to estimate the average claims function and the vector of claim slopes.

Table 2: 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 reduction subsidies	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.

4.1 Estimating Demand

Estimation of equation (1) is the main focus of my work in Saltzman (2018); I provide a brief summary here. I model equation (1) 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

Table 3: 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).

nest containing only the outside option. I use this two-nest structure because a key observed substitution pattern is between the silver tier and the outside option due to the ACA's linkage of cost sharing subsidies to the purchase of silver plans. The household choice probabilities are computed as

$$q_{ij}(\mathbf{p};\boldsymbol{\theta}) \quad = \quad \frac{e^{V_{ij}/\lambda}\left(\sum_j e^{V_{ij}/\lambda}\right)^{\lambda-1}}{1+\left(\sum_j e^{V_{ij}/\lambda}\right)^{\lambda}} \tag{9}$$

where $\boldsymbol{\theta}$ is the vector of parameters in equation (1), $V_{ij} = \alpha_i p_{ij} + x_j'\beta + d_i'\varphi + \xi_j$, and λ is the nesting parameter for the exchange nest. I use maximum likelihood to estimate the value of $\boldsymbol{\theta}$ that maximizes the log-likelihood function $LL(\boldsymbol{\theta}) = \sum_{i,j} w_i c_{ij} \ln q_{ij}(\mathbf{p};\boldsymbol{\theta})$, where w_i is the household's weight and c_{ij} takes 1 if household i chose plan j and 0 otherwise. With the estimated parameter vector $\boldsymbol{\theta}$, I can estimate household i's demand $q_{ij}(\mathbf{p})$ for plan j and its partial derivatives $\partial q_{ik}(\mathbf{p})/\partial p_{ij}$ for all plans k.

The main challenge with estimating equation (1) is that the premium may be endogenous. Premiums vary across insurers, markets, and households. Unobserved product characteristics that vary at the insurer-market level, such as insurer entry decisions, provider networks, and formularies, could be correlated with premiums. Including insurer-market fixed effects in equation (1) controls for these unobservables. Ho and Pakes (2014) and Tebaldi (2017) follow a similar approach. The inclusion of fixed effects permits estimation of the premium parameter in utility equation (1) because premiums also vary across households and I estimate demand at the household-level. ACA regulations create exogenous variation in premiums across households that I exploit to identify the effect of the premium on the household's choice. Examples of this variation include the upper income limit for subsidy eligibility that creates a discontinuity in household premiums at 400 percent of FPL and sharp income-based exemptions from the individual mandate.

4.2 Estimating Claims

To estimate each firm's average claims function and vector of claim slopes, I develop a strategy that combines my demand estimates with firm-level data from several sources. Previous work typically assumes that the claims function is linear (Einav et al., 2010), implying that the claim slope $\partial c_f(\mathbf{p})\partial p_j$ is a constant. Because the medical spending distribution is highly skewed, it is possible that the rate of change in average claims varies with the premium. I specify a more flexible average claims function with the quadratic form

$$c_f(\mathbf{p}) \quad = \quad \sum_{k \in J_f} \left[\frac{1}{2} b_1 p_k^2 + b_2 x_k p_k\right] + d_f \tag{10}$$

where x_k is a vector of observed plan characteristics (including the plan actuarial value, whether the plan is a health maintenance organization (HMO), and whether the plan allows enrollees to establish a health savings account (HSA)), and d_f is an intercept. The total differential of equation (10) equals

$$dc_f(\mathbf{p}) = \sum_{k \in J_f} \frac{\partial c_f(\mathbf{p})}{\partial p_k} dp_k = \sum_{k \in J_f} \left[b_1 p_k + b_2 x_k\right] dp_k$$

where the claim slope $\partial c_f(\mathbf{p})/\partial p_k = b_1 p_k + b_2 x_k$ is linear in the premium p_k and product characteristics x_k. Given data on each plan's claim slope, premium, and product characteristics, I can estimate the claims function parameters b_1 and b_2 by regressing the claim slope on the premium and product characteristics. I estimate these parameters using ordinary least squares, as well as two-stage least squares to address potential endogeneity of the premium. I use the instruments suggested by Berry et al. (1995) that measure each plan's isolation in the product space. I recover the claims function intercept d_f for each firm using the observed averaged claims and the predicted claim slopes as the initial condition.

The main empirical challenge with this approach is that I do not observe the vector of claim slopes. To obtain estimates of the claim slope, I assume that the exchanges are in equilibrium, allowing me to invert first-order conditions (14) to obtain non-parametric estimates of average marginal claims. I then solve for the claim slopes in formula (11). 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. In particular, formula (11) for average marginal claims does not necessitate knowledge of the claims cross-partial derivatives (i.e., how a firm's average claims respond to the base premium of plans sold by one of a firm's competitors). In the industrial organization literature, inversion of the first-order conditions is often used to recover firm cost. In this case, I have average cost data and instead use the first-order conditions to recover the claim slopes, accounting for the likely presence of adverse selection and moral hazard.

A shortcoming of average claims function specification (10) is that it only includes the premiums of plans sold by firm f. I exclude the premiums of plans sold by other plans because I do not have enough first-order conditions to obtain estimates of the claims cross-partial derivatives. This exclusion could bias the average claims estimates, although the direction of the bias is unclear and the magnitude of the bias is likely to be small in a market with a large number of firms and plans. As an alternative, I specify average claims as a function of the demand for plans sold by firm f in Appendix C. In this specification, average claims are a function of all exchange premiums because the demand functions are a function of all exchange premiums. However, I find this alternative specification adds to the computational burden and is difficult to fit because of the generated regressors.

5 Demand and Claims Estimates

5.1 Demand Estimates

I present complete results of the demand estimation in Saltzman (2018) and provide a brief summary here. The first two columns of Table 4 report the mean own-premium elasticity of demand, which is the percentage change in a plan's enrollment associated with a one percent increase in its premium, and the mean own-premium semi-elasticity of demand, which is the percentage change in a plan's enrollment associated with a $\$100$ increase in its annual premium. Consumers have a mean own-premium elasticity of -9.1 and mean own-premium semi-elasticity of -21.8. These estimates are higher than those of Tebaldi (2017) and Drake (2018), but lower than Domurat (2017)'s estimates. I also find low-income individuals, males, and young adults between the ages of 18 and 34 are more premium sensitive. The second two columns report the elasticity for exchange coverage, which is the percentage change in exchange enrollment associated with a one percent increase in the base premium of all exchange plans, and the semi-elasticity for exchange coverage, which is the percentage change in exchange enrollment associated with a $\$100$ annual increase in all exchange premiums. California consumers have an elasticity for exchange coverage of -1.2 and a semi-elasticity for exchange coverage of -3.3. These estimates are similar to those of Tebaldi (2017).

5.2 Claims Estimates

Table 5 shows estimates of the parameters b_1 and b_2 in average claims function (10) for the California exchange. The estimates are similar for both ordinary least squares and two-stage least squares. Only the coefficients for the base premium and the actuarial value are statistically significant. The estimated coefficients for the base premium and the actuarial value have an intuitive interpretation that decomposes the effects of adverse selection and moral hazard on the claim slope. In particular, the coefficient b_1 measures how the claim slope responds to premiums, given the plan actuarial value and any associated moral hazard. The positive value of b_1 indicates that selection worsens as the premium increases. Conversely, the negative coefficient on the actuarial value coefficient indicates that more generous

Table 4: 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 elasticities and semi-elasticities by demographic group. The first two columns report mean own-premium elasticities and semi-elasticities. The second two columns report mean elasticities and semi-elasticities for exchange coverage. I use the plan market shares as weights to compute the mean elasticities and semi-elasticities.

plans have a lower claim slope, controlling for selection by holding the base premium fixed. A small increase in the premium of a more generous plan is likely to incentivize consumers to substitute to a less generous plan under which they consume less, reducing average claims. Overall, the model predictor variables explain about half of the variation in the claim slope.

6 Impact of Risk Adjustment

To examine the impact of risk adjustment in the ACA exchanges, I compute equilibrium premiums in a counterfactual scenario where the risk adjustment program is eliminated. Table 6 compares average premiums for a 40-year-old by metal tier and by insurer in this counterfactual scenario (column 1) to average premiums in the baseline ACA scenario where the ACA risk adjustment program is in place

Table 5: Predicting the Claim Slope ($\partial c_f(\mathbf{p})/\partial p_j$)

	Ordinary Least Squares	Instrumental Variables
Base Premium	0.010	0.008
	(0.001)	(0.002)
Actuarial Value	−7.685	−6.910
	(0.754)	(1.175)
HMO	−0.002	0.022
	(0.087)	(0.087)
HSA	0.299	0.307
	(0.190)	(0.193)
Observations	149	149
R^2	0.494	0.488
Adjusted R^2	0.480	0.474

Notes: Robust standard errors are in parentheses. Table shows parameter estimates for the linear regression of the claim slope on the premium and plan characteristics in the California exchange. Each observation is a plan-year combination.

(column 2). Risk adjustment leads to reductions in platinum and gold premiums by 25 and 15 percent, respectively, and increases in bronze and silver premiums by 11 and 2 percent, respectively. The second panel of Table 6 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 7 shows how risk adjustment affects insurance coverage. Column 1 reports simulated coverage in the counterfactual scenario where I eliminate risk adjustment and column 2 reports observed coverage in the ACA exchanges with risk adjustment in place. 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.

Before concluding that risk adjustment mitigates underinsurance without reducing enrollment, it is important to consider effect of the ACA's price-linked sub-

Table 6: Effect of Risk Adjustment on (Pre-Subsidy) Premiums

	No Risk Adjustment	Risk Adjustment: ACA Subsidies	Risk Adjustment: Vouchers
Metal			
Bronze	$198	$221	$218
Silver	$267	$273	$269
Gold	$367	$315	$310
Platinum	$474	$353	$346
Insurer (Silver Premium)			
Anthem BC	$271	$291	$284
Blue Shield	$279	$262	$261
Chinese Community	$268	$342	$354
Contra Costa	$334	$355	$367
Centene/Health Net	$222	$233	$229
Kaiser	$286	$292	$288
L.A. Care	$238	$259	$247
Molina	$247	$261	$262
Sharp	$380	$324	$332
Valley	$286	$353	$350
Western	$412	$396	$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 6 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 simulated scenarios. The first column presents simulated premiums without risk adjustment. The second column presents observed premiums with risk adjustment when ACA risk adjustment formula (12) is used. The third column presents simulated premiums with risk adjustment when ACA risk adjustment formula (12) is used and vouchers replace ACA price-linked subsidies. The household's voucher is set equal to the subsidy each household receives in the scenario without risk adjustment (column 1).

sidy design. Consumers receive larger subsidies in the baseline ACA scenario than in the counterfactual scenario where risk adjustment is eliminated because higher silver plan premiums increase the subsidies that consumers receive. To control for subsidy levels, I construct a second counterfactual scenario where consumers receive a voucher equal to the subsidy that they receive in the first counterfactual scenario where risk adjustment is eliminated. The third column of Tables 6 and 7

Table 7: Effect of Risk Adjustment on Insurance Coverage

	No Risk Adjustment	Risk Adjustment	
		ACA Subsidies	Vouchers
Catastrophic	26,319	9,174	9,075
Bronze	322,483	314,528	304,852
Silver	870,704	850,537	818,946
Gold	70,420	72,079	75,964
Platinum	26,331	64,216	71,757
Total Coverage	1,316,258	1,310,535	1,280,594

Notes: Table shows the impact of risk adjustment on insurance coverage by metal tier in California. The first column presents the simulated insurance coverage distribution without risk adjustment. The second column presents the observed insurance coverage distribution with risk adjustment when ACA risk adjustment formula (12) is used. The third column presents the simulated insurance coverage distribution with risk adjustment when ACA risk adjustment formula (12) is used and vouchers replace ACA price-linked subsidies. The household's voucher is set equal to the subsidy each household receives in the scenario without risk adjustment (column 1).

shows the impact of risk adjustment when consumer subsidies are fixed at the level in the first column. Premiums and the enrollment distribution across the metal tiers are similar in columns 2 and 3 of Table 6, but total coverage is lower in column 3 than in column 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 therefore addresses underinsurance, but exacerbates underenrollment.

In Table 8, 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. Under ACA subsidies, risk adjustment increases consumer surplus by about $200 per consumer per year 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 column 3, I report the welfare impact of risk adjustment under vouchers that are set at the level in column 1. The most significant difference is the drop in consumer surplus of about $200 per year, instead of an increase of about $200 per year in the baseline ACA scenario. 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.

Table 8: Effect of Risk Adjustment on Annual Per-Capita Social Welfare

		Risk Adjustment	
	No Risk Adjustment	ACA Subsidies	Vouchers
Consumer Surplus	$5,035	$5,231	$4,826
Profit	-$2	-$94	-$234
Government Spending			
Premium Subsidies	-$1,288	-$1,511	-$1,277
CSRs	-$122	-$131	-$130
Mandate Revenue	$188	$192	$195
Uncompensated Care	-$998	-$1,002	-$1,027
Social Welfare	$2,814	$2,685	$2,353

Notes: Table shows the impact of risk adjustment on annual per-capita social welfare in California. The first column presents the simulated welfare distribution without risk adjustment. The second column presents the welfare distribution with risk adjustment when ACA risk adjustment formula (12) is used. The third column presents the simulated welfare distribution with risk adjustment when ACA risk adjustment formula (12) is used and vouchers replace ACA price-linked subsidies. The household's voucher is set equal to the subsidy each household receives in the scenario without risk adjustment (column 1). The calculations for consumer surplus, profit, premium subsidies, cost sharing subsidies, individual mandate revenue are endogenous to the model. I calculate uncompensated care by multiplying the number of uninsured that I estimate 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).

7 Impact of the Individual Mandate

To examine the impact of individual mandate in the ACA exchanges, I compute equilibrium premiums in a counterfactual scenario where the individual mandate is repealed. Table 9 compares premiums for a 40-year-old by metal tier in this counterfactual scenario (column 2) to average premiums in the baseline ACA scenario where the mandate is in effect (column 1). The mandate reduces bronze plan premiums by about 4 percent, while platinum plan premiums increase by 1.7 percent. Silver and gold plan premiums also decrease modestly. Column 1 of Table 10 reports observed coverage under the ACA mandate and column 2 reports simulated coverage in the counterfactual scenario. The individual 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 11 indicates that the mandate decreases consumer surplus by about $\$150$ per consumer per year or 2.6 percent 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.

Table 9: Effect of the Individual Mandate on (Pre-Subsidy) Premiums

		No Individual Mandate	
	Individual Mandate	ACA Subsidies	Vouchers
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 simulated scenarios. The first column presents the observed premiums with the mandate in effect. The second column presents simulated premiums without the individual mandate and ACA price-linked subsidies in place. The third column presents simulated premiums without the individual mandate when vouchers replace ACA price-linked subsidies. The household's voucher is set equal to the subsidy the household receives under the ACA with the mandate in effect.

Table 10: Effect of the Individual Mandate on Insurance Coverage

	Individual Mandate	No Individual Mandate	
		ACA Subsidies	Vouchers
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

Notes: Table shows the impact of the individual mandate on insurance coverage by metal tier in California. The first column presents the observed coverage distribution with the mandate in effect. The second column presents the simulated coverage distribution without the individual mandate and ACA price-linked subsidies in place. The third column presents the simulated coverage distribution without the individual mandate when vouchers replace ACA price-linked subsidies. The household's voucher is set equal to the subsidy the household receives under the ACA with the mandate in effect.

I construct a second counterfactual scenario where consumers receive a voucher equal to the subsidy that consumers receive under the ACA with the mandate in effect. The third columns of Tables 9, 10, and 11 show the impact of the mandate when consumer subsidies are fixed at the level in the first column. The effect of the mandate on premiums is not particularly sensitive to the subsidy design, but total exchange enrollment is lower in column 3 than in column 2. The mandate increases annual per-capita consumer surplus by 6.6 percent under vouchers because consumers benefit from the lower bronze, silver, and gold 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.

8 Conclusion

Mitigating underinsurance and underenrollment due to adverse selection is a key challenge in the design of efficient health insurance markets. In this paper, I study whether it is possible to address both underinsurance and underenrollment simul-

Table 11: Effect of the Individual Mandate on Per-Capita Social Welfare

	Individual Mandate	No Individual Mandate: ACA Subsidies	No Individual Mandate: Vouchers
Consumer Surplus	$5,231	$5,373	$4,909
Profit	-$94	-$131	$40
Government Spending			
Premium Subsidies	-$1,511	-$1,251	-$1,088
CSRs	-$131	-$121	-$103
Mandate Revenue	$192	$0	$0
Uncompensated Care	-$1,002	-$1,198	-$1,226
Social Welfare	$2,685	$2,672	$2,532

Notes: Table shows the impact of the individual mandate on annual per-capita social welfare. The first column presents the welfare distribution with the mandate in effect. The second column presents the simulated welfare distribution without the individual mandate and ACA price-linked subsidies in place. The third column presents the simulated welfare distribution without the individual mandate when vouchers replace ACA price-linked subsidies. The household's voucher is set equal to the subsidy the household receives under the ACA with the mandate in effect. The calculations for consumer surplus, profit, premium subsidies, cost sharing subsidies, individual mandate revenue are endogenous to the model. I calculate uncompensated care by multiplying the number of uninsured that I estimate 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).

taneously. 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 in the ACA exchanges. I find that risk adjustment addresses underinsurance, but may reduce enrollment in the absence of price-linked subsidies that shield consumers from premium increases. Conversely, the individual mandate increases enrollment, but also increases underinsurance.

My analysis has several limitations. I assume that product characteristics such as plan provider networks and formularies are exogenous. Firms could use narrow provider networks and restrictive formularies to attract low-risk consumers, particularly in the absence of risk adjustment. In my model, I assume that the exchanges are in equilibrium and firms have perfect knowledge of their own and their competitors' claims functions. Several years or more may be required for firms to learn about consumer preferences, enrollee utilization, and strategic interactions with their competitors. Another issue concerns inversion of the firms' first-order conditions to estimate the claim slope. Inversion may fail or result in an overestimate of the claim slope if the sum of the efficiency score and reinsurance factor is close to 1. Large estimates of the claim slope could magnify the impact of premium changes.

There are several dimensions along which the analysis in this paper could be extended. Most of my results are empirical, and it would be particularly valuable to establish theoretical conditions under which the underinsurance-underenrollment tradeoff occurs. 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: Mathematical Formulas in Model

In this appendix, I write the variables in the model in terms of four variables: (1) the household choice probability $q_{ij}(\mathbf{p})$; (2) the partial derivative $\partial q_{ik}/\partial p_{ij}(\mathbf{p})$ for all plans j and k; (3) the firm's average claims function $c_f(\mathbf{p})$; and (4) the vector of claim slopes with elements $\partial c_f(\mathbf{p})/\partial p_j$.

Demand Variables

Formulas for plan demand $q_j(\mathbf{p})$, firm demand $q_f(\mathbf{p})$, market demand $q(\mathbf{p})$, and the risk-adjusted share are given by

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

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

$$q(\mathbf{p}) = \sum_{l \in J} q_l(\mathbf{p}) = \sum_{i \in I, l \in J} q_{il}(\mathbf{p})$$

$$rs_f(\mathbf{p}) = \frac{\sum_{i \in I, k \in J_f} h_k q_{ik}(\mathbf{p})}{\sum_{i \in I, l \in J} h_l q_{il}(\mathbf{p})}$$

where h_j is an expected utilization measure that accounts for the actuarial value of plan j and associated moral hazard.

Revenue Variables

Formulas for total firm premium revenue $R_f(\mathbf{p})$ and total premium revenue across all firms $R(\mathbf{p})$ are given by

$$R_f(\mathbf{p}) = \sum_{i \in I, k \in J_f} r_{ik} p_k q_{ik}(\mathbf{p})$$

$$R(\mathbf{p}) = \sum_{f \in F} R_f(\mathbf{p}) = \sum_{i \in I, l \in J} r_{il} p_l q_{il}(\mathbf{p})$$

Claims Variables

Formulas for total firm claims $C_f(\mathbf{p})$ and total incurred claims across all firms $C(\mathbf{p})$ are given by

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

$$C(\mathbf{p}) = \sum_{f\in F} C_f(\mathbf{p}) = \sum_{f\in F} c_f(\mathbf{p}) \left(\sum_{i\in I, k\in J_f} q_{ik}(\mathbf{p}) \right)$$

Market-wide average claims $c(\mathbf{p})$ can be written as

$$c(\mathbf{p}) = \frac{\sum_{f\in F} q_f(\mathbf{p})c_f(\mathbf{p})}{\sum_{f\in F} q_f(\mathbf{p})} = \frac{\sum_{f\in F} c_f(\mathbf{p}) \left(\sum_{i\in I, k\in J_f} q_{ik}(\mathbf{p})\right)}{\sum_{f\in F} q_f(\mathbf{p})}$$

Administrative Cost Variables

Variable administrative cost can be written as

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

where v_f is the per-member, per-month variable administrative cost.

Demand Partial Derivatives

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

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

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

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

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

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

$$\begin{aligned} MR_j(\mathbf{p}) &= \frac{\partial R_f(\mathbf{p})}{\partial q_j(\mathbf{p})} = \left(\frac{\partial q_j(\mathbf{p})}{\partial p_j}\right)^{-1} \sum_{i\in I} \left(r_{ij} q_{ij}(\mathbf{p}) + \sum_{k\in J_f} r_{ik} p_k \frac{\partial q_{ik}(\mathbf{p})}{\partial p_j} \right) \\ MC_j(\mathbf{p}) &= \frac{\partial C_f(\mathbf{p})}{\partial q_j(\mathbf{p})} = \left(\frac{\partial q_j(\mathbf{p})}{\partial p_j}\right)^{-1} \left[c_f(\mathbf{p}) \frac{\partial q_f(\mathbf{p})}{\partial p_j} + q_f(\mathbf{p}) \frac{\partial c_f(\mathbf{p})}{\partial p_j} \right] \\ \overline{MC}_j(\mathbf{p}) &= \frac{\partial (rs_f(\mathbf{p}) C(\mathbf{p}))}{\partial q_j(\mathbf{p})} = \left(\frac{\partial q_j(\mathbf{p})}{\partial p_j}\right)^{-1} \left[C(\mathbf{p}) \frac{\partial rs_f(\mathbf{p})}{\partial p_j} + rs_f(\mathbf{p}) \frac{\partial C(\mathbf{p})}{\partial p_j} \right] \end{aligned} \tag{11}$$

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

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

The formula for $\partial C(\mathbf{p})/\partial p_j$ does not require data on the claims cross-partial derivatives. That is, it is not necessary to calculate $\partial C_f(\mathbf{p})/\partial p_j$ if plan j is not sold by firm f. Elimination of the cross-partial derivatives makes empirical estimation of the model feasible when only firm-level cost data is available.

Appendix B: Risk Adjustment Under the ACA

In this appendix, I derive the ACA risk adjustment formula and price equilibrium in the ACA setting. 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).[4] Pope et al. (2014) show that the per-member per-month risk

[4] 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 et al. (2014)'s second appendix does not account for certain differences

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 $c_j(\mathbf{p})/c(\mathbf{p})$. 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 formula:

$$RA_f(\mathbf{p}) = \frac{\phi_f C_f(\mathbf{p})R(\mathbf{p})}{C(\mathbf{p})} - rs_f(\mathbf{p})R(\mathbf{p}) \tag{12}$$

Adding the ACA transfer (12) to firm f's profit function yields

$$\pi_f(\mathbf{p}) = (1 - rs_f(\mathbf{p}))R(\mathbf{p}) + \phi_f C_f(\mathbf{p})R(\mathbf{p})/C(\mathbf{p}) - (1-\tau_f)C_f(\mathbf{p}) - V_f - FC_f \tag{13}$$

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such as variation in geographic cost. Instead, Pope et al. (2014) account for these differences by applying factors in the transfer formula.

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

$$MR_j(\mathbf{p}) \;=\; \overline{MR}_j(\mathbf{p}) - \phi_f MC'_j(\mathbf{p}) + (1-\tau_f)MC_j(\mathbf{p}) + v_f \frac{\partial q_f(\mathbf{p})/\partial p_j}{\partial q_j(\mathbf{p})/\partial p_j} \quad (14)$$

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

$$\begin{aligned}
\overline{MR}_j(\mathbf{p}) &= \frac{\partial(rs_f(\mathbf{p})R(\mathbf{p}))}{\partial q_j(\mathbf{p})} = \left(\frac{\partial q_j(\mathbf{p})}{\partial p_j}\right)^{-1}\left[R(\mathbf{p})\frac{\partial rs_f(\mathbf{p})}{\partial p_j} + rs_f(\mathbf{p})\frac{\partial R(\mathbf{p})}{\partial p_j}\right] \\
MC'_j(\mathbf{p}) &= \frac{\partial}{\partial q_j(\mathbf{p})}\left(\frac{C_f(\mathbf{p})R(\mathbf{p})}{C(\mathbf{p})}\right) \\
&= \frac{C(\mathbf{p})\left[\frac{\partial C_f(\mathbf{p})}{\partial p_j}R(\mathbf{p}) + C_f(\mathbf{p})\frac{\partial R(\mathbf{p})}{\partial p_j}\right] - C_f(\mathbf{p})R(\mathbf{p})\frac{\partial C(\mathbf{p})}{\partial p_j}}{\frac{\partial q_j(\mathbf{p})}{\partial p_j}[C(\mathbf{p})]^2} \\
&= MC_j(\mathbf{p})\frac{R(\mathbf{p})}{C(\mathbf{p})} + \\
&\quad \frac{C_f(\mathbf{p})\sum_{f'\in F}\sum_{k'\in J_{f'}}\left(C(\mathbf{p})MR_{k'}(\mathbf{p}) - R(\mathbf{p})MC_{k'}(\mathbf{p})\right)\frac{\partial q_{k'}(\mathbf{p})}{\partial p_j}}{[C(\mathbf{p})]^2}
\end{aligned}$$

where

$$\begin{aligned}
\frac{\partial R(\mathbf{p})}{\partial p_j} &= \sum_{f'\in F}\sum_{k'\in J_{f'}}\frac{\partial P_{f'}(\mathbf{p})}{\partial q_{k'}(\mathbf{p})}\frac{\partial q_{k'}(\mathbf{p})}{\partial p_j} = \sum_{f'\in F}\sum_{k'\in J_{f'}} MR_{k'}(\mathbf{p})\frac{\partial q_{k'}(\mathbf{p})}{\partial p_j} \\
\frac{\partial C(\mathbf{p})}{\partial p_j} &= \sum_{f'\in F}\sum_{k'\in J_{f'}}\frac{\partial C_{f'}(\mathbf{p})}{\partial q_{k'}(\mathbf{p})}\frac{\partial q_{k'}(\mathbf{p})}{\partial p_j} = \sum_{f'\in F}\sum_{k'\in J_{f'}} MC_{k'}(\mathbf{p})\frac{\partial q_{k'}(\mathbf{p})}{\partial p_j}
\end{aligned}$$

Appendix C: Alternative Formulation of Average Claims Function

An alternative formulation of average claims function (10) that I consider is

$$c_f(\mathbf{p}) = \sum_{k\in J_f}\left[b_1\log(q_k(\mathbf{p})) + b_2 x_k q_k(\mathbf{p})\right] + d_f \quad (15)$$

The total differential of equation (15) equals

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

where $\partial c_f(\mathbf{p})/\partial q_k(\mathbf{p}) = b_1/q_k(\mathbf{p}) + b_2 x_k$ 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 $\partial c_f(\mathbf{p})/\partial q_k(\mathbf{p})$ 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 $\partial c_f(\mathbf{p})/\partial q_k(\mathbf{p})$ for all $k \in J_f$ as the initial condition. I estimate the partial derivative $\partial c_f(\mathbf{p})/\partial q_k(\mathbf{p})$ by dividing the claim slope $\partial c_f(\mathbf{p})/\partial p_k$ by the demand partial derivative $\partial q_k(\mathbf{p})/\partial p_k$.

Table 12 presents the estimated parameters of average claims function (15). Only the coefficients for demand and the actuarial value are statistically significant. The negative coefficient of inverse demand indicates that adverse selection worsens as demand decreases.

Table 12: Predicting the Partial Derivative $\partial c_f(\mathbf{p})/\partial q_j(\mathbf{p})$

	Ordinary Least Squares
Inverse Demand	-896.285
	(67.142)
Actuarial Value	20.624
	(6.016)
HMO	1.233
	(1.546)
HSA	-0.353
	(3.060)
Observations	149
R^2	0.602
Adjusted R^2	0.591

Notes: Robust standard errors are in parentheses. Table shows parameter estimates for the linear regression of the partial derivative $\partial c_f(\mathbf{p})/\partial q_j(\mathbf{p})$ on inverse demand and plan characteristics. Each observation is a plan-year combination.