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**ABSTRACT**

Insurance markets often feature consumer sorting along both an extensive margin (whether to buy) and an intensive margin (which plan to buy). We present a new graphical theoretical framework that extends the workhorse model to incorporate both selection margins simultaneously. A key insight from our framework is that policies aimed at addressing one margin of selection often involve an economically meaningful trade-off on the other margin in terms of prices, enrollment, and welfare. For example, while a larger penalty for opting to remain uninsured reduces the uninsurance rate, it also tends to lead to unraveling of generous coverage because the newly insured are healthier and sort into less generous plans, driving down the relative prices of those plans. While risk adjustment transfers shift enrollment from lower- to higher-generosity plans, they also sometimes increase the uninsurance rate by raising the prices of less generous plans, which are the entry points into the market. We illustrate these trade-offs in an empirical sufficient statistics approach that is tightly linked to the graphical framework. Using data from Massachusetts, we show that in many policy environments these trade-offs can be empirically meaningful and can cause these policies to have unexpected consequences for overall social welfare.

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# 1 Introduction

Some of the most important problems in health insurance markets stem from adverse selection, or the tendency of sicker consumers to exhibit higher demand for insurance. Concerns about adverse selection have motivated a variety of regulatory interventions in the U.S. and around the world, including insurance mandates, penalties for being uninsured, subsidies for purchasing insurance, risk adjustment transfers, benefit regulation, and reinsurance. Policy discussions about how to address adverse selection have become salient in the U.S. as many public programs have shifted toward providing health insurance via regulated markets (Gruber, 2017).

But, a deeper look reveals that not all policies combating adverse selection are targeted at the same problem. Policies such as mandates and subsidies combat selection on the *extensive margin* (or "against the market"). This type of selection is characterized by sicker people being more likely to buy insurance. It leads to higher insurer costs and higher consumer prices and causes some healthy people to opt out. Policies such as risk adjustment and benefit regulation, on the other hand, combat selection on the *intensive margin* (or "within the market"). This type of selection is characterized by sicker people being more likely to purchase more generous plans within the market. Intensive margin selection drives up the price of generous plans relative to skimpy ones and results in too many consumers choosing skimpy plans. In some cases, selection within the market may be so strong that generous contracts cannot be sustained, and the market for them unravels entirely (Cutler and Reber, 1998).

Prior work has recognized these two problems and has studied policies targeted at each. However, this literature has largely considered these two forms of selection in isolation—either assuming all consumers buy insurance and focusing on the intensive margin (e.g., Handel, Hendel and Whinston, 2015), or assuming all contracts within the market are identical and focusing on the extensive margin (e.g., Hackmann, Kolstad and Kowalski, 2015). By ignoring one margin or the other, the selection problem is usefully simplified. In empirical work, it becomes amenable to a sufficient statistics approach based on demand and cost curves defined in reference to a single price—either the price of insurance or the price difference between a generous vs. a skimpy plan (Einav, Finkelstein and Cullen, 2010). However, this simplification does not allow for potential *interactions* between these two margins of selection.

In this paper, we generalize the canonical insurance market framework to address both margins simultaneously. The benefit of doing so is not merely a technical curiosity. It has first-order policy importance in settings like the ACA Marketplaces where both the generosity of coverage and rates of uninsurance are serious concerns. To see why, consider an insurance mandate—a policy that aims to correct extensive margin selection by bringing healthy marginal consumers into the market. Our framework shows how a mandate that succeeds in increasing rates of insurance coverage will likely *worsen* selection on the intensive margin. Intuitively, the mandate brings more healthy/low-cost consumers into the market. Because these new consumers tend to select the lower-price (and lower-quality) plans, the risk pools of those plans will get even healthier. In equilibrium, these plans will further reduce prices, siphoning additional consumers away from higher-quality plans on the intensive margin, causing prices for high-quality coverage to spiral upwards. These two offsetting effects (improving take-up and inducing within-market unraveling) represent a clear example of the intensive/extensive margin interactions that are the focus of our paper. Recent theoretical insights from Azevedo and Gottlieb (2017), as well as empirical findings from Saltzman (2017) indicate that this is an important omission in contexts like the ACA Marketplaces, where both margins of selection matter. In practice, we show that the size of such effects are first-order in terms of plan choices and welfare.

One of our main contributions is to provide a *graphical* demand-cost framework that lets economists visualize (and teach) the two-margin selection problem in a transparent way. To do so, we build on the influential work of Einav, Finkelstein and Cullen (2010) and Einav and Finkelstein (2011), who show how to visualize selection markets in terms of demand, average cost, and marginal cost curves. We generalize their model to allow for two vertically ranked plans—a more generous $H$ plan and a less generous $L$ plan—plus an outside option of uninsurance ($U$). Although stylized, this vertical model captures the core intuition of the two selection margins: an intensive margin difference in generosity ($H$ vs. $L$) and an extensive margin option to exit the market (by choosing $U$). It also captures the key feature of adverse selection: that higher-risk consumers have greater willingness to pay for generous coverage—both for $H$ relative to $L$, and for $L$ relative to $U$. Our vertical model is the simplest framework that captures these features, and is useful for developing intuition around a potentially multi-dimensional problem by allowing the market to be represented in standard two-dimensional graphs with familiar demand and cost curves. Equilibrium prices, market shares, and social surplus can all be easily visualized.

As in Einav, Finkelstein and Cullen (2010), there is a tight link between our model and the estimation of sufficient statistics used to characterize equilibrium and welfare. Econometric identification is analogous, though exogenous price variation along two margins is required—for example, independent variation in the price of a skimpy plan and in the price of a generous plan.[1]

After developing the graphical framework, we use it to show how policies and regulatory actions that counteract selection on one margin can interact with the other. The relevance of these "cross-margin" interactions is the key conceptual take-away of our paper. We show that a mandate's impact on plan generosity is, in fact, an instance of a broader phenomenon that encapsulates many relevant policy interventions currently in place in insurance markets. These include plan benefits requirements, network adequacy rules, risk adjustment, reinsurance, subsidies, and behavioral interventions like plan choice architectures or auto-enrollment. Each involves a potential trade-off. Policies that aim to address intensive margin selection tend to worsen extensive margin selection, and vice-versa.

The graphical model helps show why these cross-margin interactions occur. The key insight is that for each plan, either its demand or average cost curve is not a price-invariant model primitive (as is true in a two-option model) but an *equilibrium object* that depends on the other plan's price. Policies that target one selection margin typically influence market prices (e.g., the mandate lowers $P_L$ relative to $P_H$), which in turn shifts demand or cost curves that determine the other margin (e.g., the lower $P_L$ reduces demand for $H$). This cross-plan dependence of demand and average costs is the key missing piece when the two margins are analyzed separately. We show how the geometry of the demand/cost curves generates this dependence and lets analysts think about cross-margin interactions in a structured way.

With the intuition and price theory in place, we analyze the model's insights empirically using demand and cost estimates from Massachusetts' CommCare program, a precursor to the state's ACA health insurance Marketplace. CommCare was introduced in 2006 to provide subsidized health insurance coverage to low-income residents who did not qualify for Medicaid. In this setting, Finkelstein, Hendren and Shepard (2019) document significant adverse selection both into the market and within the market between a narrow-network, lower-quality option and a set of wider-network, higher-quality plans. In a regression discontinuity design that exploits discontinuities in the income-

[1] Or alternatively, variation in a market-wide subsidy for selecting any plan and independent variation in the price difference between bare bones and generous plans.

based premium subsidy scheme, they construct demand and cost curves for the lower and higher quality plans. We use these demand and cost curves in a number of counterfactual exercises that simulate equilibrium as we vary benefit design rules, mandate penalties, and risk adjustment strength.

The empirical exercise, beyond demonstrating how our framework can be used, generates several policy insights. The size of the unintended cross margin effects can be large enough to imply significant impacts on market shares. We find that a strong mandate sufficient to move all consumers into insurance—increasing enrollment by around 25 percentage points in our setting—can cause the market share of more generous plans to shrink by more than 15 percentage points, or 35% of baseline market share. In the other direction, strengthening risk adjustment transfers to the point where the market "upravels" to include only generous coverage can substantially reduce market-level consumer participation—in our setting by as much as 15 percentage points or 60% of the baseline uninsurance rate. With the additional assumption that consumer choices reveal plan valuations, we find that the cross-margin welfare impacts can be similarly large (and often first-order), under a range of parameters describing the external social cost of remaining uninsured.

Further, we show that in some settings, cross-margin interactions are critical for determining optimal policy. When intensive margin policies (such as risk adjustment) are weak, it can be optimal to also have weak extensive margin policies (such as an uninsurance penalty). But when intensive margin policies are strong, on the other hand, it can be optimal to also have strong extensive margin policies. These results show that in these markets, regulators are operating in a world of the second-best and must consider interactions between the two margins of selection in order to determine constrained optimal policy. This is true whether optimality is viewed from a formal social surplus perspective or reflects a political preference over rates of insurance coverage on the one hand and insurance quality on the other.

Our paper contributes to a growing literature on adverse selection in health insurance markets. Our main contribution is to provide a graphical model that unites the two key strands of this literature that were previously somewhat disconnected. The first strand focuses on extensive margin selection and stems from the seminal work of Akerlof (1970), with more recent theoretical advances by Hendren (2013), Hendren (2018), and Mahoney and Weyl (2017) and empirical applications by Einav, Finkelstein and Cullen (2010), Bundorf, Levin and Mahoney (2012), Hackmann, Kolstad and Kowalski (2015), Tebaldi (2017), Einav, Finkelstein and Tebaldi (2018) and others. The second strand focuses on intensive margin selection, studying sorting across fixed contracts within the market (Handel, Hendel and Whinston, 2015; Shepard, 2016) as well as papers that study the effects of intensive margin selection on the contracts insurers offer (Glazer and McGuire, 2000; Veiga and Weyl, 2016; Carey, 2017; Lavetti and Simon, 2018; Geruso, Layton and Prinz, 2019). The most directly connected work is a prior theoretical contribution by Azevedo and Gottlieb (2017) that points out the potential cross-margin effects of a mandate, and a complementary analysis (concurrent with ours) by Saltzman (2017) that investigates cross margin effects using a structural model.

Our insights about cross-margin interactions are relevant for active policy debates in the ACA and other insurance settings. For example, recently states have been given increasing flexibility to weaken ACA Essential Health Benefits or risk adjustment transfers (intensive margin policies)—with the stated goal being to lower plan prices and reduce uninsurance (a cross-margin effect). On the other hand, state efforts to simplify enrollment (Domurat, Menashe and Yin, 2018), auto-enroll certain consumers (Shepard, 2019), or enact mandate penalties (all extensive margin policies) may create unintended consequences on the intensive margin. More broadly, our model is also relevant to other settings with two selection margins, including the Medicare program (with its Medicare Advantage option), employer programs with a plan choice decision and a participation decision (e.g., CalPERS), national health insurance systems with an opt-out (e.g., Germany), other insurance markets such as auto insurance and long-term care insurance where both the intensive and extensive margins may be important, and other non-insurance markets like consumer credit where there is evidence of both extensive and intensive margin risk selection (Adams, Einav and Levin, 2009; Einav, Jenkins and Levin, 2012).

The rest of the paper is organized as follows. Section 2 presents the graphical vertical model. Section 3 applies the model to show two-margin impacts of various policies. Sections 4-6 apply the model with simulations: section 4 discusses methods; section 5 shows price and enrollment results; and section 6 shows welfare results. Section 7 concludes.

## 2 Model

Our goal in this section is to develop a theoretical and graphical model that depicts insurance market equilibrium and welfare in the spirit of Einav, Finkelstein and Cullen (2010) ("EFC"), while allowing for the possibility that interventions affecting selection on one margin may affect selection on another.

This requires an insurance plan choice set with at least three options. Consider two fixed contracts, $j = \{H, L\}$, where $H$ is more generous than $L$ on some metric, and an outside option, $U$. In the focal application of our model to the ACA's individual markets, $U$ represents uninsurance.

Each plan $j \in \{H, L\}$ sets a single community-rated price $P_j$ that (along with any risk adjustment transfers—see below) must cover its costs. Consumers make choices based on these prices and on the price of the outside option, $P_U = M$.[2] In our focal example, $M$ is a mandate penalty. The distinguishing feature of $U$ is that its price is exogenously determined; it does not adjust based on the consumers who select into it. This is natural for the case where $U$ is uninsurance or a public plan like Traditional Medicare. $P = \{P_H, P_L, P_U\}$ is the vector of prices in the market.

In the most general formulation, demand in this market cannot be easily depicted in two-dimensional figures. To make the cross-margin effects of interest clearer, we impose a *vertical model* of demand, which assumes contracts are identically preference-ranked across consumers. Although the strict vertical assumption is not necessary for many of our main insights to hold, it captures the key features of the issues raised by simultaneous selection on two margins in a simple way that allows for graphical representation. In the next subsections, we present the vertical model, then add the cost curves, and finally show how to find equilibrium and welfare. In the appendix, we discuss the implications of relaxing the vertical demand assumption.

## 2.1 Demand

The model's demand primitives are consumers' willingness-to-pay (WTP) for each plan. Let $W_{i,H}$ be WTP of consumer $i$ for plan $H$, and $W_{i,L}$ be WTP for $L$, both defined as WTP relative to $U$ ($W_{i,U} \equiv 0$). We make the following two assumptions on demand:

**Assumption 1.** ***Vertical ranking:*** *$W_{i,H} > W_{i,L}$ for all $i$*

**Assumption 2.** ***Single dimension of WTP heterogeneity:*** *There is a single index $s \sim U[0,1]$ that orders consumers based on declining WTP, such that $W'_L(s) < 0$ and $W'_H(s) - W'_L(s) < 0$ for all $s$.*

These assumptions, which are a slight generalization of the textbook vertical model,[3] involve

[2] Below, we allow that consumers may receive a subsidy, $S$, so that choices are based on post-subsidy prices, $P_j^{cons} = P_j - S$.

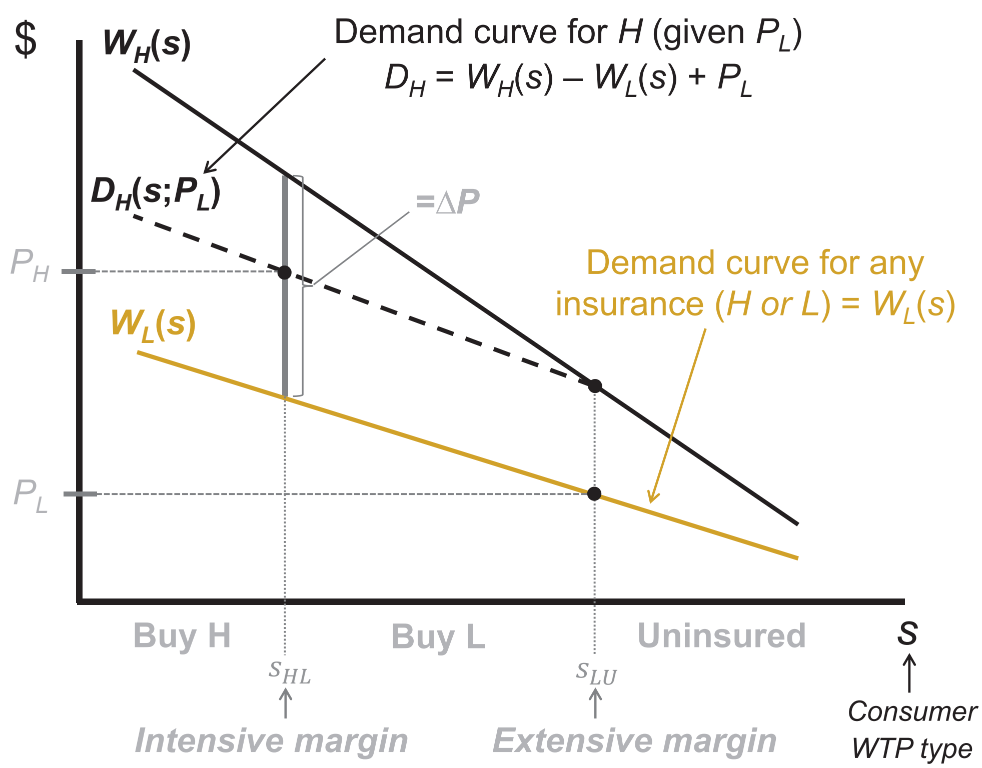
[3] Our vertical model follows the format of Finkelstein, Hendren and Shepard (2019). It is a generalization of the textbook vertical model in which products differ on quality ($Q_j$) and consumers differ on taste for quality ($\beta_i$), so that WTP equals: $W_{i,j} = \beta_i Q_j$ and utility equals $U_{i,j} = W_{i,j} - P_j = \beta_i Q_j - P_j$.

two substantive restrictions on the nature of demand. First, the products are vertically ranked: all consumers would choose $H$ over $L$ if their prices were equal. This is a statement about the *type of setting* to which our model applies. The vertical model applies best when plan rankings are clear—e.g., a low- vs. high-deductible plan, or a narrow vs. complete provider network plan. Importantly, these are precisely the settings where intensive margin risk selection is most relevant. When plans are horizontally differentiated (such as in the Covered California market; see Tebaldi, 2017, Saltzman, 2017, Einav, Finkelstein and Tebaldi, 2018), it is less likely that high-risk consumers will heavily select into a single plan or type of plan. In such cases, the existing EFC framework can capture the main way risk selection matters: in vs. out of the market (the extensive margin). Our model is designed to study the additional issues that arise when *both* intensive and extensive margins matter simultaneously. Even in settings without apparent vertical differentiation across plans within the market, our model can be useful in assessing counterfactual policies that might generate this type of differentiation. In particular, our examples below imply that a regulator encouraging vertically differentiated entrants may generate unintended cross-margin effects on the rates of uninsurance.[4]

Second, consumers' WTP for $H$ and $L$—which in general could vary arbitrarily over two dimensions—are assumed to collapse to a single-dimensional index, $s \in [0, 1]$. Higher $s$ types have both lower $W_L$ *and* a smaller gap between $W_H$ and $W_L$. Lower $s$ types both care more about having insurance ($L$ vs. $U$) and more about the generosity of coverage ($H$ vs. $L$). This assumption is natural in many cases; indeed it holds exactly in a model where plans differ purely in their coinsurance rate (see, e.g., Azevedo and Gottlieb, 2017). Substantively, Assumption 2 restricts consumer *sorting and substitution patterns* among options when prices change. The primary consequence of this assumption is that consumers are only on the margin between adjacent-generosity options–between $H$ and $L$ or between $L$ and $U$. No consumer is on the margin between $H$ and $U$, so if the price of $U$ (the mandate penalty) increases modestly, the newly insured all buy $L$ (the cheaper plan), not $H$. This restriction captures in a strong way the general (and testable) idea that these are the *main* ways consumers substitute in response to price changes. With this restriction in place (and under a price vector at which all options are chosen), consumers sort into plans with the highest-WTP types choosing $H$, intermediate types choosing $L$, and low types choosing $U$. We show that weakening this assumption—allowing an

[4] Further, an apparent lack of vertical differentiation in a market may itself be an equilibrium outcome reflecting forces that our vertical model captures. For example, a market for generous coverage may have already unraveled due to cross-margin effects, leaving only lower-quality, horizontally differentiated plans.

**Figure 1:** Demand and Consumer Sorting under Vertical Model




**Notes:** The graph shows demand and consumer sorting under the vertical model. $W_H(s)$ and $W_L(s)$ are willingness to pay for the $H$ and $L$ plans. $D_H(s; P_L)$ is the demand curve for $H$ (as a function of $P_H$), which depends on the value of $P_L$. See the body text for additional description.

$H$-$U$ margin—does not change the key implications of the model as long as most consumers exhibit vertical preferences (see Appendix A).

Figure 1 plots a simple linear example of $W_H(s)$ and $W_L(s)$ curves that satisfy these assumptions. The x-axis is the WTP index $s$, so WTP declines from left to right as usual. Let $s_{LU}(P)$ be the extensive-marginal type who is indifferent between $L$ and $U$ at a given set of prices $P$. Assuming for now that $P_U \equiv M = 0$, this cutoff type is defined by the intersection of $L$'s WTP curve $W_L$ and $L$'s price:

$$W_L(s_{LU}) = P_L. \tag{1}$$

Consumers to the right of $s_{LU}$ go uninsured. Those to the left buy insurance. Therefore, $W_L(s)$ represents the *(inverse) demand curve for any formal insurance* ($H$ or $L$). [5]

[5] In the more general case where consumers receive subsidies for purchasing insurance or pay a penalty when choosing $U$, $W_L(s)$ and the (inverse) demand curve for insurance will diverge. Specifically, $D_L(s) = W_L(s) + S + M$. For simplicity,

Let $s_{HL}(P)$ be the intensive-marginal type who is just indifferent between $H$ and $L$. This cutoff type is defined by:

$$\Delta W_{HL}(s_{HL}) \equiv W_H(s_{HL}) - W_L(s_{HL}) = P_H - P_L \tag{2}$$

Consumers to the left of $s_{HL}$ buy $H$ because their incremental WTP for $H$ over $L$—which we label $\Delta W_{HL}$—exceeds the incremental price. With demand for $H$ and for $H+L$ thus determined by Equations (1) and (2), demand for $L$ equals the difference between the two.[6]

Rearranging equation (2) yields the (inverse) demand for $H$, given a fixed $P_L$:

$$D_H(s; P_L) \equiv W_H(s) - W_L(s) + P_L \tag{3}$$

Figure 1 shows $D_H(s; P_L)$ with a dashed line. One can draw $D_H$ by noting that it intersects the $W_H$ curve at the cutoff type $s_{LU}$ (since $W_L(s_{LU}) = P_L$).[7] It then proceeds leftward at a slope equal to that of $\Delta W_{HL}$, and its intersection with $P_H$ determines $s_{HL}$. $D_H(s; P_L)$ is flatter than $W_H$ because its slope equals that of $\Delta W_{HL}(s)$.

Most importantly, $D_H(s; P_L)$ is not a pure primitive that could be identified off of exogenous price variation, but instead depends on both WTP primitives ($W_H$, $W_L$) and, critically, on $P_L$. Because demand for $H$ depends on the price of $L$, policies targeted at altering the allocation of consumers on the extensive margin of insurance/uninsurance can affect the sorting of consumers across the intensive $H/L$ margin if these policies affect the price of $L$. The dependency of demand for $H$ on the price of $L$ generates an interaction between the intensive and extensive margins, a key theme of this paper.

we ignore the subsidy and penalty terms here but fully incorporate consumer subsidies when we use the model to study the effects of common policies (Section 3) as well as in the empirical exercise (Section 5).

[6] Formally, the demand functions for the general case where $M \neq 0$ are defined by the following equations, where $\Delta P \equiv P_H - P_L$:

$$\begin{aligned} D_H(P) &= s_{HL}(\Delta P) \\ D_L(P) &= s_{LU}(P_L - M) - s_{HL}(\Delta P) \\ D_U(P) &= 1 - s_{LU}(P_L - M) \end{aligned}$$

[7] $D_H$ is not defined to the right of $s_{LU}$, since if $P_H$ falls further than its level at this point, nobody buys $L$. As a result, the demand curve for $H$ thereafter equals $W_H(s)$.

## 2.2 Costs

The model's cost primitives are expected insurer costs for consumers of type $s$ in each plan $j$.[8] These "type-specific costs" are defined as:

$$C_j(s) = E\left[C_{ij} \mid s_i = s\right] \tag{4}$$

$C_j(s)$ is analogous to "marginal cost" in the EFC model—so called because it refers to consumers on the margin of purchasing at a given price. However, to avoid confusion in our model where there are two purchasing margins, we refer to $C_j(s)$ as type-specific costs, or simply costs. In addition, we define $C_U(s)$ as the expected costs of uncompensated care of type-$s$ consumers if they were uninsured. Along with adverse selection, external uncompensated care costs motivate subsidy and mandate policies.

Plan-specific average costs, which are important in determining the competitive equilibrium, are defined as the average of $C_j(s)$ for all types who buy plan $j$ at a given set of prices:

$$AC_j(P) = \frac{1}{D_j(P)} \int_{s \in D_j(P)} C_H(s) ds \tag{5}$$

where (abusing notation slightly) $s \in D_j(P)$ refers to $s$-types who buy plan $j$ at prices $P$.

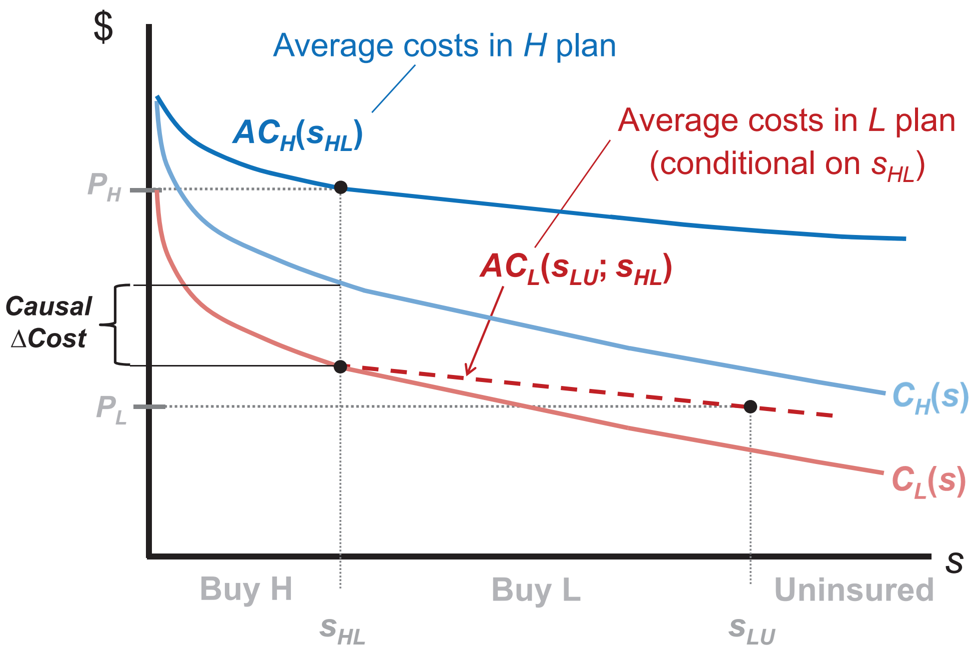
We illustrate the construction of these cost curves in Figure 2. We show a case where cost curves $C_H$ and $C_L$ are downward sloping, indicating adverse selection—though the framework could also be applied to advantageous selection. The gap between the two curves for a given $s$-type describes the difference in plan spending if the $s$-type consumer enrolls in $H$ vs. $L$. We refer to this gap as the "causal" plan effect, since it reflects the true difference in insurer spending for a given set of people.[9]

We start by deriving $AC_H(P)$, the average cost curve for the $H$ plan. To avoid ambiguity later, it is helpful to redefine the argument of $AC_H$ as the marginal type that buys $H$ at price $P$, $s_{HL}(P)$.

[8] A key insight of the EFC model is that—while costs may vary widely across consumers of a given WTP type—it is sufficient for welfare to consider the cost of the *typical* consumer of each type. The reason is that with community rated pricing, consumers sort into plans based only on WTP. There is no way to segregate consumers more finely than WTP type, and since insurers are risk-neutral, only the expected cost within type matters. We note, however, that this argument breaks down when leaving the world of community rated prices, as pointed out by Bundorf, Levin and Mahoney (2012), Geruso (2017), and Layton et al. (2017). Our model (like the model of EFC) thus cannot be used to assess the welfare consequences of policies that allow for consumer risk-rating.

[9] As in EFC, the causal plan effect reflects both a difference in coverage (e.g., lower cost sharing) conditional on behavior, and any behavioral effect (or moral hazard) of the plans.

**Figure 2:** Cost Curves under Vertical Model




**Notes:** The graph shows the cost curves for $H$ and $L$ plans under the vertical model. $C_H(s)$ and $C_L(s)$ are the consumer type-$s$ specific costs. $AC_H(s_{HL})$ and $AC_L(s_{LU}; s_{HL})$ are the average cost curves for $H$ and $L$ given that the intensive margin type is $s_{HL}$ and the extensive margin type is $s_{LU}$. Adverse selection makes the price difference $P_H - P_L$ larger than the causal cost difference.

We use this notation in Figure 2. $AC_H$ integrates over individual costs ($C_H$) from the left: For $s_{HL} = 0$, the only consumers enrolled in $H$ are the very sickest consumers. For these consumers, $s = 0$, implying that $AC_H(s_{HL} = 0) = C_H(s = 0)$. Then, as $s_{HL}$ increases, moving right along the horizontal axis, $H$ includes more relatively healthy consumers, resulting in a downward sloping average cost curve. Eventually, when $s_{HL} = 1$ and all consumers are enrolled in $H$, $AC_H(s_{HL} = 1)$ is equal to the average cost in $H$ across *all* consumers. Because $H$ only has one marginal consumer type (the intensive margin), the derivation of $AC_H(s_{HL})$ is identical to that of the average cost curve in EFC. For each value of $s_{HL}$, there is only one possible value of $AC_H$. This implies that the curve can be calculated directly from a market primitive (by integrating over $C_H(s)$) and is not an equilibrium object.

The average cost curve for $L$, on the other hand, is more complicated because it is an average over a range of consumers, $s \in [s_{HL}, s_{LU}]$, with two endogenous margins. For each value of $s_{LU}$ that defines sorting between $U$ and $L$, there are many possible values of $AC_L$, depending on consumer sorting between $H$ and $L$. This fact makes it impossible to plot a single fixed $AC_L$ curve as we did with $AC_H$. Nonetheless, it is possible to plot $AC_L(s_{LU})$ *conditional* on $s_{HL}(P)$. We denote this curve $AC_L(s_{LU}; s_{HL})$ and illustrate it with a dashed line in Figure 2. There are many such iso-$s_{HL}$ plots of $AC_L$ (not pictured) that hold $P_H$ fixed at various levels. The leftmost point of the $AC_L$ curve depends on the $s_{HL}$ cutoff type determined by $P_H$. Higher values of $s_{HL}$ imply that $AC_L(s_{LU}; s_{HL})$ starts from a higher point. Just as $AC_H$ equals $C_H$ at $s = 0$, $AC_L$ equals $C_L$ at $s = s_{HL}$. Moving rightward from $s = s_{HL}$, plan $L$ adds more relatively healthy consumers, resulting in a downward sloping average cost curve.

In summary, while $AC_H$ is fixed and does not depend on the price of $L$, $AC_L$ is an equilibrium object in that it changes as $P_H$, and therefore $s_{HL}$, changes. This implies that the average cost of $L$ and thus the price of $L$ in equilibrium depends on the price of $H$. Recognizing such dependencies is critical for analyzing policy interventions. For example, a subsidy targeted to $H$ that results in a lower (net) $P_H$ and a larger $H$ enrollment (a rightward-shifted $s_{HL}$) would cause the leftmost point on $AC_L$ to shift down and rightward and would cause the curve to have a less-steep slope. In a competitive market, this would likely result in a lower $P_L$, causing additional consumers to enter the market.

### 2.3 Competitive Equilibrium

We consider competitive equilibria where plan prices, $P^e$, exactly equal their average costs:[10]

$$P_H = AC_H(P) \qquad \text{and} \qquad P_L = AC_L(P) \tag{6}$$

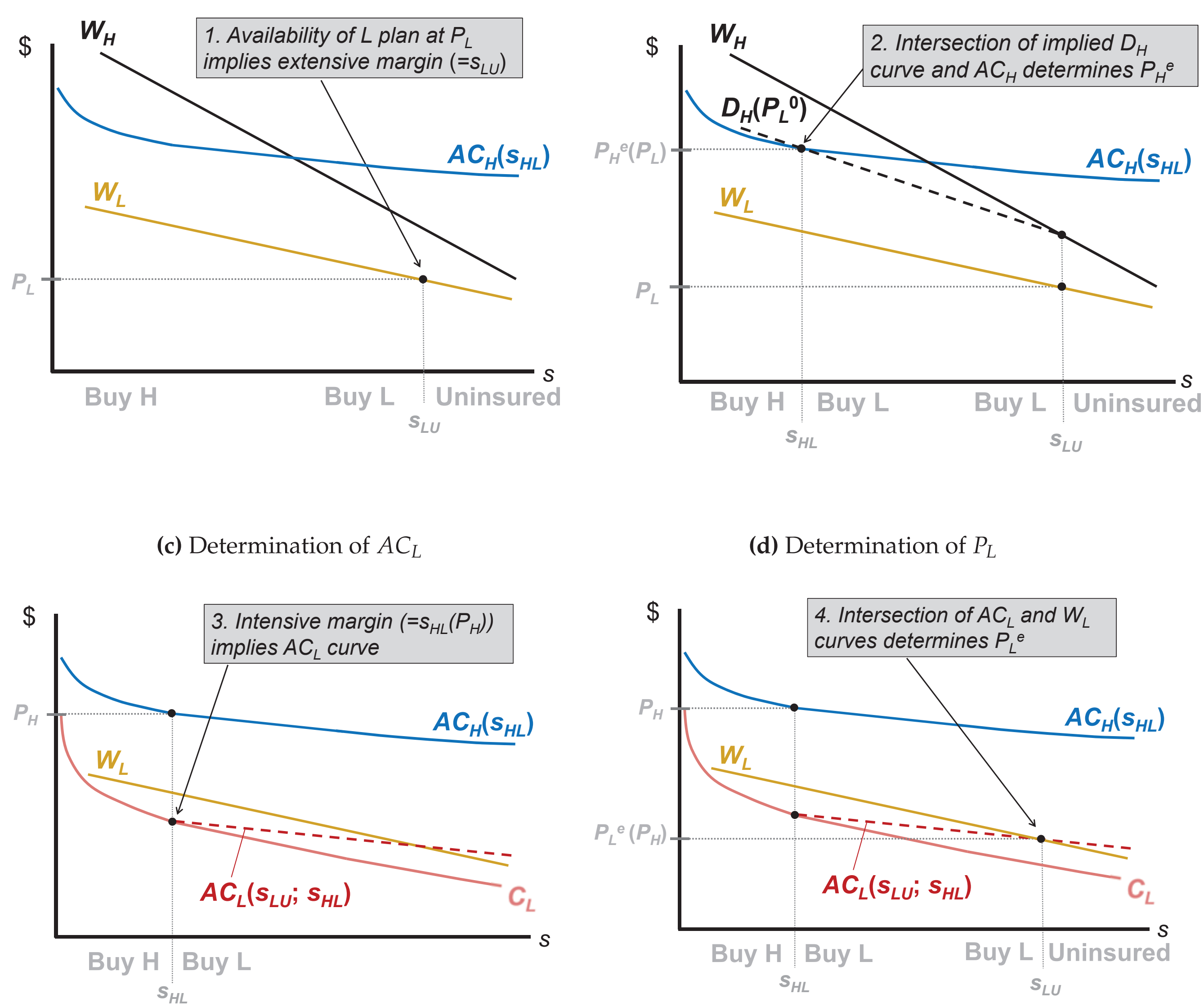
In some settings, there will be multiple price vectors that satisfy this definition of equilibrium, including vectors that result in no enrollment in one of the plans or no enrollment in either plan. Because of this, we follow Handel, Hendel and Whinston (2015) and limit attention to equilibria that meet the requirements of the Riley Equilibrium (RE) notion. We discuss these requirements and provide an algorithm for empirically identifying the RE in Appendix C.3.

With the outside option of uninsurance, the equilibration process for the prices of $H$ and $L$ differs somewhat from the more familiar settings explored by EFC and Handel, Hendel and Whinston (2015). In those settings, it is assumed that all consumers choose either $H$ or $L$. Assuming full in-

[10] This definition of equilibrium prices differs slightly from the definition of Einav, Finkelstein and Cullen (2010) who consider a "top-up" insurance policy where only the price of $H$ is required to be equal to its average cost, while the price of $L$ is fixed. It is consistent, however, with the definition of Handel, Hendel and Whinston (2015)

surance conveniently simplifies the equilibrium condition from two expressions to one: Namely, that the differential average cost must be set equal to the differential price.

**Figure 3:** Determination of Equilibrium with H, L, and Outside Option




**(a)** Determination of Extensive Margin ($s_{LU}$) **(b)** Determination of $P_H$

**(c)** Determination of $AC_L$ **(d)** Determination of $P_L$

**Notes:** Figures show how competitive equilibrium is determined in the vertical model with $H$ and $L$ plans and an outside option (uninsured). Panels (a) and (b) show the determination of $P_H(P_L)$: a value of $P_L$ implies the extensive margin ($s_{LU}$), which in turn implies the demand curve for $H$ and the equilibrium $P_H$. Panels (c) and (d) show the determination of $P_L(P_H)$: a value of $P_H$ implies the intensive margin ($s_{HL}$), which implies $AC_L$ and the equilibrium value of $P_L$.

To provide intuition for determining the equilibrium in our more complex setting, we build up from the classic case considered by EFC, which includes only $H$ and $U$ as plan options.[11] The EFC

[11]The correct analogy from EFC to our framework considers the choice between $H$ and $U$ rather than between $H$ and $L$ because the distinguishing feature of $U$ is that its price is exogenously determined, like the lower coverage option in the

equilibrium can be seen in Panel (a) of Figure 3, if one ignores the $W_L$ curve. It is defined by the intersection of $W_H$ and $AC_H$, which determines the competitive equilibrium price. Absent an $L$ plan, any $s$-type whose WTP for $H$ exceeds the price of $H$ will buy $H$ and all other $s$-types will opt to remain uninsured.

We next add $L$ to the EFC choice set. To illustrate the equilibrium, we proceed in four steps, corresponding to the four panels in Figure 3. Panels (a) and (b) show how $P_H$ is determined, given a fixed price of $L$. Panel (a) shows that the fixed $P_L$ implies a given extensive margin cutoff, $s_{LU}$. Panel (b) shows that this in turn implies an $H$ plan demand curve, $D_H(P_L)$ (in dashed black). The intersection of $D_H(P_L)$ with $H$'s average cost curve determines $P_H$ and the intensive margin cutoff $s_{HL}$. This process determines the reaction function $P^e_H(P_L)$, which is the break-even price of $H$ for a given price of $L$.

Panels (c)-(d) of Figure 3 show how $P_L$ is determined, given a fixed $P_H$. Panel (c) shows that the fixed $P_H$ implies a given intensive margin cutoff ($s_{HL}$), which in turn fixes the $AC_L$ curve. Panel (d) shows how the intersection of $AC_L$ with $W_L$ determines $P_L$ and the extensive margin cutoff $s_{LU}$. This process determines the reaction function $P^e_L(P_H)$, which gives the break-even price of $L$ for a given fixed price of $H$.

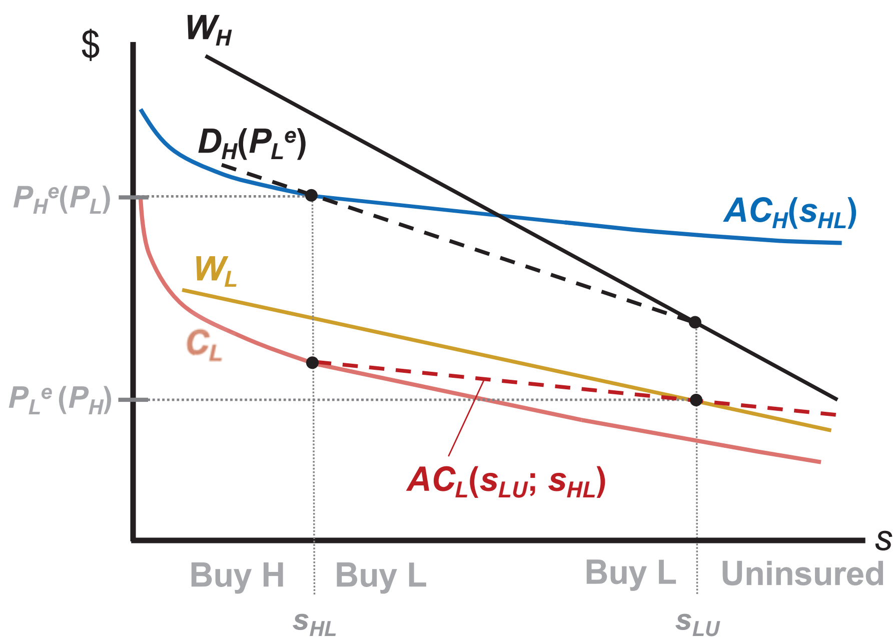
In equilibrium, the reaction functions must equal each other: $P_H = P^e_H(P_L)$ and $P_L = P^e_L(P_H)$. Figure 4 depicts the equilibrium, including the $AC_L$ and $D_H$ curves as dashed lines. These dashed lines are themselves equilibrium outcomes, even holding fixed consumer preferences and costs. In other words, there were many possible "iso-$s_{HL}$" $AC_L$ curves and many possible "iso-$P_L$" $D_H$ curves. The equilibrium vector of prices are the prices at which demand for $L$ generates the equilibrium $D_H(P^e_L)$ *and* this demand for $H$ simultaneously implies the equilibrium $AC_L(s_{HL})$ curve.

### 2.4 Social Welfare

We now show how our framework can be used to assess the welfare consequences of different policies. We define social welfare in the conventional way, as total social surplus. We provide a formal definition below, but we start by showing what we mean graphically. In order to make the figures simpler and more intuitive, we set $C_U$, the social cost of uninsurance, equal to zero. We nonetheless allow for a positive social cost of uninsurance in our empirical application below.

EFC setting.

**Figure 4:** Final Equilibrium




**Notes:** The graph shows the final equilibrium under the vertical model with two plans ($H$ and $L$) and an outside option ($U$). The black dots mark the key intersections defining equilibrium prices and sorting. The intersection of $AC_L$ and $W_L$ determines $P_L$ and the extensive margin type ($s_{LU}$). The $D_H$ curve starts at this extensive margin (where it equals $W_H$), and its intersection with $AC_H$ determines $P_H$ and the intensive margin type ($s_{HL}$). This $s_{HL}$ type marks the start of the $AC_L$ curve (where it equals $C_L$).

To build intuition, we start in Panel (a) of Figure 5 by illustrating the case where $L$ is a pure cream-skimmer. That is, $L$ has low average costs because it attracts low-cost individuals, but it has no causal effect on costs, so $C_L = C_H$ for any individual. For this case, given $W_H$, $W_L$, and $C_L = C_H$ we can find total social surplus for any allocation of consumers across plans described by the equilibrium cutoff values $s^e_{HL}$ and $s^e_{LU}$.

Panel (a) of Figure 5 shows that social surplus consists of two pieces. The first piece ($ABHG$) is the social surplus for consumers purchasing $H$, given by the area between $W_H$ and $C_L = C_H$ for consumers with $s < s_{HL}$. The second piece ($EFIH$) is the social surplus for consumers purchasing $L$, given by the area between $W_L$ and $C_L = C_H$ for consumers with $s \in [s_{HL}, s_{LU}]$. Panel (a) of Figure 5 also illustrates foregone surplus for the allocation of consumers across plans. Here, the foregone surplus consists of three components. The first is the foregone surplus due to the fact that consumers with $s \in [s_{HL}, s_{LU}]$ purchased $L$ when they would have generated more surplus by purchasing $H$, and it is described by the area between $W_H$ and $W_L$ for these consumers ($BCFE$). The second component is the foregone surplus due to the fact that consumers with $s > s_{LU}$ did not purchase insurance when they would have generated positive surplus by purchasing $H$, and it is described by the area between $W_H$ and $\max\{W_L, C_L\}$ ($CDJF$). We refer to these two components as "intensive margin loss". The third component is the foregone surplus due to the fact that consumers with $s \in [s_{LU}, s^*_{LU}]$ did not purchase insurance when they would have generated positive surplus by purchasing $L$, and it is described by the area between $W_L$ and $C_L$ for those consumers.

The figure thus shows how our graphical framework can be used to estimate welfare for any allocation of consumers across $H$, $L$, and $U$. Further, the framework makes it easy to determine the optimal allocation of consumers between insurance and uninsurance and between $H$ and $L$. In the case of the particular demand and cost primitives drawn in Panel (a), the optimal allocation of consumers across plans is for all consumers to be in $H$. If $H$ were not available, however, the optimal allocation of consumers across $L$ and $U$ would consist of all consumers with $s < s^*_{LU}$ purchasing $L$ and all other consumers remaining uninsured.

In Panel (b) of Figure 5, we show how our framework can also accommodate the case where it is efficient for some consumers to be enrolled in $L$ rather than in $H$ and for others to remain uninsured rather than be enrolled in $L$. To do this, we change the assumption that $L$ is a pure cream-skimmer and instead assume that costs in $H$ are higher than in $L$ for each consumer and that the cost gap is constant across consumers: $\Delta C_{HL}(s) \equiv C_H(s) - C_L(s) = \delta > 0$. Intuitively, in this scenario consumers prefer $H$ because it provides more or better services—at a higher cost to the insurer. It is convenient to define a new curve $W_H^{Net}(s) = W_H(s) - \Delta C_{HL}(s)$, or WTP for $H$ net of the incremental cost of $H$ vs. $L$. Under the assumption that $\delta$ is constant, $W_H^{Net}(s)$ will be parallel to and below $W_H$. This is shown in Panel (b) of Figure 5: As $L$'s cost advantage over $H$ increases, $W_H^{Net}$ shifts further down.[12]

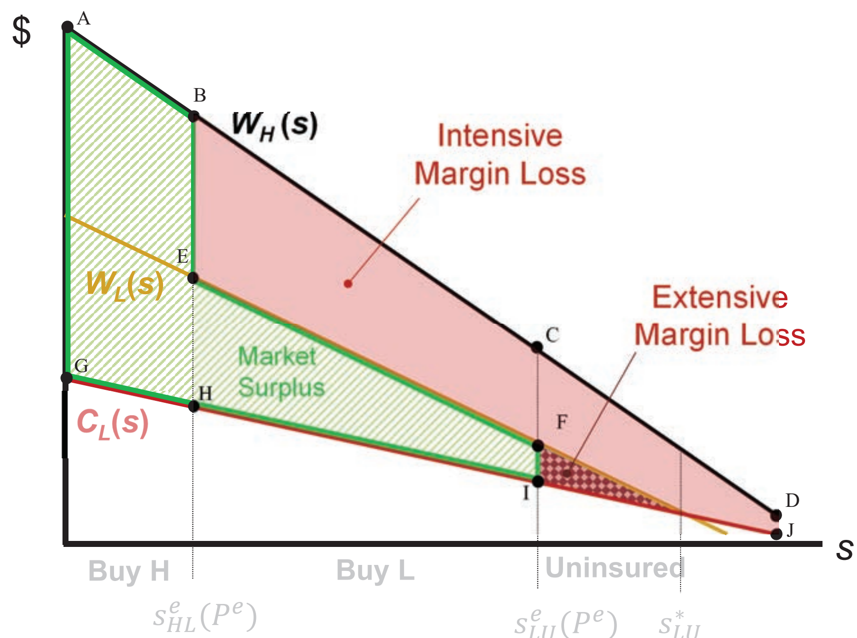
Given this new $W_H^{Net}$ curve, social welfare is still fully characterized by the three curves, $W_H^{Net}$, $W_L$, and $C_L$, and social surplus and foregone surplus are defined in a similar manner to Panel (a). Social surplus still consists of two components. The first is the surplus generated by the consumers enrolled in $H$, and it is characterized by $ABHG$, the area between $W_H^{Net}$ and $C_L$ for consumers with $s < s_{HL}$.[13] This component is smaller than it was in Panel (a) due to the fact that now $H$ has higher costs than $L$. In Panel (b) it is thus less socially advantageous for these consumers to be enrolled in

[12] Heterogeneity in $L$'s cost advantage across $s$ types could also be accommodated and would result in $W_H^{Net}$ not being parallel to $W_H$.

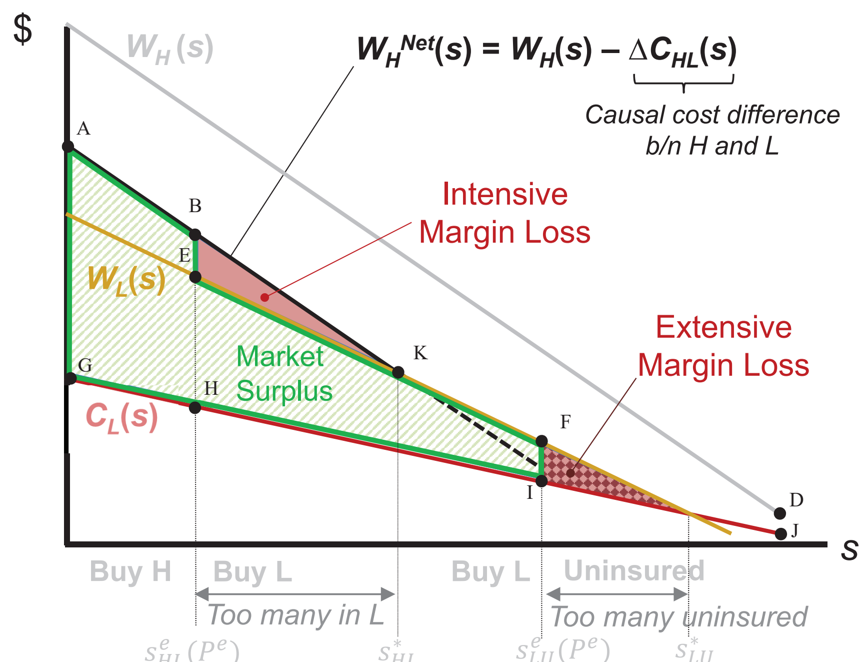
[13] To see this, note that this gap is equal to $W_H^{Net}(s) - C_L(s) = W_H(s) - (C_H(s) - C_L(s)) - C_L(s) = W_H(s) - C_H(s)$.

**Figure 5:** Welfare

**(a)** Welfare when L Is a Pure Cream-Skimmer




**(b)** Welfare when L Has a Cost Advantage




**Notes:** The graphs show welfare given equilibrium prices $P^e$ and implied consumer sorting between $H$, $L$, and uninsured. Panel (a) shows the case where the $L$ plan is a pure cream-skimmer ($\Delta C_{HL} = C_H(s) - C_L(s) = 0$), while panel (b) shows the case where $L$ has a causal cost advantage ($\Delta C_{HL} > 0$). The market surplus is shaded in green; the loss due to intensive margin misallocation (between $H$ and $L$) is shaded in red; and the loss due to extensive margin misallocation (between $L$ and $U$) is shaded in thatched red.

$H$ vs. $L$. The second component is the surplus generated by the consumers enrolled in $L$, and it is characterized exactly as before by $EFIH$, the area between $W_L$ and $C_L$ for consumers with $s^e_{HL} < s < s^e_{LU}$. Foregone surplus is illustrated in the figure in Panel (b) similar to the illustration in Panel (a).[14] In summary, Figure 5 shows how our model can accommodate settings in which it is not socially efficient for all consumers to be enrolled in $H$ or even in $L$, such as settings where there is moral hazard, administrative costs, etc.

We now derive a formal expression for welfare, allowing for cases where $C_U$ is non-zero—e.g., if the outside option involves social costs like uncompensated care. We define social welfare as:

$$\widehat{SW}(P) = \int_0^{s_{HL}(P)} \left(W_H(s) - C_H(s)\right) ds + \int_{s_{HL}(P)}^{s_{LU}(P)} \left(W_L(s) - C_L(s)\right) ds - \int_{s_{LU}(P)}^{1} C_U(s)\, ds \tag{7}$$

Recall that the level of utility was normalized above by setting $W_U = 0$. As in the figures, we can express welfare in terms of three curves and two areas (integrals) if we make the following transformations. First, add a constant equal to total potential cost of $U$, defining $SW = \widehat{SW} + \int_0^1 C_U(s)\, ds$. Second, define "net costs" of $L$ (in excess of $C_U$) as $C_L^{Net}(s) \equiv C_L(s) - C_U(s)$. Rearranging and simplifying, this yields the following expression for social welfare:

$$SW = \underbrace{\int_0^{s_{HL}(P)} \left(W_H^{Net}(s) - W_L(s)\right) ds}_{\text{Intensive Margin Surplus from } H \text{ vs. } L} + \underbrace{\int_0^{s_{LU}P)} \left(W_L(s) - C_L^{Net}(s)\right) ds}_{\text{Extensive Margin Surplus from } L \text{ vs. } U} \tag{8}$$

The first term is the intensive margin surplus ($H$ vs. $L$) for consumers who buy $H$, $s \in [0, s_{HL}]$. Notice that $W_H^{Net}(s) - W_L(s) = \Delta W_{HL} - \Delta C_{HL}$, so this is indeed capturing the intensive margin surplus. The second term is the extensive margin surplus from insurance (in $L$) relative to uninsurance, which applies to everyone who buys insurance, $s \in [0, s_{LU}]$. Equation (8) shows that it is straightforward to calculate welfare even when $C_U \neq 0$, as long as the researcher has information about $C_U$.

[14] Here, forgone surplus again consists of two components. The first is the foregone intensive margin surplus due to the fact that consumers with $s \in [s^e_{HL}, s^*_{HL}]$ are enrolled in $L$ but would generate more surplus if they were enrolled in $H$. It is characterized by the area between $W_H^{Net}$ and $W_L$ for these consumers ($BKE$). (Unlike in Panel (a), with $H$'s higher costs it is now inefficient for any consumer with $s > s^*_{HL}$ to enroll in $H$.) The second component represents the extensive margin foregone surplus, and it is identical to the extensive margin foregone surplus in Panel (a).

# 3 Two-Margin Impacts of Risk Selection Policies

In this section, we use our model to assess the consequences of three policies commonly used to combat adverse selection in insurance markets: benefit regulation, the mandate penalty on uninsurance, and risk adjustment transfers. Each of these policies is targeted at one margin of adverse selection, but our model shows how they affect the other. We discuss each policy in turn and provide graphical illustrations for their consequences. We conclude with a discussion of other policies where cross-margin impacts on selection may be relevant, including behavioral interventions targeting take-up.

## 3.1 Benefit Regulation

We start by examining benefit regulation. In Figure 6, we consider a rule that eliminates $L$ plans from the market. This thought experiment captures a variety of policies that set a binding floor on plan quality—e.g., network adequacy rules, caps on out-of-pocket limits, and the ACA's "essential health benefits." These policies seek to address *intensive margin* adverse selection problems by eliminating low-quality, cream-skimming plans. But, as we show, they can also have unintended *extensive margin* consequences.

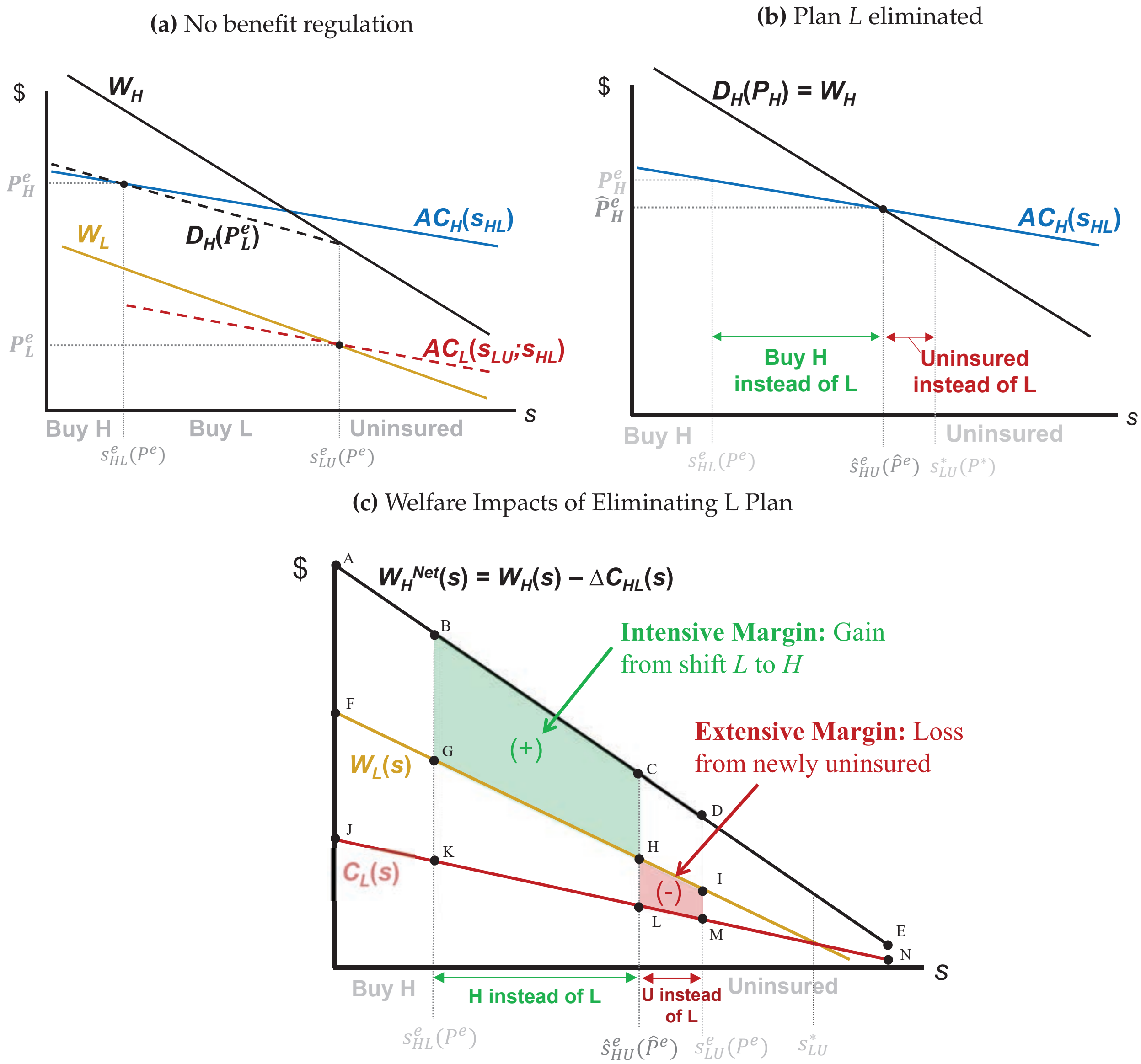
Panel (a) of Figure 6 shows the baseline equilibrium with both $H$ and $L$ plans, while Panel (b) shows equilibrium with $L$ plans eliminated, which reduces to the classic EFC equilibrium. Panel (c) shows the welfare impact of benefit regulation. This involves two competing effects: Some consumers formerly in $L$ shift to $H$ (the intended consequence), and some consumers formerly in $L$ become uninsured (the unintended consequence).

In the textbook cream-skimming case, where $H$ is the socially efficient plan for everyone (though most consumers still generate more social surplus in $L$ vs. $U$), these two effects have opposing welfare consequences. The first (intended) effect *increases social surplus* by shifting people out of $L$—an inefficient plan that exists only by cream-skimming—and into $H$. The second (unintended) effect, however, *lowers social surplus* by shifting some $L$ consumers into uninsurance. Thus, even in this textbook case where the $L$ plan is an inefficient cream-skimmer, banning it has ambiguous welfare consequences.[15]

What explains this counter-intuitive result? This can be thought of as an example of "theory of

[15] The net welfare impact depends on the market primitives ($W_H$, $W_L$, $C_H$, $C_L$) and the social cost of uninsurance, $C_U$. Section 2 presents the framework for how these can be measured and the net welfare impact quantified.

**Figure 6:** Impact of Benefit Regulation




**Notes:** The figure shows the impact on equilibrium (panels a and b) and welfare (panel c) of a benefit regulation that eliminates the $L$ plan. This thought experiment captures a variety of policies that set a binding floor on plan quality, thus eliminating low-quality plans. For welfare impacts, we show the textbook case where $H$ is the efficient plan for all consumers and $L$ is more efficient than $U$.

the second best"-style interactions that emerge with two margins of selection. Regulation that bans a pure cream-skimming $L$ plan addresses an intensive margin selection problem. But it has the unintended side effect of worsening the extensive margin selection problem of too much uninsurance. Put differently, a pure cream-skimming $L$ plan adds no social value *within* the market, but by segmenting the healthiest people into a low-price plan, it can improve welfare by bringing new consumers *into* the market.[16]

### 3.2 Mandate Penalty on Uninsurance

Next we consider the consequences of a mandate penalty for remaining uninsured (choosing $U$). The analysis is also applicable for analyzing the effect of providing larger insurance subsidies, which likewise reduce consumers' net price of buying insurance relative to remaining uninsured.

The mandate penalty has both a direct effect and an indirect effect through equilibrium price adjustments. The direct effect of a mandate penalty is to increase the demand for insurance. Panel (a) of Figure 7 shows this via an upward shift in $W_L$ and $W_H$ by $\$M$, reflecting that both become cheaper relative to $U$ (whose utility and price are normalized to zero). As a result of this shift, some people who were previously uninsured buy insurance in the $L$ plan. This is the intended effect of the penalty.

Panel (b) depicts the unintended, equilibrium effects of the penalty. By definition under extensive margin adverse selection, the newly insured individuals are relatively healthy. Because they buy the low-price $L$ plan, they lower $L$'s average costs (i.e., a movement down the $AC_L$ curve, not a shift in the $AC_L$ curve) and therefore its price. The lower $P_L$ leads some consumers to shift on the *intensive margin* from $H$ to $L$—as captured by the downward shift in $H$'s demand curve, $D_H(P_L)$. This is the main unintended effect of the penalty: although it is intended to reduce uninsurance, the penalty also shifts people toward lower-quality plans on the intensive margin.[17]

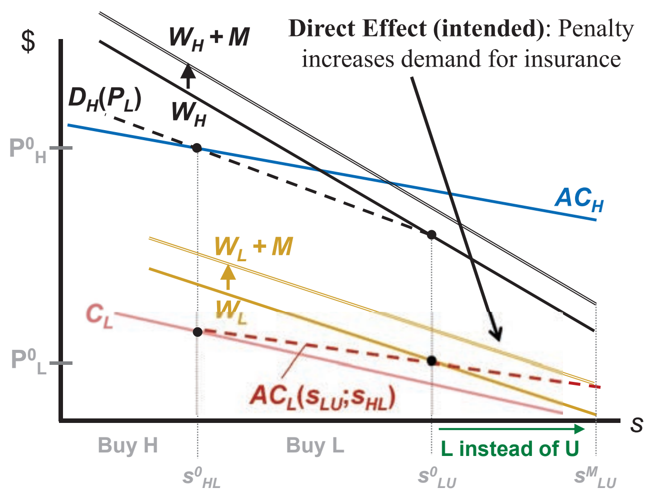
There is a second equilibrium effect from this shift in consumers from $H$ to $L$. The consumers who shift are high-cost relative to $L$'s previous customers, pushing up $L$'s average costs. In panel (b), this is depicted via an upward shift in the $AC_L(P_H)$ curve, which has to occur because of the higher $P_H$ and the leftward shift in the marginal $s_{HL}$ type. The higher average costs in $L$ partly offset the fall in $P_L$ due to the mandate and dampen the impact of the mandate on the price of $L$. Thus our model shows how and why cross-margin effects may make a mandate less effective than one would predict from its direct effects alone: The penalty induces healthy people to enter the market but also

[16] Of course, this reasoning depends on the market stabilizing to a separating equilibrium where both $H$ and $L$ survive. If the market unravels to the $L$ plan, insurance coverage will typically not be higher: the price of $L$ will not be low (since it attracts all consumers), and because the quality of $L$ is lower, uninsurance will typically be higher than in an $H$-only equilibrium where $L$ is banned. Whether the market stabilizes to a separating equilibrium or unravels to $L$/upravels to $H$ depends on the market primitives.

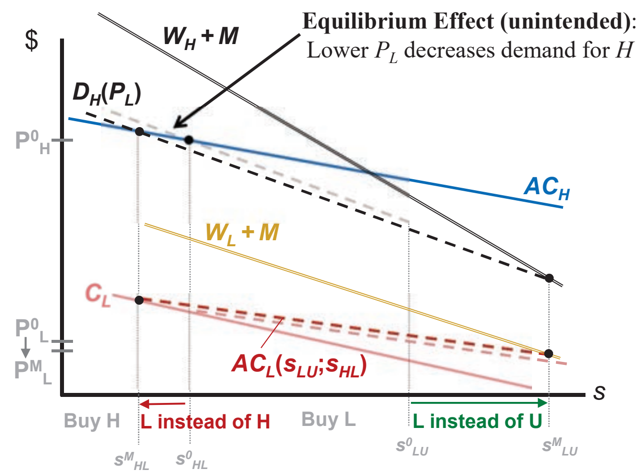
[17] We show in our simulations and in Appendix A that this prediction is largely robust to relaxing the vertical model. It is driven by two properties: (1) that the newly uninsured are relatively healthy (extensive margin adverse selection), and (2) that the newly insured mostly choose the low-priced $L$ plan.

**Figure 7:** Impact of Mandate Penalty on Uninsurance

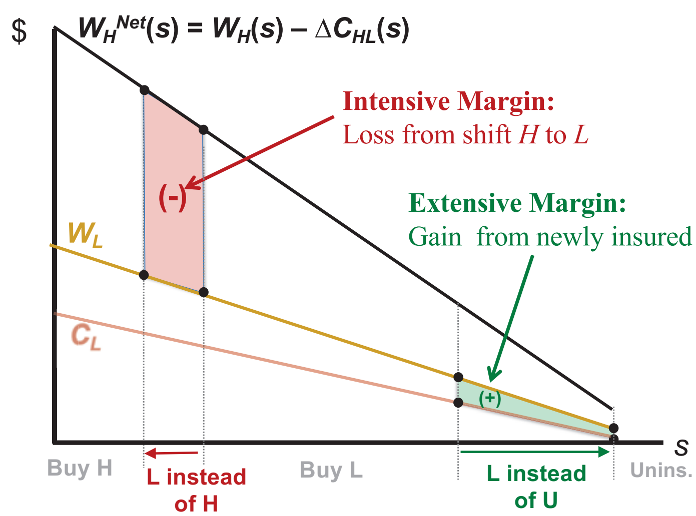
**(a)** Direct Effect




**(b)** Equilibrium Effect




**(c)** Welfare Effects




**Notes:** The figure shows the impact of a mandate penalty in our framework. Panel (a) shows the direct effect: higher demand for insurance. Panel (b) shows the unintended equilibrium effect: an intensive margin shift from $H$ to $L$. Panel (c) shows the welfare effects in the textbook case where $H$ is the efficient plan for all consumers and $L$ is more efficient than $U$.

induces relatively sick people to move from $H$ to $L$. Nonetheless, as long as the original equilibrium is stable, one can show that on net, a larger penalty decreases $P_L$ and uninsurance (see Appendix A for a formal derivation).

Panel (c) of Figure 7 shows the welfare effects in the textbook case where $H$ is the efficient plan for all consumers. There are again competing effects: (intended) welfare gains from newly insured consumers and (unintended) welfare losses from consumers moving from $H$ to the lower-quality $L$ plan. Thus, the interaction of the two margins of selection makes the welfare impact of a mandate ambiguous even in this textbook case. In the extreme, a penalty could even lead to a market where high-quality contracts are unavailable to consumers (i.e., market unraveling to $L$).

### 3.3 Risk Adjustment Transfers

Of the three policies we consider, risk adjustment is the most difficult to illustrate graphically because the policy adds new risk-adjusted cost curves (for both $L$ and $H$) that crowd the figure. Additionally, risk adjustment transfers cause $RAC_H$ (the risk-adjusted cost curve) to become an equilibrium object rather than a stable market primitive (like $AC_H$), as any effects of selection into the market are at least partially shared between $L$ and $H$ due to the risk-based transfers. Despite this complexity, because risk adjustment is an important policy lever used to combat intensive margin selection, we illustrate in Appendix B how it works in our graphical model. Specifically, in Figure A2 we graph how *perfect* risk adjustment, where transfers perfectly capture all variation in $C_L$ across consumer types, affects equilibrium outcomes.

We show that perfect risk adjustment has two effects. First, it causes the average cost curve for $H$ to rotate downward until it is flat. This rotation of the cost curve causes $s_{HL}$ to shift right, indicating a shift of consumers from $L$ to $H$. This is the intended effect of risk adjustment, and it is caused by a transfer from $L$ to $H$ to compensate $H$ for the externality imposed on it by intensive margin selection from $L$. Second, it causes the average cost curve for $L$ to both rotate and shift up.[18] This change in $AC_L$ causes $s_{LU}$ to shift left, indicating a shift of consumers from $L$ to $U$. This is the unintended effect of risk adjustment. It occurs because the transfer to $H$ comes from $L$, resulting in an increase in $L$'s costs and price, forcing some consumers out of the market.

While perfect risk adjustment is a useful thought experiment, most markets include an imperfect form of risk adjustment where transfers are based on individual risk scores computed from diagnoses appearing in health insurance claims. (See Geruso and Layton (2015) for an overview.) For instance, in the ACA Marketplaces, the per-enrollee transfer to plan $j$ is determined by the following formula:[19]

[18] The curve remains downward-sloping because perfect risk adjustment only addresses intensive margin selection, leaving selection on the extensive margin in place.

[19] The actual formula used in the Marketplaces is a more complicated version of this formula that adjusts for geography, actuarial value, age, and other factors. Our insights hold with or without these adjustments, so we omit them for simplicity.

$$T_j(P) = \left(\frac{\overline{R}_j(P)}{\overline{R}(P)} - 1\right) \cdot \overline{P}(P) \tag{9}$$

where $\overline{R}_j(P)$ is the average risk score of the consumers enrolling in plan $j$ given price vector $P$, $\overline{R}(P)$ is the (share-weighted) average risk score among all consumers purchasing insurance, and $\overline{P}(P)$ is the (share-weighted) average price in the market. Note that the transfer is positive as long as $j$'s average risk score is larger than $-j$'s average risk score. Also note that the sum of $H$'s and $L$'s transfers is always zero, making the transfer system budget neutral.

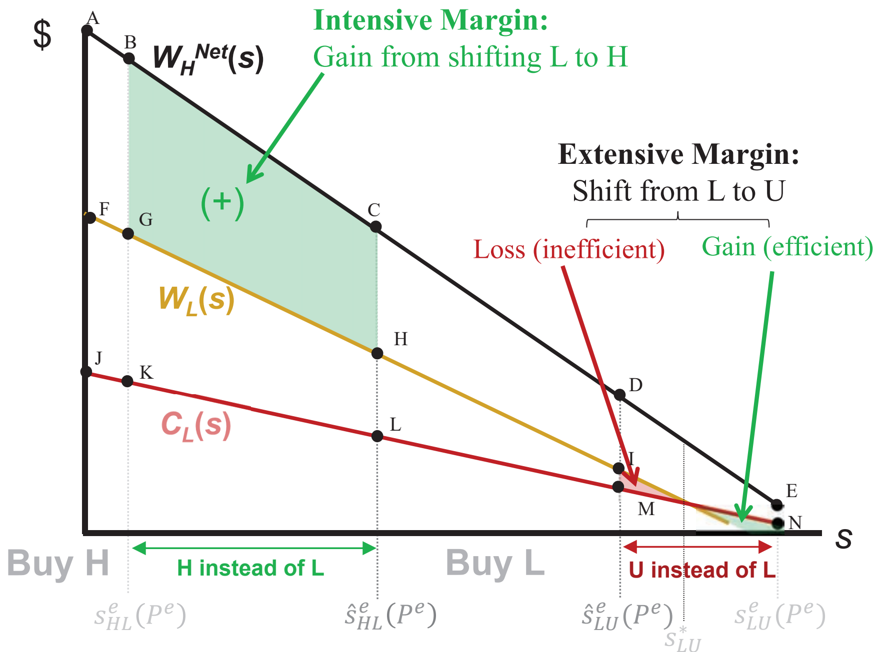
In Appendix A we introduce a parameter $\alpha$ and define the transfer from $L$ to $H$ as $\alpha \cdot T(P)$ so that $\alpha$ describes the strength of risk adjustment with $\alpha = 0$ implying no risk adjustment, $\alpha = 1$ implying ACA risk adjustment, $\alpha = 2$ implying transfers twice as large as ACA transfers, and so on. We then derive some comparative statics describing the effect of an increase in $\alpha$ (i.e., a magnification of the imperfect transfers) on $P_H$ and $P_L$. These comparative statics mimic the simulations we perform in the empirical section where we simulate equilibria under no risk adjustment and with increasingly large risk adjustment transfers (i.e., increasingly large values for $\alpha$). Adjusting $\alpha$ also corresponds to ongoing policy activity, as we discuss below.

The comparative statics reveal that larger values of $\alpha$ (i.e., stronger transfers) unambiguously lower the price of $H$, as in the perfect risk adjustment case above. The effect of an increase in $\alpha$ on the price of $L$, however, is ambiguous. In addition to risk adjustment's direct effect to push up $L$'s average costs by transferring money from $L$ to $H$ (which drove the results under perfect risk adjustment), there is a second, indirect effect. The consumers who shift from $L$ to $H$ tend to be $L$'s most expensive enrollees, even net of imperfect risk adjustment. This lowers $L$'s risk-adjusted average costs, pushing the price of $L$ downward. This indirect effect will be larger when intensive margin adverse selection is severe (even after risk adjustment) and when consumers are highly price elastic on the intensive margin. Indeed, we find in some of our simulations that the indirect effect is large, and risk adjustment has minimal effects or even decreases $P_L$.[20] In Appendix A and Appendix D.4.1 we also explore (both theoretically and empirically) how the effects of risk adjustment are affected by the relaxation of our vertical model assumption, finding that the presence of consumers with non-vertical preferences can act to weaken the unintended effects of risk adjustment on the extensive margin.

In summary, our model provides predictions for the unintended effects of risk adjustment on

[20]This is particularly likely to happen when one allows for $L$ to have no cost advantage over $H$.

**Figure 8:** Welfare Effects of Risk Adjustment




**Notes:** The figure shows the welfare effects of a risk adjustment policy that shifts consumers on the intensive margin from $L$ to $H$ (by lowering $P_H - P_L$) and on the extensive margin from $L$ to $U$ (by raising $P_L$). We show a case where $H$ is globally more efficient than $L$, so the intensive margin shift is welfare improving, but where $U$ is sometimes more efficient than $L$. Optimal sorting across the extensive margin occurs when $s_{LU} = s^*_{LU}$.

uninsurance. However, these predictions vary considerably with the primitives and market design. If risk adjustment is perfect, it will often lead to countervailing effects with some consumers opting for $H$ instead of $L$ and other consumers opting for $U$ instead of $L$. With imperfect risk adjustment, the unintended extensive margin effect may or may not occur, depending on the relative sizes of the direct and indirect effects. We examine various cases empirically below.

Figure 8 depicts the welfare effects of a risk adjustment policy where the direct effect dominates such that the policy shifts consumers from $H$ to $L$ and also has some effect on the extensive margin, shifting consumers from $L$ to $U$. Again, we illustrate welfare for the textbook case where $H$ is the efficient plan for all. As with benefit regulation and the mandate penalty, there are opposing effects: a welfare gain from the intensive margin shift from $L$ to $H$ and a welfare loss from the extensive margin shift from $L$ to uninsurance. (There is also a welfare gain on the extensive margin due to the fact that some of the people induced to choose uninsurance instead of $L$ generate negative social surplus when enrolled in $L$.) This suggests that, like the other policies, the welfare effects of risk adjustment are theoretically ambiguous. Again, our model provides a simple framework for estimating the net welfare effects given the relevant sufficient statistics (willingness-to-pay and cost curves).

### 3.4 Other Policies

The same price theory can be applied to other policies not explicitly discussed above. The key insight is that *anything* that affects selection on one margin has the potential to affect selection on the other margin, as firms adjust prices in equilibrium to compensate for the changing consumer risk pools.

For example, consider reinsurance, a federal policy in place from 2014 to 2016 in the ACA Marketplaces. Reinsurance has gained research attention for desirable market stabilization and incentive properties (Geruso and McGuire, 2016; Layton, McGuire and Sinaiko, 2016) and has been adopted in various forms by some states since the federal program expired.[21] To the extent reinsurance is implemented as a system of budget-neutral enforced transfers based on insurer losses for specific conditions, it generates effects similar to those we document for risk adjustment. To the extent that reinsurance is implemented as an external subsidy into the market by fees assessed on plans outside of the market (as in the ACA), it shares properties of both the mandate penalty (by providing an overall insurance subsidy, making both $H$ and $L$ cheaper) and risk adjustment (by targeting the subsidy to higher-cost enrollees more likely to be in $H$ than in $L$), resulting in simultaneous extensive and intensive margin effects that would be difficult to assess in models focusing only on one margin or the other.[22]

It is important to understand that the cross margin effects are relevant not only for policies that *aim* to address selection, but also for policies for which selection impacts are incidental or a nuisance. Handel (2013), for example, shows how addressing inertia through "nudging" can exacerbate intensive margin selection in an employer-sponsored plan setting. Our model implies that in other market settings, where uninsurance is a more empirically-relevant concern, there is a further effect of nudging: Worsening risk selection on the intensive margin (i.e., increasing the market segmentation of healthy enrollees into $L$ and sick enrollees into $H$) through behavioral nudges may improve risk selection on the extensive margin by pushing down the equilibrium price of $L$. This may counterbal-

[21] In policy practice, the term "reinsurance" is used to describe a wide gamut of regulatory interventions. see Harrington (2017) for a typology.

[22] In particular, like risk adjustment, reinsurance affects shifts the net average cost curves. Unlike risk adjustment, reinsurance will push *both* cost curves down, though typically having a larger effect on $H$'s cost curve due to $H$ being more likely to enroll the high-cost individuals who trigger reinsurance payments.

ance the welfare harm documented in Handel (2013). Similar insights apply to any behavioral intervention that even incidentally affects the sorting of consumer risks (expected costs) across plans.[23] Similarly, behavioral interventions intended to increase take-up of insurance, such as information interventions or simplified enrollment pathways, may have important intensive margin consequences similar to the effects of a mandate.

# 4 Simulations: Methods

Any set of reduced form estimates of willingness-to-pay and cost functions could be used to demonstrate how our model can be applied empirically. Here, we draw on estimates of demand and costs from the Massachusetts pre-ACA subsidized health insurance exchange, known as Commonwealth Care or "CommCare," from Finkelstein, Hendren and Shepard (2019), which we abbreviate as "FHS". We combine the FHS primitives, which describe lower-income consumers, with estimates for higher-income Massachusetts households in the unsubsidized part of the individual market, known as "CommChoice." The latter estimates come from Hackmann, Kolstad and Kowalski (2015), which we abbreviate as "HKK". Both sets of demand and cost curves are well-identified using exogenous variation in net consumer prices. FHS use a regression discontinuity design based on three household income cutoffs that generate discrete changes in consumer subsidies. HKK use a difference-in-differences design leveraging the introduction of an uninsurance penalty in Massachusetts. Additional details about the estimation of the FHS and HKK curves can be found in Appendix C.1 as well as in the respective papers.

We make two key modifications to the baseline FHS and HKK estimates. First, to allow for broader policy counterfactuals, we extrapolate the curves over the full range of $s$-types. Second, we combine the two sets of estimates to form one set of aggregated demand and cost curves, reflecting ACA markets that include subsidized (low-income) and unsubsidized (high-income) enrollees. Details on the construction of these demand and cost curves, as well as figures showing the final curves, are in Appendix C.1.

[23] This is relevant not only as it relates to inertia (Polyakova, 2016), but also to misinformation (Kling et al., 2012; Handel and Kolstad, 2015; Bundorf, Polyakova and Tai-Seale, 2019), complexity (Ericson and Starc, 2016; Ketcham, Kuminoff and Powers, 2019), and other behavioral concerns. It is also relevant for non-behavioral policy changes in other markets, including Medicare. For example, Decarolis, Guglielmo and Luscombe (2017) document that intensive margin risk selection was affected by a Medicare policy change that allowed mid-year plan switching across Medicare Advantage plans. This could have—through an effect on costs and therefore prices—extensive margin impacts on who chooses Medicare Advantage versus Traditional Medicare.

Given these demand and cost curves, it is straightforward to estimate equilibrium prices and allocations of consumers across $H$, $L$, and $U$ under a given set of policies. Our method for finding equilibrium is based on the approach described in Figure 3. We start by considering price vectors resulting in positive enrollment in both $H$ and $L$. For each potential $P_L$ we find the $P_H$ such that $P_H = AC_H$ and for each potential $P_H$ we find the $P_L$ such that $P_L = AC_L$. We then find where these two "reaction functions" intersect. The intersection is the price vector at which both $H$ and $L$ break even. We then also consider price vectors where there is zero enrollment in $H$, zero enrollment in $L$, or zero enrollment in both $H$ and $L$. We then use a Riley equilibrium concept to choose which breakeven price vector is the equilibrium price vector.[24] This method results in a unique equilibrium for each policy environment we consider.

We then simulate market equilibrium under different specifications of two policies: a mandate penalty (ranging from \$0 to \$60 per month) and risk adjustment transfers (ranging from zero to 3 times the size of ACA transfers). We study the effects of these policies in a 2×2 matrix of market environments. The first dimension of the environment we vary is subsidy design, with two regimes: (1) "ACA-like" subsidies that are *linked* to the price of the cheapest plan and (2) "fixed" subsidies set at an exogenous dollar amount.[25] In both subsidy cases, low-income consumers receive subsidies only if they purchase $H$ or $L$, and the subsidy is identical no matter which plan they choose. High-income consumers do not receive subsidies.

The second dimension we vary is whether $L$ is a pure cream-skimmer (i.e. $C_L(s) = C_H(s)$ for all $s$) or has a cost advantage (i.e. $C_L(s) < C_H(s)$ for all $s$). FHS find no evidence that $L$ has lower costs than $H$ in CommCare, motivating our cream-skimmer case. To illustrate another possibility, we simulate the case where $L$ has a 15% cost advantage (i.e. $C_L(s) = 0.85C_H(s)$). Of particular interest is how the welfare consequences of risk adjustment and the uninsurance penalty vary across these two cases. We explore these in Section 6.

[24] See Appendix C.4 for additional details. A breakeven price vector is a Riley equilibrium if there is no weakly profitable deviation resulting in positive enrollment for the deviating plan that survives all possible weakly profitable responses to that deviation. We describe how we empirically implement this equilibrium concept in the appendix.

[25] For (1) we follow the ACA rules by setting the subsidy such that the net-of-subsidy price of the index plan equals 4% of income for consumers at 150% of the federal poverty line (FPL) in 2011 (or \$55 per month), the year on which our estimated demand and cost curves are based. The ACA subsidy rules actually link the subsidy to the price of the second-lowest cost silver plan. Our subsidy rule mimics this rule in spirit (in a way that is compatible with our CommCare setting) by linking the subsidy to the price of $L$.

# 5 Simulation Results: Prices and Enrollment

In this section, we present results on how prices and market shares change under (1) stronger mandate penalties and (2) stronger risk adjustment. In Appendix D.2 we also present results on how prices and market shares change under benefit regulation, where we implement benefit regulation by eliminating $L$ from the consumers' choice set. In Appendices D.4.1 and D.4.2 we explore the sensitivity of our results to relaxing the vertical model and modifying the primitives (specifically, consumers' incremental WTP for $H$ vs. $L$), finding that the key results are quite robust.

## 5.1 Mandate/Uninsurance Penalties

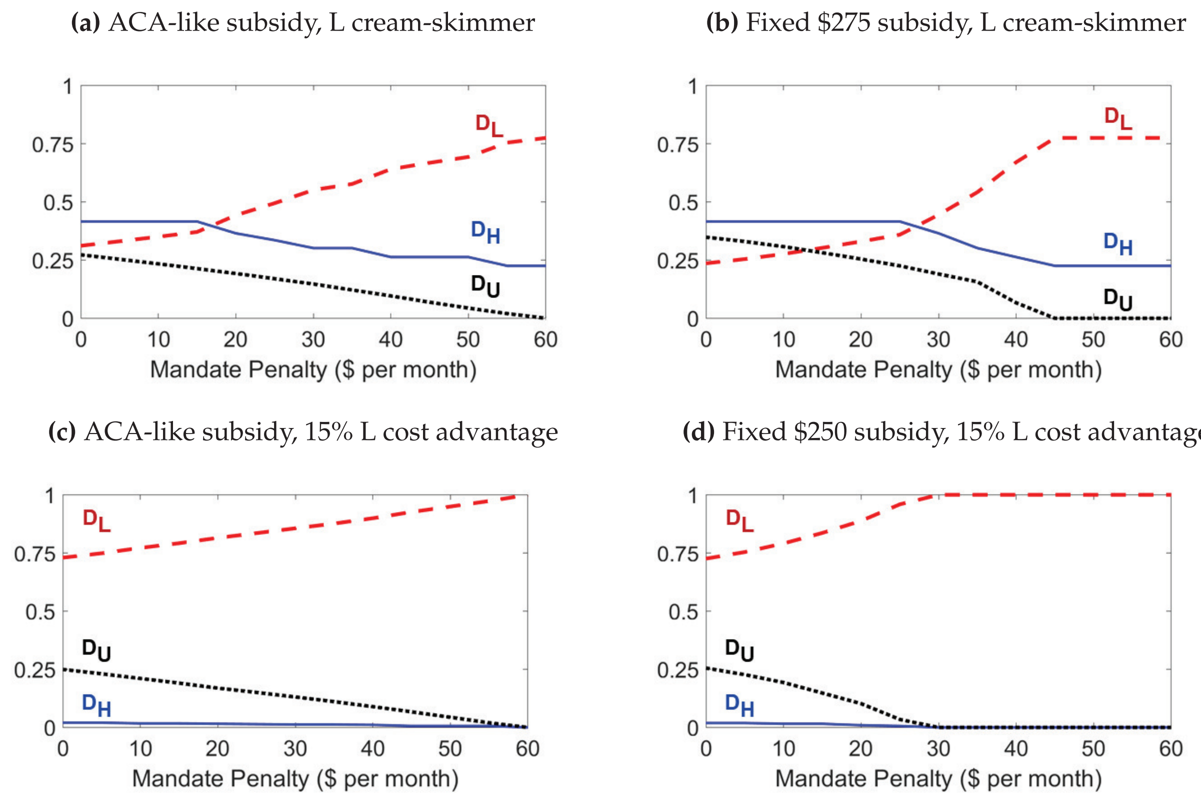
Figure 9 presents equilibrium market shares for each option, $H$, $L$, and $U$, under different levels of a mandate penalty for remaining uninsured ($P_U \equiv M$). We consider penalties in increments from \$0 to \$60.[26] In all cases we include ACA-style risk adjustment (described in detail in Section 5.2 below). The top two panels of Figure 9 contain the results for the case where $L$ is a pure cream-skimmer. The bottom two panels contain results for the case where $L$ has a 15% cost advantage. The cases with ACA-like price-linked subsidies are shown in the left panels and the cases with a fixed subsidy are in the right panels.[27] All results are also reported in Appendix Table A1.

For the two ACA-like subsidy cases (left), the patterns are qualitatively similar regardless of modeling $L$ as a cream skimmer (top) or as having a cost advantage (bottom). When there is no mandate penalty, some consumers choose each of the three options, $H$, $L$, and $U$, though the share in $H$ is extremely low in the cost advantage case. As the penalty increases, the uninsurance rate decreases, with no consumers remaining uninsured at a penalty of \$60/month. However, there are also intensive margin consequences: As the penalty increases, there is a shift of consumers from $H$ to $L$. In the case where $L$ is a pure cream-skimmer, $H$'s market share decreases from 42% with no penalty to 23% with a penalty of \$60/month. This represents a significant decline in $H$'s market share and a significant deterioration of the average generosity of coverage among the insured. In the case where $L$ has a 15% cost advantage (bottom), the patterns are similar, though $H$'s initial market

[26] We find that in all cases studied here, $P_U = 60$ is sufficient to drive the uninsurance rate to 0 in the presence of ACA risk adjustment transfers.

[27] Fixed subsidies are equal to \$275 in the case where $L$ is a pure cream-skimmer and \$250 in the case where $L$ has a 15% cost advantage. These values were chosen in order to ensure that risk adjustment and the uninsurance penalty have some effect on market shares. With subsidies that are "too large" no consumers opt to be uninsured and with subsidies that are "too small" no consumers opt to purchase insurance, making the simulated policy modifications uninformative.

**Figure 9:** Market Shares with Varying Mandate Penalty ($M$)




**Notes:** The figures show market shares for $H$, $L$, and uninsurance ($U$) from our simulations with varying sizes of the mandate penalty (x-axis, in $ per month). The panels represent different subsidy designs and specifications for the $L$ plan's causal cost advantage vs. $H$ (i.e., $\Delta C_{HL}$). In panels (a) and (b), $L$ is a pure cream-skimmer ($\Delta C_{HL} = 0$), while in panels (c) and (d) $L$ has a 15% cost advantage. Panels (a) and (c) have "ACA-like subsidies" linked to the price of $L$, while panels (b) and (d) have fixed subsidies of the indicated dollar amounts.

share with no penalty is much lower ($\approx$ 2%), so the intensive margin consequences are less stark.

The two fixed subsidy cases are presented in the right panels of Figure 9. When $L$ is a pure cream-skimmer (top), in the absence of a penalty consumers are split across $H$, $L$, and $U$. As the penalty increases from zero, consumers move from $U$ to $L$, the intended effect of the policy. At a penalty of just under \$30/month the influx of relatively inexpensive consumers into $L$ causes $P_L$ to get low enough relative to $P_H$ that some consumers previously in $H$ begin to opt for $L$. As the penalty continues to increase, consumers move into $L$ from both $U$ and $H$ until the mandate reaches just over \$40/month and all consumers are enrolled in insurance. At this point 23% of the market is enrolled in $H$ and 77% of the market is enrolled in $L$. This represents an intended decline in the uninsurance rate from 35% to 0% but also an unintended decline in $H$'s market share from 42% to 23%.[28]

[28] In the case where $L$ has a 15% cost advantage, the penalty again decreases both the uninsurance rate (intended) and $H$'s market share (unintended), but $H$'s market share with a \$0 penalty is so low (around 3.5%) that the decline in $H$'s

In each of the empirical cases we consider in Figure 9, a larger insurance mandate penalty has the intended consequence of decreasing the portion of consumers opting to remain uninsured *and* the unintended consequence of shifting consumers from $H$ to $L$. This finding holds when we relax the vertical assumptions of the model in Appendix Figure A9. [29] This is consistent with implications of our graphical model as well as the comparative statics we outline in Sections 2 and 3. The unintended intensive margin effect is most stark in the case where $L$ is a perfect cream-skimmer, highlighting how the market primitives can amplify the cross-margin impacts of policy changes.[30]

### 5.2 Risk Adjustment

We now consider the effects of risk adjustment. We start with risk adjustment transfers implied by the ACA risk adjustment transfer formula (see Eq. 9). We first calculate risk scores for each individual using the HHS-HCC risk adjustment model used in the ACA Marketplaces. (This is a straightforward mechanical application of the regulator's algorithm to our individual-level claims data.) We then use those scores plus the FHS regression discontinuity design to estimate a "risk score curve" $RA(s)$ describing the average risk score across consumers of a given $s$-type. Because this curve is novel to this paper and not estimated by FHS, we describe the estimation of it in Appendix C.2. We plot this curve alongside the cost curve in Appendix Figure A4. It is apparent that while risk scores explain part of the correlation between willingness-to-pay and costs, they do so only imperfectly. Specifically, we find that risk scores account for about one-third of the correlation between willingness-to-pay and costs, implying substantial selection on costs net of the ACA's imperfect risk adjustment policy. (Although incidental to our aims here, this is a novel finding.)

We use the risk score curve to determine the average risk scores for $H$ and $L$ for any given allocation of consumers across $H$, $L$, and $U$. This is similar to constructing average cost curves from marginal costs. We then enter these average risk scores into the risk adjustment transfer formula (Eq. 9) to determine the transfer from $L$ to $H$ for a given price vector $T(P)$. Finally, we find the equilibrium prices. These satisfy $P_H = AC_H(P) - T(P)$ and $P_L = AC_L(P) + T(P)$ when $L$ and $H$ have

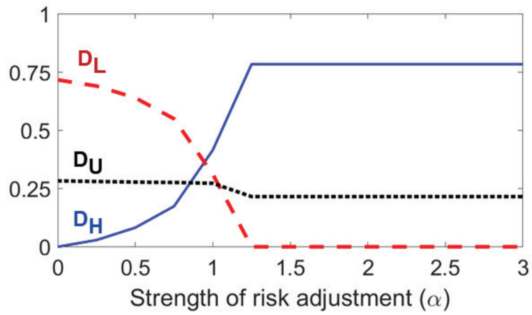
market share (to zero) is relatively insignificant.

[29] In Appendix D.4.1 we explore the sensitivity of these results to the vertical model assumption, finding that the results are largely robust to modest relaxation of the assumption. See Figure A9. In addition, in Appendix D.4.2 we show that these results are also robust to varying the incremental WTP for $H$ vs. $L$.

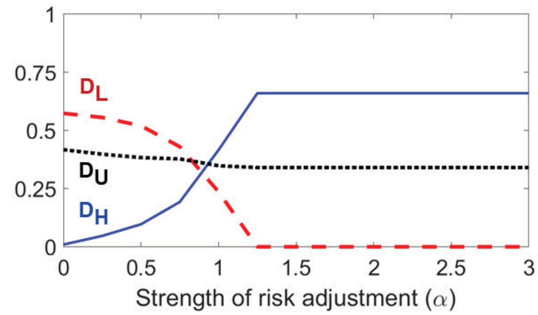
[30] To see why the effect would be larger for the cream-skimmer case, note that for fixed consumer preferences, it is relatively more difficult to achieve high levels of enrollment in $H$ when $L$ has an actual cost advantage versus when $L$ has similar costs to $H$. This leads to lower enrollment in $H$ even at low levels of the mandate penalty, and less opportunity for a reduction in $H$'s market share.

**Figure 10:** Market Shares with Varying Strength of Risk Adjustment ($\alpha$)

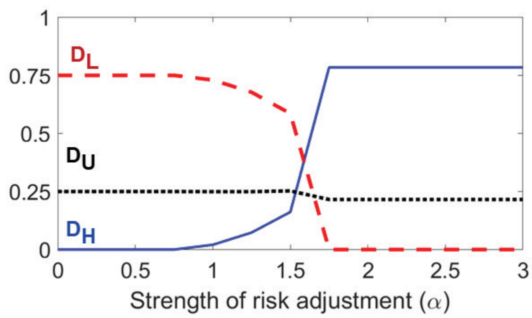
**(a)** ACA-like subsidy, L cream-skimmer



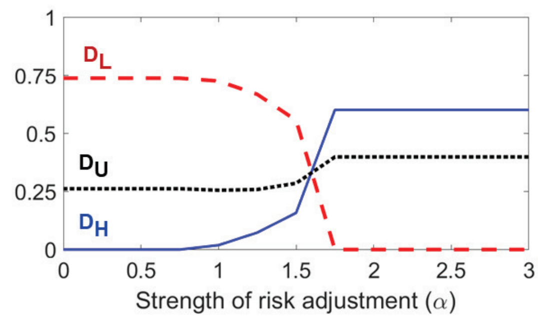

**(b)** Fixed \$ 275 subsidy, L cream-skimmer




**(c)** ACA-like subsidy, 15% L cost advantage




**(d)** Fixed \$ 250 subsidy, 15% L cost advantage




**Notes:** The figures show market shares for $H$, $L$, and uninsurance ($U$) from our simulations with varying strength of risk adjustment $\alpha$ (on the x-axis). As described in text, $\alpha$ is a multiplier on the risk adjustment transfer: $\alpha = 0$ implies no risk adjustment; $\alpha = 1$ is baseline risk adjustment using the ACA formula; and $\alpha > 1$ is over-adjustment. The panels represent different subsidy designs and specifications for the $L$ plan's causal cost advantage vs. $H$ (i.e., $\Delta C_{HL}$). In panels (a) and (b), $L$ is a pure cream-skimmer ($\Delta C_{HL} = 0$), while in panels (c) and (d) $L$ has a 15% cost advantage. Panels (a) and (c) have "ACA-like subsidies" linked to the price of $L$, while panels (b) and (d) have fixed subsidies of the indicated dollar amounts.

non-zero enrollment.

To vary the strength of risk adjustment transfers we maintain the original risk scores and structure of the transfer formula, but we multiply transfers by a scalar $\alpha$ (as in the comparative statics in Appendix A) so that transfers from $L$ to $H$ are some multiple of the transfers implied by the ACA formula. We allow $\alpha$ to vary from 0 (no risk adjustment) to 3 (risk adjustment transfers 3 times the size of ACA transfers). The case of ACA transfers occurs where $\alpha = 1$. This approach to evaluating strengthening or weakening risk adjustment reflects real-world policy experimentation: The federal government recently reduced $\alpha$ from 1 to 0.85 in the ACA Marketplaces and gave states the ability to further reduce $\alpha$.[31] Our approach thus maps to feasible policy interventions, rather than assuming

[31]The reduction of $\alpha$ from 1 to 0.85 occurred when the federal government decided to "remove administrative costs" from the benchmark premium that multiplies insurer risk scores to determine transfers in the transfer formula described by Eq. 9.

that the regulator can increase the predictive power of risk scores.

Equilibrium market shares for different levels of $\alpha$ in the cases without and with a cost advantage for $L$ are found in the top and bottom panels of Figure 10, respectively. Market shares under ACA-like subsidies are presented in the left panels and market shares under fixed subsidies are found in the right panels. Results are also found in Appendix Table A2. With ACA-like subsidies, patterns are qualitatively similar when $L$ is a pure cream-skimmer and when $L$ has a 15% cost advantage. In both cases, when there is no risk adjustment ($\alpha = 0$), the market unravels to $L$: No consumers choose $H$, and the market is split between $L$ and uninsurance. As the strength of risk adjustment transfers increases, consumers shift from $L$ to $H$. This is the intended consequence of risk adjustment. When $L$ is a pure cream-skimmer, transfers about 1.25 times the size of ACA transfers are sufficient to cause the market to "upravel" to $H$. When $L$ has a 15% cost advantage transfers need to be 1.6 times the size of ACA transfers to generate the same outcome. In both cases, there is no extensive margin effect except at the level of $\alpha$ where the market initially upravels to $H$. At that point, there is a small reduction in the uninsurance rate. This reduction is due to the fact that there the subsidy becomes linked to the (higher) price of $H$ instead of the (lower) price of $L$ due to the exit of $L$ from the market. With the larger subsidy, more consumers purchase insurance.[32]

The right column of Figure 10 presents market shares under fixed subsidies with different levels of $\alpha$. Here, we again see that stronger risk adjustment transfers have the intended effect: Higher levels of $\alpha$ result in more consumers choosing $H$ instead of $L$. In the case where $L$ is a pure cream-skimmer, we see only a small extensive margin effect, with a small decrease in the uninsurance rate as $\alpha$ increases. This is consistent with our comparative statics from Section 3: The direct effect of increasing the transfer from $L$ to $H$ is more than fully offset by the indirect effect of the costliest (net of imperfect risk adjustment) $L$ enrollees leaving $L$ and joining $H$, resulting in a decrease in $P_L$ and a corresponding decrease in the uninsurance rate. (See Section 3 and Appendix A for a fuller discussion of this result.)

On the other hand, in the case where $L$ has a 15% cost advantage we see a different unintended extensive margin consequence of stronger risk adjustment transfers: More consumers opt to remain

[32]This reduction seemingly goes against the intuition we present in Section 3 where we showed that in many cases risk adjustment may *increase* the uninsurance rate rather than decrease it as we see here. Note, however, that in the cases here the subsidy is linked to the extensive margin price. This results in risk adjustment having no effect on the net-of-subsidy extensive margin price faced by the low-income consumers (except where $L$ exits the market), limiting (and in this case eliminating) any unintended extensive margin consequence.

uninsured. In this case, with no risk adjustment ($\alpha = 0$) all insured consumers opt for $L$, with no consumers choosing $H$ and the market split between $L$ and $U$. ACA risk adjustment transfers ($\alpha = 1$) barely alter these market shares. As transfers are strengthened above ACA levels, consumers begin to opt for $H$ instead of $L$. At the higher levels of $\alpha$, extensive margin consequences also start to appear with some consumers exiting the market and opting for uninsurance. When transfers are strengthened to two times the size of ACA transfers, the market upravels to $H$ with all insured consumers opting for $H$ instead of $L$. At $\alpha = 2$ the uninsurance rate reaches almost 50%, an increase of 15 percentage points (60%) compared to the case with no risk adjustment. This indicates that this shift of consumers to more generous coverage on the intensive margin had a substantial extensive margin impact. We show that the same result holds when we relax the vertical model assumptions in Appendix Figure A9.[33]

These results provide important lessons for where the unintended extensive margin effects of risk adjustment will matter most. First, ACA-like price-linked subsidies protect against the unintended extensive margin effects of risk adjustment, even when those subsidies are only targeted to the low-income consumers making up 60% of the market (though there may be important effects on the size of the subsidies themselves, and thus the cost to the government). Second, the unintended extensive margin effects are more likely to occur when $L$ has a larger cost advantage over $H$. In cases where $L$ and $H$ have similar costs, extensive margin effects are likely to be small. But when $L$ has a large cost advantage, stronger risk adjustment can have significant effects on the portion of consumers in the market who opt to be uninsured.

# 6 Simulation Results: Welfare

We next analyze the changes in social surplus associated with the policy simulations of Section 5. We characterize welfare at a baseline equilibrium, then trace the gains and losses associated with illustrative policy changes, and finally determine optimal policy. Importantly, we show that the optimal size of the mandate is dependent on the parameter determining the strength of risk adjustment and vice versa. One straightforward implication is that if mandate penalties were altered by legislative action or court outcomes, a constrained optimal response from a regulator would likely be to adjust

[33]In Appendix D.4.1 we explore the sensitivity of these results to the vertical model assumption, finding that the results are robust to modest relaxation of the assumption. See Figure A9. Also, in Appendix D.4.2 we show that these results are largely robust to varying the incremental WTP for $H$ vs. $L$.

risk adjustment strength in concert. (Unlike altering a mandate penalty, a regulator would typically have authority to tune risk adjustment without further changes to law.)

We begin by noting the possibility that in many settings, social surplus may not be increased by policies that increase insurance take-up or that move consumers from less generous coverage to more generous coverage. This is because some consumers may not value insurance more than the cost of providing it to them and may not value the incremental coverage provided by more generous plans more than the incremental cost of providing that coverage. Further, we have shown above that policies may have opposing effects on the intensive and extensive margins, increasing enrollment in more generous coverage while simultaneously decreasing overall insurance take-up, or vice versa. For these reasons, it is important to understand the effects of policies not just on market allocations (which Section 5 presents), but also on welfare.

As discussed in Section 2, it is straightforward to estimate overall social surplus associated with some equilibrium market outcome (enrollment shares), given the $W_H^{Net} = W_H - (C_H - C_L)$; $W_L$; and $C_L^{Net} = C_L - C_U$ curves. From Section 4, we have all necessary primitives except $C_U$. From Section 5, we have equilibrium market shares under a variety of policy environments, which we can contrast to the social optimum defined by the primitives. Therefore, the only missing piece for estimating welfare is the social cost of uninsurance. In Section 2 we assumed $C_U = 0$ for simplicity. However, this assumption ignores uncompensated care, care paid for by other state programs, or more difficult-to-measure parameters like a social preference against others being uninsured. Because we do not have any way to directly measure the social cost of uninsurance, we specify it as linked to the observed type-specific cost of enrolling in $H$. We write the social cost of uninsurance for type $s$ as:

$$C_U(s) = \frac{(1-d)C_H(s)}{1+\phi} + \omega \tag{10}$$

where $d$ is the share of total uninsured healthcare costs that the uninsured pay out of pocket, $\phi$ is the assumed moral hazard from insurance, and $\omega$ is some fixed cost of uninsurance. For $d$ and $\phi$, we use the values as derived from Finkelstein, Hendren and Shepard (2019) and assume that $d = 0.2$ and $\phi = 0.25$.[34] We set the fixed cost $\omega = -\$97$ per month, which is the $\omega$ value consistent with 95% of the population being optimally insured when $L$ has a 15% cost advantage.

[34] We note that without this assumption (i.e. if we assume $C_U = 0$), it is inefficient for any consumer to purchase insurance, as no consumer values either $H$ or $L$ more than the cost of enrolling them in $H$ or $L$. This fact plus a full discussion of the derivation of the assumed values of $d$ and $\phi$ can be found in Finkelstein, Hendren and Shepard (2019).

Before showing how to use our graphical model to estimate welfare, we provide an important caution: As is standard in the literature, our welfare estimation depends critically on inferring consumer valuation of $H$ and $L$ from estimates of the demand-response to exogenous variation in the prices of these products. Our welfare estimates are accurate only to the extent that demand curves accurately reflect true valuations. Behavioral frictions might cause consumer demand to deviate from valuations (Handel, Kolstad and Spinnewijn, 2019). Liquidity constraints could also cause valuation and demand to diverge (Casaburi and Willis, 2018). A separate issue is that our specification of $C_U$ is *ad hoc* and may not reflect the actual social costs of uninsurance. Indeed, many of our welfare conclusions will necessarily be sensitive to our assumptions about $C_U$. (We present welfare results for alternative assumptions about $C_U$ in Appendix D.3.2.) We thus present these welfare results to (1) show how our framework can be used to analyze welfare and (2) to build intuition for the welfare trade-offs involved with various policies. But we do not make any normative conclusions about the specific market we study.

Importantly, considerations about choice frictions or about the difficulty of measuring $C_U$ do not threaten the use of our model for the positive analysis of Section 5, which consists of predictions of prices and market shares under different counterfactual mandate penalties and risk adjustment. Such predictions do not rely on assumptions about $C_U$ or about demand reflecting underlying consumer valuation.

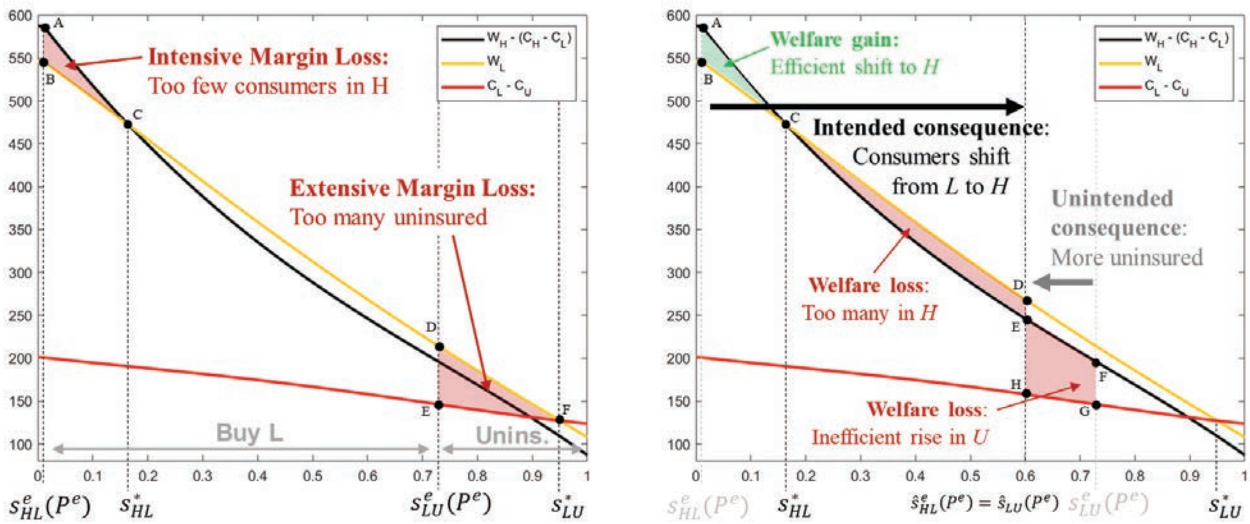
### 6.1 Welfare and Changes to Risk Adjustment

We now show how to estimate welfare with our graphical model. For parsimony, we focus in the main text on the case of strengthening risk adjustment transfers. In Appendix D.3 we show the case of an uninsurance penalty. Figure 11 plots the empirical analogs to our welfare figures from Section 2. Panel (a) depicts foregone surplus relative to the social optimum under a baseline case with ACA risk adjustment ($\alpha = 1$), no mandate penalty, and a fixed subsidy equal to \$250. Panel (b) depicts the difference in social surplus between the baseline case and a similar case where risk adjustment is strengthened ($\alpha = 2$), reflecting the simulation reported in the bottom-right panel of Figure 10. Instead of plotting $C_L$, we plot $C_L^{Net} = C_L - C_U$, as in Eq. (8) to account for the fact that $C_U \neq 0$. We also plot $W_H^{Net} = W_H - (C_H - C_L)$ as in Section 2.

In Panel (a), we indicate the equilibrium $s$ cutoffs for $\alpha = 1$. The intensive margin equilibrium

**Figure 11:** Empirical Welfare Effects from Simulations

**(a)** Baseline Sorting and Welfare Loss **(b)** Welfare Effects of Stronger Risk Adjustment




**Notes:** In both panels (a) and (b), we assume that there is a fixed subsidy equal to \$250 and $L$ has a 15% cost advantage over $H$. Further, 60% of the population is low-income and 40% of the population is high-income, so WTP curves are weighted sums of both types. Panel (a) shows welfare losses in this setting under no mandate and $\alpha = 1$, relative to efficient sorting. Efficient cutoffs are indicated with a * while equilibrium outcomes are denoted with an $e$ superscript. Panel (b) shows welfare changes under a risk adjustment policy where $\alpha = 2$, relative to the baseline risk adjustment policy where $\alpha = 1$.

cutoff is $s^e_{HL}$ and the extensive margin cutoff is $s^e_{LU}$. Thus, consumers with $s < s^e_{HL}$ enroll in $H$, consumers with $s^e_{HL} < s < s^e_{LU}$ enroll in $L$, and consumers with $s > s^e_{LU}$ remain uninsured.

Efficient sorting of consumers across options is indicated by $s^*$ cutoff types. Consumers with $s < s^*_{HL}$ should be in $H$, consumers with $s^*_{HL} < s < s^*_{LU}$ should be in $L$, and the few consumers with $s > s^*_{LU}$ should be uninsured to maximize social surplus. In panel (a) of Figure 11, we depict the foregone surplus in the baseline ACA setting with shaded areas. Intensive margin foregone surplus (lost surplus due to consumers choosing $L$ instead of $H$) is indicated by the welfare triangle $ABC$, representing a welfare loss of \$19.71.[35] Extensive margin foregone surplus is represented by the welfare triangle $DEF$. Welfare loss on this margin amounts to \$33.47. Combining these, the (average per consumer) foregone surplus in the baseline setting in panel (a) of Figure 11 is thus \$53.18.

Panel (b) of Figure 11 shows the welfare consequences of strengthening risk adjustment. To show the effects of strengthening risk adjustment, we increase $\alpha$ from 1 to 2, so that risk adjustment transfers are increased to two-times the ACA transfers. We hold all other policy parameters fixed. Recall from the bottom-right panel of Figure 10 that moving from $\alpha = 1$ to $\alpha = 2$ in this setting shifts

[35]These shapes are more triangle-ish than triangular.

nearly 60% of consumers in the market from $L$ to $H$ but also shifts 13% of consumers in the market from $L$ to $U$. Overall, no consumers remain in $L$ when $\alpha = 2$.

The first effect of increasing $\alpha$ is the intended consequence of risk adjustment, and here it implies both welfare gains and losses. Welfare gains occur when consumers whose incremental valuation for $H$ vs. $L$ exceeds the incremental cost of $H$ vs. $L$ (i.e. those with $W_H^{Net}(s) > W_L(s)$) enroll in $H$ instead of $L$. These gains are represented by the green welfare triangle $ABC$, and they amount to \$19.71. Welfare losses occur when consumers whose incremental valuation for $H$ vs. $L$ is less than the incremental cost of $H$ vs. $L$ (i.e. those with $W_H^{Net}(s) < W_L(s)$) enroll in $H$ instead of $L$ as $L$ unravels. These offsetting welfare losses occur when "too many" consumers enroll in $H$, and they are represented by the red welfare triangle $CDE$ and amount to \$19.24. In other settings, where it is always more efficient for consumers to be enrolled in $H$ instead of $L$ (such as the pure cream-skimming case), there will only be welfare gains on this margin. In the case of panel (b) of Figure 11, the two effects nearly cancel each other out so that the net welfare gain due to the intended consequence of shifting consumers from $L$ to $H$ amounts to just \$0.47.

The second effect of increasing $\alpha$ is the unintended consequence of risk adjustment, and here it implies welfare losses. Because risk adjustment leads to a higher price of $L$, some consumers exit the market, increasing the uninsurance rate. In this case, all consumers who exit the market value insurance more than the (net) cost of insuring them, $C_L^{Net} = C_L - C_U$, causing the welfare consequences of this shift of consumers out of the market to be unambiguously negative. The size of the welfare loss is represented by the area of $EFGH$, which we estimate to be \$68.30. Combining the intended and unintended consequences of risk adjustment, we estimate that in this setting doubling risk adjustment transfers by shifting from $\alpha = 1$ to $\alpha = 2$ would decrease welfare by \$67.83, on average per consumer.

Welfare results for all settings studied in Figures 9 and 10, for the full range of levels of $\alpha$, and under different assumptions about $C_U$ are found in Appendix D.3.2. These results indicate that under our baseline assumption of $C_U$ (Equation 10), with ACA-like subsidies, increasing the strength of risk adjustment transfers always improves welfare when $L$ is a pure cream-skimmer. In this case, there is no effect of risk adjustment on the extensive margin due to the linkage of the subsidy to the price, leaving only intensive margin consequences. The intensive margin effects of moving consumers from $L$ to $H$ are also unambiguously positive, as it is inefficient for any consumer to be enrolled in $L$

vs. $H$. When $L$ has a cost advantage, increasing the strength of risk adjustment transfers improves welfare given low initial levels of $\alpha$ but decreases welfare given higher initial levels of $\alpha$, with the welfare-maximizing risk adjustment policy having an $\alpha$ around 1.25, or 1.25 times the strength of ACA risk adjustment transfers. This non-monotonic result is due to the fact that increases in $\alpha$ from low initial levels of $\alpha$ induce only those consumers who value $H$ highest relative to $L$ to enroll in $H$, with consumers whose incremental WTP does not exceed their incremental cost remaining enrolled in $L$.

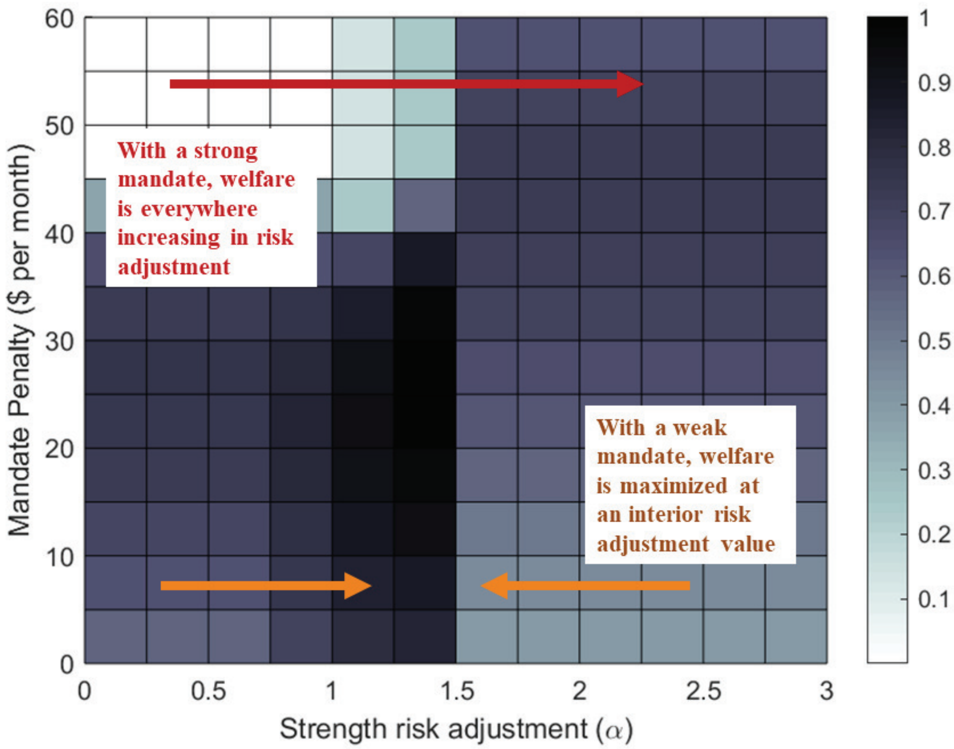
With fixed subsidies, the welfare consequences again depend on whether $L$ has a cost advantage. Recall that when $L$ is a pure cream-skimmer, extensive margin consequences of risk adjustment are limited. It is inefficient for any consumers to be enrolled in $L$ vs. $H$ in the cream-skimmer case, implying that the intensive margin effects of moving consumers from $L$ to $H$ are unambiguously positive. When $L$ has a cost advantage, patterns in the fixed subsidy case are similar to the ACA-like subsidy case, with welfare increasing with the strength of risk adjustment at low initial levels of $\alpha$ and decreasing at higher levels. Here, in addition to moving some consumers who should not be in $H$ into $H$, stronger risk adjustment also pushes consumers out of the market, further worsening the negative effects of risk adjustment. Overall, risk adjustment is most likely to improve welfare in a setting with ACA-like subsidies and when $L$ plans do not have a cost advantage. However, policymakers should be cautious when strengthening risk adjustment in settings where subsidies are fixed and/or plans are heterogeneous in their cost structures.

### 6.2 Optimality under Interacting Policies

The findings above suggest the necessity of a second-best approach to policy: optimal extensive margin policy (penalties and subsidies) will often depend on the intensive margin policies (risk adjustment and benefit regulation) currently in use in a market. Here we show how our model can be used to assess optimal policy, allowing for these interactions.

We again consider uninsurance penalties and risk adjustment. We compute social welfare over a grid of uninsurance penalties and levels of $\alpha$. We do this for the case in which $L$ has a 10% cost advantage and low-income consumers (who comprise 60% of the market) receive a fixed subsidy equal to \$250 when purchasing insurance. The social cost of uninsurance is once again set to $C_U(s) = 0.25C_H(s) - 97$ as in the previous section. We "cherry-pick" this case because the two policies interact

**Figure 12:** Welfare under Interacting Extensive and Intensive Margin Policies




**Notes:** The figure shows social welfare outcomes (darker = higher welfare) from the model simulations under different parameters for the strength of risk adjustment ($\alpha$, x-axis) and for the size of the uninsurance mandate penalty ($ per month, y-axis). The key point is that the optimum for one policy depends on the other: with weak risk adjustment a weaker mandate is optimal, while with strong risk adjustment a strong mandate is optimal.

in interesting ways. For completeness, we perform similar analyses for all other settings studied in Figures 9 and 10. Results are reported in Appendix D.3.

Figure 12 presents the welfare estimates graphically as a heat map, where darker areas represent higher values of social surplus.[36] Under a 10% cost advantage, the socially efficient allocation is for 33% of the population to be in $H$, 60% of the population to be in $L$, and the remainder to be uninsured. We can examine how the optimal level of risk adjustment changes with different values of the mandate penalty. The figure shows that in this setting, when the mandate penalty is high, welfare is increasing in the strength of risk adjustment (i.e. higher $\alpha$). At these high values of the mandate penalty, all consumers purchase insurance, eliminating any potential unintended extensive margin consequences. Under such high market enrollment, it is optimal to use strong risk adjustment

[36] Consider a given $\alpha$, mandate combination that generates a level of welfare $W(\alpha, \text{mandate})$. We scale/normalize the heat map shading as follows: $W^{\text{norm}}(\alpha, \text{mandate}) = \frac{W(\alpha,\text{mandate})-\min(W)}{\max(W)-\min(W)}$, where the maximum and minimum are taken over all possible $\alpha$, mandate combinations for the setting.

to sort more people into $H$ instead of $L$. With low levels of the mandate penalty, however, risk adjustment has important unintended extensive margin consequences. Thus, the benefits of shifting consumers from $L$ to $H$ must be traded off against the costs of shifting consumers out of the market and into $U$. The results in Figure 12 indicate that with a small penalty, social surplus is maximized at $1.25 < \alpha < 1.5$, somewhat stronger than ACA risk adjustment but weaker than the optimal level of $\alpha$ under a strong penalty, which is $> 1.5$.

We can also use Figure 12 to consider the optimal mandate penalty for each level of $\alpha$. With weak risk adjustment, starting from low levels of the mandate penalty, social surplus is increasing in the size of the penalty. However, starting from high levels of the penalty, the sign is opposite, with social surplus *increasing* rapidly as the penalty is *reduced*. This occurs because while a strong mandate penalty increases social surplus by inducing consumers to enroll in insurance, it also has the first-order offsetting effect of shifting consumers from $H$ to $L$. Ultimately, an intermediate penalty level (around \$30) maximizes social surplus, though any level of the penalty below \$40 achieves much higher levels of social surplus than the level achieved by a penalty exceeding \$40. When risk adjustment is strong, social surplus is increasing in the mandate penalty. Here, strong risk adjustment causes the market to "upravel" to $H$, eliminating any potential unintended intensive margin consequences of increasing the level of the penalty. With strong risk adjustment, a stronger mandate thus only induces consumers to move from $U$ to $H$, generating higher levels of social surplus.

In terms of optimal policy, Figure 12 reveals that social surplus is highest for an intermediate level of both the uninsurance penalty and risk adjustment. Given such a combination of policies, consumers sort themselves to each of $H$, $L$, and $U$, which is the socially efficient outcome in this particular setting. Note that the lowest-surplus combinations are a strong mandate with weak risk adjustment or a weak mandate with strong risk adjustment.

In Appendix D.3 we show that other settings have different optimal policies. In the case where $L$ is a pure cream-skimmer and subsidies are linked to prices (ACA-like subsidies), optimal policy is to have strong risk adjustment (high $\alpha$) and a weak mandate. In the case where $L$ has a cost advantage, a weak mandate with weak to moderate risk adjustment is the optimal policy. In all cases, it is clear that these two policies interact with each other, implying that evaluating one policy in isolation from the other can be misleading. Specifically, market designers should not only consider consumer preferences for high- vs. low-quality coverage and consumer valuation of insurance but also the interaction between intensive and extensive margin selection when determining the optimal combination of policies.

## 7 Conclusion

Adverse selection in insurance markets can occur on either the extensive (insurance vs. uninsurance) or intensive (more vs. less generous coverage) margin. While this possibility has been recognized for a long time, most prior treatments of adverse selection focus on only one margin or the other. This focus misses important cross-margin trade-offs inherent to many selection policies.

In this paper, we develop a simple graphical framework that generalizes the framework of Einav, Finkelstein and Cullen (2010) by adding the option to remain uninsured. Our setup allows for and highlights simultaneous selection on both margins. We use this framework to build intuition for the unintended intensive margin consequences of extensive margin policies and vice versa. We show that the extent to which these cross margin effects occur depends on the primitives of the market.

We also show that it is straightforward to take the graphical framework directly to the data with variation that identifies two sets of demand and cost curves. We do this with estimates from Massachusetts and find that the extensive/intensive margin trade-off is empirically relevant for evaluating the consequences of various policies. Specifically, (1) strengthening uninsurance penalties can help some consumers by getting them into the market while hurting other consumers by inducing them to enroll in lower-quality coverage, and (2) strengthening risk adjustment transfers can help some consumers by inducing them to enroll in higher-quality coverage while hurting other consumers by forcing them out of the market. Additionally, we find that price-linked subsidies for low-income consumers can weaken some of these trade-offs (i.e. effects of risk adjustment and benefit regulation) but not others (i.e. mandates/uninsurance penalties). Finally, we show that trade-offs related to risk adjustment are often more pronounced when the advantageously selected plan has a cost advantage.

Because many policies lead to coverage gains on one margin and coverage losses on the other, in some cases the unintended effects of policies are first-order with respect to welfare. We show cases in which the welfare losses from coverage losses on the unintended margin exceed welfare gains from coverage gains on the intended margin. This happens most often with a penalty for choosing to be uninsured.

The simplicity of our approach is not without some costs. The assumption of perfect vertical ordering of demand, in particular, is required to maintain simplicity in the figures, though we show in both theory and empirics that our results are largely robust to the relaxation of this assumption. What matters is that the *primary* way in which plans are differentiated is vertically. Some of our insights may differ in more complex markets, and these complexities are an important area for future research.

The issues we highlight here are relevant for future reform of the individual health insurance markets in the U.S. Many have observed that the overall quality of coverage available to consumers is low in these settings, with most plans characterized by tight provider networks, high deductibles, and strict controls on utilization. Additionally, others have observed that take-up is far from complete, with many young, healthy consumers opting out of the market altogether and choosing to remain uninsured (Domurat, Menashe and Yin, 2018). These two observations are consistent with adverse selection on the intensive and extensive margins, respectively. Our framework highlights the unfortunate but important conceptual point that budget-neutral policies that target one of these two problems are likely to exacerbate the other due to the inherent trade-off between extensive and intensive margin selection. This point is often absent from discussions of potential reforms by policymakers and economists, and our intention is to correct this potentially costly omission.

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# Online Appendix for:
# **The Two Margin Problem in Insurance Markets**

## A Analysis in a General Model (Relaxing Vertical Assumptions)

In this appendix, we present a formal mathematical analysis of the equilibrium impacts of tuning the parameters governing the two main policies discussed in Section 3: the mandate penalty and risk adjustment. We implement this analysis in a general model that does not invoke the vertical assumptions used for our graphical approach. This lets us show how the vertical assumptions interact with the model's main predictions.

Horizontal differentiation allows for an additional margin of substitution, between $H$ and $U$, that the vertical model shuts down. As we show below, this adds additional terms to the comparative statics defining the policy effects on prices and market shares. But as long as these $H$-$U$ substitution terms are not too large—e.g., as long as when $M$ increases, most of the newly insured buy the cheaper $L$ plan, not $H$—then they do not reverse the sign of the vertical model predictions. Thus, our results are not a knife-edge case driven by the assumption of pure vertical differentiation. Rather, as long as vertical differentiation is the "main" way that $H$ and $L$ compete, the model provides a useful approximation. This is consistent with the findings of our empirical robustness check that allows for horizontal differentiation in Appendix D.4.1.

### A.1 Model Setup

The setup is identical to that of Section 2, with two plans $H$ and $L$ and $P = \{P_H, P_L\}$ denoting insurer prices. Let $G = \{S_H, S_L, M\}$ denote plan-specific government subsidies ($S_j$) and the mandate penalty ($M$). Throughout this section (as in Section 2), we assume $S_H = S_L = S$, though the framework would generalize if this were not true. Nominal consumer prices equal $P_j^{cons} = P_j - S$ for $j = \{L, H\}$ and $P_U^{cons} = M$.

Unlike in the vertical model, we will not assume that $W_H$ and $W_L$ are perfectly correlated. Instead, we allow consumers to vary along both willingness to pay dimensions. Each consumer type is characterized by an ordered pair $s = (s_H, s_L)$, where $s_H$ indexes WTP for $H$ and $s_L$ indexes WTP for $L$. We once again normalize $W_U \equiv 0$. Note that a single $s$-index is no longer sufficient to characterize consumer willingness-to-pay. Without loss of generality, the $s$ index takes a bivariate uniform distribution, so it represents an index of the percentile of the WTP distribution for $H$ and $L$.

The set of consumers who choose a given option $j \in \{H, L, U\}$ is defined as $A_j(P, G) = \{s : W_j(s) - P_j^{cons} \geq W_k(s) - P_k^{cons}\ \forall k\}$. Demand is defined as the size of this group: $D_j(P, G) = \int_{A_j(P,G)} ds$.

For each "WTP-type," we once again have a plan-specific expected cost $C_j(s)$. We again make the adverse selection assumption that costs in a given plan are increasing in WTP for that plan. Hence $\partial C_j(s_H, s_L)/\partial s_j < 0$ for plan $j$. Average costs for plan $j \in \{L, H\}$ equal the average of $C_j(s)$ over the enrolling set of consumers:

$$AC_j(P; G) = \frac{1}{D_j(P; G)} \int_{A_j(P,G)} C_j(s)ds \tag{11}$$

Similarly, we can define the average risk score functions:

$$\overline{R}_j(P; G) = \frac{1}{D_j(P; G)} \int_{A_j(P,G)} R(s)ds \tag{12}$$

where $R(s)$ is the average risk score among type-$s$ consumers. The baseline per-enrollee risk adjustment transfer from $L$ to $H$ is a function of these average risk scores, the (share-weighted) average risk score in the market ($\equiv \overline{R}(P;G)$) and the (share-weighted) average price in the market ($\equiv \overline{P}(P;G)$):

$$T(P;G) = \left(\frac{\overline{R}_H(P;G)}{\overline{R}(P;G)} - 1\right)\overline{P}(P;G) \tag{13}$$

Finally we introduce a parameter $\alpha \in (0,1)$ that multiplies the transfer, $\alpha \cdot T(P;G)$, allowing us to vary the strength of risk adjustment by scaling the transfers up or down such that $\alpha = 0$ represents no risk adjustment, $\alpha \in (0,1)$ is partial risk adjustment, $\alpha = 1$ is full-strength risk adjustment, and $\alpha > 1$ is over-adjustment.

We define equilibrium as prices equal average costs net of risk adjustment transfers:

$$\begin{aligned} P_H &= AC_H\left(P;G\right) - \alpha T(P;G) \equiv AC_H^{RA}(P;G,\alpha) \\ P_L &= AC_L\left(P;G\right) + \alpha T(P;G) \equiv AC_L^{RA}(P;G,\alpha) \end{aligned} \tag{14}$$

where $AC_j^{RA}(P;G,\alpha)$ are risk-adjusted costs for plan $j = \{L,H\}$.

## A.2 Approach and Assumptions on Signs of Demand/Cost Curve Slopes

We now consider the equilibrium response to an increase in the uninsurance penalty $M$ and an increase in $\alpha$, i.e. the strength of the risk adjustment transfers. Our goal is to understand the cross-margin interactions—the effect of $M$ on demand for $H$ and the effect of risk adjustment on the share uninsured. To do so, we use the equilibrium conditions to derive the relevant comparative statics, $\frac{dD_H}{dM}$ and $\frac{dD_U}{d\alpha}$. The comparative statics take account of both direct effects—denoted with partial derivatives below (e.g., $\frac{\partial AC_H}{\partial P_H}$)—and equilibrium effects on market prices—denoted with total derivatives (e.g., $\frac{dP_H}{dM}$). These comparative statics allow us to show the features of demand and cost that determine the sign and magnitude of the cross-margin effects.

In analyzing these comparative statics, we will assume a *stable equilibrium* that is characterized by *adverse selection*. These assumptions let us sign the slopes of several demand/cost curves that enter the equations. In particular, we assume:

- **Equilibrium stability**, which requires that $1 - \frac{\partial AC_j}{\partial P_j} > 0$ for $j = \{H,L\}$ locally to the equilibrium point.
- **Adverse selection**, which requires that (on average) the highest-cost types buy $H$, middle-cost types buy $L$, and the lowest-cost choose $U$. More specifically, we assume:
  1. The marginal $H$ consumer is lower-cost than the average $H$ consumer and higher-cost than the average $L$ consumer—which implies that $\frac{\partial AC_H}{\partial P_H} > 0$ and $\frac{\partial AC_L}{\partial P_H} > 0$.
  2. The consumer on the margin of $H$ and $L$ is lower-cost than the average $H$ consumer—so $\frac{\partial AC_H}{\partial P_L} < 0$
  3. The marginal uninsured consumers are lower-cost than the average consumer of $H$ or $L$, so $\frac{\partial AC_H}{\partial M} \leq 0$ and $\frac{\partial AC_L}{\partial M} \leq 0$.

For the analysis of risk adjustment, we also assume that the analogous stability and adverse selection conditions hold for *risk-adjusted* average costs $AC_H^{RA}$ and $AC_L^{RA}$. This is true in our empirical simulations, where we find that risk adjustment is imperfect, so risk-adjusted cost curves are characterized by adverse selection.

Further, while we do not impose the vertical model, it is useful to note its implications for several relevant partial derivatives:

- **Vertical model** assumes that no consumers are on the $H$-$U$ margin, which implies that $\frac{\partial D_H}{\partial M} = \frac{\partial AC_H}{\partial M} = \frac{\partial D_U}{\partial P_H} = 0$.

In the analysis below, we color in red the terms that are zero under the vertical model. This lets readers see where relaxing the vertical assumptions adds additional terms to the comparative statics.

### A.3 Increase in Uninsurance Penalty ($M$)

We derive comparative statics for enrollment in $H$ in response to a change in the uninsurance penalty $M$. Throughout this section, we assume that there is no risk adjustment in place, which simplifies the math.

We start by analyzing $\frac{dD_H}{dM}$, the cross-margin effect of a mandate penalty on enrollment in $H$. This comparative static is comprised of two parts. First, in red is the direct enrollment change in $H$ for a change in $M$, holding fixed $P_H$ and $P_L$. In the vertical model, this $\frac{\partial D_H}{\partial M}$ term would be zero. The second term is the indirect effect on $D_H$ through the change in relative prices of $H$ and $L$. Formally:

$$\frac{dD_H}{dM} = \underbrace{\frac{\partial D_H}{\partial M}}_{\text{HU margin}} + \underbrace{\underbrace{\frac{\partial D_H}{\partial \Delta P_{HL}}}_{(-)} \cdot \left(\frac{dP_H}{dM} - \frac{dP_L}{dM}\right)}_{\text{HL margin}} \tag{15}$$

In the vertical model, $\frac{\partial D_H}{\partial M} = 0$, so under the vertical assumption the sign of $\frac{\partial D_H}{\partial M}$ would be fully determined by the change in the incremental price of $H$ vs. $L$ caused by an increase in $M$. If an increase in $M$ leads to an increase in $\Delta P_{HL} = P_H - P_L$, then an increase in $M$ will lead to lower demand for $H$. This positive relationship between $M$ and $\Delta P_{HL}$ would occur under our assumptions about adverse selection because an increase in $M$ would induce a fall in $P_L$ as the consumers on the margin between $L$ and $U$ who are induced to purchase $L$ are relatively healthy. If the vertical model does not hold, $\frac{\partial D_H}{\partial M} > 0$, which would partly offset the decrease in $D_H$ but not fully do so as long as it is small in magnitude.

Thus, to sign the cross-margin effect, we need to show that $\frac{dP_H}{dM} - \frac{dP_L}{dM} > 0$. We now fully differentiate $P_H$ and $P_L$ with respect to $M$ to characterize this relationship more explicitly.

$$\begin{aligned} \frac{dP_H}{dM} &= \frac{\partial AC_H}{\partial M} + \frac{\partial AC_H}{\partial P_H}\frac{dP_H}{dM} + \frac{\partial AC_H}{\partial P_L}\frac{dP_L}{dM} \\ \frac{dP_L}{dM} &= \frac{\partial AC_L}{\partial M} + \frac{\partial AC_L}{\partial P_H}\frac{dP_H}{dM} + \frac{\partial AC_L}{\partial P_L}\frac{dP_L}{dM} \end{aligned} \tag{16}$$

Notice, that unlike under the purely vertical model, a change in $M$ impacts direct costs for both $H$ and $L$. Solving this system of equations again for $\frac{dP_H}{dM}$, we get the expression below.

$$\frac{dP_H}{dM} = \left[\frac{\partial AC_H}{\partial M} + \frac{\partial AC_L}{\partial M}\frac{\partial AC_H}{\partial P_L}(1 - \frac{\partial AC_L}{\partial P_L})^{-1}\right] \times \Phi_H^{-1} \tag{17}$$

where $\Phi_H = \{1 - \frac{\partial AC_H}{dP_H} - \frac{\partial AC_H}{\partial P_L}\frac{\partial AC_L}{\partial P_H}(1 - \frac{\partial AC_L}{\partial P_L})^{-1}\}$.

We now can sign $\frac{dP_H}{dM}$ as follows:

$$\frac{dP_H}{dM} = \left[ \underbrace{\frac{\partial AC_H}{\partial M}}_{\text{Ext. Margin Selection}(\leq 0)} + \underbrace{\underbrace{\frac{\partial AC_L}{\partial M}}_{(-)} \cdot \underbrace{\frac{\partial AC_H}{\partial P_L}}_{(-)} \underbrace{\left(1 - \frac{\partial AC_L}{\partial P_L}\right)^{-1}}_{(+)}}_{\text{Substitution to } L\ (+)} \right] \times \underbrace{\Phi_H^{-1}}_{(+)} \tag{18}$$

and $\Phi_H = \underbrace{(1 - \frac{\partial AC_H}{dP_H})}_{(+)} - \underbrace{\frac{\partial AC_H}{\partial P_L}\frac{\partial AC_L}{\partial P_H}}_{(-)} \underbrace{(1 - \frac{\partial AC_L}{\partial P_L})^{-1}}_{(+)} > 0$ , where all signs are determined by the adverse selection and stability assumptions laid out above.

Therefore, we can sign $\frac{dP_H}{dM} > 0$ under the vertical model. The intuition is as we have already described: the mandate penalty lowers $P_L$, leading relatively healthy $H$ consumers to leave $H$ and substitute to $L$, which raises $AC_H$ and therefore $P_H$. When the vertical model does not hold, extensive margin selection of consumers on the $HU$ margin into $H$ ($\frac{\partial AC_H}{\partial M} < 0$) pushes in the other direction. But as long as extensive margin substitution is not too large, the main effect of substitution to $L$ will dominate.

We derive the expression for $\frac{dP_L}{dM}$ in a similar way:

$$\frac{dP_L}{dM} = \left[ \underbrace{\frac{\partial AC_L}{\partial M}}_{\text{Ext. Margin Selection}(-)} + \underbrace{\underbrace{\frac{\partial AC_H}{\partial M}}_{(\leq 0)} \cdot \underbrace{\frac{\partial AC_L}{\partial P_H}}_{(+)} \underbrace{\left(1 - \frac{\partial AC_H}{\partial P_H}\right)^{-1}}_{(+)}}_{\text{Substitution to } H(\leq 0)} \right] \times \underbrace{\Phi_L^{-1}}_{(+)} \tag{19}$$

where $\Phi_L = \{1 - \frac{\partial AC_L}{dP_L} - \frac{\partial AC_L}{\partial P_H}\frac{\partial AC_H}{\partial P_L}(1 - \frac{\partial AC_H}{\partial P_H})^{-1}\} > 0$ as with $\Phi_H$ above.

Thus, under the vertical model where $\frac{\partial AC_H}{\partial M} = 0$, we can unambiguously say that $P_L$ falls with a higher mandate penalty ($\frac{dP_L}{dM} < 0$). This conclusion also holds when we relax the vertical model (as shown by the negative substitution term), as any extensive margin substitution into $H$ acts to lower the price of $H$, drawing the sickest consumers away from $L$ and pushing $L$'s costs and price even further down.

Returning now to $\frac{dD_H}{dM}$, we observe under the vertical model that $\left(\frac{dP_H}{dM} - \frac{dP_L}{dM}\right) < 0$, which implies that $\frac{dD_H}{dM} > 0$. In other words, the "unintended consequence" of decreasing enrollment in $H$ should always occur under the vertical model. When we relax the vertical model, this result will also hold as long substitution on the $HU$ margin is not too large.

### A.4 Increasing the Strength of Risk Adjustment ($\alpha$)

We now consider in our more general model the effect of a small increase in the $\alpha$ parameter on the share of the population that is uninsured. As in the previous section, we color in red the terms that are zero under the vertical model. This lets readers see where relaxing the vertical assumptions adds additional terms to the comparative statics.

The change in the share of the uninsured population given a change in $\alpha$ is comprised of two parts: changes in enrollment from the $HU$ margin (in red) and $LU$ margin (in black). Under the vertical model assumptions, the $HU$ margin is not present.

$$\frac{dD_U}{d\alpha} = \underbrace{\underbrace{\frac{\partial D_U}{\partial \Delta P_{HU}}}_{\geq 0} \frac{d\Delta P_{HU}}{d\alpha}}_{\text{HU margin}} + \underbrace{\underbrace{\frac{\partial D_U}{\partial \Delta P_{LU}}}_{(+)} \frac{d\Delta P_{LU}}{d\alpha}}_{\text{LU margin}} \tag{20}$$

where $\Delta P_{HU} = P_H - S - M$ and $\Delta P_{LU} = P_L - S - M$ are the net prices of $H$ and $L$ relative to uninsurance.

By the law of demand, $\frac{\partial D_U}{\partial P_H} \geq 0$, $\frac{\partial D_U}{\partial P_L} > 0$. Under the vertical model, $\frac{\partial D_U}{\partial P_H} = 0$, so the cross-margin effect of risk adjustment on uninsurance is entirely determined by the sign of the LU margin. We now consider the impact of a change in $\alpha$ on $\Delta P_{HU}$ and $\Delta P_{LU}$. The change in prices depends on the nature of subsidies. With subsidies linked to the price of $L$, $\Delta P_{LU}$ $(= P_L - S - M)$ is fixed by construction. Therefore, the LU margin of substitution is shut down. In the vertical model, we will have $\frac{dD_U}{d\alpha} = 0$.

Let us now consider the case where there is a fixed subsidy and therefore prices can be affected by the level of transfers. We fully differentiate (14) and rearrange to get a system of equations. These are identical under both the horizontal and vertical model.

$$\frac{dP_H}{d\alpha} = \underbrace{T(.)}_{(+)} \times \left[ \underbrace{-1}_{\text{Direct}(-)} + \underbrace{\frac{\partial AC_H^{RA}}{\partial P_L} \left(1 - \frac{\partial AC_L^{RA}}{\partial P_L}\right)^{-1}}_{\text{Substitution from L } (-)} \right] \times (\Phi_H^{RA})^{-1} < 0$$

where $\Phi_H^{RA} \equiv 1 - \frac{\partial AC_H^{RA}}{\partial P_H} - \frac{\partial AC_L^{RA}}{\partial P_H} \frac{\partial AC_H^{RA}}{\partial P_L} (1 - \frac{\partial AC_L^{RA}}{\partial P_L})^{-1}$. As in the mandate section above, this $\Phi_H^{RA}$ term must be positive under the assumptions on stability and adverse selection we have made.

The term in brackets is composed of two effects. First, there is a direct effect of stronger risk adjustment transferring money to $H$, which tends to lower $P_H$. Second, there is an indirect substitution effect, arising from substitution of relatively healthy consumers on the margin between $H$ and $L$ opting for $H$ and lowering $H$'s average cost and thus its price. Thus, $\frac{dP_H}{d\alpha} < 0$ because both the direct and indirect effects push $P_H$ down.

Doing the same for $\frac{dP_L}{d\alpha}$ gives

$$\frac{dP_L}{d\alpha} = \underbrace{T(.)}_{(+)} \times \left[ \underbrace{1}_{\text{Direct}(+)} + \underbrace{\left(-\frac{\partial AC_L^{RA}}{\partial P_H}\right) \left(1 - \frac{\partial AC_H^{RA}}{\partial P_H}\right)^{-1}}_{\text{Substitution to H } (-)} \right] \times \underbrace{(\Phi_L^{RA})^{-1}}_{(+)}$$

where $\Phi_L^{RA} \equiv 1 - \frac{\partial AC_L^{RA}}{\partial P_L} - \frac{\partial AC_H^{RA}}{\partial P_L} \frac{\partial AC_L^{RA}}{\partial P_H} (1 - \frac{\partial AC_H^{RA}}{\partial P_H})^{-1}$, which must be positive under the stability and adverse selection assumptions.

Here, the direct effect is positive because larger transfers take money from $L$, driving up the price of $L$. However, the indirect substitution effect is negative—since $\frac{\partial AC_L^{RA}}{\partial P_H} > 0$ by adverse selection. Intuitively, stronger risk adjustment transfers increase the price of $L$, causing consumers on the $H$-$L$ margin to opt for $H$ instead of $L$. These consumers are the highest-cost $L$ enrollees, implying that their exit from $L$ will lower $L$'s average cost and thus its price. Therefore, the indirect substitution effects will mute (or even fully offset) the direct effect of risk adjustment on $P_L$. Because of this direct and indirect effect, it is ambiguous whether $P_L$ will increase or decrease, and in general, any change in $P_L$ will be smaller than one would expect from the direct effect alone.

Further, the question of whether the direct or indirect effect dominates depends on whether the substitution term is greater than or less than 1 in absolute value. If it is greater than 1, then the substitution term will dominate. This will occur if $\frac{\partial AC_L^{RA}}{\partial P_H} > 1 - \frac{\partial AC_H^{RA}}{\partial P_H}$. This will tend to occur when intensive margin adverse selection is very strong (even after risk adjustment) so that both $\frac{\partial AC_L^{RA}}{\partial P_H}$ and $\frac{\partial AC_H^{RA}}{\partial P_H}$ are large. Conversely, if adverse selection is weak, the direct effect will dominate.

This expression also tells us how the size of any cost advantage for $L$ may affect the effects of increasing $\alpha$. When $L$ has no cost advantage over $H$ (the cream-skimmer case), the only reason $L$ gets any demand is intensive margin adverse selection. When adverse selection is strong in the cream-skimmer case, $L$ exists but the substitution effect is also large, muting the direct effect of risk adjustment. When adverse selection is weak in the cream-skimmer case, $L$ fails to exist. Thus, it is more likely that increasing $\alpha$ will have little or no (or possibly negative) effect on $P_L$ in the case where $L$ has no cost advantage than in the case where $L$ has a cost advantage.

To summarize the case with fixed subsidies, $\frac{dD_U}{d\alpha}$ is ambiguous even under the vertical model because we cannot theoretically sign the change in $P_L$ when when $\alpha$ increases. If the direct effect dominates, then $P_L$ will increase with $\alpha$ and uninsurance will rise under the vertical model. If the substitution to $H$ dominates, then $P_L$ will fall and uninsurance will also fall.

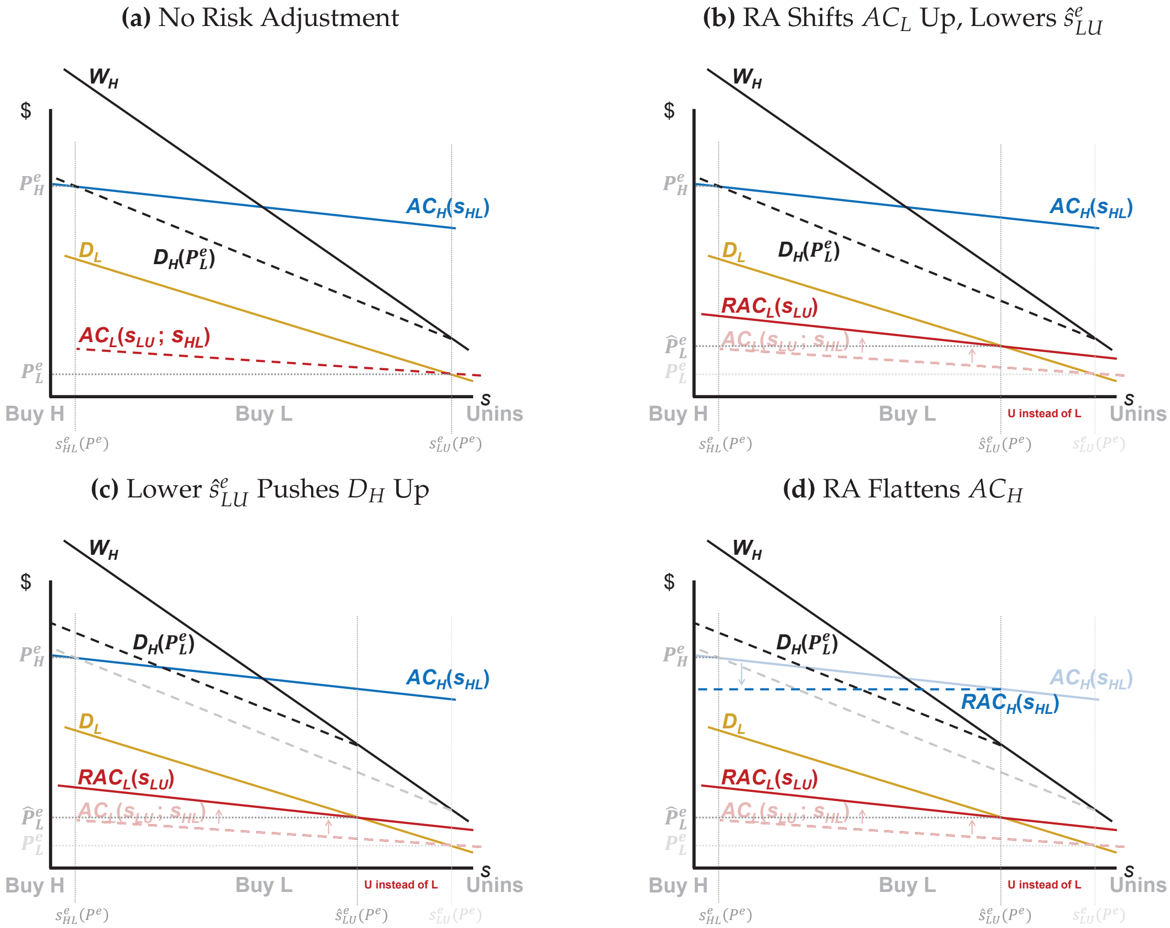
When we relax the vertical assumptions, the potential for stronger risk adjustment to increase uninsurance is further mitigated by the presence of the $HU$ extensive margin. The term $\frac{\partial D_U}{\partial P_H}\frac{dP_H}{d\alpha}$ in equation (20) will be positive. Because $\frac{dP_H}{d\alpha} < 0$, consumers on the $HU$ margin will tend to become insured (in $H$) when risk adjustment is strengthened. This may offset any rise in uninsurance along the $LU$ margin if $P_L$ rises, as more consumers leave uninsurance to buy $H$.

# B Appendix: Graphical Analysis of Perfect Risk Adjustment

In this section, we illustrate how our graphical model can be used to show the effects of perfect risk adjustment on equilibrium prices and market shares. To simplify exposition, we assume that the causal cost difference between $H$ and $L$ equals a constant value of $\delta$ for all consumer types $s$. We define perfect risk adjustment as transfers such that the average cost in $H$ net of risk adjustment always equals the average cost in $L$ net of risk adjustment plus $\delta$: $RAC_H(P) = RAC_L(P) + \delta$. Under perfect risk adjustment, the average risk-adjusted cost in $H$ and $L$ does not depend on consumer sorting between $H$ and $L$. Instead, the average cost of both plans depends only on consumer sorting between insurance and uninsurance. If new healthy consumers join the market (buying the $L$ plan), the risk transfers share the improved risk pool equally between $H$ and $L$, maintaining the $\delta$ difference between their average costs. The important simplifying feature of *perfect* risk adjustment is that when it comes to average costs, there is only one relevant margin of adjustment: the extensive margin. With *imperfect* risk adjustment, residual intensive margin selection that is not compensated by risk adjustment remains relevant, complicating the graphical analysis.

We depict the perfect risk adjustment case in Figure A1. Note that here we do not assume that $L$ is a pure cream-skimmer but instead that $L$ has a cost advantage equal to $\delta$. Risk adjustment affects the curves in a number of ways. First, as depicted in panel (b), risk adjustment causes the average cost curve for $L$ to shift upward and rotate slightly to make it parallel with the original, unadjusted average cost curve for $H$. This shift reflects the risk transfer away from $L$ (and to $H$) that raises $L$'s effective costs. $RAC_L(s_{LU})$ still slopes down because of extensive margin adverse selection, but it is

**Figure A1:** Equilibrium under Perfect Risk Adjustment



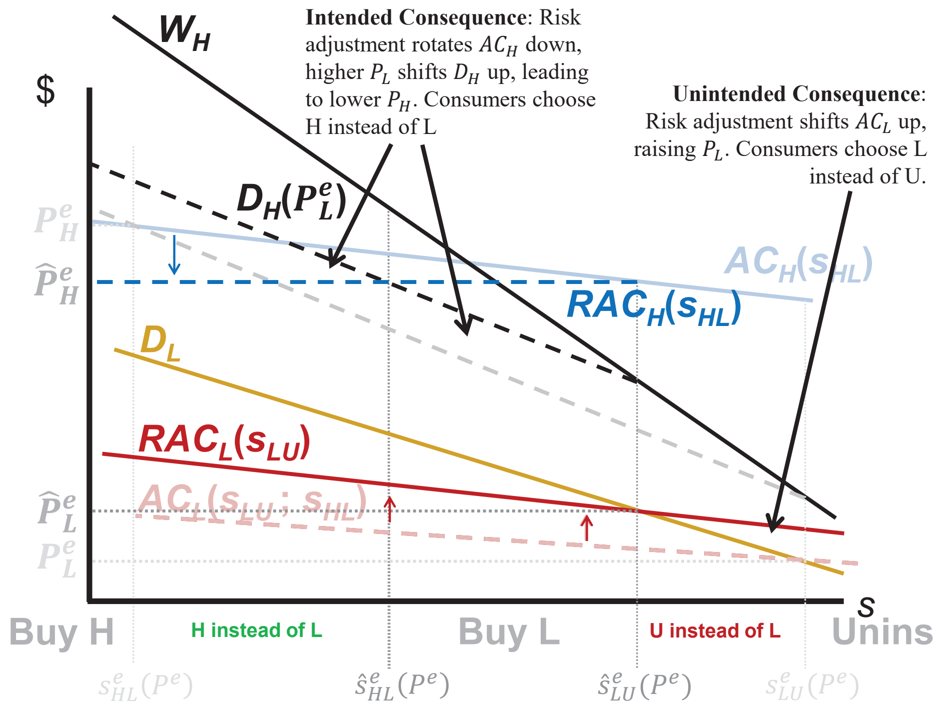

**Notes:** Starting from equilibrium in panel (a) and introducing perfect risk adjustment in panel (c), perfect risk adjustment shifts up the average cost of $L$ from $AC_L(s_{LU})$ to $RAC_L(s_{LU})$, reflecting the transfer away from $L$ to $H$. Unlike $AC_L$, the risk adjusted $RAC_L$ only depends on the extensive margin $S_{LU}$, not on the allocation across plans ($s_{HL}$). The risk adjusted curve $RAC_L(s_{LU})$ intersects $D_L$ at a lower point, shifting out the extensive margin from $s^e_{LU}$ to $\hat{s}^e_{LU}$. Next, in panel (c) we see that this lower extensive margin-type $\hat{s}^e_{LU}$ shifts up $D_H$. Finally, in panel (d) we see that risk adjustment flattens the risk adjusted average cost of $H$, $RAC_H$, which like $RAC_L$ no longer varies depending on sorting between the two plans, $s_{HL}$.

now a fixed curve that does not depend on the price of $H$ or sorting between $H$ and $L$.[37] The new, higher average cost curve for $L$, $RAC_L$ implies a new, higher equilibrium price for $L$, $\hat{P}^e_L$. This higher price of $L$ implies a new demand curve for $H$, shifted upward from the previous demand curve and depicted in panel (c) of Figure A1. This higher demand curve for $H$ reflects the fact that the higher price of $L$ makes $L$ less attractive relative to $H$.

Panel (d) of Figure A1 illustrates the second direct effect of risk adjustment. For the $H$ plan, risk adjustment causes the average cost curve, $RAC_H(s_{HL})$, to be *rotated downward* relative to the unadjusted curve, $AC_H(s_{HL})$. $RAC_H$ is now a flat line, since sorting between plans (i.e., the value of $s_{HL}$) does not affect average costs. The level of $RAC_H$ equals $AC_H(s_{LU})$—the average cost if the entire population up to the extensive margin type $s_{LU}$ were to enroll in $H$.

Figure A2 shows how this shift in $H$'s average cost curve combines with the shift in $H$'s demand curve to produce a new lower equilibrium price of $H$, $\hat{P}^e_H$ and a higher quantity of consumers enrolling in $H$.

**Figure A2:** Equilibrium under Perfect Risk Adjustment




**Notes:** Under perfect risk adjustment, the risk-adjusted average cost curve for $H$ is completely flat for a given $s_{LU}$. Equilibrium occurs at $s_{HL}$ and $s_{LU}$ values such that $RAC_H$ intersects $D_H$ and $RAC_L$ intersects $D_L$.

Therefore, perfect risk adjustment has two effects. First, it narrows the average cost and therefore the price gap between $H$ and $L$, leading consumers to shift on the intensive margin towards the $H$ plan. This is the intended effect. Second, it pushes up the average cost and therefore the price of $L$. This results in some consumers who would have chosen $L$ in the absence of risk adjustment instead choosing to be uninsured. This is the unintended, cross-margin consequence of risk adjustment. In Section 3 we also provide a graphical description of the welfare consequences of risk adjustment,

[37]One can show that $RAC_L$ is parallel to the old $AC_H$ since it is capturing the overall average costs of everyone from $s = 0$ up to a given $s_{LU}$ cutoff.

both perfect and imperfect.

# C Appendix: Simulation Method Details

## C.1 Constructing Demand and Cost Curves

As discussed in section 4, we draw on separate demand and cost estimates for both low-income subsidized consumers from Finkelstein, Hendren and Shepard (2019) (abbreviated "FHS") and high-income unsubsidized consumers from Hackmann, Kolstad and Kowalski (2015) (abbreviated "HKK"). We describe how each respective paper produced its primitives as well as our modifications below.

### C.1.1 Low-Income Demand and Costs: FHS (2019)

**FHS Primitives**

- Population: FHS estimate insurance demand in Massachusetts' pre-ACA subsidized health insurance exchange, known as "CommCare." CommCare was an insurance exchange created under the state's 2006 "Romneycare" reform to offer subsidized coverage to low-income non-elderly adults (below 300% of poverty) without access to other health insurance (from an employer, Medicare, Medicaid, or another public program). This population was similar, though somewhat poorer, than the subsidy-eligible population under the ACA.

- Market structure: CommCare participation was voluntary: consumers could choose to remain uninsured and pay a (small) penalty. As FHS show, a large portion of consumers (about 37% overall) choose the outside option of uninsurance, despite the penalty and large subsidies. The CommCare market featured competing insurers, which offered plans with standardized (state-specified) cost sharing rules but which differed on their provider networks. In 2011, the main year that FHS estimate demand, the market featured a convenient vertical structure among the competing plans. Four insurers had relatively broad provider networks and charged nearly identical prices just below a binding price ceiling imposed by the exchange. One insurer (CeltiCare) had a smaller provider network and charged a lower price. FHS pool the four high-price, broad network plans into a single "$H$ option"—technically defined as each consumer's preferred choice among the four plans—and treat CeltiCare as a vertically lower-ranked "$L$ option." FHS present evidence that this vertical ranking is a reasonable characterization of the CommCare market in 2011.

- FHS Estimation: To estimate demand and costs, FHS use a regression discontinuity design leveraging discontinuous cutoffs in subsidy amounts based on household income. Because subsidies vary across income thresholds, there is exogenous net price variation that can transparently identify demand and cost curves with minimal parametric assumptions. FHS leverage discontinuous changes in net-of-subsidy premiums at 150% FPL, 200% FPL, and 250% FPL arising from CommCare's subsidy rules. They estimate consumer willingness-to-pay for the lowest-cost plan ($L$) and incremental consumer willingness-to-pay for the other plans ($H$) relative to that plan.[38] This method provides estimates of the demand curve for particular ranges of $s$. The same variation is used to estimate $AC_H(s)$ and $C_H(s)$, the average and marginal cost curves for $H$. Our goal is not to innovate on these estimates but rather to apply them as primitives in our policy simulations to understand the empirical relevance of our conceptual framework.

[38] Because the base subsidy for $L$ and the incremental subsidy for $H$ change discontinuously at the income cutoffs, there is exogenous variation in both the price of $L$ and the incremental price of $H$.

**Our Modifications to FHS Primitives**

- Extrapolating to extremes of $s$ distribution: The FHS strategy provides four points of the $W_L(s)$ curve and four points of the $W_{HL}(s) = W_H(s) - W_L(s)$ curve. As shown in Figure 10 from FHS, for the $W_L$ curve these points span from $s = 0.36$ to $s = 0.94$ and for the $W_{HL}$ curve these points span from $s = 0.31$ to $s = 0.80$. Because our model allows for the possibility of zero enrollment in either $L$ or $H$ or both, we need to modify the curves, extrapolating to the full range of consumers, $s \in [0, 1]$. We start by extrapolating linearly, and then we "enhance" demand for $H$ among the highest WTP consumers, as we view this as more realistic than a linear extrapolation. (We explore the sensitivity of our empirical results to alternative assumptions about this WTP enhancement in Appendix D.4.2) We then smooth the enhanced demand curves to eliminate artificial kinks produced by the estimation and extrapolation.

  **(1) Linear demand:** For the linear demand curves, we extrapolate the curves linearly to $s = 0$ and $s = 1.0$. Call these curves $W_L^{lin}(s)$ and $W_H^{lin}(s)$, with incremental WTP defined as $W_{HL}^{lin} = W_H^{lin} - W_L^{lin}(s)$.

  **(2) Enhanced demand:** For the enhanced demand curves $\left(W_L^{enh}(s) \text{ and } W_H^{enh}(s)\right)$, we inflate consumers' relative demand for $H$ vs. $L$ in the extrapolated region, relative to a linear extrapolation. We implement enhanced demand in an *ad hoc* but transparent way: We first generate $W_L^{enh}(s) = W_L^{lin}(s)$ for all $s$. For all $s >= 0.31$ (the boundary of the "in-sample" region of $W_{HL}(s)$), we likewise set $W_{HL}^{enh}(s) = W_{HL}^{lin}(s)$. For $s = 0$, we set $W_{HL}^{enh}(s = 0) = 3W_{HL}^{lin}(s = 0)$, so that the maximum enhanced incremental willingness-to-pay is three times the value suggested by the primitives. We then linearly connect the incremental willingness to pay between s=0 and s=0.31, setting $W_{HL}^{enh}(s < 0.31) = W_{HL}^{lin}(s) + 3 \times \frac{(0.31-s)}{0.31} \times W_{HL}^{lin}(0)$ so that the enhanced curve is equal to the linear curve for $s >= 0.31$, equal to three times the linear curve at $s = 0$, and linear between $s = 0.31$ and $s = 0$. This approach assumes that there exists a group of (relatively sick) consumers who exhibit very strong demand for $H$ relative to $L$, which seems likely to be true in the real world. Thus,

$$W_{HL}^{enh}(s) = \begin{cases} W_{HL}^{lin}(s) & \text{for } s \in [0.31, 1] \\ W_{HL}^{lin}(s) + 3 \times \frac{(0.31-s)}{0.31} \times W_{HL}^{lin}(0) & \text{for } s \in [0, 0.31) \end{cases} \tag{21}$$

  and

$$W_H^{enh}(s) = W_L^{lin}(s) + W_{HL}^{enh}(s) \tag{22}$$

  Both the linear and the enhanced WTP curves are shown in the top panel of Figure A3.

- Cost of $L$ plan: We need to produce estimates of $C_L(s)$ to complete the model. FHS provide suggestive evidence that $C_L(s)$ is quite similar to $C_H(s)$—i.e., that for a given enrollee, $L$ does not save money relative to $H$. We conducted further analyses to provide additional evidence on this question (leveraging entry of the $L$ plan in some areas but not others, leveraging additional price variation for $L$ vs. $H$, etc.), consistently finding a lack of evidence of any cost advantage for $L$ among the enrollees marginal to these sources of variation. While $L$ may indeed be a pure cream-skimmer in this setting, the assumption that $C_H(s) = C_L(s)$ for all $s$ seems unlikely to hold in many other settings. Thus, we consider both the setting where $L$ has a 15% cost advantage so that $C_L(s) = 0.85C_H(s)$ and the setting where, consistent with the empirical evidence, $L$ is a pure cream-skimmer, i.e. $C_L(s) = C_H(s)$.

- Smoothing primitives: Because they were estimated using a regression discontinuity design, the primitives above all have discrete "kink points" at which the slope of the curve with respect to the share of the population enrolled changes discretely. In these regions, equilibrium allocations are extremely sensitive to small changes in policy parameters. To avoid this unrealistic sensitivity, we smooth the cost curves as well as the enhanced demand curves using a fourth degree polynomial. Specifically, for primitive $Y(s)$, we run the following regression.

$$Y = \hat{\beta}_0 + \hat{\beta}_1 s + \hat{\beta}_2 s^2 + \hat{\beta}_3 s^3 + \hat{\beta}_4 s^4 + \epsilon$$

Using the fitted coefficients, we then use the predicted value $\hat{Y}$,

$$\hat{Y} = \hat{\beta}_0 + \hat{\beta}_1 s + \hat{\beta}_2 s^2 + \hat{\beta}_3 s^3 + \hat{\beta}_4 s^4$$

This "smoothing" process was done on both the WTP curves as well as the cost curve primitives.

### C.1.2 High-Income Demand and Costs: HKK (2015)

For our simulations, we also consider demand of higher-income groups, which allows us to simulate policies closer to the ACA. Under the ACA, low-income households receive subsidies to purchase insurance while high-income households do not. We construct WTP curves for high-income households using estimates of the demand curve for individual-market health insurance coverage in Massachusetts from Hackmann, Kolstad and Kowalski (2015) ("HKK").

**HKK Primitives**

- Population: HKK estimate demand in the unsubsidized pre-ACA individual health insurance market in Massachusetts, which is for individuals with incomes above 300% of poverty (too high to qualify for CommCare).
- Estimation: HKK use the introduction of the state's individual mandate in 2007-08 as a source of exogenous variation to identify the insurance demand and cost curves. HKK only estimate demand for a single $L$ plan.

**Our Modifications to HKK Primitives**

- Constructing $W_L^{HI}(s)$ : We start by constructing $W_L^{HI}(s)$, based on the estimates from Hackmann, Kolstad and Kowalski (2015). The superscript $HI$ refers to high income. The HKK demand curve takes the following form:

$$W_{HKK}(s) = -\$9,276.81 * s + \$12,498.68 \tag{23}$$

  This demand curve is "in-sample" in the range of $0.70 < s < 0.97$. As with the low-income, subsidized consumers, we linearly extrapolate $W_{HKK}(s)$ out-of-sample to construct $W_L^{HI,lin}(s)$. Specifically, we let $W_L^{HI,lin}(s) = W_{HKK}(s)$ for all $s$.

- Constructing $W_H^{HI,lin}(s)$ and $W_H^{HI,enh}(s)$: HKK only estimate demand for a single $L$ plan. Similar to FHS, we start by estimating a linearly extrapolated WTP for $H$, $W_H^{HI,lin}(s)$, and then "enhance" demand for $H$ among the highest WTP types, $W_H^{HI,enh}(s)$, using the $W_{HL}^{lin}$ and $W_{HL}^{enh}$ as constructed for the low-income population above (i.e. we assume that extensive margin WTP for insurance is different between the high-income and low-income groups, but intensive margin WTP for $H$ vs. $L$ is the same):

$$W_H^{HI,lin}(s) = W_L^{HI} + W_{HL}^{lin}(s)$$
$$W_H^{HI,enh}(s) = W_L^{HI} + W_{HL}^{enh}(s)$$

- Constructing $C_L^{HI}(s), C_H^{HI}(s)$: We assume that the cost curves for this group are equivalent to the cost curves of the subsidized population, Thus,

$$C_H^{HI}(s) = C_H(s)$$
$$C_L^{HI}(s) = C_L(s)$$

  where $C_H(s)$ is drawn from FHS and $C_L(s)$ is the curve as constructed in the previous section. We note that these assumptions imply that the high-income consumers have a level shift in WTP with no difference in the extent of intensive or extensive margin selection from the low-income consumers.

- Smoothing primitives: Similar to above, we also smooth primitives.

We thus have two demand systems: one for low-income consumers and one for high-income consumers. Both exhibit WTP for $H$ that is "enhanced" for the highest WTP types beyond what a simple linear extrapolation would imply. We combine these systems to form one set of demand and cost curves, by assuming that 60% of the market is low-income and 40% of the market is high-income, consistent with the population in the ACA Health Insurance Marketplaces.

## C.2 Estimation of Risk Score Curve

Like WTP and costs, we use FHS's regression discontinuity approach to estimate a risk adjustment function for each $s$-type, $R(s)$. This function characterizes the *expected* cost of each $s$-type, as predicted by the actual risk scores of each enrollee, $RA_i^{HCC}$. We compute these scores for each individual in our data, based on diagnosis codes present in the individual-level claims. All risk scores are computed using the Hierarchical Condition Categories (HCC), a risk adjustment model used by the Centers for Medicare and Medicaid Services for the ACA Marketplaces.[39]

We leverage the same subsidy thresholds used in Finkelstein, Hendren and Shepard (2019) to estimate changes in average risk score across the discontinuities. We then estimate the implied "marginal" risk score curve $R(s)$ in a manner similar to the construction of marginal costs from average costs. We then connect and smooth segments in a similar fashion to our construction of the cost and WTP curves to generate the $R(s)$ we use in our analysis.

Figure A4 shows a measure of risk-adjusted costs for the $H$ plan in comparison to raw costs $C_H(s)$. It plots $C_H(s)$ and $C_H(s)/R(s)$; the latter would be constant in $s$ under perfect risk adjustment. Consistent with risk adjustment being meaningful but imperfect, the risk-adjusted cost curve is much flatter than raw costs but still downward sloping. Over the $s \in [0,1]$ interval, the risk-adjusted cost curve falls by about \$130, compared to a fall of \$367 in raw costs. Thus, by this measure, risk scores net out about 35% of the cost variation along the marginal cost curve for $H$.

## C.3 Riley Equilibrium Concept

We follow Handel, Hendel and Whinston (2015) and consider equilibria that meet the requirements of the Riley Equilibrium (RE) notion. In words, a price vector $P$ is a Riley Equilibrium if there is no profitable deviation for which there is no "safe" (i.e. weakly profitable) reaction that would make the deviating firm incur losses.[40] It is straightforward to show that in our setting no price vector that earns positive profits for either $L$ or $H$ is a RE (see Handel, Hendel and Whinston, 2015 for a proof). This limits potential REs to the price vectors that cause $L$ and $H$ to earn zero profits. We refer to these price vectors as "breakeven" vectors, and we denote the set of breakeven price vectors, $\mathcal{P}^{BE} = \{P : P_H = AC_H, P_L = AC_L\}$. This set consists of the following potential breakeven vectors:

1. **No Enrollment**: Prices are so high that no consumer enrolls in $H$ or $L$
2. $L$**-only**: $P_H$ is high enough that no consumer enrolls in $H$ while $P_L$ is set such that $P_L$ equals the average cost of the consumers who choose $L$.
3. $H$**-only**: $P_L$ is high enough that no consumer enrolls in $L$ while $P_H$ is set such that $P_H$ equals the average cost of the consumers who choose $H$.
4. **H and L**: $P_L$ and $P_H$ are set such that both $L$ and $H$ have positive enrollment and $P_L$ is equal to the average cost of the consumers who choose $L$ and $P_H$ is equal to the average cost of the consumers who choose $H$.

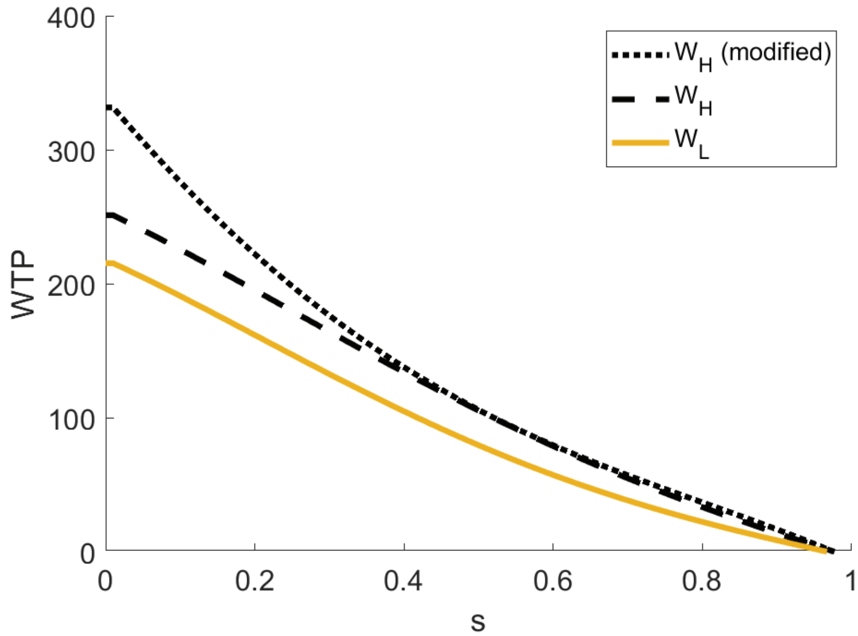
To simplify exposition, in Section 2 we assume that there is a unique RE in $\mathcal{P}_4^{BE}$, or the set of breakeven vectors where there is positive enrollment in both $H$ and $L$. However, we note that under certain conditions there will not be an RE in $\mathcal{P}_4^{BE}$ and the competitive equilibrium will instead consist of

[39] In practice, the methodology involves grouping diagnoses into different conditions, such as diabetes, etc. Individuals are then assigned risk scores based on the weighted value of all of their conditions. CMS publishes its weights annually on its website (https://www.cms.gov/medicare/health-plans/medicareadvtgspecratestats/risk-adjustors.html)

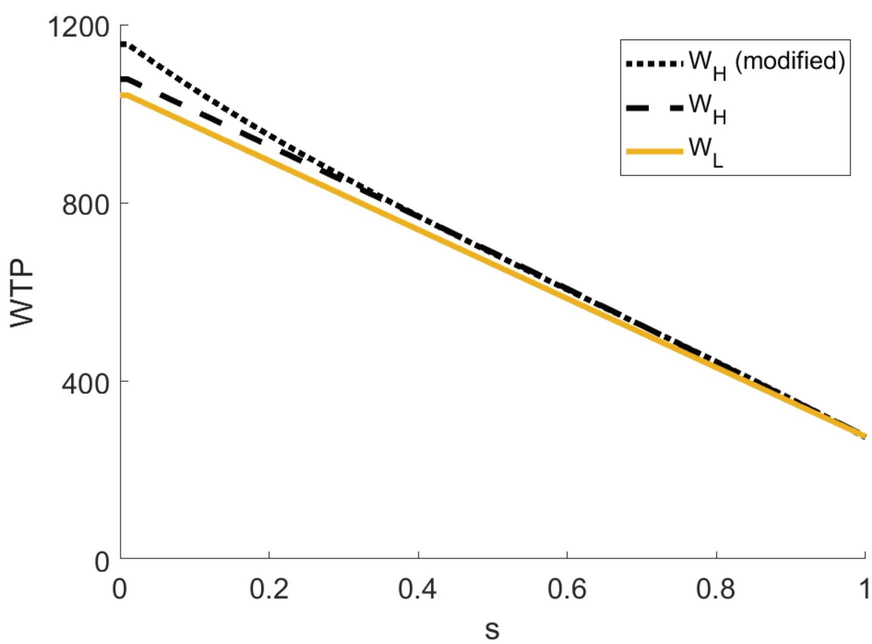
[40] Formally, a "Riley Deviation" (i.e. a deviation that would cause a price vector to not be a Riley Equilibrium) is a price offer $P'$ that is strictly profitable when $P \cup P'$ is offered and for which there is no "safe" (i.e. weakly profitable) reaction $P''$ that makes the firm offering $P'$ incur losses when $P \cup P' \cup P''$ is offered.

**Figure A3:** WTP Curves for $H$ and $L$

**(a)** Low-Income

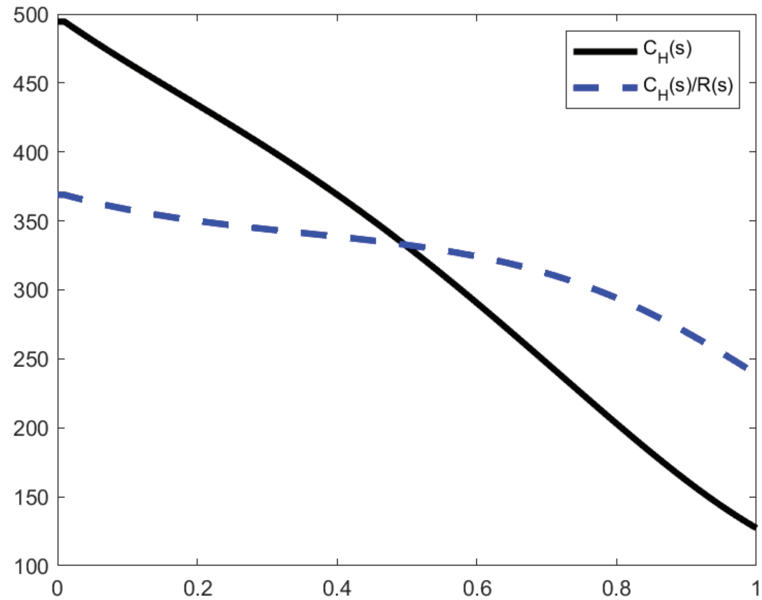



**(b)** High-Income




**Notes:** Figure shows WTP Curves for $H$ and $L$, $W_H(s)$ and $W_L(s)$. The top panel shows curves for low-income group which come from (Finkelstein, Hendren and Shepard, 2019). The bottom panel shows curves for high-income group which come from (Hackmann, Kolstad and Kowalski, 2015). Linear curves extrapolate linearly over the out-of-sample range [0,0.31]. Modified (i.e. "enhanced") curves assume that the lowest $s$-types have very high incremental WTP for $H$.

**Figure A4:** Raw Costs ($C_H$) versus Risk-Adjusted Costs




**Notes:** Figure shows raw $C_H$ (black, continuous line) and risk-score normalized $C_H$ (blue, dashed). While the risk score is able to flatten out the cost curve somewhat, not all risk is captured by the score, leaving some slope.

positive enrollment in only one or neither of the two plan options. We allow for these possibilities in the empirical portion of the paper.[41] Given the assumption that in equilibrium there is positive enrollment in $H$ and $L$, we have the familiar equilibrium condition that prices are set equal to average costs:

$$\begin{aligned} P_H &= AC_H\left(P\right) \\ P_L &= AC_L\left(P\right) \end{aligned} \tag{24}$$

We use this expression to define equilibrium throughout Section 2.

## C.4 Reaction Function Approach to Finding Equilibrium

**Evaluating demand, profits:** For each uninsurance penalty, risk adjustment strength, L-plan cost advantage, and subsidy type setting, we find the equilibrium $P_L$ and $P_H$ pair using the following grid-search method. We construct a grid of $P_L$, $P_H$ price combinations, with $H$ on the vertical axis and $L$ on the horizontal axis. For most simulations, we use a coarse grid with \$1 units. For each pair, we evaluate $H$ and $L$ profits using the demand, cost, and risk-adjustment equations as detailed in the body of the paper. For insurance types $H$, $L$ and uninsurance $U$ we evaluate demand by finding the “indifference points"–the first and the last points in the $s$ distribution such that each type of insurance’s enrollment conditions are satisfied. Because of the vertical model, we can attribute all intermediate points of the $s$ distribution between these indifference points to a given plan. If no

[41] Handel, Hendel and Whinston, 2015 show that there is a unique RE in the setting where there is no outside option. With an outside option, their definition of a Riley Equilibrium requires a slight modification in order to achieve uniqueness. Specifically, instead of requiring the deviation to be strictly profitable, we require the deviation to be weakly profitable but also to achieve positive enrollment for the deviating plan. In the empirical exercise below, we use this definition to find the competitive equilibrium for each counterfactual simulation.

points on the $s$ vector satisfy the plan's enrollment conditions, the plan has zero enrollment. We have indifference points $s_{HL}, s_{LU}$ if both $H$ and $L$ have non-zero enrollment and $s_{HU}, s_{LU}$ if $L$ or $H$ has zero enrollment, respectively. If there is non-zero demand for both $H$ and $L$, we calculate the average risk of those enrolled in each plan and construct transfers from the less risky plan to the more risky plan, per the ACA risk adjustment formula (see equation 9). (In some counterfactual policy simulations, the transfer is multiplied by $\alpha$.) Finally, average costs are calculated for each plan with non-zero enrollment. The function returns the $H, L$ profit grids $\Pi^H, \Pi^L$ with which we can then evaluate equilibrium.

**Finding equilibrium:** For a given grid coarseness, we set a tolerance value $T$ equal to the increment between grid points. A plan is considered to have zero profits if its profits are between $-T$ and $T$. Potential equilibria are all price pairs where (1) only $H$ exists and is making zero profits (2) only $L$ exists and is making zero profits (3) both $H$ and $L$ exist and are both making zero profits. Given the coarseness of the grid, there are usually multiple potential equibria of each type. We use the following process to refine this set down to the final equilibrium point.

- **Single plan equilibria:** First, we refine our $L-$only and $H-$only equilibria. For the remainder of this paragraph, we will refer to the potential $L-$only equilibria, but the methodology also applies to potential $H-$only equilibria. Given the curved nature of the primitives, for some settings, especially those where $L$ has a large cost advantage, there are multiple $L-$only prices $P_L^{L-only}$ that are potential $L-$only equilibria. For each of these $P_L^{L-only}$, we evaluate a single point $(P_L^{L-only}, P_H)$. For a given $L-$only equilibrium price $P_L^{L-only}$, there are typically a set of $P_H > P_H^{min}$ that satisfy the conditions (1) $L$ makes zero profit and (2) $H$ has zero enrollment. To cut down on the number of potential equilibria we must evaluate, for each $P_L^{L-only}$, we evaluate only the pair that contains the smallest $P_H$: $(P_H^{min}, P_L^{L-only})$. For each potential $P_L^{L-only}$, we need only to evaluate this minimum price since any potential $H$ deviations from $(P_H^{min}, P_L)$ would also be deviations from $(P_H, P_L)$, $P_H > P^{min}$. Once a set of potential $L-$only equilibria prices have been refined to unique $(P_L^{only}, P_H)$ pairs, we then evaluate each $P_L^{L-only}$ to determine if it is a Riley Equilibrium. We begin with the minimum $P_L^{L-only}$. The Riley Equilibrium code involves three nested loops. First, the outer loop evaluates each grid point $\Pi^H(P_L^{L-only}, P'_H)$, $P'_H < P_H$ to identify potential H-deviations where $\Pi_H(P_L^{L-only}, P'_H) > T$. If no such potential $H$-deviations are found, $(P_L^{L-only}, P_H)$ is considered a RE. If a potential $H$-deviation is found, the second loop is called. This loop evaluates each grid point $(P'_L, P'_H), P'_L < P_L$ to identify potential $L$-retaliations where $\Pi^L(P'_L, P'_H) > -T, \Pi^H(P'_L, P'_H) < -T$. If no such potential retaliations are found for a given potential $H$-deviation, then $(P_L^{L-only}, P_H)$ is not a Riley Equilibrium. If a potential retaliation is found, a third loop is activated to evaluate if there is any point $(P'_L, P''_H)$, $P''_H < P'_H$ that makes a given retaliation "unsafe" where unsafe is defined as $\Pi_L < -T$. If no such "unsafe" point exists, then the retaliation point is safe and the potential deviation would not succeed. The next potential deviation point for this $P_L^{L-only}$ is then evaluated. If no retaliation-proof deviation exists for a given $(P_L^{only}, P_H)$, then the point is a RE. If a deviation does exist, the next larger $P_L^{L-only}$ is tested.
- **H-L equilibria:** Because of the coarseness of the grid, there are usually multiple connected points where both $H$ and $L$ have enrollees and are making zero profits. We pick the point with the lowest $P_L$ to evaluate. For each potential $HL$ equilibrium, we test if any single-plan deviations exist. This consists of checking whether any $H-$deviations or $L-$deviations exist, using

the same set of RE loops described in the previous paragraph. If either an $H$ deviation or an $L$ deviation is found, the $HL$ equilibrium is not an RE.

# D Appendix: Additional Simulation Results

## D.1 Simulation Results for Mandate/Uninsurance Penalty

Tables A1 and A2 Show additional outcomes for the mandate/uninsurance penalty simulations discussed in Section 5 and shown in Figure 9. In all cases, the welfare measure represents the social surplus under the particular policy setting as a percent of the difference between minimum possible social surplus and maximum possible social surplus achieved.

**Table A1:** Varying Mandate Penalty

**(a)** ACA-like subsidy, L cream-skimmer

| mandate | 0 | 15 | 30 | 45 | 60 |
|---|---|---|---|---|---|
| price H | 382 | 374 | 371 | 360 | 349 |
| price L | 352 | 344 | 337 | 325 | 313 |
| share H | .42 | .42 | .3 | .26 | .23 |
| share L | .31 | .37 | .55 | .67 | .77 |
| share U | .27 | .21 | .15 | .069 | 0 |
| subsidy | 297 | 289 | 282 | 270 | 258 |
| welfare | .91 | .76 | .49 | .24 | 0 |

**(b)** Fixed $275, L cream-skimmer

| mandate | 0 | 15 | 30 | 45 | 60 |
|---|---|---|---|---|---|
| price H | 387 | 381 | 373 | 349 | 349 |
| price L | 357 | 351 | 341 | 313 | 313 |
| share H | .42 | .42 | .37 | .23 | .23 |
| share L | .24 | .3 | .44 | .77 | .77 |
| share U | .35 | .28 | .19 | 0 | 0 |
| subsidy | 275 | 275 | 275 | 275 | 275 |
| welfare | .93 | .79 | .56 | 0 | 0 |

**(c)** ACA-like subsidy, L cost advantage

| mandate | 0 | 15 | 30 | 45 | 60 |
|---|---|---|---|---|---|
| price H | 414 | 409 | 404 | 399 | . |
| price L | 307 | 300 | 292 | 283 | 273 |
| share H | .021 | .017 | .013 | .0065 | 0 |
| share L | .73 | .79 | .86 | .93 | 1 |
| share U | .25 | .19 | .13 | .067 | 0 |
| subsidy | 252 | 245 | 237 | 228 | 218 |
| welfare | .95 | .75 | .52 | .27 | 0 |

**(d)** Fixed $250 , L cost advantage

| mandate | 0 | 15 | 30 | 45 | 60 |
|---|---|---|---|---|---|
| price H | 415 | 404 | . | . | . |
| price L | 307 | 294 | 273 | 273 | 273 |
| share H | .019 | .016 | 0 | 0 | 0 |
| share L | .73 | .84 | 1 | 1 | 1 |
| share U | .26 | .15 | 0 | 0 | 0 |
| subsidy | 250 | 250 | 250 | 250 | 250 |
| welfare | .27 | .16 | 0 | 0 | 0 |

**Notes:** Table A1 contains equilibrium prices, market shares, subsidy levels and relative welfare under varying levels of mandate penalties. Panels (a) and (b) are results for when $L$ is a cream-skimmer ($\Delta C_{HL} = 0$) while panels (c) and (d) are for when $L$ has a 15% cost advantage. In panels (a) and (c), the market has a price-linked subsidy while in panels (b) and (d), the market has a fixed subsidy. Relative welfare is calculated as $\frac{welfare - min(welfare)}{max(welfare) - min(welfare)}$ where max and min are taken over integer mandate penalty values 0 to 60 under the panel's same $L$ cost advantage, subsidy scheme.

## D.2 Simulations of Benefit Regulation

Tables A3 and A4 characterize equilibrium results with and without an $L$-plan offered when the $L$-plan is a pure cream-skimmer and when $L$ has a 15% cost advantage. For a given setting, the welfare loss is reported in dollars and represents loss relative to welfare under the optimal allocation.

**Table A2:** Varying Risk Adjustment ($\alpha$)

**(a)** ACA-like subsidy, L cream-skimmer

| $\alpha$ | 0 | .5 | 1 | 1.5 | 2 |
|---|---|---|---|---|---|
| price H | . | 437 | 382 | 362 | 362 |
| price L | 372 | 362 | 352 | . | . |
| share H | 0 | .082 | .42 | .78 | .78 |
| share L | .72 | .64 | .31 | 0 | 0 |
| share U | .28 | .28 | .27 | .22 | .22 |
| subsidy | 317 | 307 | 297 | 307 | 307 |
| welfare | .46 | .59 | .91 | .91 | .91 |

**(b)** Fixed $275, L cream-skimmer

| $\alpha$ | 0 | .5 | 1 | 1.5 | 2 |
|---|---|---|---|---|---|
| price H | 495 | 438 | 387 | 377 | 377 |
| price L | 381 | 369 | 357 | . | . |
| share H | .0095 | .097 | .42 | .66 | .66 |
| share L | .57 | .52 | .24 | 0 | 0 |
| share U | .42 | .38 | .35 | .34 | .34 |
| subsidy | 275 | 275 | 275 | 275 | 275 |
| welfare | .68 | .73 | .93 | 1 | 1 |

**(c)** ACA-like subsidy, L cost advantage

| $\alpha$ | 0 | .5 | 1 | 1.5 | 2 |
|---|---|---|---|---|---|
| price H | . | . | 414 | 361 | 362 |
| price L | 308 | 308 | 307 | 313 | . |
| share H | 0 | 0 | .021 | .16 | .78 |
| share L | .75 | .75 | .73 | .59 | 0 |
| share U | .25 | .25 | .25 | .25 | .22 |
| subsidy | 253 | 253 | 252 | 258 | 307 |
| welfare | .93 | .93 | .95 | .99 | .58 |

**(d)** Fixed $250, L cost advantage

| $\alpha$ | 0 | .5 | 1 | 1.5 | 2 |
|---|---|---|---|---|---|
| price H | . | . | 415 | 365 | 381 |
| price L | 309 | 309 | 307 | 316 | . |
| share H | 0 | 0 | .019 | .16 | .6 |
| share L | .74 | .74 | .73 | .56 | 0 |
| share U | .26 | .26 | .26 | .29 | .4 |
| subsidy | 250 | 250 | 250 | 250 | 250 |
| welfare | .24 | .24 | .27 | .48 | 1 |

**Notes:** Table A2 contains equilibrium prices, market shares, subsidy levels and relative welfare under varying strengths of risk adjustment $\alpha$. Panels (a) and (b) are results for when $L$ is a cream-skimmer ($\Delta C = 0$) while panels (c) and (d) are for when $L$ has a 15% cost advantage. In panels (a) and (c), the market has a price-linked subsidy while in panels (b) and (d), the market has a fixed subsidy. relative welfare is reported as $\frac{welfare - min(welfare)}{max(welfare) - min(welfare)}$ where max and min are taken over integer mandate penalty values 0 to 60 under the panel's same $L$ cost advantage, subsidy scheme.

The results indicate that for the ACA-like price-linked subsidies, removing $L$ from the choice set always (weakly) improves welfare. This is because removing $L$ results in a higher subsidy and more people entering the market. In the fixed subsidy cases, we find that removing $L$ often causes both an increase in $H$'s market share and an increase in the uninsurance rate (especially when $L$ has a 15% cost advantage). However, we find that in all cases, benefit regulation improves welfare, implying that the welfare losses from more people being uninsured are more than offset by welfare gains from more people enrolling in $H$.

## D.3 Additional Welfare Results from Simulations

### D.3.1 Graphical Illustration of Welfare Consequences of an Uninsurance Penalty

In this appendix we show how to estimate the welfare consequences of an uninsurance penalty with our graphical model. This exercise corresponds to the similar exercise analyzing the welfare consequences of risk adjustment in the main text. Panel (a) of Figure A5 plots the empirical analogs to our welfare figure from Section 2 for the case where $L$ is a pure cream-skimmer. Instead of plotting $C_L$, we plot $C_L^{Net} = C_L - C_U$, as in Eq. (8) to account for the fact that $C_U \neq 0$. We indicate the equilibrium $s$ cutoffs for the baseline ACA setting, where subsidies are linked to the price of the lowest-priced plan, $\alpha = 1$, and there is no uninsurance penalty. The intensive margin equilibrium cutoff is $s_{HL}^e$ and the extensive margin cutoff is $s_{LU}^e$. Thus, consumers with $s < s_{HL}^e$ enroll in $H$, consumers with

**Table A3:** Benefit Regulation : L-plan Cream Skimmer

| | ACA-like all sub | | Fixed = Avg. Cost | | Fixed = 300 | | Fixed = 275 | | Fixed =2 50 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | L offered | No L | L offered | No L | L offered | No L | L offered | No L | L offered | No L |
| price H | 382 | 362 | 353 | 390 | 429 | 429 | 448 | 448 | 461 | 461 |
| price L | 352 | . | 308 | . | . | . | . | . | . | . |
| share H | .42 | .78 | .29 | .65 | .43 | .43 | .31 | .31 | .22 | .22 |
| share L | .31 | 0 | .71 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| share U | .27 | .22 | 0 | .35 | .57 | .57 | .69 | .69 | .78 | .78 |
| subsidy | 297 | 307 | 322 | 322 | 300 | 300 | 275 | 275 | 250 | 250 |
| welfare | -229 | -225 | -266 | -213 | -211 | -211 | -219 | -219 | -228 | -228 |

**Notes:** Table A3 contains equilibrium prices, market shares, subsidy levels and welfare for various subsidy settings with and without the $L$ plan offered. All results are for a setting where $L$ is a cream-skimmer ($\Delta C_{HL} = 0$). The first two columns contain results for ACA-like price-linked subsidies. The following columns are for various fixed subsidies. Welfare is calculated under the baseline assumption, $C_U(s) = 0.64 C_H(s) - 97$.

**Table A4:** Benefit Regulation : L-plan 15% cost advantage

| | ACA-like all sub | | Fixed = Avg. Cost | | Fixed = 300 | | Fixed = 275 | | Fixed =2 50 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | L offered | No L | L offered | No L | L offered | No L | L offered | No L | L offered | No L |
| price H | 414 | 362 | . | 390 | . | 429 | 441 | 448 | 462 | 461 |
| price L | 307 | . | 273 | . | 273 | . | 345 | . | 373 | . |
| share H | .021 | .78 | 0 | .65 | 0 | .43 | .066 | .31 | .088 | .22 |
| share L | .73 | 0 | 1 | 0 | 1 | 0 | .47 | 0 | .25 | 0 |
| share U | .25 | .22 | 0 | .35 | 0 | .57 | .46 | .69 | .67 | .78 |
| subsidy | 252 | 307 | 322 | 322 | 300 | 300 | 275 | 275 | 250 | 250 |
| welfare | -406 | -236 | -469 | -224 | -469 | -222 | -345 | -230 | -298 | -239 |

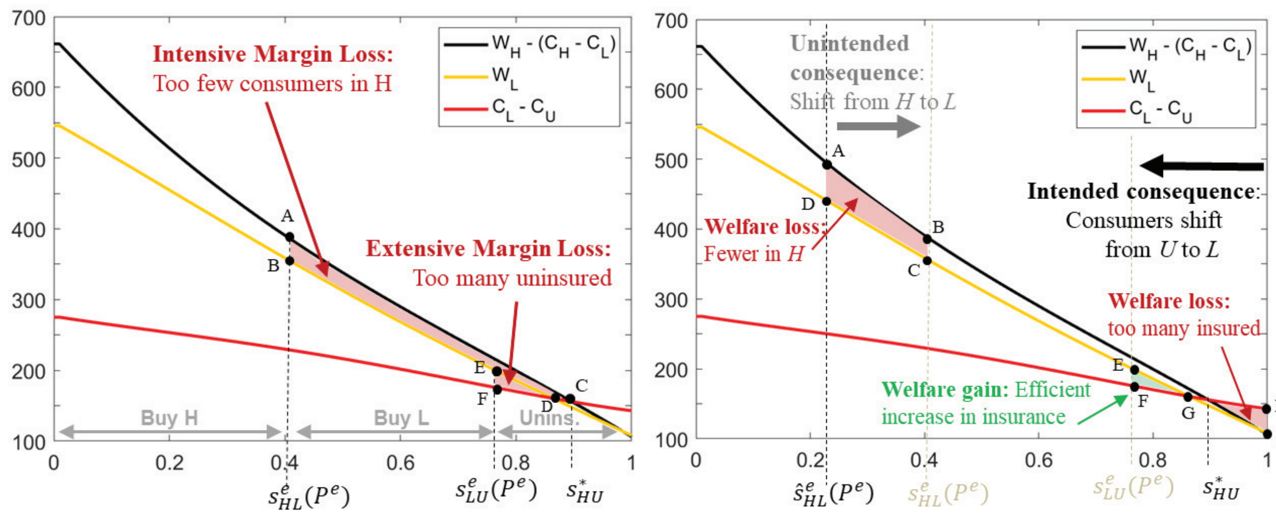
**Notes:** Table A4 contains equilibrium prices, market shares, subsidy levels and welfare for various subsidy settings with and without the $L$ plan offered. All results are for a setting where $L$ has a 15% cost advantage. The first two columns contain results for ACA-like price-linked subsidies. The following columns are for various fixed subsidies. Welfare is calculated under the baseline assumption, $C_U(s) = 0.64 C_H(s) - 97$.

$s^e_{HL} < s < s^e_{LU}$ enroll in $L$, and consumers with $s > s^e_{LU}$ remain uninsured.

**Figure A5:** Empirical Estimates of Foregone Surplus

**(a)** Baseline Foregone Surplus

**(b)** Impose $60 Penalty




**Notes:** Panels (a) and (b) show welfare losses under ACA-like subsidies relative to efficient sorting, when $L$ is a cream-skimmer and when $L$ has a 15% cost advantage over $H$, respectively. In both settings, 60% of the population is low-income and 40% of the population is high-income, so WTP curves are weighted sums of both types. Efficient cutoffs are indicated with a * while equilibrium outcomes are denoted with an $e$ superscript. For both panel (a) and (b), we assume $C_U(s) = 0.64C_H(s) - 97$.

It is apparent that, from a social surplus perspective, no consumer should be in $L$ because $W_H - (C_H - C_L)$ is everywhere above $W_L$. This is because $L$ is a pure cream-skimmer: All consumers value $H$ more than $L$ and $L$ has no cost advantage over $H$. In addition, in this setting some consumers (those with $s > s^*_{HU}$) should not be insured at all. These consumers do not value either $H$ or $L$ more than the (net) cost of enrolling them, making it inefficient for them to be insured. In the figure, we depict the foregone surplus in the baseline ACA setting with shaded areas. The foregone intensive margin surplus in panel (a) (lost surplus due to consumers choosing $L$ instead of $H$) is described by the area between $W_H^{Net}$ and $W_L$ for the consumers not enrolled in $H$, $ACDB$. This area represents a welfare loss of \$41.92. The foregone extensive margin surplus (lost surplus due to consumers choosing $U$ instead of $L$) is given by the area between $W_L$ and $C_L^{Net}$ for the consumers who are not enrolled in insurance but should be, $EDF$. This area represents a welfare loss of \$16.58. The total foregone surplus in the baseline ACA setting in panel (a) of Figure A5 is \$58.50.

Panel (b) of Figure A5 shows how we estimate the welfare consequences of adding an uninsurance penalty of \$60 per month to the baseline case from Panel (a). Recall from the top-left panel of Figure 9 that the imposition of a \$60 mandate (1) induces all previously uninsured consumers to purchase insurance and (2) causes a shift of 19% of the market from $H$ to $L$. Effect (1) is the intended consequence of the penalty, and it implies both welfare gains and losses. Welfare gains occur among those consumers who value $L$ more than $C_L^{Net} = C_L - C_U$ and who newly enroll in $L$ (green welfare triangle $EFG$). Welfare losses occur among those consumers who value $L$ less than $C_L^{Net}$ and who newly enroll in $L$ (red welfare triangle $GHI$). Together, the intended consequence of the penalty, inducing all consumers to purchase insurance, implies a net welfare gain of \$16.59. Effect (2) is the unintended consequence of the penalty, shifting consumers from $H$ to $L$. Here, it implies a welfare loss of \$57.83, which arises because $H$ and $L$ have similar costs but all consumers value $H$ more than

$L$. Overall a \$60 uninsurance penalty leads to a welfare loss of \$41.25 in this setting.

We report welfare impacts of a mandate in other market settings in Appendix D.3.2. Those results, which correspond to the cases in Figures 9, show that it is common for an uninsurance penalty to negatively affect welfare. Given the demand and cost primitives we consider, the unintended consequence of shifting consumers from $H$ to $L$ often more than offsets welfare gains from inducing some consumers who value insurance more than its cost to become insured. This is true both when $L$ is a cream-skimmer and when $L$ has a cost advantage. However, it is not clear that this result would generalize to other settings with different consumer willingness-to-pay for $H$ vs. $L$.

#### D.3.2 Additional Welfare Estimates Corresponding to Market Share Simulations

Figures A6 and A7 present welfare results corresponding to the market shares in Figures 9 and 10. For a given parameter setting $k$, we report here welfare normalized as follows: $W_k = \frac{welfare - min(welfare)}{max(welfare) - min(welfare)}$. We characterize welfare under three different assumptions of the cost of uninsured individuals. The first baseline assumption is the same as in the body of the text:

$$C_U(s) = \frac{(1-d)C_H(s)}{1+\phi} + \omega,$$

where the share of total uninsured health care costs that the uninsured pay out of pocket is $d = 0.2$, the assumed moral hazard from insurance is $\phi = 0.25$, and the fixed cost of uninsurance is $\omega = -97$. In addition to this baseline specification, we also show welfare results where we assume uninsured individuals to have the same cost as they would in $H$ ($C_U = C_H$) and where uninsured individuals have no cost $C_U = 0$.

When the cost of the uninsured is high ($C_U = C_H$), a stronger mandate is generally optimal in all settings. When the uninsured are less costly, however, lower mandates and higher risk adjustment are generally optimal.

#### D.3.3 Optimality under Interacting Policies, Further Results

In Figure A8, we present welfare results under interacting extensive margin (mandate) and intensive margin (risk adjustment $\alpha$ parameter) policies for all settings studied in Figures 9 and 10 in the main text. These results are similar to the results we report in Section 6 but correspond to different market and policy settings. We see that the optimal mandate and risk adjustment combination depends on both the subsidy as well as the cost structure. When the $L$ plan is a cream-skimmer, moderate to strong risk adjustment is preferable in order to induce more consumers to enroll in $H$ vs. $L$. When $L$ has a cost advantage, however, weaker risk adjustment is preferable. Further, when $L$ is a cream-skimmer, the optimal mandate for a given level of risk adjustment also varies, with ACA-like subsidies warranting a lower mandate compared to the fixed subsidy case.

### D.4 Empirical Robustness: Varying Simulation Model Assumptions

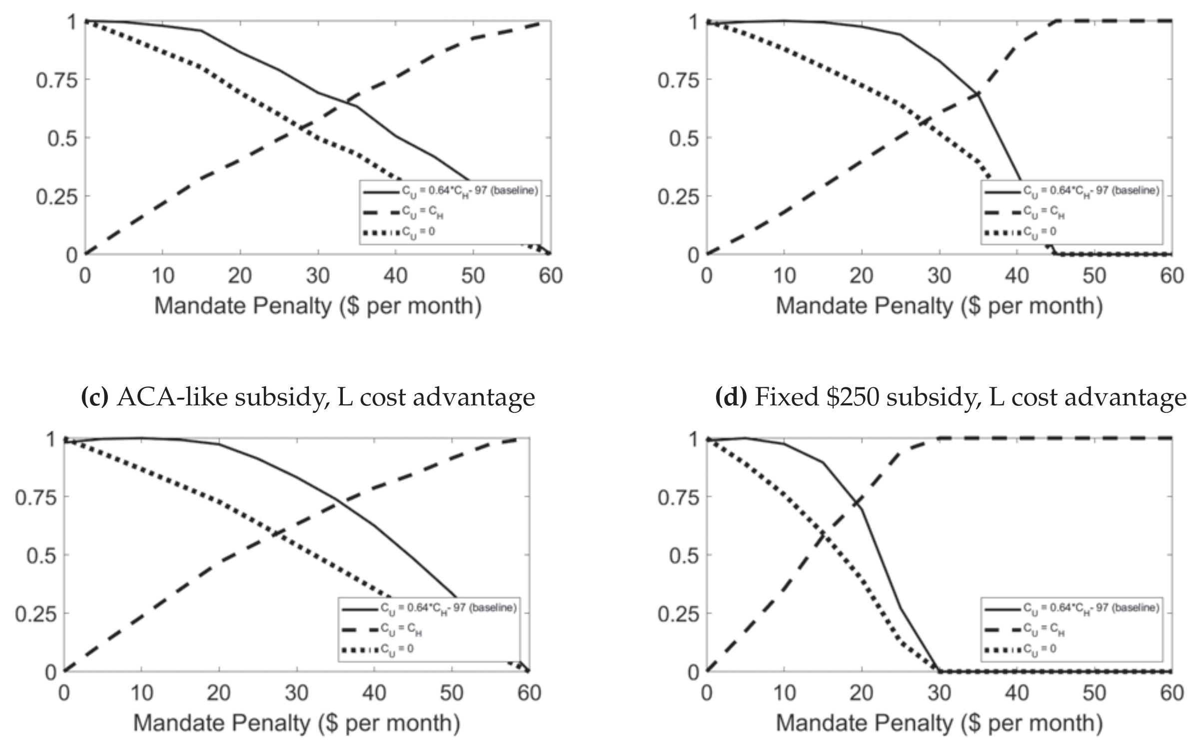
#### D.4.1 Empirical Robustness: Relaxing the Vertical Model

The demand primitives from Finkelstein, Hendren and Shepard (2019) were estimated in a setting where insurance options could be clearly ranked from most to least desirable for all consumers and where WTP was assumed to vary along a single dimension of heterogeneity. As a result, these primitives are consistent with a vertical demand structure. In effect, this means that throughout our main

**Figure A6:** Welfare with Varying Mandate Penalty ($M$)

**(a)** ACA-like subsidy, L cream-skimmer  **(b)** Fixed \$275 subsidy, L cream-skimmer

**(c)** ACA-like subsidy, L cost advantage  **(d)** Fixed \$250 subsidy, L cost advantage




**Notes:** Figure A6 depicts equilibrium relative welfare under varying levels of the mandate penalty. The simulations are the same as in figure 9. Panels (a) and (b) are results for when $L$ is a cream-skimmer ($\Delta C_{HL} = 0$) while panels (c) and (d) are for when $L$ has a 15% cost advantage. In panels (a) and (c), the market has a price-linked subsidy while in panels (b) and (d), the market has a fixed subsidy. For each set of simulations, we present relative welfare under three different assumptions about the social cost of uninsurance. Relative welfare is calculated as $\frac{welfare - min(welfare)}{max(welfare) - min(welfare)}$ where max and min are taken over the possible mandate penalties within a set of simulations and $C_U$ assumptions.

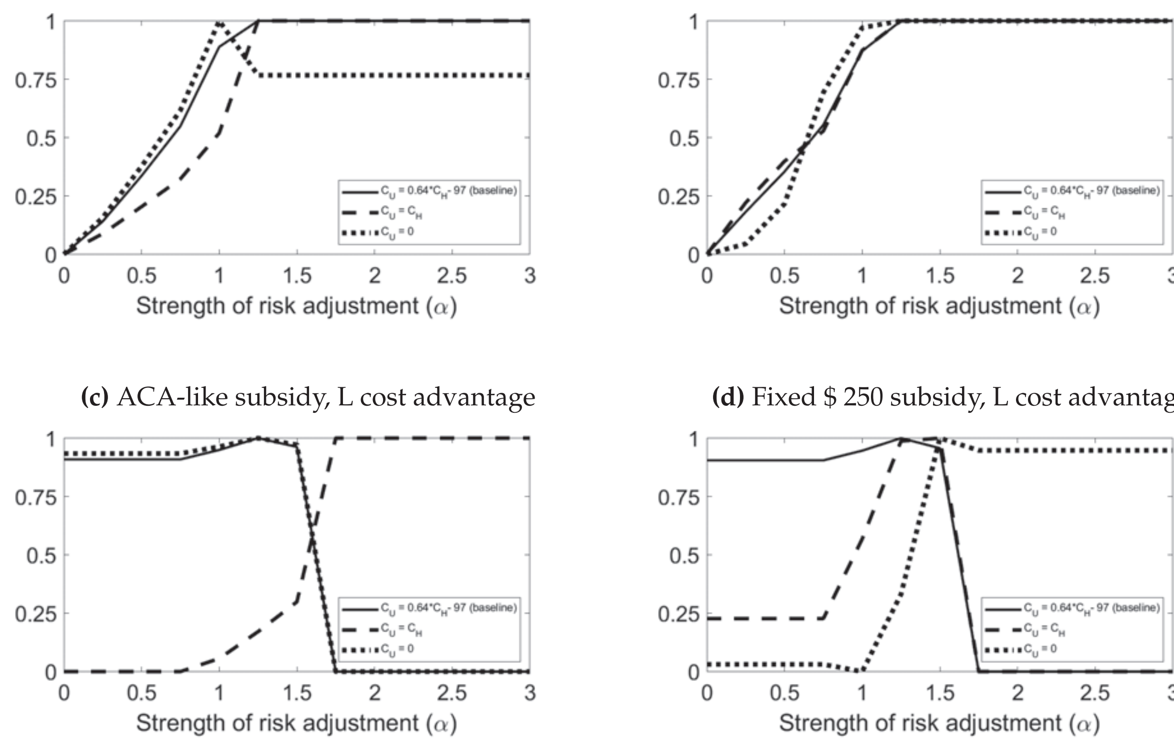
simulations, individuals are only on the margin between $H$ and $L$ or $L$ and $U$, never on the margin between $H$ and $U$ (except in cases where the market "upravels" and nobody chooses $L$). As the theoretical analysis in Appendix A shows, allowing for an $HU$ substitution margin that would be present with horizontal differentiation adds additional terms to the comparative statics defining cross-margin policy effects.

We can investigate how robust our empirical results are to the vertical model by assuming some portion of the population does not value $L$ at all and is thus solely on the margin between $H$ and $U$. To do this, we perform the following exercise:

### Simulation modifications

- From our standard population comprising 60% subsidized low income types and 40% unsubsidized high income types, we assume $\gamma$ percent of each type do not value $L$ so that they may only choose between $H$ and $U$
- We assume that this $\gamma$ portion has the standard $W_H(s)$ and $W_H^{HI}(s)$ curves and same $s$ distribution as in our baseline simulations

**Figure A7:** Welfare with Varying Strength of Risk Adjustment ($\alpha$)




**(a)** ACA-like subsidy, L cream-skimmer

**(b)** Fixed $ 275 subsidy, L cream-skimmer

**(c)** ACA-like subsidy, L cost advantage

**(d)** Fixed $ 250 subsidy, L cost advantage

**Notes:** Figure A6 depicts equilibrium relative welfare under varying strengths of risk adjustment $\alpha$. The simulations are the same as in figure 10. Panels (a) and (b) are results for when $L$ is a cream-skimmer ($\Delta C_{HL} = 0$) while panels (c) and (d) are for when $L$ has a 15% cost advantage. In panels (a) and (c), the market has a price-linked subsidy while in panels (b) and (d), the market has a fixed subsidy. For each set of simulations, we present relative welfare under three different assumptions about the social cost of uninsurance. Relative welfare is calculated as $\frac{welfare - min(welfare)}{max(welfare) - min(welfare)}$ where max and min are taken over the possible $\alpha$ values within a set of simulations and $C_U$ assumptions.

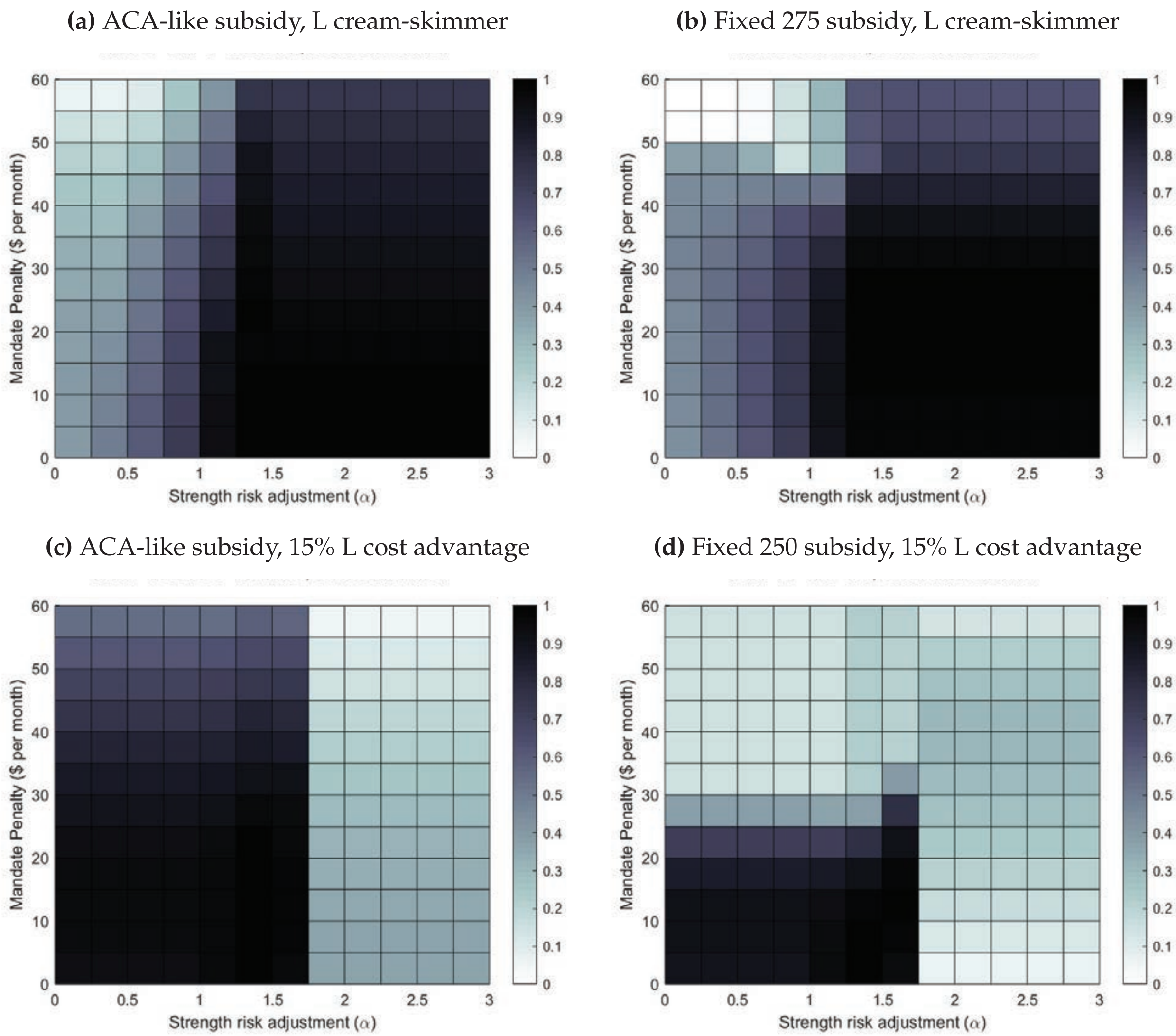
- The remaining $1 - \gamma$ portion of the population has the standard demand primitives and may choose between $H$, $L$, and $U$ as normal
- For a given price bid, $P_H$ and $P_L$, and subsidy, we allow both types to choose plans, estimating profits and equilibrium in the typical way

**Impact of $HU$ margin types on mandate results**

In panel (a) of Figure A9 we estimate demand shares with ACA-like subsidies where the $L$ plan is a pure cream-skimmer and with increasingly larger values of $\gamma$ (i.e., increasing proportions of $HU$ margin types) from 0% up to 20%. For every mandate penalty level, the market allocation to $H$ is everywhere higher with larger shares of $HU$ margin types. As the uninsurance penalty increases, consumers move from $U$ to $L$ *and* from $U$ to $H$. There is still an unintended shifting of consumers from $H$ to $L$ as highlighted in Section 5 of the paper, but there are countervailing forces, composed of (1) the shifting of consumers from $U$ to $H$, and (2) the fact that the presence of some lower-cost $HU$ margin types in $H$ lowers the price of $H$ and the price differential between $H$ and $L$.

On net, $D_H$ still declines with a stronger mandate with a $\gamma$ of 10% or 20%. This shows that the empirical "unintended" effect of the mandate on $D_H$ is robust to some horizontal differentiation.

**Figure A8:** Welfare under Interacting Extensive and Intensive Margin Policies




**Notes:** Figure A8 depicts equilibrium relative welfare under varying levels of the mandate penalty and strength of risk adjustment $\alpha$. Panels (a) and (b) are results for when $L$ is a cream-skimmer ($\Delta C_{HL} = 0$) while panels (c) and (d) are for when $L$ has a 15% cost advantage. In panels (a) and (c), the market has a price-linked subsidy while in panels (b) and (d), the market has a fixed subsidy. Relative welfare is calculated as $\frac{welfare - min(welfare)}{max(welfare) - min(welfare)}$ where max and min are taken over all the possible mandate penalties and risk adjustment strengths within a subsidy and cost setting. For all simulations, we use our baseline assumption of the social cost of uninsurance, $C_U = 0.64 C_H - 97$.

However, the net decline is increasingly muted as $\gamma$ increases, and a level of $\gamma$ much larger than 20% would eventually result in $D_H$ being flat or increasing with the mandate penalty.

**Impact of $HU$ margin types on risk adjustment results**

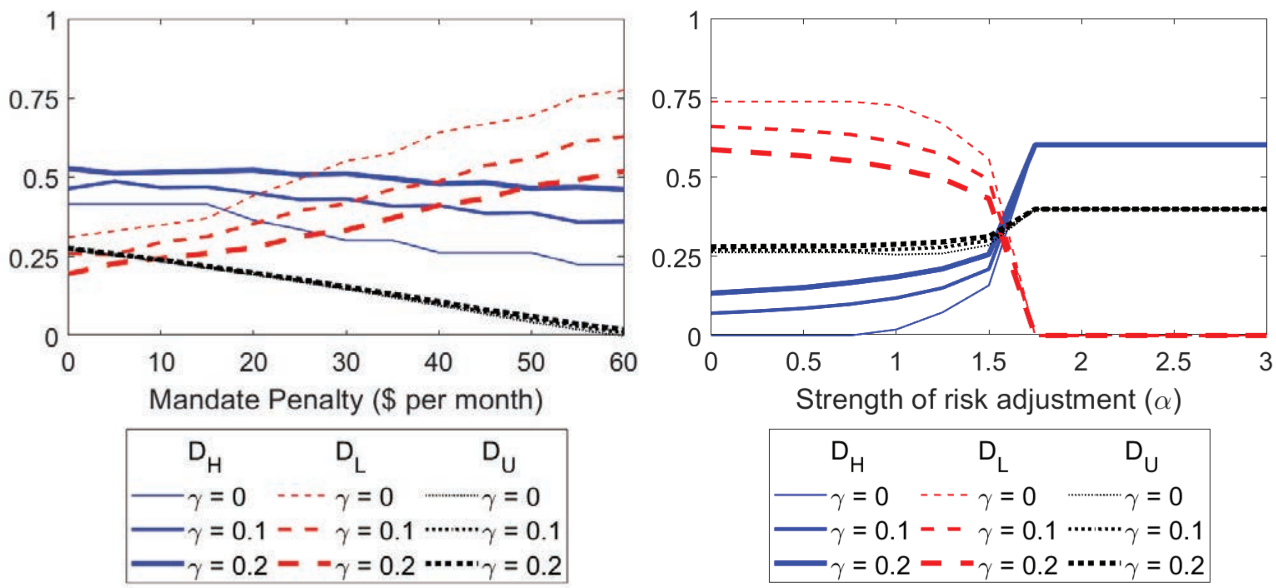
Next, in panel (b) of Figure A9 we estimate demand shares as we vary risk adjustment strength for the case of fixed subsidies when $L$ has a 15% cost advantage. Recall that this is the risk adjustment simulation where we saw a trade-off between extensive and intensive margin selection: Stronger risk adjustment induced consumers to move from $L$ to $H$ but it also induced some consumers to exit the market and opt for $U$.

Similar to our mandate simulations allowing for some consumers to be on the $HU$ margin, we see that the initial allocations to $H$ absent risk adjustment are higher when we have more $HU$ margin types compared to our baseline setting. Because lower cost $HU$ margin types will enroll in $H$ compared to our baseline types, the cost differential between the two plans is lower with larger shares of $HU$ margin types. Consequently, the size of risk adjustment transfers for a given $\alpha$ are lower. However, the level of $\alpha$ that causes the market to "upravel" to $H$ is the same for all levels of $\gamma$. Further, the uninsurance rate also depends very little on $\gamma$, with the $U$ market share at any given level of $\alpha$ being similar across levels of $\gamma$. This indicates that our result that under certain conditions risk adjustment can unintentionally increase the uninsurance rate while simultaneously shifting consumers from $L$ to $H$ is largely robust to our vertical model assumption for the market primitives we examine.

**Figure A9:** Relaxing vertical model

**(a)** Mandate penalty — ACA-like subsidy, Cream-skimming L plan

**(b)** Risk adjustment — Fixed subsidy = \$250, 15% cost advantage L plan




**Notes:** Panels (a) and (b) of Figure A9 depicts equilibrium market shares of $H$,$L$, and uninsurance under varying levels of the mandate penalty and risk adjustment strength ($\alpha$), respectively. Three separate simulations are presented. The thinnest line is our baseline simulation where no individuals are on the margin between $H$ and uninsurance ($\gamma = 0$) while the thickest lines correspond to when 20% of individuals do not consider $L$ and are thus on the margin between $H$ and $U$ ($\gamma = 0.2$). All simulations in panel (a) are for a cream-skimming $L$ plan and ACA-like price linked subsidy and all simulations in panel (b) are for an $L$ plan with a 15% cost advantage and fixed subsidy of \$250 for both plans.

### D.4.2 Empirical Robustness: Varying $\Delta W_{HL}$

Demand for $H$ critically depends on the incremental willingness to pay for $H$ relative to $L$, $\Delta W_{HL} = W_H(s) - W_L(s)$. Below, we see how sensitive our results are to variations in this incremental willingness to pay. Specifically, we estimate equilibrium under simulations where we hold fixed $W_L(s)$ at baseline but scale $\Delta W_{HL}(s)$ by a multiplier $\rho \in [0.25, 4]$:

$$\Delta W_{HL}^{adj}(s) = \Delta W_{HL}(s)^{raw} * \rho$$

$$W_H^{adj}(s) = W_L(s) + \Delta W_{HL}^{adj}(s)$$

This scaling changes both the level and slope of $W_H(s)$, as seen in Figure A10.

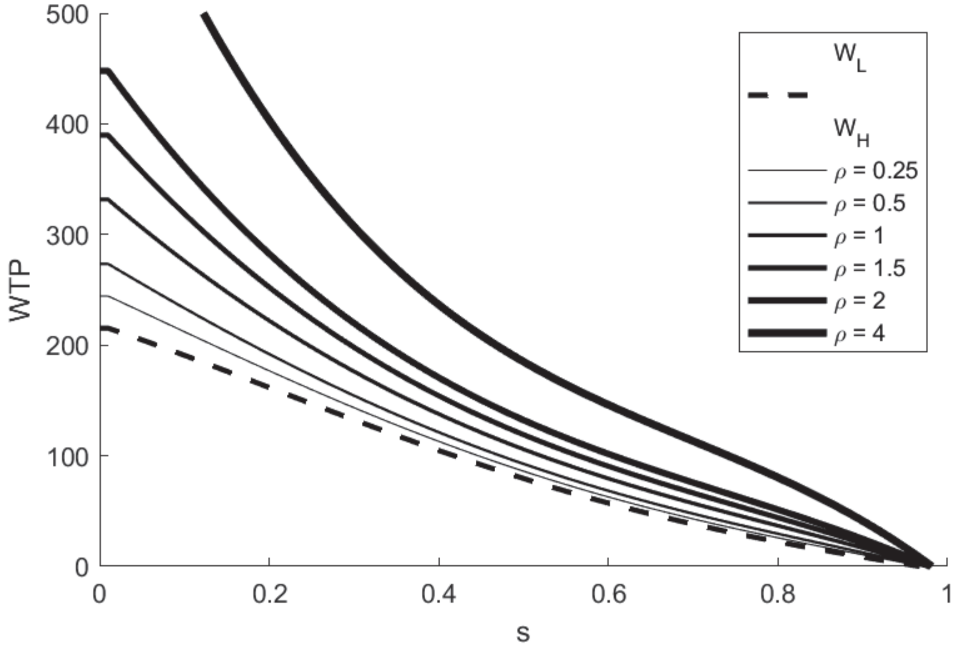
Using our typical counterfactual process, we estimate equilibrium market shares under these modified primitives for varying levels of the mandate penalty and risk adjustment strength. Simulation results are presented in Figure A11. We find that under both increased and decreased incremental willingness to pay (i.e. higher and lower $\rho$), the general patterns of our counterfactual exercises do not change.

Panel (a) shows that demand for $H$ declines with a larger mandate penalty, except at the very high scalar $\rho = 4$. When $\rho = 4$, the marginal willingness to pay for $H$ relative to $L$ is sufficiently high that an incrementally higher mandate penalty induces individuals to enter the market and then choose $H$ over $L$. As a result, demand for $H$ is weakly increasing in the mandate penalty throughout the range of penalties tested while demand for $L$ only rises for high levels of the mandate. The rise in $L$ only occurs in the range of mandate penalties where the individuals induced to enter the market are of sufficiently low marginal willingness to pay that some choose $L$ instead of $H$. Because this is a relatively small group, the cost differential between $H$ and $L$ remains small.

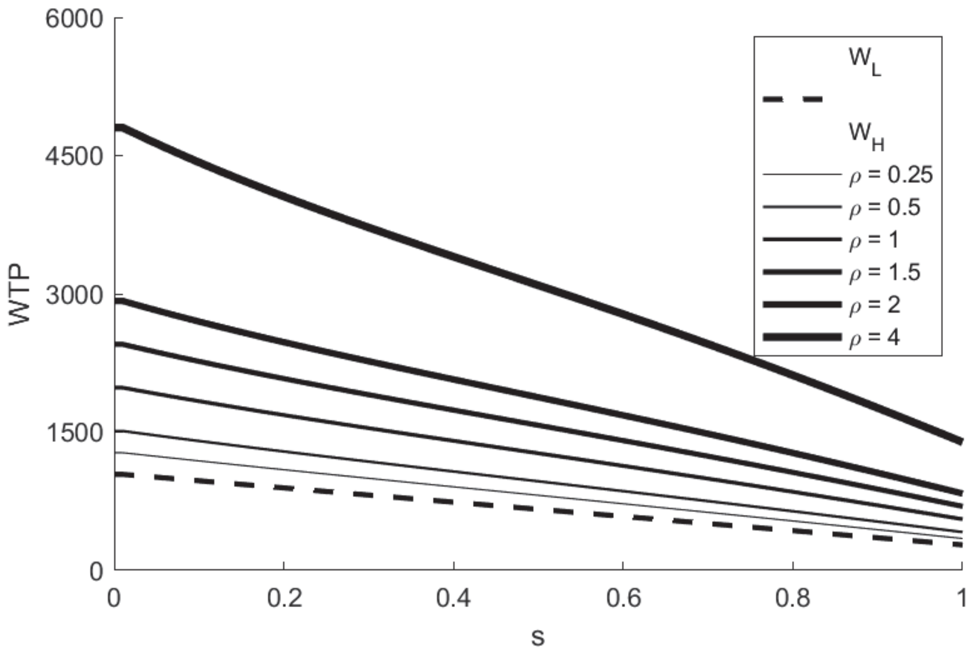
Panel (b) shows that increasing the strength of risk adjustment has similar effects at all levels of $\rho$. Initially, stronger risk adjustment induces consumers to choose $H$ instead of $L$. But in all cases, there is also eventually an unintended increase in the uninsurance rate. The effect of modifying $\rho$ is that the shifts in market share (both from $L$ to $H$ and from $L$ to $U$) occur at different levels of $\alpha$ with shifts occurring at lower levels of $\alpha$ for higher levels of $\rho$. That is, when marginal willingness to pay for $H$ relative to $L$ is higher, a lower level of risk adjustment is needed to induce changes in market shares.

**Figure A10:** Scaled $WTP_H$

**(a)** Low income demand




**(b)** High income demand




**Notes:** Panels (a) and (b) of A10 depicts willingness to pay curves for high and low-income consumers, respectively, under various scaling factors $\rho$ of $\Delta W_{HL}^{adj} = \rho \Delta W_{HL}$. The thickest lines are for high marginal WTP for $H$ relative to $L$. Baseline is for $\rho = 1$. Willingness to pay for $L$ is the dashed line and remains unmodified.

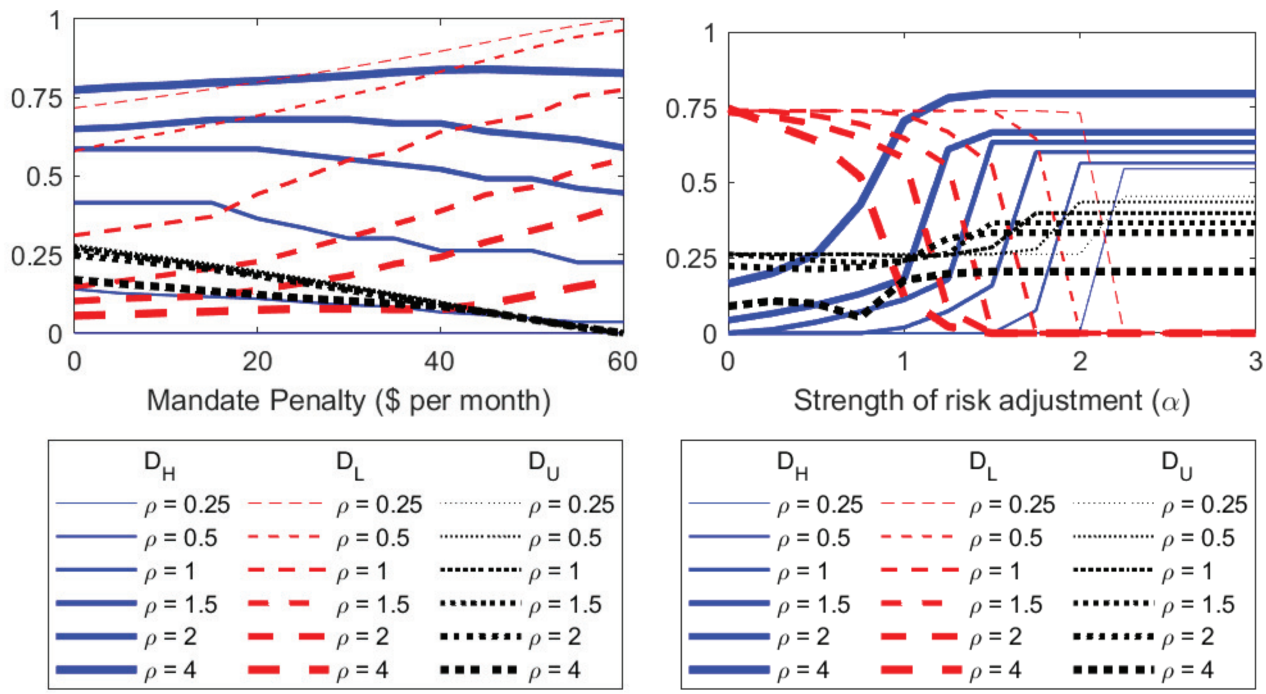
**Figure A11:** Scaling $\Delta WTP$

**(a)** Mandate penalty

ACA-like subsidy, Cream-skimming L plan

**(b)** Risk adjustment

Fixed subsidy = $250, 15 % cost advantage L plan




**Notes:** Figure A11 shows market shares for $H$,$L$, and uninsurance under the different scaled $\Delta WTP$ curves depicted in figure A10. Panel (a) depicts shares for different mandate penalties under an ACA-like price-linked subsidy and cream-skimming $L$ plan ($\Delta C_{HL} = 0$). Panel (b) depicts shares for different strengths of risk adjustment ($\alpha$) under a fixed subsidy and a 15% $L$ plan cost advantage. As in figure A10, thicker lines correspond to market shares when marginal willingness to pay for $H$ relative to $L$ is set higher (higher $\rho$).