Insurer Risk and Public Risk-Sharing: Quantifying the Value of Reinsurance *

Paul H.S. Kim Anran Li†

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Abstract

We study the role of public risk-sharing in markets where firms face substantial cost uncertainty, focusing on public reinsurance in health insurance. We develop a model where insurers internalize cost uncertainty through risk charges that raise effective marginal costs, and create a role for reinsurance. Public reinsurance lowers both expected costs and cost volatility, particularly for smaller insurers, reducing prices and enhancing competition. Using an event study of staggered state-level reinsurance programs, we show that public reinsurance leads insurers to lower prices and private reinsurance purchases, benefiting financially constrained insurers the most. Structural estimates indicate that risk charges account for a substantial share of the premium-cost wedge, and highlight public reinsurance's comparative advantage over premium subsidies by providing risk protection and enhancing competition. Our results underscore the importance of accounting for firms' risk exposure in policy design and provide a general framework for understanding public risk-sharing policies.

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†Kim: Department of Economics, Michigan State University, kimpaul7@msu.edu. Li: Department of Economics, University of Minnesota - Twin Cities, anranli@umn.edu.

1. Introduction

In many markets, firms face substantial uncertainty that can limit their ability to participate effectively. To mitigate this, governments often play a central role in providing risk-sharing policies. For instance, in public procurement, cost-sharing arrangements reduce risk and encourage private participation in large, uncertain projects. In credit markets, public loan guarantees for small businesses, student loans, and mortgages shield private lenders from default risk. Similarly, in insurance markets, public reinsurance helps insurers share the financial burden of catastrophic losses from natural disasters or health shocks. Without such policies, increased risk exposure could lead firms to raise prices, reduce coverage, or exit altogether, ultimately limiting affordable consumer access.

This issue is particularly salient in insurance markets, where firms inherently face substantial cost uncertainty. In recent years, many insurance markets have become increasingly unstable. In property and casualty insurance, rising climate risks - from wildfires to hurricanes - have triggered sharp premium hikes and insurer exits. Health insurance markets, especially newer and smaller ones like the ACA exchanges, have faced similar pressures due in part to a skewed claims distribution, where rare but costly cases pose significant financial risk. In response, governments have intervened to share this risk, most notably through public reinsurance programs that reimburse insurers for high-cost enrollees. Yet, despite their prevalence, the mechanisms by which public risk sharing shapes firm behavior and market outcomes remain understudied.

A key challenge in studying government risk sharing is that most economic models assume risk-neutral firms that simply maximize their expected profit. In such frameworks, reinsurance that merely reduces cost uncertainty, without altering expected cost, should not affect firm behavior. In practice, however, firms actively internalize cost uncertainties and financial risk through various risk management strategies. Insurers, for example, purchase private reinsurance to buffer against large fluctuations in claims; banks hold capital reserves against potential loan defaults; and producers hedge against input cost volatility. These behaviors reflect crucial indirect costs associated with financial risk and uncertainty that standard models often omit. Our contribution is to develop a new framework in which firms explicitly internalize risk and uncertainty in their decision-making. We then apply this framework to study the impact and design of public reinsurance in the individual health insurance market (hereafter, the exchange).

We focus on health insurance for several reasons. First, this market provides exceptionally rich and high-quality data compared to other contexts. Granular individual-level panels of medical claims offer detailed insights into risk distributions in the downstream product market, while transaction-level records of reinsurance purchases reveal insurers' upstream risk-offloading behavior. Second, several states have implemented state-run public reinsurance programs, creating quasi-experimental variation that exogenously alters insurers' risk exposure. We leverage this variation to analyze how changes in risk exposure impact insurer behavior and consumer welfare.

We begin with a stylized pricing model of a monopoly insurer that accounts for the costs of financial risks stemming from claims cost uncertainty. In addition to the standard expected claims cost, the insurer incurs an additional cost of bearing claims uncertainty, which we term a "risk charge." This risk charge can reflect financial or regulatory frictions insurers face related to financial insolvency or distress. As a result,

the insurer behaves as if risk-averse and passes these additional risk charges into prices.

Using this framework, we identify two distinct mechanisms through which public reinsurance influences insurer behavior. The first is a *cost subsidy*: by reimbursing a portion of high-cost claims without requiring an actuarially fair premium upfront, public reinsurance lowers the insurer's expected cost of coverage. The second, often overlooked, is *risk protection*: by providing ex-post payments to extreme health shocks, reinsurance - whether public or private - provides certainty to the insurer's profit across different enrollees' health realizations, thereby decreasing claims uncertainty and mitigating the implicit costs of taking on risk. Consequently, for insurers facing a risk charge, public reinsurance not only acts as a direct cost subsidy but also reduces the additional costs of bearing risk, which are ultimately passed through to consumer prices.

Our framework also rationalizes why costly private reinsurance can still be valuable, despite increasing an insurer's net expected cost. In a standard model, an insurer without a risk charge would have no incentive to purchase such a contract. However, an insurer facing a risk charge may find it beneficial to buy private reinsurance due to its risk protection benefit, trading off expected cost increase and cost volatility decrease.

We next present evidence that health insurers face cost uncertainty and internalize costs associated with bearing that risk. First, using medical claims data for all commercially insured individuals in the Colorado All Payer Claims Data (CO APCD), we show that the distribution of claims costs has a long right tail. Both simulations and observed cost-to-price realizations indicate that insurers face significant cost uncertainties and, thus, a non-negligible probability of cost overrun.

Second, to illustrate that insurers engage in risk-management behaviors, we examine primary insurers' reinsurance transactions from the National Association of Insurance Commissioners (NAIC)[1]. We document that 62% of health insurers purchase private reinsurance coverage, despite paying average markups of 1.54. Smaller, less financially solvent insurers are more likely to purchase private reinsurance, consistent with financial risk playing a key role in shaping these decisions.

Third, we conduct an event study exploiting the staggered initiation of state-level free public reinsurance programs on the exchange market. We find that public reinsurance reduces health insurance premiums by 15%, and the estimated pass-through rate is 1.3: for every dollar the government spends on reinsurance, premiums fall by more than a dollar. This finding aligns with our theoretical framework, demonstrating that public reinsurance reduces both expected claims and risk exposure, thereby lowering insurers' cost of risk bearing. Furthermore, insurers substitute away from purchasing private reinsurance. The responses in premiums and private reinsurance are larger for more financially constrained insurers. We find no evidence that public reinsurance affects insurers' entry or exit, overall costs of care (moral hazard), or private reinsurance markups they face. Taken together, these results suggest that the cost of financial risk influences both insurer pricing and private reinsurance purchases.

Motivated by these facts, we develop an equilibrium model to quantify the impacts of risk exposure and explore optimal policy design. Consumers' demand for insurance follows a standard discrete choice model, with heterogeneous price elasticities by age and health risk groups to capture rich demand curvatures. Insurers simultaneously choose health insurance prices and the amount of private reinsurance coverage to purchase. The novelty is that insurers face additional risk charges when their portfolio of enrollees is riskier,

[1] NAIC does not endorse any analysis or conclusions based on the use of its data.

which they can mitigate by purchasing private reinsurance. Insurers' key primitives include marginal costs of coverage and coefficients of risk charges, i.e., the extent to which the riskiness of their enrollee portfolio inflates effective marginal costs. We estimate the model in the CO exchange, employing their administrative records on enrollment and medical claims, as well as reinsurance contracts from NAIC.

Model estimates quantify how risk exposure affects insurance pricing. First, regional insurers that are subject to risk charges incur, on average, 9.8% higher costs than national insurers that do not, due to additional private reinsurance expenses and risk charges. These extra costs are passed through to prices, hindering smaller insurers' ability to compete effectively with larger, more capitalized insurers. Second, risk charges, i.e., incremental charges associated with holding a riskier enrollee portfolio, account for at least half the wedge between premiums and marginal claims costs. This indicates that financial risks are at least as important as market power in driving high prices for small regional insurers.

We use the model to examine why public reinsurance is uniquely effective. Beyond its role as direct cost subsidies, public reinsurance improves market efficiency due to improved risk-sharing and intensified competition. First, by shielding insurers from extremely adverse health shocks, public reinsurance lowers risk charges and private reinsurance expenses. Second, by easing financial risk burdens, public reinsurance enables smaller regional insurers that face risk charges to compete more effectively, increasing competitive pressure on larger national insurers. Together, these two channels account for an additional quarter of the equilibrium price reductions. Because the cost of financial risk disproportionately raises premiums for smaller insurers, addressing these supply-side distortions makes public reinsurance a particularly effective tool for fostering competition and improving insurance affordability.

Lastly, we conduct a bang-for-buck analysis, comparing the effectiveness of public reinsurance transfers versus premium subsidies, a common policy tool. Given limited state budgets, it is critical to assess whether public reinsurance matches or exceeds previous state efforts to expand affordable coverage. We find that reinsurance is more efficient, shaped by the relative effect of risk reduction and markup inflation. Firstly, reinsurance provides risk protection and reduces risk charges, shifting down marginal cost curves more than premium subsidies, which leaves insurers' risk dispersions unaffected. Conversely, reinsurance flattens marginal cost curves and raises markup, whereas premium subsidies do not. As the degree of financial risk is considerable concurrently, the risk reduction effect dominates, making public reinsurance more effective than premium subsidies in bringing down prices. This analysis highlights public risk-sharing as a cost-effective regulatory scheme. Ignoring the risk protection benefits from ex-post supply-side transfers may misinform policymakers the relative effectiveness of such policy tools.

The implications of firms internalizing cost uncertainties and financial risks extend beyond health insurance. Public risk-sharing could be critical in markets exposed to rising uncertainties and volatile financial risks, such as floods, hurricanes, or property and casualty insurance. In these settings, the threat of costly shocks and limited capital reserves can lead to premium hikes or market exits. By similar logic, government risk-sharing programs like reinsurance can help firms better manage risk, resulting in lower premiums and increased insurance take-up. Thus, our framework informs ongoing policy debates about the appropriate scope and scale of public reinsurance in other contexts, including wildfire insurance (Araullo, 2025), flood insurance (Panteloucos, 2024), home insurance (MN Fair Plan, 2024), and Medicare Part D (Medicare

Payment Advisory Commission, 2020).

Our analysis offers insights into policy designs to improve the functioning of insurance markets. A core premise of the managed competition paradigm is that private insurers create value through price competition. However, small regional insurers that are more financially constrained may be forced to raise premiums in response to cost uncertainties, undermining the efficiency of this model. We show that public reinsurance can alleviate these upward pricing pressures, especially for smaller insurers, thereby strengthening competition and improving welfare. These findings underscore the importance of addressing supply-side distortions to promote effective and equitable market outcomes.

Related Literature. This paper's primary contribution is to quantify the role of public risk-sharing using a new framework that incorporates firms' risk preferences and cost uncertainties.

There has been a growing body of work on public risk-sharing policies across markets. For example, the role of public reinsurance in insuring disaster risks in property insurance (Froot, 2001; Lewis and Murdock, 1996; Solomon, 2025), or loan guarantee programs in credit markets (Bachas et al., 2021; Stillerman, 2024). Within health insurance, we extend the work on risk adjustment and reinsurance (Einav et al., 2019; Layton et al., 2016; McGuire et al., 2020; Polyakova et al., 2021) by highlighting the distinction between ex ante and ex post risk sharing when insurers internalize the cost of financial risk. We provide new causal and structural evidence on how government risk-sharing interacts with insurers' risk exposure, and offer a new insight into the role of public reinsurance as both a cost and risk subsidy.

Our paper relates to work on firm behavior under financial risk. While most models assume risk-neutral firms in product markets, a few strands of literature examine settings where firms internalize risk. In empirical auctions, many studies document and model risk-averse bidding behavior (Bajari and Hortacsu, 2005; Guerre et al., 2009; Luo et al., 2018). Closer to our context, Koijen and Yogo (2015, 2016) show that life insurers pass financial frictions through to insurance pricing, while Kim (2022) estimates a model of risk-averse health insurers to study risk-sharing in Medicare Part D. More broadly, we build on work showing how financial market imperfections can induce effectively risk-averse behavior in firms (Masson, 1972; Hakansson, 1970; Froot and Stein, 1998). Our contribution is to document the cost of financial risk among health insurers, leveraging novel data on reinsurance purchases, and to develop a new framework for evaluating how insurers' internalizing risk shapes the effects of public reinsurance and consumer welfare.

Lastly, our paper adds to the large literature on policy design in insurance markets. Most prior studies focus on demand-side frictions, such as adverse selection and moral hazard (Mahoney and Weyl, 2017; Shepard, 2022; Tebaldi, 2025); see Handel and Ho (2021) for a comprehensive review. A smaller set of studies examines supply-side frictions: Aizawa and Ko (2025) analyzes how dynamic pricing regulation affects insurers' responses to aggregate risk in long-term care insurance; Koijen and Yogo (2022) studies how supply-side regulations influence premiums and product design in annuity markets when insurers face financial frictions. Our analysis provides a new perspective on how a distinct supply-side friction, insurers' cost of financial risk, can shape the effectiveness of public interventions. We show that public risk-sharing policies can improve market outcomes by mitigating this distortion, especially for smaller insurers.

This paper proceeds as follows. In section 2, we begin with a stylized theoretical model of insurer internalizing financial risk from cost uncertainties, and the impact of public reinsurance. Section 3 describes the

institutional background. Section 4 presents data and descriptive evidence of insurers facing and internalizing financial risk. Section 5 shows reduced-form evidence consistent with the stylized model. Section 6 presents our empirical model of consumers' insurance demand and insurers' price and reinsurance purchase decisions. Section 7 outlines the estimation methods and reports the model estimates. Section 8 presents our main empirical analysis on the effectiveness of public reinsurance. Section 9 concludes.

2. Stylized Framework

This section presents a stylized model in which the insurer internalizes financial risk stemming from cost uncertainty through risk charges. Using the model, we demonstrate how these risk charges interact with public risk sharing via reinsurance and impact the insurer's pricing decisions.

2.1. Effect of Risk Charge on Insurance Pricing

Consider a monopoly insurer selling a single insurance plan[2], facing an elastic, downward-sloping demand of $q(p)$.[3] For each individual i the insurer enrolls, it faces a random cost $\tilde{c}_i \sim F(c_i, \sigma_i^2)$, where $\tilde{c}_i \in [0, \bar{c}]$, and F is a distribution function with mean c_i and variance σ_i^2. Let $\tilde{C} = \sum_i^{q(p)} \tilde{c}_i$ denote the insurer's random total cost. The monopoly insurer chooses its price p by maximizing the following objective function:

$$\max_p \quad \underbrace{pq(p)}_{\text{premium revenue}} - \underbrace{E\left[\tilde{C}|q(p)\right]}_{\text{expected claims cost}} - \underbrace{L\left(S\left(\tilde{C}|q(p)\right)\right)}_{\substack{\text{cost of financial risk} \\ \text{i.e. } \textit{risk charge}}}. \tag{1}$$

The insurer's objective function in Equation (1) consists of two main parts. The first two components, premium revenue and expected claims cost, represent the standard term of expected profit for a monopoly. The third component, $L(S)$, is the *risk charge*, which represents the insurer's cost of bearing financial risk from cost uncertainty. This term is a novel addition that departs from the standard models by explicitly having firms internalize the costs of financial risk. We assume $L(S)$ is continuous and increasing in S, where S is a risk measure of cost uncertainty. For instance, S could represent higher-order moments of the cost distribution, such as variance or other risk measures like Value at Risk.[4] In essence, the insurer internalizes the uncertainty in its cost by acting "as if risk averse" (Froot and Stein, 1998).

This flexible formulation of the insurer's objective encompasses several important economic primitives. For example, it can capture an expected utility-maximizing monopoly insurer with CARA utility under certain distributional assumptions. Beyond representing direct risk aversion, $L(S)$ can also reflect the costs insurers face when holding or raising capital due to regulatory or financial frictions, similar to frameworks in Koijen and Yogo (2022). We derive examples of these underlying microfoundations in Appendix C2.

For the main stylized model, we make additional assumptions to tractably illustrate the main impact of risk charge on insurer pricing and how reinsurance affects these decisions. First, we assume $\tilde{c}_i$ are $i.i.d.$

[2]For simplicity, this section uses a single-product monopoly insurer to illustrate the impact of risk charges. Our empirical model, presented in Section 6, accommodates multi-product insurer competition.

[3]We further assume that $q(p)$ is a continuous and thrice-differentiable function.

[4]Here, we primarily focus on uncertainty from randomness in ex-post cost. However, the model can be generalized to encompass any uncertainty in firm profit.

with $c_i = c_0, \sigma_i^2 = \sigma_0^2, \forall i$.[5] Second, we assume $L(S) = \rho S, \rho \geq 0$, and define S as the standard deviation of total claims cost. Then, the insurer maximizes the following mean-standard deviation objective function, where it trades off expected profit and risk (Jean-Baptiste and Santomero, 2000).

$$\max_p \quad \underbrace{pq(p)}_{\text{premium revenue}} - \underbrace{c_0 q(p)}_{\text{expected claims cost}} - \underbrace{\rho \overbrace{\left(\frac{\sigma_0}{\sqrt{q(p)}} q(p) \right)}^{\text{std. dev. of cost}}}_{\text{risk charge}}. \tag{2}$$

The insurer's risk charge is defined as the risk charge coefficient ρ times the standard deviation of the total cost. ρ can be interpreted as either the marginal cost of financial risk or the induced risk preference parameter.

Given the insurer's objective in (2), the insurer's first-order condition (FOC) is

$$\underbrace{p + \frac{q(p)}{q'(p)}}_{\text{marginal revenue}} = \underbrace{c_0}_{\text{marginal claims cost}} + \underbrace{\rho \overbrace{\left(\frac{\sigma_0}{2\sqrt{q(p)}} \right)}^{\text{marginal std. dev.}}}_{\text{marginal risk charge}}. \tag{3}$$

This FOC mirrors the standard monopoly FOC where marginal revenue equals marginal cost with one key distinction: the insurer's effective marginal cost includes two terms. The first is the standard marginal expected claims cost, and the second is the marginal risk charge. Notably, if insurers face no risk charge ($\rho = 0$), the FOC collapses to the standard monopoly case.

Our model formulation yields several desirable features. First, it connects the insurer's business scale with the uncertainty it faces, and captures risk pooling. The marginal standard deviation decreases as the size of the insured population (the "risk pool") grows. As $q \to \infty$, the marginal risk charge term vanishes. Although this represents the maximal benefit of risk pooling under independent costs, introducing correlation across individual costs could still make risk pooling hold.[6]

Second, the marginal risk charge term has clear interpretations and parallels in the existing literature. It is equivalent to the marginal surplus cost described in Boomhower et al. (2024); Kreps (1990), capturing the implied financial cost of bearing additional risk. More broadly, it can be viewed as the marginal cost of regulatory capital, where ρ reflects the product of the cost of capital and a distributional statistic. Appendix C2 presents derivations of these models being isomorphic. This setup thereby flexibly accounts for risk frictions without specifying a particular financial or regulatory mechanism.

Let $p_0^*(\rho)$ denote the optimal price under coefficient ρ. Equation (3) implies that, all else equal, insurers facing heightened financial risk, whether due to a higher risk charge coefficient parameter (ρ), or increased cost uncertainty (σ_0), will charge higher prices.

[5] Appendix C3 and C4 show how the $i.i.d.$ cost assumption can be extended to allow for selection or correlated risk.

[6] While we assume individual costs are independent, which more accurately reflects health insurance claims, the model can accommodate arbitrary correlation across individual costs as in property and casualty insurance. See Appendix C3 for details.

2.2. *Effect of Reinsurance on Insurance Pricing*

We examine how reinsurance affects the insurer's pricing behavior. For simplicity, suppose the reinsurer, either the government or a third-party private reinsurer, offers stop-loss reinsurance that fully reimburses the insurer for any costs beyond the deductible κ. In this stylized framework, we consider the deductible level κ exogenous. Our empirical model in Section 6 allows insurers to choose reinsurance coverages endogenously.

If an individual's ex-post cost is larger than the deductible, $\tilde{c}_i > \kappa$, the reinsurer fully reimburses the insurer for any cost that exceeds κ. So, the amount or generosity of reinsurance decreases in κ, where $\kappa = 0$ implies full reinsurance, and $\kappa = \bar{c}$ implies no reinsurance. Given such a reinsurance scheme, the insurer's ex-post cost, $\tilde{c}_i(\kappa)$, and the reinsurer's ex-post reinsurance cost, $\tilde{r}_i(\kappa)$, for an individual i are given by

$$\tilde{c}_i(\kappa) = \begin{cases} \tilde{c}_i & \text{if } \tilde{c}_i \leq \kappa \\ \kappa & \text{if } \tilde{c}_i > \kappa \end{cases}, \quad \tilde{r}_i(\kappa) = \tilde{c}_i - \tilde{c}_i(\kappa). \tag{4}$$

Let $c(\kappa)$ and $\sigma^2(\kappa)$ denote the insurer's expected cost and the variance of an individual's cost under a reinsurance policy with deductible κ, respectively. For any $\kappa < \bar{c}$, equation (4) suggests that reinsurance lowers both the expected cost and the variance of each individual's cost, i.e.

$$c(\kappa) = \mathbb{E}[\tilde{c}_i(\kappa)] < \mathbb{E}[\tilde{c}_i] = c_0, \quad \sigma^2(\kappa) = \text{Var}[\tilde{c}_i(\kappa)] < \text{Var}(\tilde{c}_i) = \sigma_0^2.$$

Given equation (4), the actuarial value of the reinsurance is given by $r(\kappa) = E[\tilde{r}_i(\kappa)] = c_0 - c(\kappa) \geq 0$. Reinsurance reduce the volatility of claims costs paid by insurer, $\Delta\sigma(\kappa) = \sigma_0 - \sigma(\kappa) > 0$.

Before an individual's cost is realized, the reinsurer charges the insurer a reinsurance premium equal to $p_r = \theta r(\kappa)$, where $\theta \geq 0$ governs the markup, or the degree of subsidization of the reinsurance contract. While $\theta > 1$ is usually the case for private reinsurance markets, $\theta \in [0, 1]$ generally represents government reinsurance. If $\theta = 1$, the government as reinsurer charges an actuarially fair value of reinsurance. If $\theta = 0$, the government fully subsidizes public reinsurance, and reinsurance will be free for the insurer.

Given the reinsurance contract, the insurer's new objective is

$$\begin{aligned} \max_p \quad & pq(p) \quad - \underbrace{c(\kappa)q(p)}_{\text{expected claims cost}} - \underbrace{\theta r(\kappa)q(p)}_{\text{expected reinsurance cost}} - \underbrace{\rho\sigma(\kappa)\sqrt{q(p)}}_{\text{risk charge}} \\ = \quad & pq(p) - \underbrace{\Big[c_0 - \overbrace{(1-\theta)r(\kappa)}^{\substack{\text{reinsurance} \\ \text{cost subsidy}}}\Big]q(p)}_{\text{net expected cost}} - \underbrace{\rho\Big[\sigma_0 - \overbrace{\Delta\sigma(\kappa)}^{\substack{\text{reinsurance} \\ \text{risk protection}}}\Big]\sqrt{q(p)}}_{\text{risk charge}}. \end{aligned} \tag{5}$$

And the insurer's new first-order condition is

$$p + \frac{q(p)}{q'(p)} = \underbrace{\Big[c_0 - \overbrace{(1-\theta)r(\kappa)}^{\substack{\text{reinsurance} \\ \text{cost subsidy}}}\Big]}_{\text{marginal net expected cost}} + \underbrace{\frac{\rho}{2}\frac{1}{\sqrt{q(p)}}\Big[\sigma_0 - \overbrace{\Delta\sigma(\kappa)}^{\substack{\text{reinsurance} \\ \text{risk protection}}}\Big]}_{\text{marginal risk charge}}. \tag{6}$$

Equations (5), (6) show that reinsurance contracts affect insurance prices in two ways. First, reinsurance provides certainty to the insurer's profit across different enrollees' health realizations, acting as a *risk pro-*

tection mechanism. That is, it reduces the standard deviation of the cost, lowering the insurer's risk charge. Second, in the case of public reinsurance ($\theta \leq 1$ cases), it weakly reduces the insurer's net expected cost, acting as a *cost subsidy*. That is, the government is subsidizing the expected cost of reinsurance and, as a result, acting as an ex-post subsidy mechanism. In the case of private reinsurance ($\theta > 1$ cases), reinsurance contracts raise insurers' net expected costs, as insurers pay reinsurers to reduce cost dispersion.

Let $p^*(\kappa;\rho)$ denote the optimal price under reinsurance with deductible κ and the insurer's risk charge coefficient ρ. Without any reinsurance (i.e., $\kappa = \bar{c}$), $p_0^*(\rho) = p^*(\bar{c};\rho)$. Proposition 1 compares $p^*(\kappa;\rho)$ and $p_0^*(\rho)$ to illustrate how reinsurance contract affects insurance pricing.

Proposition 1. *(i) Suppose the reinsurance contract is actuarially fair priced, i.e., $\theta = 1$. If the insurer faces a risk charge ($\rho > 0$), reinsurance lowers the insurer's price, $p^*(\kappa;\rho) < p_0^*(\rho), \forall\, \kappa < \bar{c}$. If the insurer does not face the risk charge ($\rho = 0$), reinsurance does not affect insurer pricing, $p^*(\kappa;0) = p_0^*(0), \forall \kappa$.*

(ii) Suppose the reinsurance contract is subsidized, i.e., $\theta < 1$. Regardless of the insurer's risk charges, reinsurance lowers the insurer's price, $p^*(\kappa;\rho) < p_0^*(\rho), \forall\, \kappa < \bar{c}$, $\rho \geq 0$. Furthermore, if the inverse hazard rate of demand, $\mu(p) = -q(p)/q'(p)$, is weakly convex, the pass-through of public reinsurance, defined as $\frac{dp^*(\kappa;\rho)}{d\kappa} / \frac{dc(\kappa)}{d\kappa}$ will be larger when insurer faces risk charges versus when it does not face risk charge.[7]

(iii) Suppose the reinsurance contract is costly, i.e., $\theta > 1$. If the insurer does not face a risk charge ($\rho = 0$), reinsurance decreases the insurer's objective in (5) and increases the insurer's price, $p^*(\kappa;0) > p_0^*(0), \forall \kappa < \bar{c}$. If the insurer faces risk charges ($\rho > 0$), the impact of reinsurance on its objective and price is ambiguous.

Appendix C1 provides a proof. Below, we discuss the intuition and testable implications of these results.

Proposition 1(i) outlines the case where the reinsurance contract is actuarially fair priced ($\theta = 1$). While such reinsurance does not affect insurers' net expected costs - the sum of expected claims and reinsurance costs - it reduces the uncertainty of claims costs. As such, when the insurer bears additional cost for taking on financial risk and internalizes cost uncertainty via risk charges, reinsurance decreases the insurer's effective marginal cost, lowering the insurer's equilibrium price. However, if an insurer does not internalize risk charges, actuarially fair reinsurance will not impact its optimal price.

In other words, if reinsurance contracts only reduce cost uncertainty without changing the expected cost and expected profit, it would not affect a risk-neutral, expected-profit-maximizing firm. This starkly contrasts empirical findings on the impact of actuarially fair public reinsurance (Solomon, 2025), highlighting the importance of modeling a firm as internalizing the financial risk of cost uncertainty.

Proposition 1(ii) analyzes the case where the government subsidizes the cost of public reinsurance ($\theta < 1$). The key intuition is that public reinsurance affects insurers via two distinct channels. First is the *risk protection* benefit, which reduces cost uncertainty, as in the previous case. Second is the *cost subsidy*, which lowers the insurer's expected cost. As a result, regardless of whether an insurer internalizes financial risk, public reinsurance reduces the effective marginal cost and, in turn, the insurer's optimal price.

[7] While the convexity of $\mu(p)$ is not a necessary condition for pass-through to be greater when $\rho > 0$, it serves as a sufficient condition adopted for technical convenience in the proof.

While subsidized public reinsurance unilaterally lowers insurer prices, Proposition 1(ii) further shows that the magnitude of the price reduction depends on the degree to which the insurer internalizes financial risk. For insurers that internalize the cost of financial risk ($\rho > 0$), reinsurance will provide both the *risk protection* benefit and a *cost subsidy*, thereby attenuating the drop in effective marginal cost compared to a simple *cost subsidy* impact. As a result, the reduction in risk charges can outweigh the reduction in expected claims liabilities (i.e., the government's reinsurance expenditure). Figure A1 depicts this intuition.

In standard models without financial risk costs, the pass-through of cost subsidies under monopoly can be muted, typically less than one due to market power (Miravete et al., 2018; Weyl and Fabinger, 2013). Introducing financial risk costs can work against this prediction: public reinsurance now acts as both a cost and a risk subsidy, increasing the potential for more-than-complete pass-through.[8] In sum, the effectiveness of public reinsurance in reducing prices hinges on the size of the risk protection benefit. The greater the insurer's cost of financial risk, the larger the expected impact of public reinsurance on pricing will be. We test this prediction in Section 5.

Lastly, Proposition 1(iii) examines the case of costly private reinsurance ($\theta > 1$), which increases the insurer's net expected costs. For an insurer not subject to a risk charge, such a reinsurance scheme offers no financial benefits, implying it would not purchase private reinsurance as long as a non-zero markup exists. Conversely, if an insurer does face a risk charge, private reinsurance still provides a valuable risk protection benefit. The net impact on the insurer's utility then depends on the trade-off between this risk protection and the net cost of reinsurance. Consequently, an insurer facing a risk charge may indeed benefit from and choose to purchase private reinsurance. We provide evidence supporting this prediction in Section 4.4.

3. Institutional Background

Our main empirical setting is the U.S. individual health insurance exchange market. Established by the Affordable Care Act (ACA) in 2014, the exchanges are state-level marketplaces that provide a centralized platform where private insurers can sell health insurance plans and individuals can compare and purchase coverage. This market primarily serves the segment of the population who are not eligible for government-provided (Medicaid or Medicare) or employer-sponsored insurance.

Although consumers buy plans from private insurers, the government plays a significant role in shaping the market through extensive rules and regulations. Products are offered at the county level and must adhere to standardized cost-sharing structures and age-rating schedules. Insurers cannot reject applicants or vary premiums based on health status, known as guaranteed issue and community rating provisions. Instead, they must charge the same price to all individuals within a defined geographic area (typically a group of counties), adjusting only for allowed rating factors such as age and tobacco use. In addition, most insurers must ensure their plans meet basic coverage requirements and specified actuarial values. Many consumers also receive federal premium tax credits—subsidies that make coverage more affordable, particularly for lower-income households. Appendix B describes additional institutional details.

Despite these regulatory safeguards, the exchange market has faced persistent challenges since its inception. Many insurers have exited the market or dramatically raised premiums, often citing large and

[8] Several other factors could explain more-than-complete pass-through of subsidies: convexity in demand curves (Weyl and Fabinger, 2013), decreasing marginal costs in competitive markets (Cabral et al., 2018).

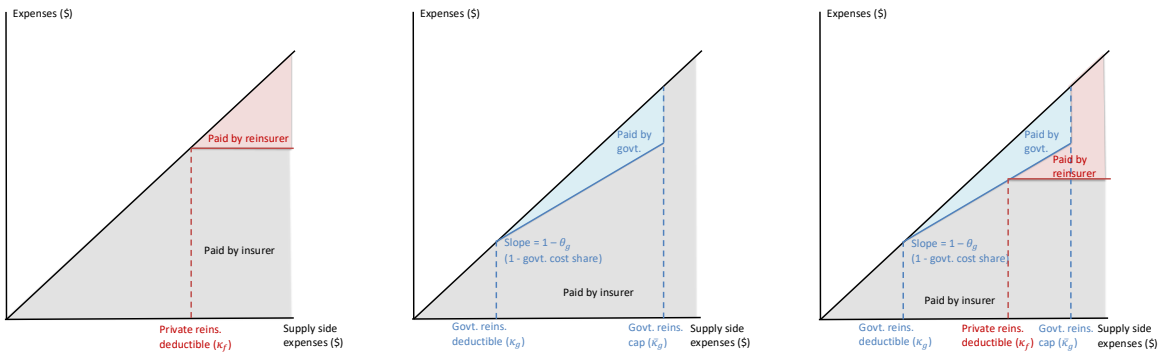
unpredictable claims costs and significant enrollee turnover. The exchange market is relatively small compared to employer-sponsored or other public insurance programs like Medicare and tends to attract a higher share of individuals with uncertain or high expected medical expenses. Frequent turnover, where consumers enter and exit each year, adds further uncertainty to insurers' risk pools. In some cases, sustained financial losses have led state insurance regulators to shut down insurers deemed insolvent or financially distressed. As such, insurers in this market often rely on private reinsurance to help manage financial risk.

3.1. Private Reinsurance.

To mitigate risk exposure, primary insurers often purchase private reinsurance from third parties to increase their underwriting ability without raising additional capital. Reinsurance is "insurance for insurance companies" and is a backstop against significant losses. Private reinsurance usually takes the form of "stop-loss" contracts, which aid primary insurers in stabilizing underwriting results and provide catastrophe protection (NAIC, 2023a). Figure 1a displays a stylized example of the division of medical claims payment between a primary health insurer and a third-party reinsurer.

Figure 1. Illustrating cost shares of reinsurance contracts

(a). Only private reinsurance (b). Only public reinsurance (c). Private and public reinsurance



Notes: This figure is a stylized example of cost divisions between reinsurance and the primary health insurer. We consider private reinsurance in a stop-loss format. The black line denotes the expenses the supply side needs to pay, i.e., ex-post total medical expenses minus consumers' out-of-pocket payments. The grey area denotes insurers' cost shares; the blue area denotes the government's cost shares; the red area denotes reinsurers' cost shares.

Each state oversees private reinsurance through the use of credit for reinsurance laws and regulations. Reinsurers must be either licensed, accredited, or trusted in a health insurer's state of domicile in order for the health insurer to take credit for the liabilities transferred to reinsurers. Historically, reinsurance policies have been widely used in property and casualty insurance, where primary insurers face the risk of a small probability of a catastrophic event. However, while health reinsurance still represents a small share of the overall reinsurance market, it has been experiencing notable growth in recent years.[9] In 2023, primary health insurers collectively ceded around 4% of their premiums to private reinsurance, reflecting an increasing reliance on reinsurance to manage financial risks for health insurers (A.M. Best, 2024).

Despite growth in the health reinsurance market, the market for private reinsurance contracts sold to health insurers remains relatively concentrated. In 2023, the largest four (ten) reinsurers account for 63%

[9]In 2023, Swiss Re, the world's largest reinsurer, collected 10% of its premiums from the health segment (A.M. Best, 2024).

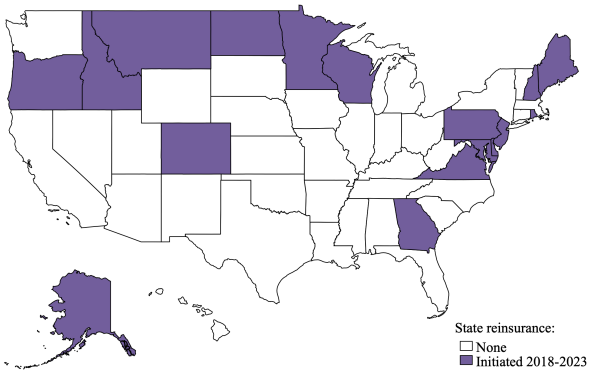
(88%) of the total contracting amount. The mean (standard deviation) of the number of health insurers a reinsurer sells to annually is 3.6 (6.7). Section 4.4 describes reinsurance contracts in our sample in detail.

3.2. Public Reinsurance.

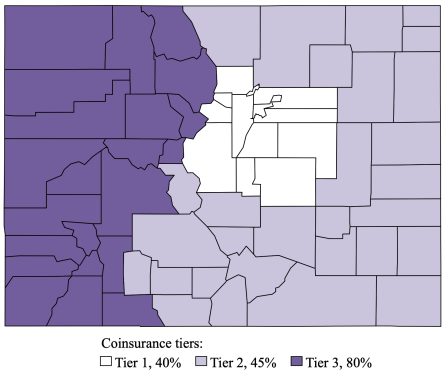
Public reinsurance is commonly observed in insurance markets with tail risk events. For example, Medicare's prescription drug insurance program includes government reinsurance since 2006, the individual health insurance marketplace in 2014, and the national flood insurance program in 2012. Public reinsurance works as secondary insurance for primary insurers: they reimburse insurers' costs to cover tail risk events, hoping that cost savings can be passed through to consumers with lower insurance premiums (Lueck, 2019).

Figure 2. Variations in public reinsurance programs

(a). State reinsurance programs, 2017-2023



(b). Reinsurance program in Colorado, 2020



Notes: Panel (a) plots the initiation of state reinsurance programs nationwide between 2018 and 2023. Panel (b) plots the differential cost-shares within the Coloratio reinsurance program, which started in 2020. Source: CMS (2024).

In the exchange market, a federal reinsurance program existed nationwide from 2014 but was phased out by 2016, exposing insurers to greater financial risk. In response to the aforementioned market turbulence, several states adopted their own public reinsurance programs as a prominent approach to stabilize the market.

As of 2023, 18 states have implemented their own reinsurance programs. Figure 2a shows the geographic distribution of these state-run programs. These programs are structured similarly: when an insurer enrolls a costly enrollee, the government shares a percentage of claims costs between a certain attachment point and a cap. Table A1 presents the detailed cost-sharing parameters for each state's reinsurance program. Figure 1b provides a stylized example of how medical claims payments are divided between a primary health insurer and the government as the reinsurer.

We examine state-run reinsurance programs in the exchange market nationwide to establish motivating facts in Section 5, and focus on Colorado for structural analysis in Sections 6–8. Colorado launched its reinsurance program in 2020, reimbursing insurers for claims costs between an attachment point of $30,000 and a cap of $400,000 per enrollee. As shown in Figure 2b, counties in CO are divided into three tiers, with government coinsurance rates ranging from 40% to 80%. Table A2 reports the program parameters in CO.

For what follows, we refer to reinsurance purchases from third parties as private reinsurance and state-provided public reinsurance as public reinsurance.

4. Data and Descriptives

4.1. Data.

4.1.1. Insurer-Level. Our primary private reinsurance data comes from the National Association of Insurance Commissioners (NAIC), a standard-setting and regulatory support organization governed by insurance regulators from each state. We collect Schedule S financial statement filings for all insurers in the life and health lines of business from 2014 to 2023. The data is at the unique reinsurance contract level and includes information on the seller's identity, the buyer's identity, the effective date, the ceded reinsurance premiums, and the realized reinsurance claims. We further extract insurers' financial solvency and capital adequacy measures using the NAIC 5-year historical financial statement filings. The insurer-year-level statement includes information on the insurers' statutory capital level and the authorized control level of capital.

We obtain information on health insurance products from the Public Use Files of the Center for Medicare and Medicaid Services (CMS) Health Insurance Exchange and the Center for Consumer Information and Insurance Oversight in 2014-2024, including premiums, cost-shares, and other financial characteristics of each health plan. This is a publicly available dataset of the universe of plans launched through the federally facilitated exchanges marketplaces and state-based marketplaces separately.

We augment reinsurance and health insurance records with the CMS Medical Loss Ratio (MLR) reports. The MLR data contains medical claims costs, health insurance premiums, and enrollment at the insurer-state-year level, separately for individual, small group, and large group markets. We focus on insurers that have business in the individual market during our sample period.

4.1.2. Consumer-Level. We obtain the universe of consumers in the Colorado exchange from 2015 to 2021 and their annual insurance choices using the administrative records from Connect for Health Colorado (C4HC), a non-profit organization that operates the CO exchange. The data contains information on consumers' age, gender, county, income bins, plans available, and the chosen plan for every consumer.

We also obtain claims records of exchange consumers from the 2014-2022 Colorado All Payer Claims Data (APCD). The APCD is an individual-year panel of enrollment and claims records for commercially insured CO residents. It also contains demographic information such as age, gender, and county location. Importantly, these claims records enable us to identify consumers whose claims costs fall between the reimbursement range of public reinsurance programs and identify insurers of these eligible consumers.

We supplement the enrollment records with uninsured counts from the Small Area Health Insurance Estimates (SAHIE) for 2015-2022. These model-based estimates from the Census Bureau provide information on uninsured rates and counts by county, age, gender, and income bins. We supplement the insured claims records with the uninsured cost distributions from the Medical Expenditure Panel Survey (MEPS) in 2014-2019. MEPS is a nationally representative two-year rotating panel with information on health insurance coverage and medical spending. We restrict both samples to uninsured individuals who are eligible for the exchange based on age and income.

4.2. Medical Claims Distribution Has a Long Right Tail.

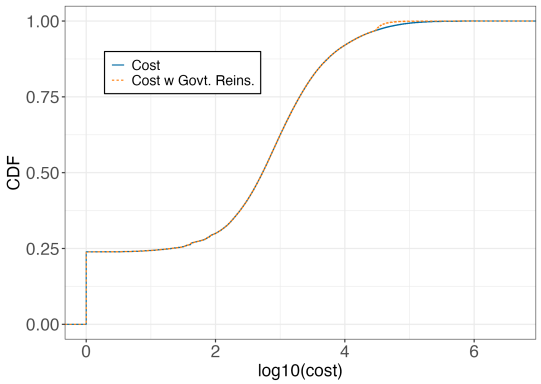
Table A3 reports consumer sample statistics. Our structural exercises focus on the years 2017-2020. We leave out the earlier years because of the unsatisfactory data quality of APCD; the latter years to net out the

systematic impact of the pandemic on the health insurance claims.

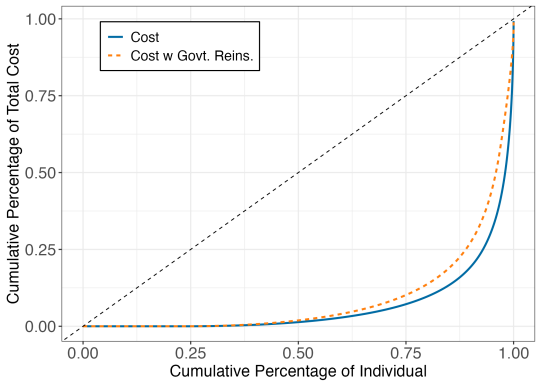
The CO exchange has about two hundred thousand enrollees annually. Both national and regional insurers operate on the CO exchange. The mean insured rate is 37%. An average of 4 insurers sell products per county. The average annual out-of-pocket premium after premium subsidy is $3,697, while the average yearly posted price before premium subsidy is $6,332. Notably, total premiums decreased in 2020 after the implementation of public reinsurance programs. The mean medical expense is $4,508 per enrollee-year, of which 80% is paid by insurers.

Figure 3. Distribution of total medical expenses

(a). CDF of log claims cost



(b). Lorentz curve of claims cost



Notes: This figure reports the empirical distribution of per-member medical claims costs. The sample includes all individuals who was enrolled in a medical plan, and whose primary insurance payer was a CO exchange health insurer from 2016-2023. Panel (a) plots the empirical CDF of the common logarithm of per-member medical claims cost. Panel (b) plots the Lorenz curve of total medical claims cost. Each observation is an individual year.

The distribution of consumer claims costs has a long right tail. Figure 3 plots the empirical cumulative distribution function and the Lorentz curve of the logarithm of claims costs. The top 5% (1%) of the consumers account for 68% (38%) of total medical expenses. The large standard deviation and 99th percentile of total medical expenses in Table A3 also echo this.

About 2.5% of consumers have their claim costs exceeding $30,000, the reinsurance threshold where the CO government starts to share costs with insurers. If the current reinsurance program had been in place throughout, the insurers' expenses would have decreased by $596 per enrollee, 16% from the baseline. The public reinsurance program makes insurers' portfolios less risky, and the occurrence of extreme tail-end risk decreases. This can be seen from the decrease in the standard deviation and 99th percentile of insurers' expenses in scenarios with and without public reinsurance.

4.3. Sources of Cost Uncertainties and Financial Risks.

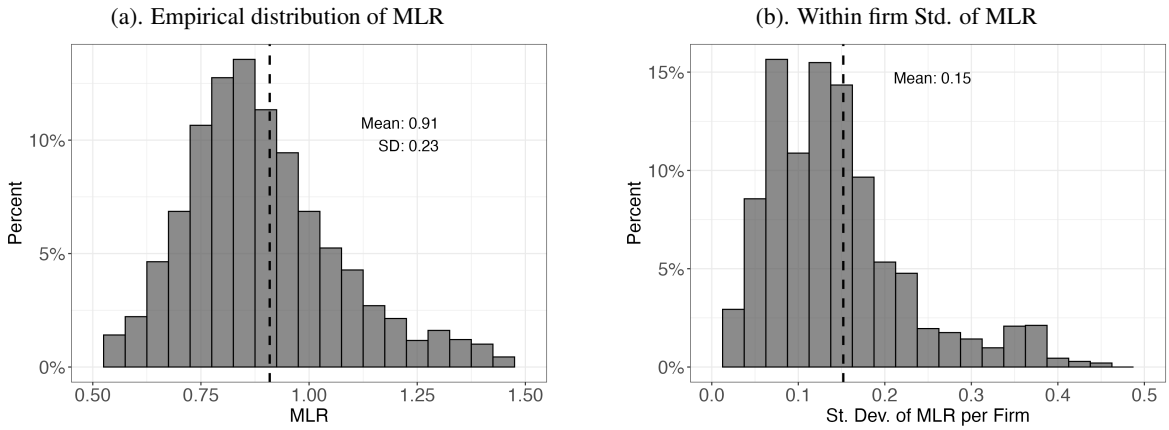
Two sources of cost uncertainties may lead insurers to financial distress: tail-end risk and aggregate risk. We describe these two risks below and how they might inflate insurers' effective marginal costs.

Tail-end risk arises from the possibility of incurring extremely high medical bills from the right tail of the claims distribution. This type of risk is especially relevant for smaller insurers, even when consumer costs are independent. Figure A2 illustrates this by simulating the probability that realized claims exceed a given percentage of expected costs as a function of enrollee size. To substantially mitigate tail-end risk, insurers need at least 100k enrollees. With only 1k enrollees, the probability that realized claims exceed expected

costs by 25% or 5% is approximately 7%, or 32%, respectively. Even with 10k enrollees, there is still a 17% chance that claims exceed expected costs by 5%. Notably, 3 (7) out of 7 insurers in the CO exchange have fewer than 10k (100k) enrollees, exposing all of them to meaningful tail-end cost fluctuations.

Empirically, the probability of cost overrun is non-negligible for exchange insurers. This is evident in Figure 4, which shows a long-tailed empirical distribution of claims costs relative to premium income. In over 24% of insurer-year observations, premium revenue falls short of realized claims. Moreover, the within-firm standard deviation of the claims-to-premium ratio is 0.15, reflecting substantial uncertainty in aggregate costs even at the firm level.

Figure 4. Illustration of cost-fluctuations



Notes: Panel (a) presents the empirical distribution of the individual market medical loss ratio (MLR) at the insurer-year level, calculated as ex-post realized claims costs over insurance premiums. Panel (b) plots the within-firm standard deviation of MLR ratios. Outcome data comes from the Medical Loss Ratio Reports in 2014-2023.

Aggregate risk arises when individual risks are correlated or when shocks to the cost distribution affect all enrollees simultaneously. Examples include systematic shocks, such as a pandemic, or localized health events like flu outbreaks. We do not observe clear evidence of systematic shocks impacting the exchange market during our sample period. As a result, our main empirical model does not explicitly incorporate correlated risks. However, in Appendix C3, we explore both sources of financial risk and discuss how systematic cost shocks could be incorporated.

Either tail-end or aggregate risk can generate cost fluctuations, and thereby adverse shocks to insurers' capital reserves, which may lead insurers to fall short of capital adequacy requirements. Insurance regulators, like NAIC, scrutinize insurers' financial strength using risk-based capital. Risk-based capital is the required capital for insurers to cover their liabilities and is usually set as an exogenous multiplier of the liabilities, i.e., total claims costs. The risk-based capital (RBC) ratio, calculated as the ratio of capital surplus, i.e., assets minus liabilities, to the required risk-based capital, indicates the solvency status of the insurer. NAIC scrutinizes companies with RBC ratios below 200% and takes various actions ranging from a company-level warning to full control of the company (NAIC, 2023b). These RBC regulations imply insurers must hold or raise a certain level of capital for the medical claims expenses they are assuming.

In response, insurers may need to raise or borrow additional capital (Masson, 1972) or purchase reinsurance to transfer some of their liabilities (Koijen and Yogo (2015); see also Section 4.4), both of which can be costly due to capital market imperfections, or the limited competition in the private reinsurance market.

4.4. A Majority of Insurers Purchase Private Reinsurance Despite High Markup.

Given the uncertainty in costs and its implications for financial risk, insurers often rely on reinsurance as a tool to offload risk and protect against adverse shocks (Jean-Baptiste and Santomero, 2000). Table 1 presents summary statistics on exchange insurers' reinsurance purchases from non-affiliate reinsurers.[10] Column (1) reports national averages, while Columns (2)-(3) present statistics separately for insurers that do and do not purchase private reinsurance.

Table 1 panel (a) summarizes characteristics of insurers' primary health insurance business. On average, insurers in our sample cover 0.34 million enrollees and operate with a claims margin of 0.13. They charge an average annual premium of $5,160 per enrollee and incur average claims costs of $4,481.

Table 1. Sample statistics, insurers on the exchange

	(1) All	(2) Has Reins.	(3) No Reins.
(a). Health insurance status			
Mean health insurance premium per enrollee	5,160	5,087	5,279
Mean health insurance claim per enrollee	4,481	4,418	4,583
Mean health insurance margin	0.130	0.128	0.133
Number of members (millions)	0.341	0.338	0.373
(b). Private reinsurance status			
Mean reinsurance premium per enrollee	28	67	-
Mean reinsurance claim per enrollee	12	25	-
Mean reinsurance margin	-	0.544	-
Share has private reinsurance	0.623	1	-
Reins. premium over health ins. premium	0.021	0.033	-
(c). Characteristics			
RBC ratio	5.612	5.527	5.819
Share non-profit	0.452	0.438	0.474
Share Ind. mkt. premium over all mkt. premium	0.356	0.376	0.322

Notes: This table reports the health insurance and reinsurance status of health insurers in MLR data in 2014-2023. Column (1) reports the averages nationwide; Columns (2) and (3) report averages by whether the insurer purchases private health insurance; We define private reinsurance as all nonaffliate reinsurance contracts in NAIC Schedule S filings. The insurance product margin is calculated by one minus the ratio of claims costs over premiums and is thus conditional on purchasing. All statistics that are not in shares or percentage are computed by computing the mean after excluding the top and bottom 2.5% outlier values.

Table 1 panel (b) shows statistics on private reinsurance purchases. 62.3% of insurers purchase private reinsurance despite a high reinsurance margin of 0.54. Markups of private reinsurance are much higher than those of health insurance. This can be explained in part by the high concentration level of the private reinsurance market, as described in Section 3.1.

The widespread use of private reinsurance at high markups suggests that insurers face meaningful costs of financial risk and rely on reinsurance as a tool to hedge against cost fluctuations. On average, private reinsurance expenses represent approximately 2.1% of health insurance premium income across all insurers, or 3.3% when conditional on purchasing reinsurance. When expressed on a per-enrollee basis, insurers spend an average of $67 annually on reinsurance premiums, while receiving an average of $25 in reinsurance

[10] We focus on reinsurance premiums ceded to non-affiliated reinsurers as a measure of private reinsurance transactions. While we do observe 25% of insurers ceding premiums to affiliated reinsurers, these tend to be very large, well-capitalized firms. As a result, such transactions may reflect internal capital management or tax strategies rather than the transfer of risk to an external party.

claims payments.

Panel (c) further compares the characteristics of insurers by their private reinsurance status. Comparing the statistics in columns (2) and (3) shows that insurers with private reinsurance tend to be smaller insurers in terms of the number of members enrolled. They are more (less) likely to be financially constrained (solvent) with a lower average RBC ratio, consistent with the hypothesis that insurers select to purchase private reinsurance due to the cost of financial risk that they face. In addition, insurers whose individual market business makes up a greater share of their overall revenue are more likely to purchase private reinsurance. As a result, government reinsurance may be especially relevant in the individual health insurance market.

5. Event Study on Effects of Public Reinsurance

5.1. Insurers Reduce Premiums and Private Reinsurance Purchases

We leverage the introduction of state-level reinsurance programs to examine their impact on insurance premiums and provide evidence of insurers facing the cost of financial risk or risk charges. These state-level reinsurance programs function as free reinsurance contracts with zero premiums, reducing both the expected cost and the variance of cost. This, in turn, lowers the risk charges that insurers may internalize due to the cost of financial risk. Using an event study framework, we examine the effect of public reinsurance on insurers' pricing strategies and private reinsurance purchasing behaviors.

Let t denote year, m denote geographic market, f denote insurer, s denote state. We run the following regression,

$$y_{fmt} = \sum_{n\in\{-6(+),-5,..,0,1,..,4,5+\}} \beta_n 1[t^*_{s(m)} + n = t] + \gamma_t + \gamma_{fm} + \varepsilon_{fmt}, \tag{7}$$

where $1[t^*_{s(m)} + n = t]$ is an indicator for whether year t in market m within state s is n years from the initiation of the reinsurance programs in t^*_s; γ_t,and γ_{fm} are year, and market-insurer fixed effects, respectively. y_{fmt} is the logarithm of the premium for a 50-year-old within a specific rating region-geographic area pre-defined by regulators for insurers to set their prices over the period 2014-2024 or the insurer-state-year level expenses on private reinsurance in 2014-2023.[11] Standard errors are clustered at the state level. The coefficient of interest is β_n. The state-level identifying variations are depicted in Figure 2a.

To explore the variation in the intensity of Colorado's reinsurance program, we examine its heterogeneous impacts on premiums across the state's three reinsurance tier regions, where the government cedes different proportions of high-cost claims (displayed in Figure 2b). Using an event-study framework similar to that in equation (7), with Colorado as the sole treatment state, we estimate the following regression, allowing coefficients to vary by tier region:

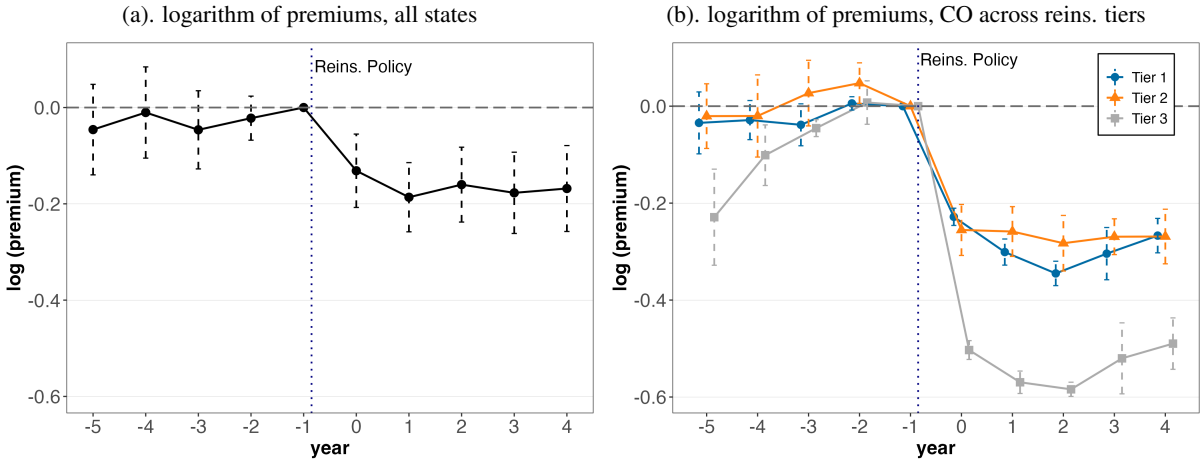
$$y_{fmt} = \sum_{n\in\{-6(+),-5,..,0,1,..,4,5+\}} \sum_{r=1}^{3} \beta_{n,r} 1[t^*_{s(m)} + n = t] D^r_{mt} + \gamma_t + \gamma_{fm} + \varepsilon_{fmt}, \tag{8}$$

where D^r_{mt} is an indicator equal to one if market m belongs to reinsurance tier region, r.

[11] The CMS HIOS issuer, i.e., firm units in premium records, and the NAIC companies, i.e., firm units in reinsurance purchasing records, do not match one-to-one. We restrict the main specification to insurers with those two records that match exactly, covering 67% of all exchange HIOS issuers. We rerun the analysis grouping HIOS issuers into NAIC companies as robustness in Table A4.

5.1.1. Reduced Health Insurance Premium, with More-Than-Unity Pass-Through. We begin by analyzing how public reinsurance affects insurers' pricing strategies. Figure 5a shows a large and statistically significant impact of public reinsurance on premiums. The lack of pre-trends suggests that these premium decreases are unlikely due to any heterogeneous changes occurring in states with public reinsurance. Pooling post-period coefficients from equation (7), we find that the initiation of public reinsurance programs lowered premiums by around 14.5%, as is reported in Table 2 column (1).

Figure 5. The effect of public reinsurance on premium and private reinsurance



Notes: This figure reports point estimates and 95% confidence interval of the effect of state reinsurance from the estimation of equation (7). The outcome variable is the logarithm of average premiums for age 50. The regression sample includes all insurers nationwide with positive health premium income and offering products on the individual exchange market. Panel (a) plots the results from pooling all states with a staggered event study framework. Panel (b) includes only CO as the treatment state and other control states without reinsurance programs. The regression is at the insurer-rating region-year level in 2014-2024, and includes insurer-rating region (or insurer-state) and year fixed effects. Standard errors are clustered at the state level for panel (a), and at the rating area level for panel (b). We allow the year fixed effects to differ by state groups, where each group has separate silver loading policies to control for the differential silver loading policies on premiums. The sample also excludes six states (DC, IL, IN, MS, TX, WV) whose silver loading policies were unclear in 2017-2020.

Figure 5b presents the results of Colorado's reinsurance program, showing heterogeneous impacts across the state's reinsurance tiers. The program significantly reduced premiums, with a 27% decrease in Tiers 1 and 2 and a 46% decrease in Tier 3, which received a particularly high level of reinsurance. We report equivalent post-period coefficients in Table A6. These reductions align with the regulator's targets of lowering premiums by 18-25%, 25-30%, and 38-44% in Tiers 1, 2, and 3, respectively (Colorado Department of Regulatory Agency, 2020).[12]

Using ex-post CO government expenditures, baseline year premium expenses, and our event-study estimates, we calculate a back-of-the-envelope pass-through rate of 1.3 for 2020. The p-value of 0.037 from a one-sided t-test indicates that this pass-through is significantly greater than 1. In other words, for every $1 the Colorado government spends on reinsurance, health insurance premiums decrease by $1.30.

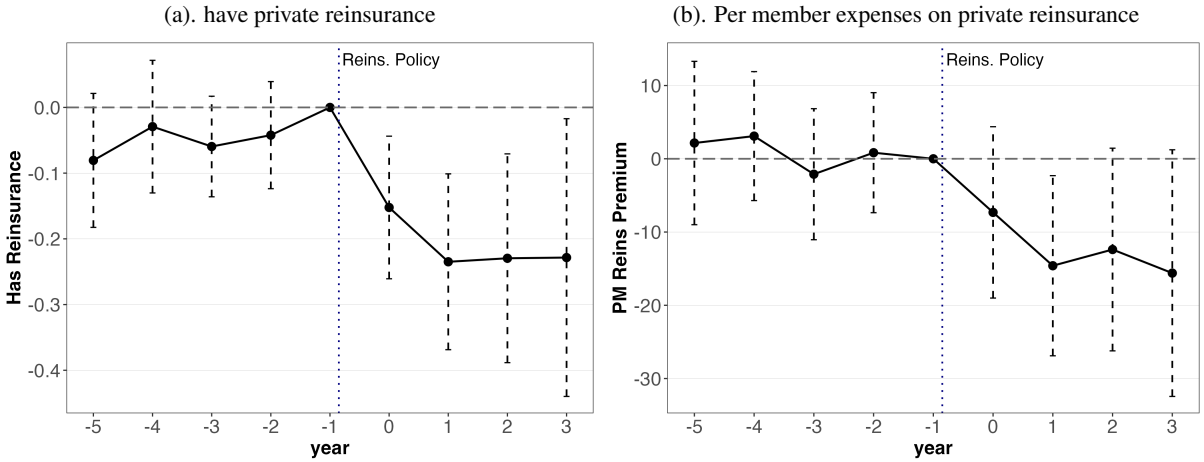
This contrasts with the typical pass-through rate of less than one in an imperfectly competitive market (Cabral et al., 2018). Given that firms likely have some degree of market power in this market, this finding aligns with our theoretical model, suggesting that price decreases come from reductions in both claims cost

[12]While no pre-trends are evident for Tiers 1 and 2, Tier 3 shows an upward pre-trend. This aligns with Tier 3 regions experiencing sharper premium increases in early ACA years, which motivated Colorado regulators to implement higher levels of reinsurance in these areas. As a result, our estimates may understate the true effect of the reinsurance program.

and risk charges. This implies that insurers internalize the cost of financial risks.

5.1.2. Reduced Private Reinsurance Purchases. Next, we investigate how public reinsurance programs affect insurers' private reinsurance purchases. We examine two primary outcomes: at the extensive margin, whether an insurer purchases private reinsurance, and at the intensive margin, the amount spent on private reinsurance per enrollee. The intensive margin captures the level of private reinsurance an insurer purchases for each enrollee.[13]

Figure 6. The effect of public reinsurance on private reinsurance



Notes: This figure reports point estimates and 95% confidence interval of the effect of state reinsurance from the estimation of equation (7). The outcome variable is whether the insurer has private reinsurance in panel (a), and expenses on private reinsurance contracts over the number of health insurance enrollees in panel (b). The regression sample includes all insurers nationwide with positive health premium income and offering products on the individual exchange market. The regression is at insurer-state-year level in 2014-2023, and includes insurer-rating region (or insurer-state) and year fixed effects. Standard errors are clustered at the state level. The sample in panel (b) excludes the top and bottom 2.5% outlier values.

Figures 6a and 6b show that insurers reduce and substitute away from their private reinsurance purchases in response to the provision of free public reinsurance. This is unsurprising, as government reinsurance reduces the risk of insurers' portfolios in the same manner as private reinsurance policies. Pooling post-period coefficients from equation (7), Table 2 indicates that public reinsurance programs reduce the probability of purchasing private reinsurance by 26%, a 42% decrease from the baseline, and lower average per-member expenses on private reinsurance by $19.5, a 68% decrease from the baseline.

5.1.3. Larger Responses from Financially-Constrained Insurers. We further examine whether insurers' responses to public reinsurance differ by the degree of financial constraints. We interact the event dummies in equation (7) with a proxy of insurer financial characteristic, x_{fmt_0}:

$$y_{fmt} = \beta_1 D_{mt} + \beta_2 x_{fmt_0} D_{mt} + \gamma_t + \gamma_{fm} + \varepsilon_{fmt}, \tag{9}$$

where D_{mt} is an indicator of whether market m has reinsurance policies in year t. For x_{fmt_0}, we use an indicator of an insurer's RBC ratio falling below three as a proxy for financial distress,[14] along with a measure

[13] We do not estimate the private reinsurance regression with Colorado (CO) as the only treatment state because such state-year level analysis is underpowered. In contrast, regressions with premiums as the outcome variable are conducted at the more granular insurer-rating region level, which enhances the statistical power of the analysis.

[14] The NAIC closely monitors insurers with RBC ratios under 300% (NAIC, 2023b). At the same time, the BCBS Association applies an internal threshold of 375% RBC ratios (Vermont Legislative Joint Fiscal Office , 2017).

of whether the insurer incurs significant private reinsurance expenses. Insurer's financial characteristics are assessed based on the year preceding the implementation of the given state's reinsurance policy.

Table 2. Effect of public reinsurance subsidies, by financial solvency status

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
		logarithm of premiums		Probability of purchasing private reinsurance		Per member reinsurance expenses	
reinsurance policy	−0.145***	−0.135***	−0.132***	−0.260**	−0.215	−19.428**	−6.840
	(0.041)	(0.037)	(0.036)	(0.117)	(0.132)	(9.342)	(4.233)
reinsurance policy		−0.161***			−0.347		−108.754**
× RBC ratio below 3		(0.050)			(0.243)		(43.639)
reinsurance policy			−0.187***				
× significant private reins.			(0.045)				
N	16,112	16,112	16,112	1,525	1,525	1,508	1,508
Baseline mean	633	633	633	0.616	0.616	28.33	28.33
Share of insurers w. RBC below 3		0.102			0.15		0.148
Share of insurers w. significant private reins.			0.074				

Notes: This table reports the point estimates and standard errors (in parenthesis) on the effect of reinsurance programs from the estimation of equation (9). The regression sample includes all insurers nationwide with positive health premium income and offering products on the individual exchange market. The regression is at the insurer-rating region-year level in 2014-2024 for Columns (1)-(3) and the insurer-state-year level in 2014-2023 for Columns (4)-(7). For Columns (5)-(6), sample excludes top and bottom 2.5% outlier values. The regression includes insurer-rating region (or insurer-state) and year fixed effects. Standard errors are clustered at the state level. *, **, *** denote statistical significance at the 10%, 5%, and 1% level, separately. Significant private reinsurance is defined as insurers spending more than 1.5% of their primary health insurance premiums on private reinsurance expenses.

Table 2 presents the results exploiting differences in insurer characteristics and staggered reinsurance implementation across states and years. The premium-reduction effects of government reinsurance are more pronounced for financially constrained insurers and those with relatively high private reinsurance expenses. Additionally, public reinsurance lead to a more significant reduction in private reinsurance purchases among financially constrained insurers. These findings suggest insurers internalize cost of financial risk.

5.1.4. Robustness. Table A4 probes the robustness of our findings. First, our results hold across different outcome measures, including benchmark premiums for the rating region and average premiums of Silver plans. Second, our estimates remain robust when aggregating at different insurer levels or running regressions at the market-year level. Third, our estimates are robust to corrections for staggered treatments in difference-in-differences designs, such as those proposed by Callaway and Sant'Anna (2021) and Borusyak et al. (2024).

5.2. Additional Analysis.

5.2.1. No Significant Effects on Insurer Entry. We examine whether government reinsurance affects market structure by encouraging more insurers to enter those markets. Using a strategy similar to equation (7), we assess the impact of government reinsurance on the number of insurers in a market, utilizing data at the rating region-year level. Figure A3a shows no statistically significant impact on market entry with public reinsurance. The lack of entry could be explained by the market becoming more competitive, so even if the gains to scale decrease due to public reinsurance, the gains to entry also decrease.

5.2.2. No Significant Effects on Private Reinsurance Markup. We investigate whether the provision of public reinsurance affects the upstream private reinsurance market. Using the same strategy as in equation (7), we examine whether public reinsurance affects the private reinsurance markups paid by primary health insurers. Specifically, we use the private reinsurance margin, defined as one minus the ratio of private reinsurance claims cost to premiums, as the outcome variable. Figure A3b shows no significant impact on the private reinsurance margin paid by primary health insurers, suggesting that public reinsurance does not meaningfully affect the cost of private reinsurance.

Two offsetting effects could explain the null results. On the one hand, Section 5.1.2 shows that health insurers substitute between public and private reinsurance. Public reinsurance could make private reinsurance demand more elastic, potentially lowering the markup on private reinsurance contracts. On the other hand, after public options are available, insurers in need of private reinsurance might be more adversely selected, having a less solvent financial status and being more inelastic than the average firm before the law change.

5.2.3. No Significant Effects on Total Medical Expenses. We examine whether insurers' moral hazard interacts with public reinsurance to shape their equilibrium strategies other than pricing and private reinsurance purchases. Suppose insurers respond to the government's risk-sharing policies with fewer cost-containment activities, such as performing less prior authorization or exerting less effort to bargain with medical providers. In that case, we expect the medical claims to increase.

Employing detailed claims records from CO APCD, we use two empirical designs[15] to investigate the effect of public reinsurance subsidies on the realized medical costs before reinsurance payments. The first design exploits variations in time and geographic markets: within the CO exchange, public reinsurance's cost-shares differ across counties. The identifying variations of differential cost-shares of public reinsurance are depicted in Figure 2b. The second design exploits variations across time and market segments: public reinsurance applies to the exchange market but not employer-sponsored commercial markets. We estimate an analogous event study at the individual level, controlling for individual, year fixed effects, and market-level characteristics. See Appendix D for the detailed specification.

Figure A4 and Table A6 find null effects of public reinsurance on monthly medical expenses per enrollee or the probability that the enrollee's annual expenses exceed the reimbursement threshold of public reinsurance. These results do not support statistically significant evidence for insurer moral hazard, i.e., insurers inflating total medical expenses in response to public reinsurance.[16] Nevertheless, our aggregate expense measure may mask separate responses in quantity and prices. We decompose different mechanisms of insurer moral hazard, such as gatekeeping utilization (quantity) or bargaining with providers (price), and examine whether these insurers' responses have any effects on enrollee health in Kim and Li (2024).

5.2.4. Evidence of Adverse Selection. We finally examine whether the impact of public reinsurance varies across different types of insurance products in different actuarial values to provide suggestive evidence for adverse selection, a well-documented phenomenon in the exchange (Einav and Finkelstein, 2011; Saltzman,

[15]The across-state variations in initiating public reinsurance (used in Section 5.1) is no longer applicable for examining insurer moral hazard, as we only have detailed claims cost data from CO, but not other states

[16]If insurers inflate medical expenses and exhibit moral hazard in response to public reinsurance, our estimated degree of risk charge would be a lower bound of the true parameter.

2021).[17]

Table A5 shows that premium reductions are much more significant for higher actuarial value plans, suggesting the existence of adverse selection: Without selection, consumers are equally represented across different metal tiers, so plans in different metal tiers experience the same degree of cost reductions following the initiation of public reinsurance programs. With adverse selection, sicker consumers select plans with higher actuarial value. Thus, we would expect a larger change in premiums for higher actuarial value products as reinsurance decreases insurers' expected cost more for sicker enrollees.

5.3. Summary and the Need for a Model.

So far, we have provided several suggestive evidence that insurers internalize cost of financial risk in Section 4 and 5. First, we show that health insurers purchase private reinsurance despite high markups. Second, we show that the pass-through of public reinsurance to health insurance prices is more than one, indicating that cost reductions include both claims and risk charges. Third, we show that health insurers substitute for private reinsurance in response to public reinsurance, and the effects are more pronounced for financially constrained insurers.

Although the reduced-form analysis proves the existence of costs of financial risks, it leaves several questions open. First, the magnitude of underlying mechanisms is unclear. To disentangle how marginal cost reductions and risk charge reductions separately contribute to changes in insurers' strategies, we need to formally model how insurers respond to the differential riskiness of their portfolios. Second, the welfare and policy implications of insurers' risk exposure remain unanswered. To further examine optimal policy in this context, we need to use a structural model.

6. Empirical Model of Prices and Reinsurance Purchase

In the previous sections, we documented evidence on insurers' financial risks and their responses to public reinsurance in pricing and private reinsurance purchases. Building on these findings, we now develop an empirical model of insurance demand, insurer pricing, and reinsurance purchasing behavior. The goal is to quantify the magnitude of insurers' risk exposure and to shed light on the design of public reinsurance and alternative policy tools.

Our model consists of the following. Consumers of different ages and health risks choose among insurance products based on heterogeneous preferences. Insurers simultaneously set premiums for products at the county level and choose the amount of private reinsurance coverage at the state level, taking into account uncertainty in claims costs. In each period, insurers move first, followed by consumers making their product choices. We analyze the Nash equilibrium of this game.

Our focus on insurers' strategies of pricing and purchasing private reinsurance coverages is informed by empirical findings in Section 5. In our primary specification, we hold market structures of health insurance fixed and do not model insurer entry or exit. We treat private reinsurance markets as exogenous and do not model reinsurer pricing. We leave out insurers' efforts in cost containment or price negotiation. Section 8 performs sensitivity analyses to assess how relaxing these assumptions might affect welfare predictions.

[17] Risk adjustment policies could, in principle, alleviate adverse selection. However, existing research shows that risk adjustment on the individual market is imperfect (Layton, 2017).

6.1. *Consumer Choices.*

Let i denote consumers, f denote insurers, m denote counties, t denote years, $j \in J_f$ denote products of f. We divide consumers into types based on their age and risk scores predicted using previous years' claims. We assume consumers of the same type have the same preference for insurance products and have their health risks drawn from the same distribution.

We group plans into metal levels so that every insurer only offers three products with distinct coverage levels: Gold (80% coinsurance), Silver (70%), Bronze (60%). Let p_{jmt} denote the posted price for consumers aged 55 and above, and ι_θ denote the price ratios between age groups according to the regulatory age rating curve. $subsidy_{\theta jmt}$ measures premium subsidies, and $p_{jmt}\iota_\theta - subsidy_{\theta jmt}$ measures consumers' out-of-pocket premium expenses. The flow utility of insurance product j for consumer i in age bin θ, quartile risk bin r, county m and year t is

$$u_{ijmt} = \alpha_i(p_{jmt}\iota_\theta - subsidy_{\theta jmt}) + \beta_i X_{jmt} + \xi_{\theta jmt} + \epsilon_{ijmt},\ j \neq 0;, \tag{10}$$

$$\alpha_i = \alpha_\theta + \alpha_r + \nu_i,\ \log(\nu_i) \sim N(0, \sigma_1^2). \tag{11}$$

$$\beta_i = \beta_\theta + \beta_r. \tag{12}$$

where X_{jmt} is financial attributes, including out-of-pocket maximum, deductibles; ϵ_{ijmt} is the logit error; ν_i is a random coefficient that follows a log-normal distribution. The outside option is uninsured, and we normalize $u_{i0mt} = \epsilon_{i0mt}$. Appendix B describes how we reconcile other institutional details of the market, such as premium subsidies.

There are two canonical ways to model health insurance choices: one where consumers with a constant absolute risk aversion (CARA) utility choose plans, integrating over spending in various health states (Handel, 2013), the other where consumers in linear utility choose plans based on product characteristics (Curto et al., 2021; Decarolis et al., 2020). Although we follow the latter approach for computational tractability, we allow consumers' preferences for financial attributes to vary flexibly by their types. Therefore, our framework is able to characterize a fairly flexible distribution of risk preferences for the population.[18]

6.2. *Insurers' Strategies.*

Our empirical model of insurer behavior closely follows the theoretical framework presented in Section 2. Insurer f in year t chooses a price vector $\vec{p}_{ft}$ across markets and a scalar of private reinsurance deductible κ_{ft} to maximize the following objective function:

$$\max_{\kappa_{ft},\vec{p}_{ft}} = \underbrace{\Pi(\vec{p}_{ft};\vec{p}_{-ft})}_{\text{premium revenue}} - \underbrace{\mathbb{E}[C_{ft}(\vec{p}_t,\kappa_{ft};\vec{p}_{-ft})]}_{\text{claims costs}} - \underbrace{R_{ft}(\vec{p}_t,\kappa_{ft};\vec{p}_{-ft})}_{\text{reinsurance costs}} - \underbrace{L_{ft}(\vec{p}_t,\kappa_{ft};\vec{p}_{-ft})}_{\text{risk charge}}. \tag{13}$$

We first describe each component in the objective function, including premium revenue, claims costs, reinsurance costs, and risk charges, and then discuss insurers' optimal strategies.

Insurers' expected premium revenue $\Pi_{ft}(\vec{p}_t)$, is the sum of premium revenue across markets and consumer types, which equals the price of each specific product for a particular consumer type $p_{jt}\iota_\theta$, times the market share of product j among consumers of type i in market mt, s_{ijmt}.

[18]The estimation and counterfactual results are robust to adding random coefficients to preferences of financial attributes, β_i.

Turning to expected claims costs, we assume health risks of risk type i, c_i, are independent and identically distributed[19] according to a log-normal distribution with finite expected value μ_i and variance σ_i^2. The log-normal specification is motivated by the observation that the distribution of individual claims has a long right tail, as shown in Figure 3. We transform health risks to claims costs with a product-specific multiplier ψ_{jmt}. ψ_{jmt} captures the differences in medical expenses for the same individual across different health plans, reflecting variation in geographic cost factors as well as insurers' relative bargaining power with providers. Let λ_j denote the cost shares of a product. Without any reinsurance policies, the claim costs paid by the insurer f for a consumer i enrolled in plan j, is $c_{ijmt} = \psi_{jmt}\lambda_j c_i$. Following the distributional assumption of health risks, c_{ijmt} is also log-normally distributed, $c_{ijmt} \sim N(\mu_i + \log(\psi_{fmt}\lambda_j), \sigma_i^2)$.

Regardless of the availability of public reinsurance, insurers always have the option to purchase private reinsurance to offload some of their financial risk. The private reinsurance contract is at the state-year level. We model private reinsurance as stop-loss contracts applied to each enrollee's expenses, the most common contract arrangement in our sample.[20,21] The contract's deductible κ_{ft} is uniform across all counties and consumer types. As each enrollee's claims c_{ijmt} is a random variable, its different realizations will result in different cost-share arrangements between the insurer and the reinsurer (see Figure 1a for visual illustration). Let c^r_{ijmt} denote the insurers' liabilities after private reinsurance, r_{ijmt} denote the reinsurers' payments:

$$c^r_{ijmt} = \begin{cases} c_{ijmt} \\ \kappa_{ft} \end{cases} ; \; r_{ijmt} = \begin{cases} 0 & \text{if } c_{ijmt} \leq \kappa_{ft} \\ c_{ijmt} - \kappa_{ft} & \text{if } c_{ijmt} > \kappa_{ft}. \end{cases} \tag{14}$$

Summing across all insured individuals gives the insurer's total claims expenses, $C_{ft}(\kappa_{ft})$, which is random. The asymptotic distribution of $C_{ft}(\kappa_{ft})$ is derived in Appendix E.

We assume insurers buy private reinsurance policies at some exogenous markup of $\tau_f > 1$ above the actuarial value. Since most exchange insurers are small, it is plausible that they are price-takers for private reinsurance coverages, instead of bargaining with the third-party reinsurer. The actuarial value per insured is the expected cost of the reinsurer, $\mathbb{E}[r_{ijmt}]$, where r_{ijmt} is distributed according to equation (14). Total reinsurance expenses $R_{ft}(\kappa_{ft})$ aggregate across all insured; see Appendix E2 for the detailed expression.

Our framework also allows for public reinsurance. Let κ_g denote the threshold at which the public program starts to reimburse the insurer, and θ_g denote the insurer's cost-sharing part above the threshold.[22] Figure 1b, 1c illustrate cost shares between the insurer, private reinsurer, and the government, under different realizations of claims c_{ijmt}. When both public and private options are available and the individual's expense exceeds any of their deductibles, we assume government payments come in first, and private reinsurers fill the remainder.[23] Let g_{ijmt} denote the public reinsuruance payments,

[19] We do not model correlated shocks, as there are no systematic health events in our estimation periods, 2017-2019. Appendix E4 shows how to extend our framework to allow for correlated shocks between individuals.

[20] We only observe the total amount of private reinsurance premiums, but not the exact contracts that contain deductibles or cost shares, so we choose the stop-loss format for simplicity. Appendix E5 shows that if, in reality, the contracts are quote-share, we underestimate risk preferences, and the magnitude of bias is innocuous.

[21] 85% of premiums of comprehensive major medical reinsurance in CO exchange are based on individual claims c_{ijmt}, rather than aggregate claims $\sum_{i,j,m} c_{ijmt}$. For computational tractability, we model all contracts as based on individual claims. Appendix E6 extends the model to accommodate group-based reinsurance.

[22] Empirically, we do not observe any individual whose cost is above the maximum reimbursement cap of public reinsurance. For simplicity, we ignore the maximum reimbursement cap in the model.

[23] Empirically, it is always the case that $\kappa_{ft} < \kappa_g$, i.e., the threshold that the public reinsurance starts to reimburse insurers is

$$c^r_{ijmt} = \begin{cases} c_{ijmt} \\ \kappa_g + \theta_g(c_{ijmt} - \kappa_g) \\ \kappa_{ft} \end{cases} ; r_{ijmt} = \begin{cases} 0 \\ 0 \\ \kappa_g + \theta_g(c_{ijmt} - \kappa_g) - \kappa_{ft} \end{cases} ; g_{ijmt} = \begin{cases} 0 & \text{if } c_{ijmt} \leq \kappa_g \\ (1-\theta_g)(c_{ijmt} - \kappa_g) & \text{if } \kappa_g < c_{ijmt} \leq \kappa_{ft} \\ (1-\theta_g)(c_{ijmt} - \kappa_g) & \text{if } c_{ijmt} > \kappa_{ft} \end{cases}. \tag{15}$$

Summing across all insured gives us the total claims expenses of the insurer $C_{ft}(\kappa_{ft}, \kappa_g, \theta_g)$, which is a random variable; and total resinsurance expenses $R_{ft}(\kappa_{ft}, \kappa_g, \theta_g)$. See Appendix E3 for expressions.

Turning to the risk charge term L_{ft}, we parameterize it as a loss function.

$$L_{ft}(\vec{p}_t) = \rho_{ft}\sqrt{\text{Var}[C_{ft}]} = \rho_{ft}\text{Std}[C_{ft}], \tag{16}$$

where ρ_{ft} is the insurer's induced risk preference parameter, or the coefficient of risk charge. Specifically, it governs the extent to which portfolio cost dispersion inflates the insurer's effective marginal cost. We allow ρ_{ft} to vary over time, reflecting changes in the insurer's financial health, such as fluctuations in capital reserves. Risk charges, $L_{ft}(\vec{p}_t)$, represent additional costs associated with holding a riskier enrollee portfolio and are embedded in insurers' pricing decisions. Consistent with the theoretical model in Section 2, we adopt a mean-standard deviation functional form to capture insurers' cost of bearing financial risks. Although higher-order moments of the cost distribution could be considered, we focus on the second-order moment for tractability.

Putting together premium revenue and the three cost terms, equation (17) writes out insurers' first-order condition of prices. In addition to the conventional marginal revenue and marginal cost terms, there are two extra terms: marginal reinsurance expenses and marginal risk charge. These are the extra costs induced by insurers' financial risks, factored into price setting.

$$\underbrace{p_{jmt} + \frac{Q(\vec{p}_t)}{Q'(\vec{p}_t)}}_{\text{marginal revenue}} = \underbrace{\frac{\partial E[C_{ft}]}{\partial p_{jmt}}}_{\text{marginal claims costs}} + \underbrace{\tau\frac{\partial E[R_{ft}]}{\partial p_{jmt}}}_{\text{marginal reins. costs}} + \underbrace{\rho_{ft}\frac{\partial \text{Std}[C_{ft}]}{\partial p_{jmt}}}_{\text{marginal risk charge}} \tag{17}$$

Equation (18) displays insurers' first-order condition of private reinsurance coverages. Private reinsurance is costly as insurers must pay a markup over the actuarial value. However, as shown in equations (14) and (15), reinsurance shrinks both the expected means and the variance of the distribution of claims paid by insurers. Reinsurance, therefore, lowers the expected claims liabilities and the probability of cost overruns, alleviating financial risks. When choosing deductibles of private reinsurance contract κ_{ft}, insurers trade off the increased reinsurance expenses versus the decreased claims and financial costs,

$$\underbrace{-\tau\frac{\partial E[R_{ft}]}{\partial \kappa_{ft}}}_{\text{reins. expenses}} = \underbrace{\frac{\partial E[C_{ft}]}{\partial \kappa_{ft}}}_{\text{claims reduction}} + \underbrace{\rho_{ft}\frac{\partial \text{Std}[C_{ft}]}{\partial \kappa_{ft}}}_{\text{risk charge reduction}} \tag{18}$$

lower than the private reinsurance deductible. We analyze the opposite case in Appendix E3.

7. Estimation and Identification

7.1. Consumer Primitives.

7.1.1. Estimation. We estimate consumer preferences using a two-step estimator following Goolsbee and Petrin (2004). We rewrite consumers' flow utility (equation (10)) as the sum of common utility terms $\delta_{\theta jmt}$ and idiosyncratic terms:

$$u_{ijmt} = \delta_{\theta jmt} + (\alpha_r + \nu_i)(p_{jmt}\iota_\theta - subsidy_{\theta jmt}) + \theta_r X_{jmt} + \epsilon_{ijmt}, \tag{19}$$

$$\delta_{\theta jmt} = \alpha_\theta(p_{jmt}\iota_\theta - subsidy_{\theta jmt}) + \beta_\theta X_{jmt} + \xi_{jmt} + \xi_{\theta mt} + \xi_{\theta jmt}. \tag{20}$$

The first step uses the individual-year panel of enrollment records to recover preference heterogeneity and uses aggregate market shares to pin down common utility terms. It is a constrained maximum likelihood estimation with parameters outlined in equation (19): preferences for price and financial attributes by quartile risk bin α_r, standard deviation of random coefficient σ, and a series of age-product-market-year level common utility $\delta_{\theta jmt}$. The constraints impose that the observed and predicted market shares match. Common utilities $\delta_{\theta jmt}$ are solved using the Berry (1994) inversion and MPEC algorithm (Su and Judd, 2012; Dube et al., 2012). The second step is an OLS estimation of equation (20), projecting the estimated common utility $\delta_{\theta jmt}$ onto its components.

7.1.2. Identification. The differential correlations between premiums (or financial attributes) and choice patterns by consumers with different health risks identify differences in price sensitivity α_r (or preferences for financial attributes) by health risk bins. The differential substitution patterns across consumers of the same type in the same market identify the standard deviation of the random coefficient, σ.

Correlations between product characteristics and choice patterns identify these mean preferences for premium α_θ. Insurers' knowledge of consumers' unobserved preferences when choosing prices creates a correlation between the second-stage residual and premiums. We address this endogeneity concern with a regulatory feature, the age rating regulation in the exchange (Tebaldi, 2025): Insurers can collect different premiums from consumers based on age, but the age gradient in premiums has to follow a pre-specified regulatory curve. This pre-specified age rating curve generates granular exogenous variations, which do not correspond to variations in unobservable demand shocks after controlling for the market (county-year)-product (insurer-metal) fixed effects ξ_{jmt}.

7.1.3. Results. Table A7 reports consumer preference estimates. While Column (3) is our preferred one, the implied elasticities are robust across different specifications. The average enrollment-weighted own-premium semi-elasticity (elasticity) is -4.02 (-7.02) in the Colorado exchange, similar to -3.2 to -4.5 (Geddes, 2022), -5.2 (Drake, 2019), -5.5 (Li, 2024), and -7.2 (Saltzman, 2019) for the Oregon, California, Utah, and Washington exchanges. We also compute the extensive margin sensitivity, measured as the percentage drop in the probability of purchasing marketplace coverage if annual posted prices of all products increase by \$100. Such price increases would reduce the insured rate by 3.7% for the Colorado exchange, consistent with 4% (Tebaldi, 2025) of the California exchange. The estimates confirm adverse selection: Elderly (or sick) consumers are less price elastic than young (or healthy) consumers, as shown in Table A7 panel (c)

7.2. Insurer Primitives.

Insurers have three sets of primitives to be backed out. The first is the marginal claims costs of insurers. The second is their risk charge coefficient, ρ_f. The third primitive is the markup of private reinsurance, τ.

7.2.1. Calibration and Estimation. We calibrate the baseline health risk parameters, μ_i, σ_i^2, from the CO APCD. We use log-normals to approximate the distribution of realized health risks by consumer types. We then use an insurer-product specific multiplier ψ_{fm} to transform the health risks distribution into the claims costs distribution. We calibrate private reinsurance markup τ using the averages of the ratio of private reinsurance premiums over private reinsurance claims from the NAIC reinsurance records, and hold it constant for the structural exercises.

We estimate the remaining supply-side parameters, marginal cost multiplier ψ_{fmt}, and risk charge coefficient ρ_f with a generalized method of moments estimator. The moments are insurers' first-order conditions of health insurance prices (equation (17)) and how much private reinsurance to purchase (equation (17)). Note that we do not observe the deductible of each private reinsurance contract; instead, we observe aggregate private reinsurance premiums per contract. To address this issue, we exploit the one-to-one mapping between coverage levels and premiums of private reinsurance given the stop-loss contract design. We thus add a moment that matches the model-implied reinsurance premium to that of the observed data:

$$\sum_{i,m,j\in J_{fm}} \left(\underbrace{\tau}_{\text{markup of reinsurance}} \underbrace{E[c_{ijmt} - c^r_{ijmt}(\kappa_{ft})]}_{\text{AV of reinsurance}} \right) D_{ijmt} = \underbrace{R^{\text{obs}}_{ft}}_{\text{observed reinsurance expense}}, \tag{21}$$

where c^r_{ijmt} is the insurers' share of claims expenses under private reinsurance, with a deductible κ_f; D_{ijmt} is the product's demand, summing across consumer types and markets.

7.2.2. Identification. When choosing deductibles of private reinsurance contracts, κ_{ft}, insurers trade off the increased reinsurance expenses versus the decreased claims and risk charges. Exploiting the relationship between reinsurance premiums and the actuarial value of reinsurance, rearranging equation (18) suggests that insurers pay a markup over the actuarial value of reinsurance for the gains of reduced dispersion of total costs.

$$\underbrace{-(\tau - 1)\frac{\partial E[R_{ft}]}{\partial \kappa_{ft}}}_{\text{markup over claims reduction}} = \underbrace{\rho_{ft}\frac{\partial \text{Std}[C_{ft}]}{\partial \kappa_{ft}}}_{\text{risk charge reduction}}. \tag{22}$$

Equation (22) shows that the correlation between aggregate cost dispersion and private reinsurance coverage identifies the risk charge coefficient ρ_{ft}. For a given amount of increase in cost dispersion, the magnitude of the associated increase in private reinsurance purchase pins down the degree of financial risk cost. In other words, holding fixed underlying cost distributions, the more reinsurance coverage the insurer buys, the larger its risk charge coefficient. Figure A5 provides a stylized illustration for this identification intuition.

The premium levels identify marginal cost multipliers ψ_{fmt}. Given the demand elasticities and derived markups, we can back out a one-to-one mapping between observed premiums and total marginal costs. Subtracting per-member reinsurance expenses and risk charges from the total marginal costs gives an estimate of the claims costs for a particular product. The ratio between product-specific claims costs and the baseline health risks pins down marginal cost multipliers.

7.2.3. Results. Table A8 reports the marginal cost multiplier within each insurer. National insurers, on average, have lower marginal costs than regional insurers for individuals of the same type. Marginal costs in the Denver metropolitan areas (the tier 1 reinsurance policy regions) are lower than those in the mountain areas (the remaining policy regions). Mean claims costs are estimated to be \$3,584, \$6,085, \$10,069 for consumers aged below 34, 35-54, and above 55; \$5,539, \$6,297, \$6,472, \$7,614 for consumers in each predicted risk quartile. As reported in Columns (3)-(4) in Table 3, the implied ratio of claims cost to price hovers around 85%, consistent with Cicala et al. (2019).

Table 3. Estimates of private reinsurance deductible and risk preferences

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Private reins.	Coeff. of	Mean per member price/cost				Share over total premium		
Insurer	deductible (κ_f)	risk charges (ρ)	Premium	Medical claims	Private reins.	Risk charge	Medical Claims	Private reins.	Risk charge
Insurer A	-	0.000	6,378	5,711	0	0	89.66%	0.00%	0.00%
Insurer B	-	0.000	9,875	8,846	0	0	89.73%	0.00%	0.00%
Insurer C	4.13	0.840	6,934	6,266	22	163	90.51%	0.32%	2.36%
Insurer D	4.71	0.266	11,598	10,612	50	338	91.69%	0.43%	2.92%
Insurer E	0.84	0.637	6,338	5,514	190	455	87.11%	3.00%	7.18%
Insurer F	1.02	1.559	10,674	8,884	323	786	83.37%	3.03%	7.37%
Insurer G	0.71	2.589	5,931	5,081	186	437	85.77%	3.15%	7.37%

Notes: This table reports insurers' estimated private reinsurance deductibles and risk preferences in 2018. We assume private reinsurance is in a stop-loss format, and the deductible reported in Column (1) is in millions. Columns (1)-(2) are parameter estimates; Column (3) is observed data; and Columns (4)-(9) are derived statistics. The averages reported are enrollment-weighted. The reinsurance deductible in Column (1) is reported in millions.

Table 3 Columns (1)–(2) report the estimated private reinsurance coverage thresholds and risk preference parameters. The monotonic relationship between private reinsurance purchases and risk preference parameter implies that insurers without private reinsurance behave as risk-neutral, i.e., they have an estimated coefficient of risk charge of zero. In contrast, insurers with positive private reinsurance purchases are estimated to behave as if risk-averse, with strictly positive risk charge coefficients. Furthermore, regional insurers are estimated to incur a larger risk charge than national insurers. This is consistent with the fact that national insurers typically have greater access to financial capital and face lower capital costs, reducing their need to impose additional risk charges to protect against adverse cost shocks.

Column (5) displays the corresponding private reinsurance expenses per insured, which match the observed values exactly, as required by the moment conditions. Most large national insurers do not purchase non-affiliate private reinsurance.[24] In contrast, regional insurers – the last four insurers in the panel - spend \$205 per insured on reinsurance coverage, equivalent to 2.84% of their health insurance revenue.

We further compute the model-implied per-member risk charge in Column (6). While national insurers' risk charges are close to zero, average risk charges for regional insurers are \$501 per member or 6.92% of their health insurance premium. This magnitude is broadly consistent with those reported in actuarial documents, which suggest that insurers' risk charges are usually 2-4% of their premiums.

Table A9 examines whether our risk charge estimates are robust to alternative specifications. Instead of

[24]National insurers on the Colorado exchange do purchase affiliate reinsurance from their parent companies. Since such transactions may reflect either internal capital management, tax strategies, or the transfer of risk to an external party, our estimated risk preference parameters for these insurers may be interpreted as a lower bound.

the standard deviation, we use the variance of total claims in insurers' objective functions to capture extra costs from financial risks. We also expand consumer types to age bins by risk quartiles. It is reassuring that the estimated percentage of risk charge to insurance price is robust to parametric assumptions.

Estimates in Table 3 demonstrate the impacts of financial risk costs on insurers' effective cost. First, regional insurers with significant risk charges face, on average, 9.8% higher costs than their observably risk-neutral national counterparts, due to the additional burden of financial risk. The additional reinsurance expenses and risk charges are passed through to prices, hindering smaller insurers' ability to compete effectively with larger, better-capitalized insurers. Second, risk charges account for at least half the margin between insurance premiums and marginal claims costs. In other words, financial risks are at least as important as market power in explaining high insurance prices for small regional insurers.

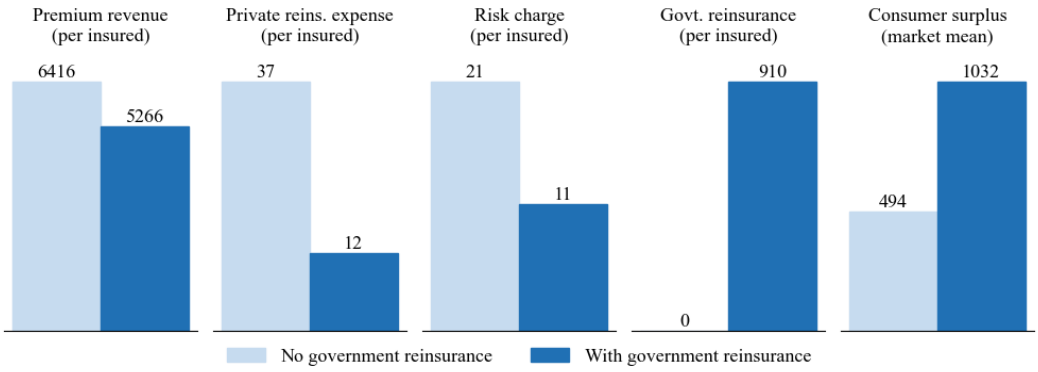
8. The Effectiveness and Design of Public Reinsurance

This section aims to understand how public reinsurance could effectively lower prices and improve welfare, and then shed light on optimal policy designs.

8.1. Simulated Policy Impacts.

As a validity check, we first simulate the effects of CO's public reinsurance.[25,26] Our main analysis focuses on the markets in the Tier 1 reinsurance region (i.e., the white areas in Figure 2b), which represents the most populous region in CO where most insurers operate in. Figure 7 reports key outcomes before and after the reinsurance program. Table A10 reports other equilibrium objects and other policy tiers.

Figure 7. Effect of public reinsurance



Notes: This figure plots the simulated equilibrium objects in the scenario with (in dark bars) and without (in light bars) government reinsurance for markets in reinsurance tier 1. The per-insured measure is averaged across all insurers.

Model simulations reassuringly align with event-study estimates in Section 5. Public reinsurance reduces health insurance prices by $1,150 per enrollee, 18% from the baseline. Simulated pass-through from public reinsurance expenses ($910 per enrollee) to price reduction is 1.26, consistent with our previous greater-than-one findings. Private reinsurance expenses fall by $25 per enrollee.

[25] Bright Health fell into liquidity issues in 2019. Hence, our simulation uses the estimated model primitives in 2018 to avoid the case that the estimated parameter reflects not only induced risk preferences but also other financial concerns of Bright Health.

[26] We use a simplified parametric assumption that consumers' types depend on age, but not risk quartiles. Estimates in Table A7 suggest that once we condition on age bins, the degree of selection is muted across risk bins. In addition, as discussed in Appendix C4, flexible selection patterns may introduce equilibrium convergence issues.

Turning to welfare outcomes, public reinsurance generates social surplus primarily through two channels. First, lower premiums encourage more consumers to enroll in insurance, generating additional gains from trade. On average, the annual surplus increases by $538 per member. Second, insurers facing risk charges benefit from improved certainty of profit across different enrollees' health realizations, similar to how insurance benefits the expected utility of risk-averse individuals. The combined effects of lower claims costs, reduced risk exposure, and expanded enrollment increase insurers' profits by $44 million. These gains in surplus persist even after accounting for the costs of public funds.

8.2. Why Reinsurance is Effective – Three Mechanisms.

Next, we use the model to examine how public reinsurance could effectively lower prices and improve welfare. We decompose the role of public reinsurance into distinct mechanisms, then use the decomposition to illustrate why reinsurance is particularly effective compared to other policy interventions.

Public reinsurance affects equilibrium outcomes through three main mechanisms. First, it lowers insurers' expected costs by directly subsidizing high claims expenses. Second, it reduces risk exposure by shielding insurers from cost fluctuations - captured by the standard deviations of costs in the model - thereby decreasing both risk charges and private reinsurance expenses. Third, it enhances competition by mitigating financial costs faced by regional insurers, allowing them to compete more effectively and exert greater downward pressure on market prices. To quantify the magnitude of each distinct mechanism, we conduct a series of counterfactuals.

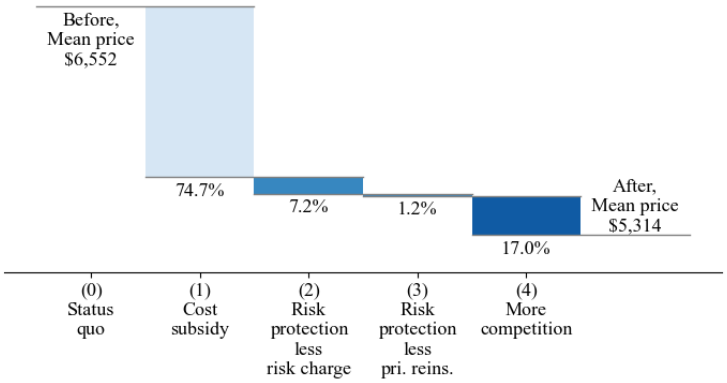
Figure 8 displays simulated premiums under each counterfactual. Table A11 reports the complete set of equilibrium statistics. The first counterfactual, denoted by (0), represents the baseline scenario without public reinsurance. The subsequent counterfactuals apply public reinsurance sequentially to regional insurers, who face significant financial risk costs, and then to national insurers, who largely do not face such costs. This allows us to separately quantify the cost reduction effect, which applies to all insurers, and the risk reduction effect, which applies only to regional insurers that face significant risk charges.

Our counterfactual (1) isolates the effect of public reinsurance on the expected claims of regional insurers. We compare the no-intervention benchmark with a situation in which the reinsurance policy affects only expected claims costs of regional insurers, but not the private reinsurance expenses or risk charges in insurers' profit functions, nor the claims costs of national insurers. We allow insurers to optimally choose prices but not private reinsurance purchases in response to this interim profit function. Under this counterfactual, reinsurance lowers expected claims costs for regional insurers by $958 per member. Moving from counterfactual (0) to (1), regional insurers lower their premium by $924, which accounts for 74.7% of the premium decreases of the regional insurers.

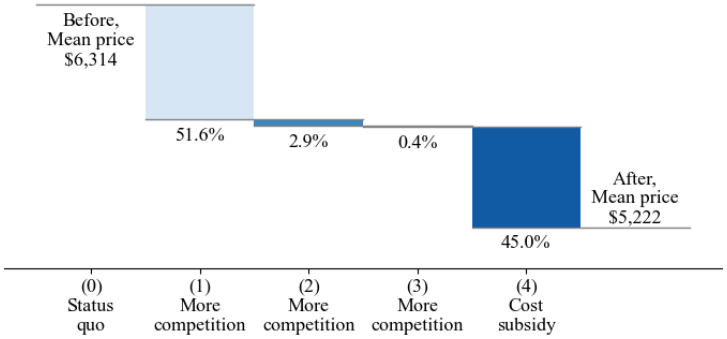
We then compute counterfactual (2), quantifying how public reinsurance lowers prices through lowering insurers' risk charges. We simulate a scenario where public reinsurance affects all cost components of regional insurers, including expected claims costs, private reinsurance expenses, and risk charges terms. We allow insurers to respond by only changing prices but not private reinsurance deductibles. Government risk-sharing lowers the probability that an enrollee's expenditure exceeds a given reinsurance reimbursement threshold, making insuring the tail risks cheaper in the private reinsurance market. This leads to a $26

Figure 8. Decompose the effect of public reinsurance on equilibrium prices

(a). Regional insurers



(b). National insurers



Notes: This figure plots simulated enrollment-weighted average prices in each counterfactual equilibrium (described in Section 8.2). The numbers denote the percentage of price reduction resulting from a particular scenario compared to the total price changes with and without government reinsurance.

reduction in private reinsurance expenses. Furthermore, by reimbursing the tail risks of claims costs, the standard deviation of total claims costs also drops, leading to a $223 reduction in risk charge. Together, these forces lead to an extra 7.2% of premium reduction of regional insurers, or $89 per insured. Given adverse selection in the market, the decreases in premiums in counterfactual (2) attract more price-elastic, healthy consumers to enroll, further reducing claims costs paid by insurers by $11.

Next, we compute counterfactual (3), measuring how adjustments in the amount of private reinsurance purchased in response to public reinsurance affect prices. We simulate a scenario where public reinsurance affects all cost components of regional insurers, and we allow insurers to choose both price and private reinsurance purchases optimally. Since public reinsurance reduce insurers' need for using the private option to lower their risk level, expenses on private reinsurance further drop by $42 per consumer from counterfactual (2) to (3). However, substituting away from private coverage also leads to an offsetting effect, where per-member claims costs and risk charges rise slightly by $24 and $15 due to reduced risk-offloading. The combined effect of reduced private reinsurance expenditures and increased claims costs and risk charges lowers premiums by $14 per consumer, or 0.4%.

Notably, even without receiving any reinsurance, national insurers' premiums decline by 55% from the

baseline under scenario (3). This underscores how public reinsurance intensifies competition by reducing risk charges faced by regional insurers, which in turn exerts downward pricing pressure for national insurers.

Finally, we compute counterfactual (4) to illuminate the overall equilibrium effects. This scenario corresponds to the equilibrium model in Section 6, where the reinsurance policy affects cost components of all insurers, and insurers optimally choose both price and private reinsurance purchases in response. The difference between counterfactuals (3) and (4) highlights the effect of public reinsurance on expected claims of national insurers. Similar to the change from counterfactual (0) to (1), public reinsurance reduces average claims expenses by $567 per member for national insurers. Consequently, national insurers lower prices by $491 per insured, which accounts for 45% of their premium decreases. The intensified competition, in turn, pushes down prices of regional insurers by $210, accounting for 17.0% of premium decreases.

Taken together, upon the initiation of public reinsurance, reductions in expected claims costs, risk mitigation, and competitive effects account for 74.6%, 8.4%, and 17.0% of premium decreases for regional insurers that face risk charges. For national insurers that do not face such cost, expected claims cost reduction and competitive effects explain 55.0% and 45.0% of the price reduction.

We further use the decomposition exercise to speak to why reinsurance is uniquely effective.

First, by contrasting counterfactuals (1) and (3), we can illustrate the difference between ex-ante risk adjustments and ex-post reinsurance. Although both risk adjustment and reinsurance are transfers to insurers that change the means of an enrollee's expected costs, i.e., the effects achieved in counterfactual (1), a significant difference is that ex-ante risk adjustment does not change the dispersion of the enrollee's cost distribution while ex-post reinsurance does. The extra risk protection, i.e., shielding insurers from tail-end medical risks, further brings down effective marginal costs and makes reinsurance more effective. Our simulations confirm this for the same amount of expenses on risk adjustment or reinsurance.

Second, comparing counterfactuals (3) and (4) shows that if the government only provides reinsurance to regional insurers, they could achieve 75% of price reduction and 61% of consumer surplus gains, compared to the case where reinsurance is offered to all insurers. Providing risk offloading to regional insurers reduces their expenses on private reinsurance and risk charges, which are passed through to prices. This puts downward pricing pressure on national insurers, further lowering the equilibrium prices. Thus, for regulators with limited budgets, addressing risk distortions for only small market participants could be a cost-effective way to improve the functioning of insurance markets.

Finally, comparing counterfactuals (1) and (4) reveals what would happen if the government charges an actuarially fair price for public reinsurance. As insurers pay to reduce their cost dispersion, the cost subsidy, i.e., effects achieved in counterfactual (1), diminishes. Yet the risk reduction and competitive effects, i.e., those achieved in counterfactuals (2)-(4), still persist and drive down equilibrium prices. Therefore, even if the regulator operates an ex-ante budget-neutral reinsurance program, the equilibrium prices would still decrease by about a quarter – budget-neutral public reinsurance creates surplus by smoothing out fluctuations in profits for insurers.

To summarize, our analysis indicates that the cost burdens of financial risks can be a significant distortion that drives up premiums for smaller market participants. Addressing these supply-side frictions makes public reinsurance a uniquely effective strategy for fostering competition and providing affordable insurance to

consumers.

8.3. Sensitivity to Moral Hazard and Insurer Entry.

We inspect the sensitivity of model predictions to various primitives fixed in the baseline analysis: insurer moral hazard and entry.

We begin by allowing insurers to respond to the government's risk-sharing policies in cost-containment activities. Suppose the initiation of public reinsurance makes insurers perform fewer utilization controls or exert less effort to bargain with medical providers. In that case, we expect total claims for consumers in the same risk type to increase after implementing the policy. Hence, insurers' moral hazard mitigates the claims reduction effect of public reinsurance and the risk reduction effect due to extended tails. Welfare gains from public reinsurance are attenuated. Figure A6 plots how equilibrium statistics change with the degree of cost inflation. If insurers inflate costs by 2.5%, the greater-than-one pass-through will flip. If insurers inflate costs by 10%, reductions in equilibrium price shrink by 36%; consumer surplus gains shrink by 40%.

We also consider how public reinsurance might affect insurers' entry and exit patterns. While our event-study estimates in Section 5.2 do not find statistically significant evidence that initiating public reinsurance encourages insurer entry, Kong et al. (2024) finds that terminating public reinsurance induces insurer exit. Since public reinsurance increases insurers' profits through reduced effective costs and expanded enrollment (shown in Section 8.1), entry of more players is theoretically possible. We thus simulate a scenario where public reinsurance induces a hypothetical small insurer to enter the market. In that case, our baseline analysis understates consumer surplus gains by 2%.

8.4. Bang-for-buck Analysis.

The allocation of healthcare funds has been the subject of intense policy debate. Given limited state budgets, it is critical to understand whether public reinsurance meets or exceeds previous state-run efforts to bring down prices and stabilize markets.

We therefore use our model to investigate the effectiveness of public reinsurance versus premium subsidies, a prevalent regulatory tool.[27] Policymakers have expressed direct concerns about the low pass-through of transfers to insurers compared to that of consumers (Liebling, 2017). Their relative efficiency is an empirical question, shaped by the degree of risk frictions insurers face and the curvature of consumer demand.[28]

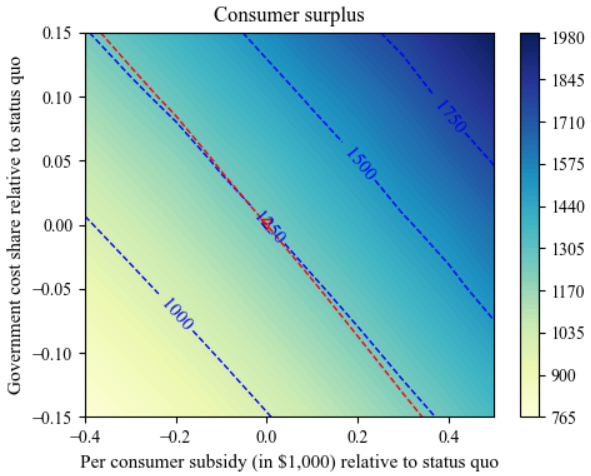
First, reinsurance provides risk-offloading for insurers, which lowers their risk charges and private reinsurance expenses. In contrast, premium subsidies do not change the dispersion of claims costs that insurers face, thus not affecting additional risk expenses for the same consumer. Besides cost subsidies, reinsurance reduces insurers' extra charges for taking on risks, further shifting down the effective marginal cost curve. This implies that, to achieve the same level of enrollment absent selection, spending on reinsurance transfers is less than uniform demand-side subsidies, which leaves risk dispersions unaffected.

Second, when adverse selection is present, reinsurance also flattens marginal cost curves by compressing variation in claims costs across risk types. The flattening could raise markups, as documented in Starc (2014); Mahoney and Weyl (2017). The marginal consumer is cheaper than the average consumer and is

[27] The comparison between reinsurance and risk adjustment, another population regulatory tool, is discussed in Section 8.2.

[28] Appendix C5 formalizes a theoretical model that derives the relative efficiency between reinsurance and premium subsidies.

Figure 9. Consumer surplus under alternative policy scheme



Notes: This figure reports the average consumer surplus under different policy regimes relative to the status quo, as reported on the horizontal and vertical axes. A darker color denotes higher consumer surplus relative to the status quo, labeled as the red triangle. Blue dashed lines are iso-utility curves. The red dashed lines are iso-cost curves where the government's total expenses on reinsurance transfers and premium subsidies are the same as the status quo.

relatively attractive to cover in an adverse selection market. This exerts downward pressure on prices and markups, as insurers are more resistant to increasing prices because the marginal buyers they would lose as a result are relatively cheaper and therefore more attractive to retain. Mitigating selection reduces the pressure on prices and leads to higher markups, partly offsetting cost cuts from risk-offloading.

Figure 9 reports consumer surplus when we perturb both the government's cost-shares in the public reinsurance program and premium subsidies transferred to consumers. Moving along the iso-cost (red) curves, as the government reallocates premium subsidies to reinsurance transfers, consumer surplus jumps to higher levels of iso-utility (blue) curves.[29] This is because distortions from the extra costs of risk bearing dominate under current market conditions, such that allocating transfers to insurers ex-post is more efficient than transfers to consumers.

These simulations demonstrate that reinsurance transfers are at least as effective as premium subsidies in improving consumer welfare. Given a limited state budget, public reinsurance programs could be an effective regulatory tool to improve the functioning of the insurance market and consumer welfare. They also highlight the importance of properly accounting for insurers' risk bearing and associated risk charges. Ignoring the risk protection benefits from ex-post supply-side transfers would give misleading recommendations on the relative effectiveness of each regulatory tool.

9. Discussion and Conclusion

This paper examines the crucial role of public risk sharing through reinsurance in insurance markets, developing a novel framework in which firms explicitly internalize the cost of financial risk due to cost uncertainty. Applying this to the U.S. individual health insurance market, we first document that health insurers actively manage risk, with a high proportion purchasing private reinsurance despite significant markups. Through

[29] One caveat is that our model does not explicitly incorporate risk-adjustment transfers. To the extent that omitting such transfers overestimates the selection insurers face, we interpret our results as conservative estimates, as shown in Appendix C5.

an event study, we then show that the free provision of public reinsurance leads to a significant reduction in private reinsurance purchases and a substantial fall in premiums.

Our equilibrium model further clarifies these impacts: public reinsurance lowers insurers' expected costs and their cost of financial risk, a burden particularly pronounced for smaller, regional insurers who face higher costs due to risk charges and private reinsurance expenses. By mitigating these costs, public reinsurance significantly enhances their ability to compete, thereby strengthening market competition. These combined effects not only explain an additional quarter of the observed price reductions but also demonstrate that public reinsurance is an efficient regulatory scheme, outperforming traditional premium subsidies in lowering prices and improving consumer surplus. This implies that ignoring the risk protection benefits from ex-post supply-side transfers can lead policymakers to significantly underestimate the full value of reinsurance.

While our study focuses on reinsurance's direct impact on risk reduction and premium pass-through, it abstracts from other potential effects. Reinsurance may alter insurer incentives for risk selection through marketing or benefit design, or decrease incentives for cost control. Although our initial findings show no immediate impacts in these areas, future work could explore longer-term insurer responses to better capture these tradeoffs and to study optimal public risk-sharing.

Beyond these specific extensions, our framework and its insights can be applied to other insurance markets. By explicitly modeling how firms internalize cost uncertainty, our work provides new insights into the role of public risk-sharing. The same principles extend to other markets increasingly exposed to severe and volatile risks, such as floods, wildfires, hurricanes, or property and casualty insurance (Boomhower et al., 2024). In these contexts, the threat of large, correlated cost shocks that may be hard to reinsure privately can drive substantial premium increases or even force market exits, leaving consumers underinsured or uninsured. Our results suggest that well-designed government risk-sharing programs, such as reinsurance, can meaningfully reduce firms' financial risk burdens, lower prices, and sustain market participation, thereby improving access in the face of growing risk. This highlights the value of reinsurance as a tool for emerging challenges such as wildfire coverage (Araullo, 2025) and flood protection (Panteloucos, 2024).

Ultimately, our findings underscore the importance of designing insurance market policies with firms' financial risk exposure in mind. Supply-side interventions that address firms' cost of risk can complement or even outperform traditional premium subsidies, offering a more efficient path to improved consumer welfare. For policymakers, this highlights the critical value of ex-post risk-sharing tools to preserve competition, affordability, and market stability as risk landscapes continue to evolve. Future work could build on this framework to examine how public and private reinsurance interact with climate change or other emerging risks, providing a richer basis for designing resilient and equitable insurance markets.

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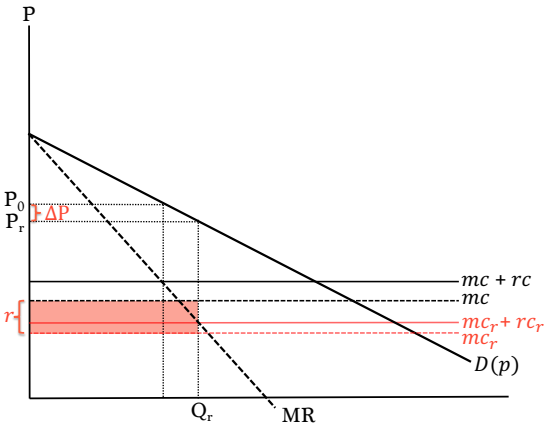
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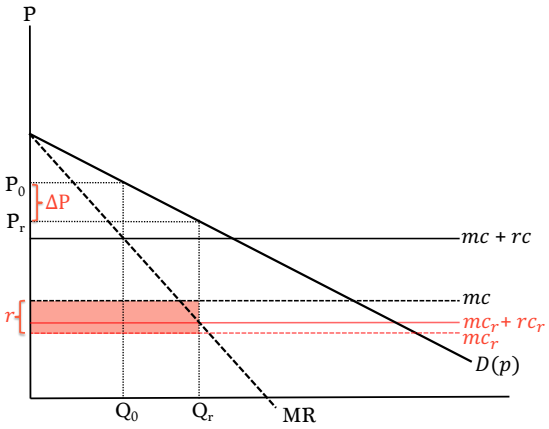
A. Supplementary Figures and Tables

Figure A1. Pass-through of Reinsurance

(a). Small Change in Risk Charge



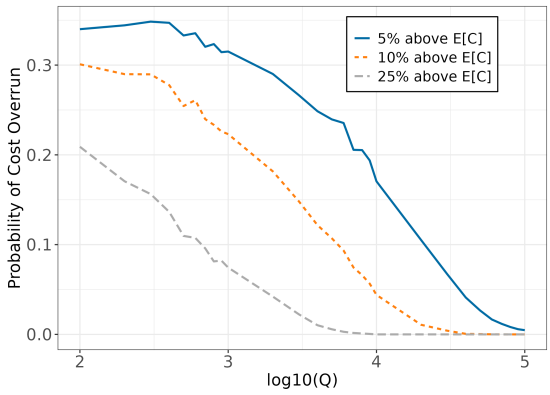
(b). Large Change in Risk Charge



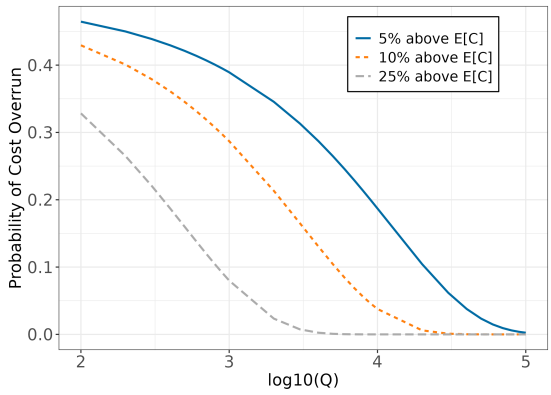
Notes: This figure illustrates the change in equilibrium price in response to reinsurance subsidy in a linear demand setting. The insurer sets the equilibrium price by equalizing the marginal revenue and the effective marginal costs. ΔP plots the changes in equilibrium price before and after public insurance. Black lines are costs before public reinsurance, and red lines correspond to costs after public reinsurance. r denotes government expenses of public reinsurance, which equal changes in expected claims liabilities. The red shaded area denotes total public reinsurance expenses. The dashed marginal cost lines (mc) correspond to expected claims liabilities. The solid marginal cost lines correspond to effective marginal cost, which equals claims costs (mc) plus risk charges (rc). The vertical distance between the solid and the dashed lines denotes insurers' risk charges (rc), or the degree of financial frictions. Panel (a) plots a case where changes in risk charge are small, as the vertical distance between the solid and dashed lines before and after public reinsurance does not change much. In contrast, panel (b) displays a case where changes in risk charge are large before and after public reinsurance. Panel (a) shows a case where the relative magnitude of change in risk charge is small, leading to a pass-through of less than one ($\Delta P < r$). Panel (b) shows a case where the relative magnitude of change in risk charge is large, leading to a pass-through of larger than one ($\Delta P > r$).

Figure A2. Illustration of tail-end risks

(a). Probability of cost overrun (empirical distribution)



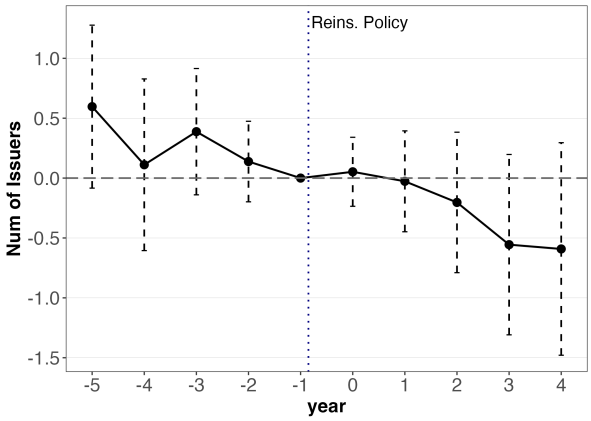
(b). Probability of cost overrun (approximated distribution)



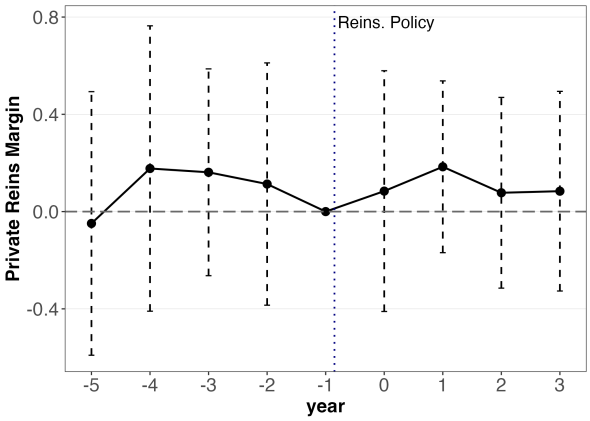
Notes: This figure shows the probability that realized claims exceed a given percentage of expected costs by enrollee size. We sample the number of enrollees (x-axis) from the empirical distribution of realized claims for panel (a) or the normal approximated distribution of total realized claims for panel (b). We then aggregate the costs of sampled enrollees and compare them to expected costs from the same distribution. The claims data comes from CO APCD, and we restrict the sample to the 2019 exchange market.

Figure A3. Effect of state reinsurance subsidies on number of insurers, private reinsurance margin

(a). Number of insurers



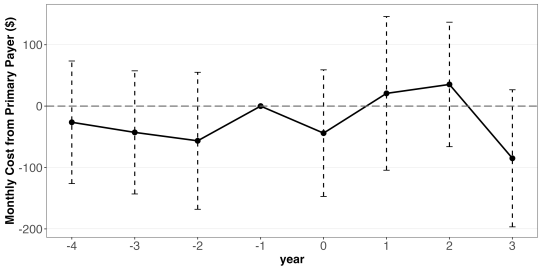
(b). Private reinsurance margin



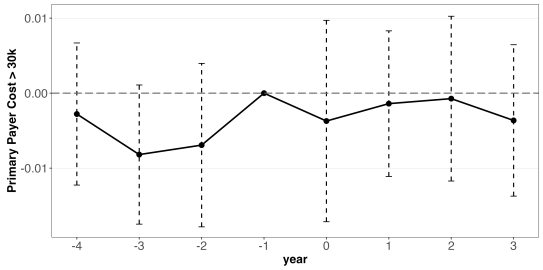
Notes: This figure reports point estimates and 95% confidence interval of the effect of state reinsurance from the estimation of equation (7). The outcome variable is the number of insurers in a rating region in panel (a), and private reinsurance margin, defined as difference in premiums to claims over premiums, in panel (b). The regression sample includes all insurers nationwide that have positive health premium income and offer products on the individual exchange market. The regeression is at the rating region-year level in 2014-2024 for panel (a), and insurer-state-year level in 2014-2022 for panel (b). The regression includes rating region (or insurer-state), and year fixed effects. Standard errors are clustered at the state level for all panels.

Figure A4. Effect of public reinsurance subsidies on medical expenses

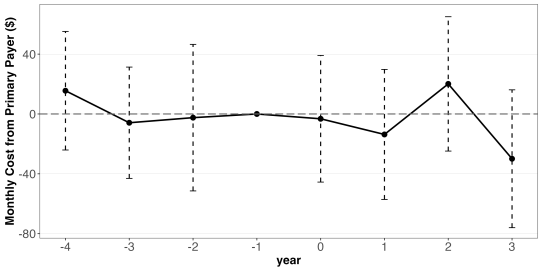
(a). Monthly expenses, across reinsurance tiers



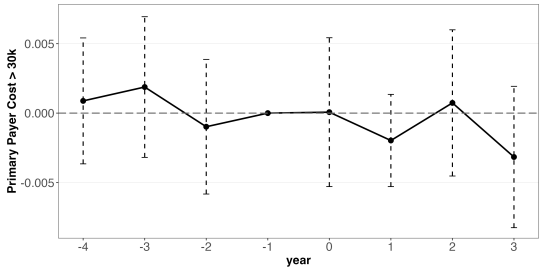
(b). Total expenses above threshold, across reinsurance tiers



(c). Monthly expenses, across market segments

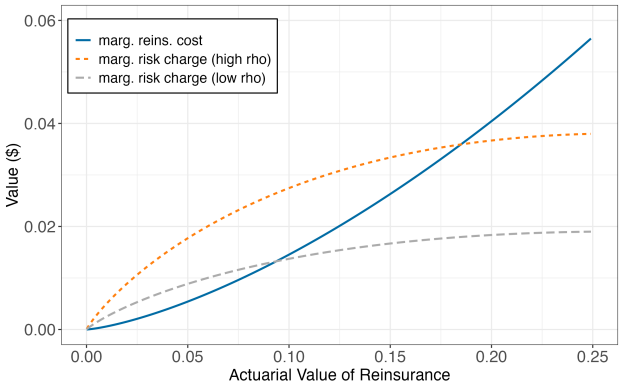


(d). Total expenses above threshold, across market segments



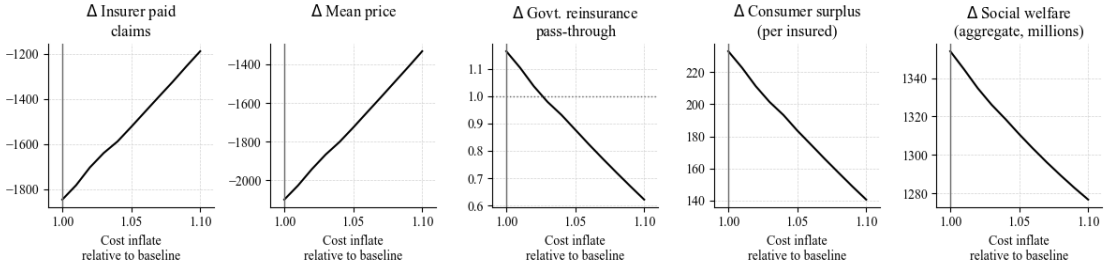
Notes: This figure reports point estimates and 95% confidence interval of the effect of state reinsurance on medical expenses from the estimation of equation (A21). The outcome variable is monthly medical expenses per enrollee in panels (a) and (c), and whether the enrollees' annual expenses exceed the reimbursement threshold of the public reinsurance program in panels (b) and (d). We restrict to individual-year units that only report one payer for medical coverage. Panels (a)-(b) include individuals that were part of the exchange and remained in the exchange for all years in 2016-2023. The treatment indicator is whether the individual's county is in the highest two tiers of public reinsurance cost-shares. Panels (c)-(d) include individuals that were part of the exchange or commercial (i.e., fully-insured small and large group) market, and remained in the same market segment for all years in 2016-2023. The treatment indicator is whether the individual's market segment in a specific year has public reinsurance in place. All regressions control for individual, year, county, market segment-insurer fixed effects. Standard errors are clustered at the county level.

Figure A5. Identification of risk preference parameter



Notes: This figure illustrates the identification of risk preferences parameters ρ_{ft}. The horizontal axis converts the reinsurance deductible κ_{ft} into the actuarial value of reinsurance contracts, or the claims reduction brought by the reinsurance contracts. The lines displayed are simulated marginal benefits or costs for reinsurance contracts, taking the markup $\tau = 1.5$ and the health distribution of risk bin 4. The blue solid line displays the left-hand side of equation (22), i.e., the marginal markup over claims cost reduction. The yellow and grey dashed line corresponds to the right-hand side, the marginal risk charge reduction for the same underlying cost distribution but high and low risk preferences, respectively. The intersection of the variance reduction and reinsurance markup curves, i.e., how much private reinsurance coverage an insurer buys, pins down the risk preference parameter.

Figure A6. Effect of public reinsurance subsidies, sensitivity to moral hazard



Notes: This figure plots simulated equilibrium prices under different reinsurance markup, using market primitives estimated in 2019. The simulation sample and specifications other than cost inflation percentage are the same as Figure 7. The averages are enrollment-weighted. The vertical dashed line denotes the status quo degree of moral hazard.

Table A1. State reinsurance programs

State	Initiation Year	Program Structure
AK	2018	Covers claims costs for one or more of 33 conditions specified in state regulation.
CO	2020	Covers 15%-35% of claims costs between $30k and $400k per consumer. The coinsurance rate depends on rating areas.
DE	2020	Covers 20% of claims costs between $65k and $335k per consumer.
GA	2022	Covers 15%-80% of claims costs between $20k and $500k per consumer. The coinsurance rate depends on rating areas.
ID	2023	Covers 70% of claims costs between $50k and $665k per consumer.
ME	2019	Covers 10% of claims costs between $65k and $95k.
MA	2019	Covers 20% of claims costs between $20k and $250k per consumer.
MN	2018	Covers 20% of claims costs between $50k and $250k per consumer.
MT	2020	Covers 40% of claims costs between $40k and $101.75k per consumer.
NH	2021	Covers 26% of claims costs between $60k and $400k per consumer.
NJ	2019	Covers 50% of claims costs between $35k and $245k per consumer.
ND	2020	Covers 25% of claims costs between $100k and $1000k per consumer.
OR	2018	Covers 50% of claims costs between $83k and $1000k per consumer.
PA	2021	Covers 40% of claims costs between $60k and $100k per consumer.
RI	2020	Covers 70% of claims costs between $40k and $155k per consumer.
VA	2023	Covers 50% of claims costs between $30k and $72k per consumer.
WI	2019	Covers 53% of claims costs between $40k and $175k per consumer.

Notes: This table reports the reinsurance program structure in the initial program year by state. Source: CMS (2024).

Table A2. Structure of the CO Reinsurance Program

Year	2020	2021	2022	2023
Planned reinsurance payment (in millions)	250	262	267.7	308
Realized reinsurance payment (in millions)	229.1	237.6	272.5	-
Attachment point	30,000	30,000	30,000	30,000
Cap	400,000	400,000	400,000	400,000
Coinsurance rate				
tier 1 (rating areas 1, 2, 3)	40%	40%	43%	42%
tier 2 (rating areas 4, 6, 7, 8)	45%	45%	50%	47%
tier 3 (rating areas 5, 9)	80%	80%	73%	72%

Notes: This table reports the structure of CO's public reinsurance programs. The attachment point and cap are the same across all policy tiers. Source: CMS (2024).

Table A3. Sample statistics, consumers in CO exchange

	(1) 2017	(2) 2018	(3) 2019	(4) 2020
Total insured	201,209	206,416	222,562	229,946
Market size	534,615	552,661	599,767	635,865
Number of insurers per county, mean	6.9	4.0	3.9	4.4
	(1.1)	(1.4)	(1.1)	(1.2)
(a). Annual premiums ($)				
Out-of-pocket premium, mean	3,305	4,112	3,911	3,420
	(3,602)	(4,286)	(4,128)	(2,658)
Full premium, mean	5,096	6,985	7,438	5,755
	(3,517)	(3,790)	(3,757)	(2,399)
(b). Realized annual medical expenses ($)				
Total annual expenses, mean (without reins. payment)	4,020	4,461	4,925	4,572
	(23,715)	(29,700)	(31,791)	(28,711)
Expenses paid by insurers, mean (without reins. payment)	3,213	3,577	3,926	3,716
	(23,127)	(29,173)	(31,233)	(28,069)
_, 25th percentile	0	0	0	0
_, 50th percentile	246	247	280	202
_, 75th percentile	871	860	945	796
_, 99th percentile	61,111	69,551	75,286	73,874
_, 99.9th percentile	248,671	281,664	287,448	309,385
(c). Counterfactual annual medical expenses with public reinsurance ($)				
Share enrollees above reins. attachment point ($30,000)	2.21%	2.45%	2.80%	2.54%
Share enrollees above reins. cap ($400,000)	0.04%	0.05%	0.05%	0.06%
Expenses paid by insurers, mean (with public reinsurance)	2,668	2,909	3,174	2,966
	(18,455)	(24,631)	(26,579)	(22,363)
_, 25th percentile	0	0	0	0
_, 50th percentile	246	247	280	202
_, 75th percentile	871	860	945	796
_, 99th percentile	45,811	49,687	52,708	51,315
_, 99.9th percentile	152,795	170,393	174,987	182,702

Notes: Standard errors are reported in parethesis. Data comes from CO APCD claims records and C4HC enrollment records.

Table A4. Effects of public reinsurance, robustness

	Logarithm of premiums		Prob. having private reins.		Per member expense private reins.	
	Coeff	Std	Coeff	Std	Coeff	Std
(1) Baseline	−0.137	(0.038)	−0.260	(0.132)	−19.428	(9.342)
(2) Alternative outcome: benchmark premium	−0.118	(0.045)				
(3) Alternative outcome: average silver premium	−0.121	(0.046)				
(4) Alternative level: rating region-year level	−0.154	(0.031)				
(5) Alternative level: NAIC insurer-state-year level	−0.124	(0.051)				
(6) Alternative level: NAIC insurer-year level			−0.231	(0.108)	−18.908	(10.314)
(7) Alternative estimator: Callaway and Sant'Anna (2021)	−0.191	(0.096)	−0.153	(0.102)	−8.229	(13.058)
(8) Alternative estimator: Borusyak et al. (2024)	−0.136	(0.024)	−0.171	(0.067)	−12.243	(4.316)

Notes: This table reports the point estimates and standard errors (in parenthesis) on the robustness of the effect of state reinsurance subsidies. The regression sample and specification are the same as that of Table 2, except for the tweaks specified in each row.

Table A5. Effects of state reinsurance subsidies on the logarithm of average premiums, by metal tiers

	(1) Catastrophic	(2) Bronze	(3) Silver	(4) Gold	(5) Platinum
reinsurance policy	-0.124^{**}	-0.163^{***}	-0.138^{***}	-0.192^{***}	-0.298^{***}
	(0.052)	(0.037)	(0.039)	(0.038)	(0.038)
Observations	3,925	4,574	4,574	4,570	1,940
Baseline Mean	380	523	674	760	909

Notes: This table reports the point estimates and standard errors (in parenthesis) on the effect of state reinsurance subsidies on the logarithm of monthly premiums, by plans' metal tiers. Catastrophic is a stop-loss plan, while Bronze, Silver, Gold, and Platinum correspond to plans with 60%, 70%, 80%, and 90% cost-sharing levels. The sample includes all states, except for 6 states (DC, IL, IN, MS, TX, WV) whose silver loading policies are unclear, in 2014-2024. All specifications include rating-region and year-fixed effects. To control for the differential silver loading policies on premiums, we allow the year-fixed effects to differ by state groups, where each group has separate silver loading policies. Standard errors are clustered at the state level. *, **, ***denote statistical significance at the 10%, 5%, and 1% level, separately

Table A6. Effect of public reinsurance in CO

	(1)	(2)	(3)	(4)	(5)	(6)
	logarithm of premiums		Per member month claim cost		Probability of member cost $>$ 30k	
reinsurance policy	-0.307^{***}	-0.276^{***}	-8.477		-0.001	
	(0.024)	(0.026)	(9.212)		(0.001)	
reinsurance policy $\times$ Tier 2		-0.0003				
		(0.027)				
reinsurance policy $\times$ Tier 3		-0.199^{***}				
		(0.028)				
reinsurance policy $\times$ Tier 2 or 3				12.212		0.002
				(26.792)		(0.004)
N	12,601	12,601	1,374,888	75,048	1,374,888	75,048
Baseline mean	642	642	393	391	0.029	0.03

Notes: This table reports the point estimates and standard errors (in parenthesis) on the effect of reinsurance programs from the estimation of differences-in-differences version of equation (8), and (A21). The regeression is at the insurer-rating region-year level in 2014-2024 for Columns (1)-(2), and individual-year level in 2016-2023 for Columns (3)-(6). For columns (1)-(2), the regression sample and specification is the same as that of Figure 5b. For columns (3)-(6), the regression sample and specification is the same as that of Figure A4. Standard errors are clustered at the rating area level for columns (1)-(2), and at the county level for columns (3)-(6). *, **, *** denote statistical significance at the 10%, 5%, and 1% level, separately.

Table A7. Consumer preferences parameter estimates

	(1)	(2)	(3)	(4)
(a). Demand estimation, first step MLE estimates				
Coefficient on premium (in $1,000), risk bin 1	-0.268 (0.003)	-1.221 (0.003)	-0.724 (0.003)	-0.813 (0.003)
Coefficient on premium (in $1,000), risk bin 2	-0.165 (0.002)	-1.200 (0.003)	-0.575 (0.003)	-0.650 (0.003)
Coefficient on premium (in $1,000), risk bin 3	-0.181 (0.005)	-0.052 (0.005)	-0.261 (0.006)	-0.212 (0.006)
Coefficient on insured option, risk bin 1	-2.969 (0.006)		-2.612 (0.007)	-2.591 (0.007)
Coefficient on insured option, risk bin 2	-3.238 (0.007)		-3.047 (0.007)	-3.068 (0.007)
Coefficient on insured option, risk bin 3	0.707 (0.020)		0.950 (0.020)	0.741 (0.022)
Coefficient on deductible (in $1,000), risk bin 1	0.143 (0.001)		0.072 (0.001)	
Coefficient on deductible (in $1,000), risk bin 2	0.133 (0.001)		0.072 (0.001)	
Coefficient on deductible (in $1,000), risk bin 3	-0.010 (0.003)		-0.034 (0.003)	
Standard deviation of random coefficient on price		0.414 (0.002)	0.505 (0.002)	0.486 (0.002)
Standard deviation of random coefficient on insured option				0.865 (0.003)
(b). Demand estimation, second step OLS estimates				
Coefficient on premium (in $1,000), age below 34	-2.058 (0.066)	-3.014 (0.123)	-2.436 (0.103)	-2.708 (0.109)
Coefficient on premium (in $1,000), age 35-54	-1.446 (0.049)	-1.830 (0.090)	-1.453 (0.075)	-1.632 (0.080)
Coefficient on premium (in $1,000), age above 55	-0.841 (0.031)	-0.636 (0.057)	-0.447 (0.049)	-0.534 (0.051)
(c). Implied mean semi-elasticity to own premium				
Age below 34	-2.01	-7.81	-6.46	-6.93
Age 35-54	-1.41	-4.51	-3.76	-4.01
Age above 55	-0.81	-1.88	-1.62	-1.69
Age below 34, risk bin 1	-2.21	-8.97	-7.28	-7.87
Age below 34, risk bin 2	-2.12	-8.93	-7.06	-7.62
Age below 34, risk bin 3	-1.86	-6.43	-5.69	-6.00
Age below 34, risk bin 4	-1.75	-6.39	-5.42	-5.81
Age 35-54, risk bin 1	-1.61	-5.45	-4.40	-4.73
Age 35-54, risk bin 2	-1.51	-5.41	-4.21	-4.53
Age 35-54, risk bin 3	-1.32	-3.54	-3.29	-3.42
Age 35-54, risk bin 4	-1.20	-3.49	-3.06	-3.25
Age above 55, risk bin 1	-0.99	-2.61	-2.08	-2.22
Age above 55, risk bin 2	-0.89	-2.58	-1.94	-2.07
Age above 55, risk bin 3	-0.79	-1.41	-1.45	-1.47
Age above 55, risk bin 4	-0.66	-1.37	-1.27	-1.32

Notes: This table reports demand estimates from different specifications (reported in each column). Standard errors (in parentheses) are derived using the delta method. The second stage demand estimation controls for market (county-year)-product (insurer-metal) fixed effects and market-age fixed effects. The fixed effects absorb the coefficient on the insured option and deductible in the second step, as all age groups face the same product financial attributes. Risk bins are four quartiles based on the predicted risk scores using claims from previous years. The omitted risk bin in the first stage is the last (sickest) quartile.

Table A8. Estimated marginal cost multiplier

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Across all markets					By reins. policy tiers		
	Weighted					weighted mean		
Insurer	mean	Mean	Std.	Min	Max	tier 1	tier 2	tier 3
Insurer A	1.956	2.076	(0.324)	1.209	2.812	1.893	2.074	2.515
Insurer B	2.927	2.727	(0.763)	1.019	4.400	2.478	2.670	3.292
Insurer C	2.159	2.236	(0.123)	2.129	2.484	2.159	-	-
Insurer D	3.124	3.107	(0.137)	2.981	3.298	-	-	3.124
Insurer E	2.037	2.054	(0.030)	2.020	2.119	2.037	-	-
Insurer F	2.839	2.609	(0.625)	1.005	3.580	2.281	2.940	3.549
Insurer G	1.906	2.146	(0.501)	1.438	3.093	1.881	-	2.586

Notes: This table reports the summary statistics of the estimated marginal cost multiplier by insurer in 2018. The marginal cost multiplier is estimated at the insurer-product (county-year-metal) level, and we summarize those estimates into moment statistics for ease of reporting. Columns (1)-(5) report statistics across all markets, while columns (6)-(8) report statistics for each reinsurance policy tier (described in Figure 2b). Columns (1) and (6)-(8) report enrollment weighted means. The dashed line means the insurer does not operate in the policy tier regions.

Table A9. Estimates of private reinsurance deductible and risk preferences, robustness

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Private reins.	Coeff. of	mean per member price/cost				Share over total premium		
Insurer	deductible (κ_f)	risk charges (ρ)	Premium	Medical claims	Private reins.	Risk charge	Medical Claims	Private reins.	Risk charge
(a). Alternative insurer objective functions									
Insurer A	-	0.000	6,378	5,711	0	0	89.66%	0.00%	0.00%
Insurer B	-	0.000	9,875	8,595	0	0	87.04%	0.00%	0.00%
Insurer C	4.13	0.080	6,934	6,266	22	82	90.51%	0.32%	1.18%
Insurer D	4.71	0.070	11,598	10,612	50	169	91.69%	0.43%	1.46%
Insurer E	0.84	0.395	6,338	5,514	190	227	87.11%	3.00%	3.59%
Insurer F	1.02	0.327	10,674	8,884	323	393	83.37%	3.03%	3.69%
Insurer G	0.71	0.469	5,931	5,081	186	218	85.77%	3.15%	3.69%
(b). Alternative consumer types									
Insurer A	-	0.000	6,378	5,030	0	0	89.52%	0.00%	0.00%
Insurer B	-	0.000	9,875	8,771	0	0	96.42%	0.00%	0.00%
Insurer C	7.35	0.842	6,934	5,713	22	143	85.29%	0.33%	2.13%
Insurer D	4.24	0.451	11,598	10,257	60	753	77.24%	0.45%	5.67%
Insurer E	1.50	0.525	6,338	5,177	190	413	84.95%	3.11%	6.77%
Insurer F	1.49	1.321	10,674	7,881	323	691	84.07%	3.45%	7.37%
Insurer G	1.34	1.625	5,931	4,627	186	384	82.79%	3.33%	6.86%

Notes: This table reports insurers' estimated private reinsurance deductibles and risk preferences under alternative model specifications. We use the variance of total claims in insurers' objective functions, Instead of the standard deviation, to capture extra costs from financial risks in panel (a). We define consumer types to age bins by risk quartiles, instead of age bins in panel (b). The reinsurance deductible in Column (1) is reported in millions. Columns (1)-(2) are parameter estimates; Column (3) is observed data; and Columns (4)-(9) are derived statistics. The estimation procedure requires Column (5) to match observed data as moments. The averages reported are enrollment-weighted.

Table A10. Effect of public reinsurance

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	All markets		Policy tier 1		Policy tier 2		Policy tier 3	
	Before	After	Before	After	Before	After	Before	After
(a). Market mean (per insured)								
Price	7,244	5,836	6,416	5,266	8,147	6,408	10,748	7,597
Claims costs	6,461	5,056	5,765	4,739	7,156	5,588	9,493	5,776
Private reinsurance expenses	37	10	37	12	51	12	20	1
Risk charge	10	5	21	11	62	29	26	11
Public reinsurance expenses	0	1,407	0	910	0	1,368	0	3,598
Premium subsidy expenses	3,994	3,697	3,330	3,064	4,855	4,282	6,624	5,709
(b). Market mean (per consumer)								
Consumer surplus	496	1,249	494	1,032	459	1,225	558	2,454
Insured rate	0.36	0.78	0.37	0.75	0.33	0.81	0.36	0.94
Total number of insured	147,965	320,912	105,048	211,873	24,358	59,927	18,560	49,112
Total number of consumers	409,115	409,115	282,653	282,653	74,201	74,201	52,261	52,261
(c). Aggregate welfare (total, in millions)								
Consumer surplus	203	511	202	422	188	501	228	1,004
Insurer profit, including risk charges	109	245	62	107	21	47	22	89
Insurer profit, excluding risk charges	110	247	65	109	23	48	23	89
Reinsurer profit	2.17	1.27	1.53	0.97	0.49	0.28	0.15	0.03
Public reinsurance expenses	0	451	0	193	0	82	0	177
Premium subsidy expenses	591	1,186	350	649	118	257	123	280
Charitable care expenses for uninsured	781	200	526	163	152	31	103	6

Notes: This table reports simulated equilibrium statistics before and after CO's public reinsurance program. Averages in the table are enrollment-weighted.

Table A11. Decompose the effect of public reinsurance

	Policy tier 1, Counterfactual					All markets, Counterfactual				
	(0)	(1)	(2)	(3)	(4)	(0)	(1)	(2)	(3)	(4)
(a). Risk-averse insurers (average per insured)										
Price	6,552	5,628	5,539	5,524	5,314	7,073	6,131	6,040	6,025	5,635
Claims costs	5,823	4,865	4,854	4,878	4,765	6,239	5,113	5,116	5,148	5,008
Private reins. expenses	86	96	60	18	24	108	130	69	19	27
Risk charge	352	219	129	144	161	321	185	106	118	136
(b). Risk-neutral insurers (average per insured)										
Price	6,314	5,750	5,718	5,713	5,222	7,334	7,123	7,144	7,150	5,957
Claims costs	5,721	5,312	5,286	5,282	4,715	6,577	6,454	6,476	6,481	5,085
Private reins. expenses	-	-	-	-	-	-	-	-	-	-
Risk charge	-	-	-	-	-	-	-	-	-	-
(c). Market mean (per insured)										
Price	6,416	5,651	5,568	5,555	5,266	7,244	6,403	6,308	6,294	5,836
Claims costs	5,765	4,950	4,924	4,943	4,739	6,461	5,481	5,447	5,466	5,056
Private reinsurance expenses	37	78	50	15	12	37	94	53	14	10
Risk charge	21	25	15	17	11	10	14	8	9	5
Public reinsurance expenses	0	764	790	794	910	0	909	948	953	1,407
Premium subsidy expenses	3,330	3,150	3,133	3,131	3,064	3,994	3,759	3,727	3,722	3,697
(d). Market mean (per consumer)										
Consumer surplus	494	776	816	823	1,032	496	764	803	809	1,249
Insured rate	0.37	0.59	0.62	0.62	0.75	0.36	0.56	0.58	0.59	0.78
(e). Aggregate welfare (total, in millions)										
Consumer surplus	140	219	231	233	292	203	312	328	331	511
Insurer profit, including risk charges	62	100	101	102	107	109	186	192	194	245
Insurer profit, excluding risk charges	65	104	104	105	109	110	189	194	196	247
Reinsurer profit	1.53	5.14	3.50	1.05	0.97	2.17	8.57	5.00	1.39	1.27
Public reinsurance expenses	0	127	138	140	193	0	208	227	230	451
Premium subsidy expenses	350	525	548	551	649	591	858	891	897	1,186
Charitable care expenses for uninsured	526	332	308	304	163	781	526	493	488	200

Notes: This table reports simulated equilibrium statistics under various counterfactual scenarios. Panel (I) reports statistics for markets in reinsurance tier 1, while panel (II) reports statistics for all markets. Averages in the table are enrollment-weighted. We group insurers into risk-averse and risk-neutral in panels (a) and (b) based on whether they have positive risk preferences estimates, as is reported in Table 3. Counterfactual (0) corresponds to the case without pubic reinsurance policy. Counterfactual (1) simulates a scenario where the reinsurance policy affects only expected claims costs of risk-averse insurers, but not the reinsurance costs or risk charges in insurers' profit functions, nor the claims costs of risk-neutral insurers. We allow insurers to choose prices optimally but not private reinsurance purchases in response to this interim profit function. Counterfactual (2) simulates a scenario where public reinsurance affects all costs components of risk averse insurers, including expected claims costs, private reinsurance expenses, and risk charges terms. We allow insurers to respond by changing only the price but not private reinsurance deductibles. Counterfactual (3) simulates a scenario where public reinsurance affects all costs components of risk-averse insurers, and we allow insurers to choose both price and private reinsurance purchases in response optimally. Counterfactual (4) simulates a scenario where the reinsurance policy affects cost components of all insurers, and insurers choose both price and private reinsurance purchases in response optimally. It is the targeted outcome after the public reinsurance policy is initiated.

B. Additional Institutional Details

This section describes additional institutional details of the exchange and how these institutions map to our empirical model.

Pricing Regulations. Insurers on the exchange set premiums subject to several regulatory constraints. First, Insurers are not allowed to reject enrollees based on pre-existing health conditions or price-discriminate based on individual health risk. Second, insurers can collect different premiums from consumers based on age, but the age gradient in premiums has to follow a pre-specified regulatory age curve. We divide consumers into age bins, and take the average premium across all ages in the estimation model. Third, insurers are required to charge the same premium for a specific product in all counties belonging to the same "rating area", a collection of counties pre-specified by each state. However, since insurers do not have to serve all counties in a rating area, we consider a county to be the exchange market boundary following Fang and Ko (2018). We calculate mean premiums across plans within the same metal level and county since the CO APCD only has information on metal-level choices but not plan-level choices.

Premium Subsidies. The Affordable Care Act offers premium subsidies to low-income participants whose income is between 100 and 400 FPL to defray the cost of the insurance premium, formally known as Advanced Premium Tax Credits (APTC). The APTC is calculated in several steps. First, the Modified Adjusted Gross Income is converted to the percent of the Federal Poverty Level (FPL). The IRS specifies a mapping between FPL levels and the maximum dollar the household should pay for insurance premiums. Households with annual income between 100 and 400 FPL are eligible for APTC. Second, calculate the maximum subsidy a household can receive by subtracting the maximum allowed premiums from the previous step from the benchmark premium, i.e., the second-lowest-cost silver plan in the household's county of residence. If the premium of the household's chosen plan is less than the maximum subsidy they can receive, the household pays zero premium; otherwise, they pay for the premium differences between the selected plan and the maximum subsidy.

Our empirical exercise abstracts from the premium subsidies regulations in two ways. First, we do not have income or household information in UT APCD. We take the income distribution from the American Community Survey for individuals eligible for the CO exchange and calculate the expected premium that a single applicant whose income is drawn from the abovementioned distribution would face. Second, in counterfactual exercises, we do not model the non-linear subsidy determination process but assume that the subsidy is paid in a fixed proportion to premiums that insurers set. This fixed proportion is the mean of observed subsidy-listed premium ratios for all exchange markets, extracted from CMS Marketplace Open Enrollment Period PUF.

Cost-Sharing Subsidies. The ACA offers cost-sharing subsidies for households purchasing a Silver plan if their income is below 250 FPL. The cost-sharing subsidies reduce households' out-of-pocket liability from deductibles, co-pays, and co-insurance. Due to implementation issues, insurers rather than the federal government paid cost-sharing subsidies, especially in later years during our sample periods (Keith, 2019). Therefore, in counterfactual exercises, we set the cost-sharing parameter for Silver products to the expected cost shares given the income distribution from ACS for the CO exchange eligibles and assume that insurers

pay for the cost-sharing subsidies.

Individual Mandates. The ACA used to have an individual mandate that required consumers nationwide to have health insurance coverage or pay a penalty, which was repealed by the Tax Cuts and Jobs Act of 2017 and became ineffective in 2019. We do not model individual mandate, i.e., impose a penalty for the outside option of uninsured for two reasons. First, the regulation is not binding in reality, and many uninsured people do not pay for the penalty (Lurie et al., 2021). Second, Fiedler (2018) and Lurie et al. (2021) show the responses to the individual mandate are relatively small, especially in the exchange.

Risk Adjustments. Risk adjustment on the exchange transfers funds from insurers with ex-ante relatively less risky enrollees to those with ex-ante relatively more risky enrollees. Risk adjustment is a budget-neutral program, and the government calculates these transfers through a risk-adjustment formula developed by the Department of Health and Human Services (Kautter et al., 2014). We do not model risk adjustment in our main specification model for two reasons. First, risk adjustment is imperfect (Layton, 2017), and insurers could select healthy enrollees in multiple ways, for example, network designs (Shepard, 2022) or formulary designs (Geruso et al., 2019). Second, we focus on policies that change the market's overall risk composition rather than the risk distribution across insurers. However, we are working on a robustness test that examines how incorporating risk adjustment affects the empirical predictions.

Medical Loss Ratio Regulations. All insurers on the fully insured commercial market are subject to the Medical Loss Ratio (MLR) regulation. MLR regulations require insurance companies that cover individuals and small businesses to spend at least 80% of their premium income on healthcare claims and quality improvement (see Cicala et al. (2019) for more descriptions). The MLR ratio on the exchange is calculated by dividing the sum of healthcare claims and quality improvement expenses over premiums net of taxes, licensing, and regulatory fees. We do not impose MLR constraints when solving for insurers' pricing or private reinsurance purchases in the stage game for two reasons. Ex-post checks show that the MLR constraint does not bind at the equilibrium solutions in most cases if we drop the fee adjustment term in the MLR denominator and impose a relaxed constraint of 0.7 following Tebaldi (2025).

C. Additional Derivations of the Theoretical Model

C1. Proof of Proposition 1

We first rewrite the insurer's objective in (5) with reinsurance deductible level κ as:

$$U(p; c_r(\kappa;\theta), \sigma(\kappa), \rho) \;=\; pq(p) \;-\; \underbrace{\big(\theta c_0 + (1-\theta)c(\kappa)\big)}_{c_r(\kappa;\theta)}\, q(p) \;-\; \rho\sigma(\kappa)\sqrt{q(p)}. \tag{A1}$$

where $c_r(\kappa;\theta)$ denote insurer's marginal expected claims cost net of reinsurance.

Lemma 1. *Let $p^*(c_r, \sigma, \rho)$ denote the optimal price that maximizes the insurer's objective in (A1) for given paramter values of c_r, σ, ρ. Then, $p^*(c_r, \sigma, \rho)$ is increasing in c_r, σ and ρ.*

Proof. By Topkis's theorem, it is sufficient to show that $U(p,\alpha)$ is supermodular in (p,α) for each $\alpha \in \{c_r, \sigma, \rho\}$. We show supermodularity by demonstrating that the cross-partial derivative is non-negative.

$$\begin{aligned}
\frac{\partial^2 U}{\partial c_r \partial p} &= -q'(p) > 0 \\
\frac{\partial^2 U}{\partial \sigma \partial p} &= -\frac{\rho}{2\sqrt{q(p)}} q'(p) > 0 \\
\frac{\partial^2 U}{\partial \rho \partial p} &= -\frac{\sigma}{2\sqrt{q(p)}} q'(p) > 0
\end{aligned}$$

where the inequality holds by assumption that the demand function is downward sloping. □

Given the result in Lemma 1, the impact of increase in κ on the optimal price will be:

$$\begin{aligned}
\frac{dp^*(\kappa)}{d\kappa} &= \frac{\partial p^*(c_r,\sigma,\rho)}{\partial c_r}\frac{dc_r(\kappa;\theta)}{d\kappa} + \frac{\partial p^*(c_r,\sigma,\rho)}{\partial \sigma}\frac{d\sigma(\kappa)}{\partial \kappa} \\
&= (1-\theta)\underbrace{\frac{\partial p^*(c_r,\sigma,\rho)}{\partial c_r}}_{>0}\underbrace{\frac{dc(\kappa)}{d\kappa}}_{<0} + \underbrace{\frac{\partial p^*(c_r,\sigma,\rho)}{\partial \sigma}}_{>0}\underbrace{\frac{d\sigma(\kappa)}{\partial \kappa}}_{<0}.
\end{aligned} \tag{A2}$$

We now provide the proofs for each part of Proposition 1.

Proof (i). If $\theta = 1$, then the insurer's objective can be rewritten as:

$$U(p; c_0, \sigma(\kappa), \rho) \;=\; pq(p) \;-\; \underbrace{c_0}_{=c_r} q(p) \;-\; \rho\sigma(\kappa)\sqrt{q(p)}.$$

So insurer's expected marginal claims cost is unaffcted by reinsurance, and hence $\frac{dc_r}{d\kappa} = 0$. If $\rho > 0$, then the reinsurance of level κ will only impact insurer's objective through $\sigma(\kappa)$. The effect of increasing reinsurance deductible level κ on price will be

$$\frac{dp^*(\kappa)}{d\kappa} = \underbrace{\frac{\partial p^*(c_r,\sigma,\rho)}{\partial \sigma}}_{>0}\underbrace{\frac{d\sigma(\kappa)}{\partial \kappa}}_{<0} < 0.$$

Given the above result, $p^*(\kappa;\rho) < p^*(\bar{c};\rho) = p_0^*(\rho),\ \forall \kappa < \bar{c},\ \rho > 0$. If $\rho = 0$, then the insurer's objective becomes

$$U(p; c_0) \;=\; (p - c_0)q(p).$$

So insurer's objective is unaffected by reinsurance level κ and hence the optimal price $p^*(\kappa;0) = p_0^*(0) \forall \kappa$. □

Proof (ii). If $\theta < 1$, then the sign of equation (A2) will be negative i.e. $\frac{dp^*(\kappa)}{d\kappa} < 0$. That is, increasing (decreasing) reinsurance deductible level κ will increase (decrease) the optimal price. So, $p^*(\kappa;\rho) < p^*(\bar{c};\rho) = p_0^*(\rho),\ \forall \kappa < \bar{c},\ \rho \geq 0$.

The corresponding first order condition with respect to price in (A1) is

$$p^*(c_r(\kappa), \sigma(\kappa), \rho) = c_r(\kappa; \theta) + \frac{\rho\sigma(\kappa)}{2\sqrt{q(p^*)}} + \underbrace{\frac{-q(p^*)}{q'(p^*)}}_{\mu(p^*)}. \tag{A3}$$

Taking the total derivative of above equation with respect to reinsurance level κ and rearranging the equation, we get:

$$\frac{dp^*(\kappa;\rho)}{d\kappa} = \frac{(1-\theta)\frac{dc(\kappa)}{d\kappa} + \frac{\rho}{2\sqrt{q(p^*)}}\frac{d\sigma(\kappa)}{d\kappa}}{1 - \mu'(p^*) + \frac{\rho\sigma(\kappa)q'(p^*)}{4q(p^*)^{3/2}}}. \tag{A4}$$

Note that from (A2), we know that $\frac{dp^*}{d\kappa} < 0$, meaning the denominator in (A4) has to be positive. We can now derive the pass-through of reinsurance as defined in the Proposition:

$$\tau(\kappa;\rho) = \frac{\frac{dp^*(\kappa;\rho)}{d\kappa}}{\frac{dc(\kappa)}{d\kappa}} = \frac{(1-\theta) + \frac{\rho}{2\sqrt{q(p^*)}}\frac{d\sigma(\kappa)/d\kappa}{dc(\kappa)/d\kappa}}{1 - \mu'(p^*) + \frac{\rho\sigma(\kappa)q'(p^*)}{4q(p^*)^{3/2}}}. \tag{A5}$$

We now show that the pass-through rate is larger if insurer faces risk charge vs. insurer that does not i.e. $\tau(\kappa;\rho') > \tau(\kappa;0), \forall \rho' > 0$.

$$\begin{aligned}
\tau(\kappa;\rho') &= \frac{(1-\theta) + \overbrace{\frac{\rho'}{2\sqrt{q(p^*)}}\frac{d\sigma(\kappa)/d\kappa}{dc(\kappa)/d\kappa}}^{>0}}{1 - \mu'(p^*(\kappa;\rho')) + \underbrace{\frac{\rho'\sigma(\kappa)q'(p^*)}{4q(p^*)^{3/2}}}_{<0}} \\
&> \frac{(1-\theta)}{1 - \mu'(p^*(\kappa;\rho'))} \\
&\geq \frac{(1-\theta)}{1 - \mu'(p^*(\kappa;0))} = \tau(\kappa;0).
\end{aligned}$$

where the first inequality follows from removing a positive term from the numerator, and remoing a negative term from the denominator whose overall value is positive. The second inequality follows from Lemma 1 that the optimal price is increasing in ρ and the assumption that $\mu(p)$ is weakly convex. □

Proof (iii). If $\theta > 1$, then we can rewrite insurer's objective as

$$U(p;\rho) = pq(p) - \underbrace{\left[c_0 + \overbrace{(\theta-1)r(\kappa)}^{>0}\right]q(p)}_{\text{net expected cost}} - \underbrace{\rho\left[\sigma_0 - \overbrace{\Delta\sigma(\kappa)}^{>0}\right]\sqrt{q(p)}}_{\text{risk charge}}. \tag{A6}$$

Furthermore, if $\rho = 0$ insurer's objective becomes:

$$U(p;\rho=0) = pq(p) - \quad c_0 q(p) \quad - \overbrace{(\theta-1)r(\kappa)q(p)}^{>0} < (p-c_0)q(p).$$

So, reinsurance will decrease insurer's objective if $\rho = 0$. To see the impact on price, if $\theta > 1$ and $\rho = 0$, the sign of equation (A2) will be positive i.e. $\frac{dp^*(\kappa)}{d\kappa} > 0$. That is, increasing (decreasing) reinsurance deductible level κ will decrease (increase) the optimal price. So, $p^*(\kappa;0) > p^*(\bar{c};0) = p_0^*(0),\ \forall \kappa < \bar{c}$. If $\rho > 0$, then we can see from (A6), impact of reinsurance on the insurer objective will be ambiguous. Similarly its impact on insurer price will be:

$$\frac{dp^*}{d\kappa} = \underbrace{(1-\theta)}_{<0} \underbrace{\frac{\partial p^*(c_r,\sigma,\rho)}{\partial c_r}}_{>0} \underbrace{\frac{dc(\kappa)}{d\kappa}}_{<0} + \underbrace{\frac{\partial p^*(c_r,\sigma,\rho)}{\partial \sigma}}_{>0} \underbrace{\frac{d\sigma(\kappa)}{\partial \kappa}}_{<0} \lessgtr 0.$$

So, the impact of reinsurance on insurer price will be ambiguous. □

C2. Alternative Model Frameworks

In this section, we explore alternative microfounded insurer models and show that the insurer problem in (2) can be isomorphic to such models.

C2.1. Model with Required Capital Consider a monopoly insurer in Section 2. Suppose now that the insurer maximizes its expected profit subject to a capital constraint, requiring it to hold capital commensurate with the risk it faces. The insurer's objective is given by

$$\max_p \quad \underbrace{(p-c_o)q(p)}_{\text{expected profit}} - \underbrace{\mathcal{L}\big(\overbrace{K_\alpha(X)}^{\text{required capital}}\big)}_{\text{cost of required capital}}, \quad \text{where} \quad X = \tilde{C} - pq(p). \tag{A7}$$

where X is the ex-post net loss with $\tilde{C}$ representing the insurer's random total cost. $K_\alpha(X)$ is the required capital for a given net-loss distribution, and stringency of requirement level, $\alpha \in (0,1)$. Lastly, $\mathcal{L}$ represents the cost of maintaining and/or raising capital which is increasing in the amount of required capital.

We make the following additional functional form assumptions. First, we assume $\tilde{C}$ is normally distributed, which could be seen as applying the normal approximation to the total cost.[1] Second, we assume that the marginal cost of capital is constant and define it as $\mathcal{L}'(K) = y$. Lastly, the required capital takes the following value-at-risk form

$$K_\alpha(X) = VaR_\alpha(X) = F_X^{-1}(1-\alpha) = \mu_x + \sigma_x \Phi^{-1}(\alpha) \tag{A8}$$

where μ_x, σ_x are mean and standard deviation of X, and Φ is the CDF of standard normal with the last equality coming from the normality assumption.

[1] Under independent cost shocks, we can apply the central limite theorem to approximate the distribution of total cost.

Then, we can rewrite the insurer's objective function as

$$\max_{p} \quad \underbrace{(p-c_o)q(p)}_{\pi(p)} - \underbrace{\mathcal{L}\big(-\pi(p)+\sigma_x(p)g(\alpha)\big)}_{\text{cost of required capital}}, \quad \text{where} \quad g(\alpha)=\Phi^{-1}(1-\alpha). \tag{A9}$$

The corresponding insurer's FOC will be given by

$$\underbrace{p+\frac{q(p)}{q'(p)}}_{\text{marginal revenue}} = \underbrace{c_0}_{\text{marginal claims cost}} + \underbrace{\overbrace{g(\alpha)}^{\text{dist. stat.}} \quad \overbrace{\frac{y}{1+y}}^{\text{capital cost}} \quad \overbrace{\left(\frac{\sigma_0}{2\sqrt{q(p)}}\right)}^{\text{marginal std. dev.}}}_{\text{marginal cost of required capital}}. \tag{A10}$$

Note that the above FOC is equavalent to the insurer's FOC in equation (3) in the main stylized model with $\rho = g(\alpha)\frac{y}{1+y}$. That is, the model of insurer internlizing uncertainty in cost through simple risk measure like the standard deviation of cost, is isomorphic to insurer needing to maintain some adequate amount of capital for the amount of risk it faces under certain parametric assumptions.

The risk charge coefficient, ρ, then can be interpreted as the product of capital cost and distribution static, both of which increases ρ. If the firm faces larger capital cost the implied marginal cost of required capital would increase. Alternatively, if the insurer's required capital level goes up (i.e. α increases), due to regulatory stringency or insurer's internal risk preferences, the implied marginal cost of required capital would increase. While our main model can't decompose the risk charge coefficient into these two separate parts, higher risk charge coefficient can be interprted as the firm facing overall heightend level of capital cost or strigency of required capital amount.

C2.2. Model with Cost of Financial Ruin Consider a similar model to Section C2.1. Now suppose that the insurer faces some large cost when it becomes financially distressed i.e. its cost exceeds its premium revenue.

The insurer's objective is given by

$$\max_{p} \quad \underbrace{(p-c_o)q(p)}_{\text{expected profit}} - \underbrace{Pr\big(X>0\big)}_{\text{prob. of financial ruin}} \quad FC. \tag{A11}$$

where FC is some fixed cost of dealing with financial ruin of its cost exeeding premium revenue. We make similar assumption to Section C2.1 and assume the total cost is normally distributed. Then, we can rewrite the insurer's objective as

$$\max_{p} \quad \underbrace{(p-c_o)q(p)}_{\pi(p)} - \underbrace{\left(1-\Phi\left(\frac{E[\pi(p)]}{\sigma_x(p)}\right)\right)}_{\text{prob. of financial ruin}} FC. \tag{A12}$$

The corresponding insurer's FOC will be given by

$$\underbrace{p + \frac{q(p)}{q'(p)}}_{\text{marginal revenue}} = \underbrace{c_0}_{\text{marginal claims cost}} + \underbrace{\overbrace{g(p)}^{\text{dist. stat.}} \overbrace{\frac{y(p)}{1+y(p)}}^{\text{capital cost}} \overbrace{\left(\frac{\sigma_0}{2\sqrt{q(p)}}\right)}^{\text{marginal std. dev.}}}_{\text{marginal cost of required capital}}, \tag{A13}$$

$$\text{where} \quad g(p) = \frac{\pi(p)}{\sigma_x(p)}, \quad y(p) = \frac{\phi(g(p))FC}{\sigma_x(p)}$$

While the above model isn't as straightforward, insurer's FOC follows similar form as in equation (A10).

C2.3. Model with Expected Utility-Maximizing Insurer Consider a monopoly insurer facing the same demand and cost as in Section 2. Now suppose the insurer maximizes its expected utility from profit:

$$\max_p \quad E_{\tilde{C}|p}\left[U\left(\underbrace{pq(p) - \tilde{C}}_{\tilde{\Pi}(p)}\right)\right]. \tag{A14}$$

Assume that the insurer's utility function is $U(x) = -e^{-\alpha x}$, where $\alpha > 0$ is the coefficient of absolute risk aversion. Furthermore, the insurer's random total cost is normally distributed, i.e. $\tilde{C} \sim N(c_0 q(p), \sigma_0^2 q(p))$.[2] Then, insurer's ex-post profit will also be normally distributed with $\tilde{\Pi} \sim N(\mu_\Pi, \sigma_\Pi^2)$, where $\mu_\Pi = (p - c_0)q(p)$, $\sigma_\Pi^2 = \sigma_0^2 q(p)$.

The expected utility of the insurer in Equation (A14) can be written as:

$$\begin{aligned}
E[U(\tilde{\pi})] &= E[-e^{-\alpha \tilde{P}i}] \\
&= -\int e^{-\alpha x} \frac{1}{\sqrt{2\pi\sigma_\Pi^2}} e^{-\frac{(x-\mu_\Pi)^2}{2\sigma_\Pi}} dx \\
&= -e^{-\alpha(\mu_\Pi - \frac{1}{2}\alpha\sigma_\Pi^2)} \\
&= U(\mu_\Pi - \frac{1}{2}\alpha\sigma_\Pi^2).
\end{aligned}$$

Since $U(x)$ is a monotonicly increasing function, maximizing the expected-utility is equivalent to maximizing the following mean variance objective:

$$\max_p \quad \underbrace{pq(p) - c_0 q(p)}_{\text{expected profit}} - \underbrace{\frac{1}{2}\alpha \overbrace{\sigma_0^2 q(p)}^{\sigma_{\tilde{C}}^2}}_{\textit{risk charge}}. \tag{A15}$$

The above objective is equivalent to Equation (1) with $L(x) = \frac{1}{2}\alpha x, S = \sigma_{\tilde{C}}^2$.

[2] This can be thought of as normal approximation to sum of independent random variables.

C3. Incorporating Correlated Cost Shocks

We explore a model in which insurers are subject to both the individual-level tail risk, and aggregate cost shocks. Consider the insurer's problem in (2). Now assume that on top of the $i.i.d.$ individual's ex-post cost, $\tilde{c}_i$, individual's cost also is subject to perfectly correlated aggregate cost shock, $x \sim F_x$ with $\mu_x = E[x], \sigma_x^2 = Var(x)$. Then individual's total ex-post cost will be given by $y_i = \tilde{c}_i + x$.

Insurer's new objective will be

$$\max_p \quad \underbrace{pq(p)}_{\text{premium revenue}} - \underbrace{(c_0 + \mu_x)q(p)}_{\text{expected claims cost}} - \underbrace{\rho \overbrace{\left(\left(\sigma_x^2 + \frac{\sigma_0^2}{q(p)} \right)^{1/2} q(p) \right)}^{\text{std. dev. of cost}}}_{\text{risk charge}}. \tag{A16}$$

And the corresponding FOC will be

$$\underbrace{p + \frac{q(p)}{q'(p)}}_{\text{marginal revenue}} = \underbrace{c_0 + \mu_x}_{\text{marginal claims cost}} + \underbrace{\rho \overbrace{\frac{1}{2} \left(\frac{\sigma_0^2}{q(p)} + 2\sigma_x^2 \right)^{1/2}}^{\text{marginal std. dev.}}}_{\text{marginal risk charge}}. \tag{A17}$$

Note that the FOC in (A17) is similar to the main theoretical model, except that the marginal claims cost and marginal risk charge now has additional term due to correlated risk. The risk charge term still increases as the variance of the cost shock increases. However, the marginal standard deviation is now composed of two components. The first part is from the independent cost shock which is decreasing in $q(p)$, reflecting the aforementioned risk-pooling effect. The new term, σ_x^2, does not go away due to correlated cost shock.

C4. Incorporating (Adverse) Selection

In this section, we explore a model with hetrogeneous costs across individuals to allow for selection in the market.

Suppose now that there are two types of individuals, low-risk type, ℓ, and high-risk type, h. Type t's cost is distributed such that $\tilde{c}_t \sim F(c_t, \sigma_t^2)$ with $c_\ell < c_h, \sigma_\ell^2 < \sigma_h^2$. Let $q_\ell(p), q_h(p)$ denote low-risk and high-risk individuals' demand, respectively. Then the total demand will be given by $q(p) = q_\ell(p) + q_h(p)$. Then the insurer's objective will be given by

$$\max_p \quad p \underbrace{\left(q_\ell(p) + q_h(p) \right)}_{q(p)} - \underbrace{\left(c_\ell q_\ell(p) + c_h q_h(p) \right)}_{\mu_c(p)} - \underbrace{\rho \overbrace{\left(\sigma_\ell^2 q_\ell(p) + \sigma_h^2 q_h(p) \right)^{\frac{1}{2}}}^{\sigma_c(p)}}_{\text{risk charge}}. \tag{A18}$$

where $\mu_c(p)$, and $\sigma_c(p)$ denote the expected cost and standard deviation of insurer's total cost. Then, the corresponding FOC will be:

$$\underbrace{p + \frac{q(p)}{\frac{\partial q(p)}{\partial p}}}_{MR} = \underbrace{\big(\lambda(p)c_\ell + (1-\lambda(p))c_h\big)}_{\text{marginal claims cost, } MCC(p)} + \underbrace{\rho \frac{1}{2\sigma_c(p)} \overbrace{\Big(\lambda(p)\sigma_\ell^2 + (1-\lambda(p))\sigma_h^2\Big)}^{\text{marginal variance, } MV(p)}}_{\text{marginal risk charge, } MRC(p)} \tag{A19}$$

Note that the FOC in (A19) is similar to the main theoretical model, except that the marginal claims cost and marginal risk charge depends on price due to selection. However, the main findings still stand. The larger the variance of the individual's cost shock, the larger the risk charge will be. Furthermore, risk-pooling effect persists as $1/\sigma_c(p)$ goes to 0 as $q(p) \to \infty$.

C5. Efficiency of Reinsurance versus Premium Subsidies

Our previous analysis shows reinsurance as an ex-post cost subsidy and risk protection mechanism, can lead to more than a simple ex-ante cost subsidy. In this section, we compare such an ex-post supply-side subsidy to a more straightforward direct-to-consumer premium subsidy. In particular, we examine the role of adverse selection and the insurer's cost of financial risk in determining the efficiency of each subsidy mechanism and their relative pass-through rates.

Consider the model with adverse selection in section C4. Given a per-quantity (or per-enrollee) demand-side premium subsidy s, the price that consumers face will be

$$p^e = p - s,$$

and the demand for insurance will be $q(p^e) = q_\ell(p^e) + q_h(p^e)$.

To compare the pass-through rate of the two subsidy mechanisms, we examine government expenditures under premium subsidies or reinsurance subsidies that yield the same price for consumers. In other words, we hold the price change constant and compare how costly each subsidy mechanism is for the government.

Let $p_r^*(\kappa)$ be the equilibrium price under reinsurance level κ, and p_s^* be the equilibrium price under demand subsidy s. For a given κ we can solve for the s such that

$$p_r^*(\kappa) = p^e = p_s^* - s.$$

That is, consumers face the same price under both reinsurance and premium subsidies. The corresponding subsidy level $s(\kappa)$ that yields the same price for the consumer as reinsurance of level κ is

$$\begin{aligned} s(\kappa) &= p_s^* - p_r^*(\kappa) \\ &= \underbrace{\lambda(p) r_\ell(\kappa) + \big(1-\lambda(p)\big) r_h(\kappa)}_{\text{marginal reinsurance cost}} + \underbrace{\rho\big(MSV(p,\bar{c}) - MSV(p,\kappa)\big)}_{\text{marginal change in risk charge}}, \end{aligned} \tag{A20}$$

$$\text{where} \quad MSV(p,\kappa) = \frac{1}{2\sqrt{q(p)}} \frac{1}{\sqrt{AV(p,\kappa)}} \underbrace{\Big(\lambda(p)\sigma_\ell^2(\kappa) + (1-\lambda(p))\sigma_h^2(\kappa)\Big)}_{MV(p,\kappa)}$$

where AV, MV denotes the average variance and marginal variance of insurer's total cost for a given price

and reinsurance level. Given the above expression for $s(\kappa)$, we want to determine the relative magnitude of $r(\kappa)$ vs. $s(\kappa)$, which depends on the relative size of average and marginal reinsurance costs, i.e., the degree of adverse selection, and the size of marginal change in risk charge, i.e., the degree of cost of financial risk.

Proposition A1. *Let adverse selection in the market be defined as* $F_\ell(t) \leq F_h(t)\ \forall\, t, c_\ell < c_h,\ \sigma_\ell^2 < \sigma_h^2$. *Then the relative magnitude of* $r(\kappa)$ *and* $s(\kappa)$ *will depend on the following:*

1. *No risk charge, no selection: If the insurer is risk neutral, i.e.,* $\rho = 0$*, and there is no selection, i.e.,* $F_\ell = F_h$*, then* $s(\kappa) = r(\kappa)$, $\forall\ \kappa$.
2. *With risk charge, no selection: If the insurer is risk averse, i.e.,* $\rho > 0$*, and there is no selection, then* $s(\kappa) > r(\kappa)$, $\forall\ \kappa$.
3. *No risk charge, with adverse selection: If the insurer is risk neutral and there is adverse selection, i.e.,* $F_\ell < F_h$*, then* $s(\kappa) < r(\kappa)$, $\forall\ \kappa$.
4. *With risk charge, with adverse selection: If the insurer is risk averse, and there is adverse selection, then the relative magnitude of* $s(\kappa)$ *and* $r(\kappa)$ *is ambiguous.*

Proposition A1 states that the pass-through rate of reinsurance and premium subsidy is the same without any financial risk cost or selection. However, when the insurer is risk averse, and there is adverse selection in the market, the relative efficiency of each subsidy mechanism will vary. Under risk aversion, reinsurance subsidy will generate large pass-through due to its ability to reduce the risk that insurers may face, further lowering the effective marginal cost. Under adverse selection, the marginal reinsurance cost will be smaller than the average reinsurance cost, making the premium subsidy have a larger pass-through rate. However, when both frictions exist in the market, the relative magnitude of the pass-through rates will be ambiguous as it will depend on the relative magnitude of each friction. See Appendix C for proofs.

Proof to Proposition A1

In the absence of financial risk cost, the insurer will face no risk charge i.e. $\rho = 0$. Furthermore, when there is no selection, individuals across different types t all are drawn from the same cost distribution i.e. $F_\ell(t) = F_h(t)\ \forall\, t$, implying $c_\ell = c_h, \sigma_\ell^2 = \sigma_h^2$.

Then the expected average reinsurance cost for given κ is

$$r(\kappa) = r_\ell(\kappa) = r_h(\kappa)$$

The expected per-enrollee subsidy will be $s(\kappa) = r(\kappa)$. That is, under no financial risk cost and no selection, both premium subsidy and reinsurance cost the government the same amount of expenditure.

Now if the insurer is risk averse i.e. $\rho > 0$ but without selection in the market, the expected reinsurance cost will remain the same. However, the expected per-enrollee subsidy will now be

$$s(\kappa) = r(\kappa) + \underbrace{\frac{\rho}{2\sqrt{q(p)}}\Delta\sigma(\kappa)}_{>0} > r(\kappa)$$

where $\Delta\sigma = \sigma_0 - \sigma(\kappa) > 0$. The difference in marginal risk charge reduces to the above as marginal variance and average variance is the same under no selection.

Hence, when there are just financial risk cost, reinsurance which is an ex-post subsidy, is more efficient in lowering the enrollee premium.

Now suppose there is adverse selection, but no financial risk cost. The expected average reinsurance cost is

$$r(\kappa) = \alpha(p) r_\ell(\kappa) + \big(1 - \alpha(p)\big)\, r_h(\kappa)$$

The expected per-enrollee subsidy is

$$s(\kappa) = \lambda(p) r_\ell(\kappa) + \big(1 - \lambda(p)\big)\, r_h(\kappa)$$

Under adverse selection, $F_h(t) < F_\ell(t)\ \forall\, t$. This directly implies that $r_\ell(\kappa) < r_h(\kappa)$. We now show that the marginal reinsurance cost is smaller than the average reinsurance cost. Given that $r_\ell(\kappa) < r_h(\kappa)$, if $\alpha(p) < \lambda(p)$ then $r(\kappa) > s(\kappa)$ as the average reinsurance cost uses $\alpha(p)$ as the weight for the type ℓ individual whereas the marginal reinsurance cost uses $\lambda(p)$. Hence $s(\kappa) < r(\kappa)$ as the marginal reinsurance cost is smaller than the average reinsurance cost due to adverse selection. So when there is just adverse selection, premium subsidy is more efficient in lowering the enrollee premium.

When there are both financial risk cost and adverse selection, the efficiency will depend on which force dominates. If selection is strong in the market, then premium subsidy might be more efficient. If financial risk cost dominate, then reinsurance might be more efficient. The results for a linear demand setting are illustrated in Figure A7.

D. Additional Details on Reduce-Form Exercises

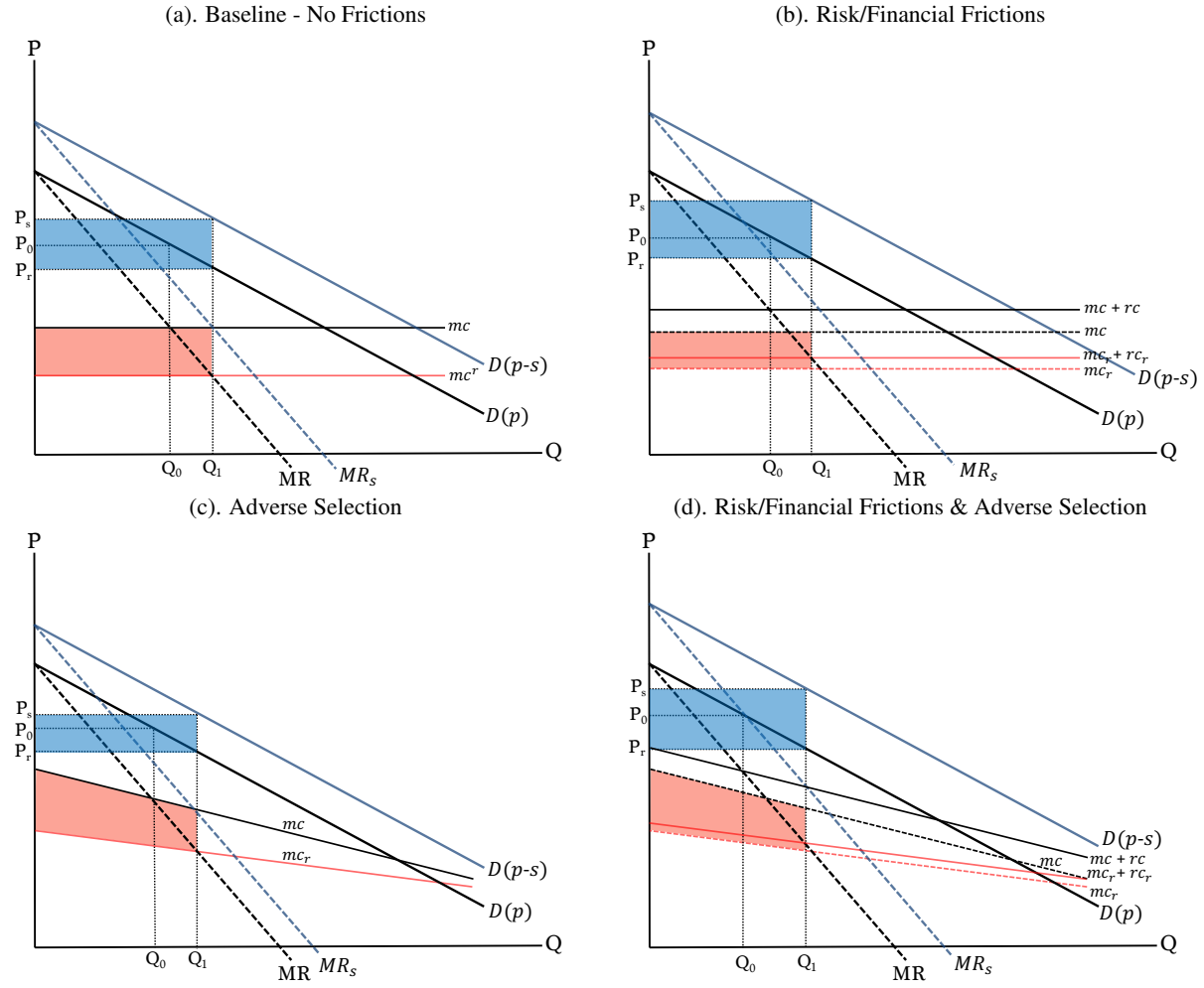
Effects of Public Reinsurance on Total Medical Expenses. Let t denote year, c denote county, m denote market segment, i denote individual. We estimate the following event-study design,

$$y_{it} = \sum_{n \in \{-4(+), -3, .., 0, 1, .., 2, 3+\}} \beta_n 1[t^* + n = t] D_{cmt} + \gamma_i + \gamma_t + \gamma X_{it} + \varepsilon_{it}, \tag{A21}$$

where $1[t^* + n = t]$ is an indicator denoting whether year t is n years from the initiation of CO reinsurance programs in t^*; D_{cmt} is an indicator for whether in year t, county c, market segment m that individual i belongs to has public reinsurance program in place, or has the highest tiers of public reinsurance cost-shares; y_{it} is the average monthly medical expenses of enrollee i in year t, or an indicator for the enrollee i's annual expenses exceeding the reimbursement threshold of public reinsurance in year t; We include individual, year fixed effects γ_i, γ_t to control for individuals' baseline health status, and year-specific cost or health fluctuations. We include covariates X_{it}, such as county, insurer-market segment fixed effects to net out the differential price level across geographic markets or payers. We cluster standard errors at the county level.

Equation (A21) exploits two sources of variation. The first is variations in time t and geographic markets c: within the CO exchange, public reinsurance's cost-shares differ across counties. The second is variations across time t and market segments c: the public reinsurance subsidies apply to the exchange market but not

Figure A7. Reinsurance vs. Uniform Demand Subsidy



Notes: This figure illustrates the relative magnitude of total government spending on uniform premium subsidy (blue shaded area) versus reinsurance subsidy (red shaded area) with linear demand in a variety of scenarios. Panel (a) shows a baseline case without any form of friction. Panel (b) shows a case where insurers are faced with financial frictions in the form of a risk charge. Panel (c) shows a case where there is adverse selection. Panel (d) shows a case with both adverse selection and financial frictions. The black demand curve $D(p)$ is consumers' linear demand without any subsidies, while the blue demand curve $D(p-s)$ applies uniform premium subsidies s. The black marginal cost curve mc captures the expected claims costs per consumer without any subsidies, while $mc + rc$ captures both claims costs and risk charges, similar to Figure A1. The red marginal cost curves mc_r are those after ex-post reinsurance transfers r. Downward-sloping marginal cost curves capture adverse selection. Equilibrium is determined by the intersection of the marginal revenue and the effective marginal costs (sum of claims and risk charges) curves.

commercial markets.

E. Additional Derivations of the Empirical Model

This subsection describes expressions for key objects in Section 6. We derive insurers' cost items in three scenarios: without any reinsurance, with only private reinsurance, and with both private and public reinsurance. For notational simplicity, we omit the subscript for time, t.

E1. Baseline Model Without Any Reinsurance.

In the case without any reinsurance, insurers' costs include their claims liabilities C_f, and risk charges L_f.

Recall that the health risk of risk type i, c_i, is log-normally distributed with finite expected value μ_i and variance σ_i^2. We derive the costs per enrollee, then aggregate them to insurers' total expenses. Applying the product-specific marginal cost multiplier and cost shares as described in Section 6, we get the claims costs paid by insurers $c_{ijm} = \psi_{jm}\lambda_j c_i$ is log-normally distributed, $\log(c_{ijm}) \sim N(\mu_i + \log(\psi_{jm}\lambda_j), \sigma_i^2)$. The expectation and variance of insurers' claims liability, c_{ijm}, is

$$\mathbb{E}[c_{ijm}] = \psi_{jm}\lambda_j \exp(\mu_i + \frac{1}{2}\sigma_i^2). \tag{A22}$$

$$\text{Var}[c_{ijm}] = \exp(\sigma_i^2 - 1)\exp(2(\mu_i + \log(\psi_{jm}\lambda_j)) + \sigma_i^2). \tag{A23}$$

Summing up the claims across consumers i and market m, the total claims costs of insurer f is

$$C_f(\vec{p}) = \sum_m \sum_i \sum_{j \in J_{fm}} N_m w_{im} s_{ijm}(\vec{p}_m) c_{ijm}, \tag{A24}$$

where N_m is the market size, w_{im} is the share of consumers in each age-risk bins, $s_{ijm}(\vec{p}_m)$ is the share of consumers choosing product j of insurer f. Note that $C_f(\vec{p})$ is also a random variable, as it is the sum of many independent and identically distributed random variables, c_{ijm}. We apply the Lyapunov Central Limit Theorem to derive the asymptotic distribution of C_f,

$$C_f(\vec{p}) \xrightarrow{d} N\Big(\mathbb{E}[C_f(\vec{p})], \text{Var}[C_f(\vec{p})]\Big), \text{ where} \tag{A25}$$

$$\mathbb{E}[C_f(\vec{p})] = \sum_{m,i,j} N_m w_{im} s_{ijm}(\vec{p}) \mathbb{E}[c_{ijm}],$$

$$\text{Var}[C_f(\vec{p})] = \sum_{m,i,j} N_m w_{im} s_{ijm}(\vec{p}) \text{Var}[c_{ijm}],$$

$\mathbb{E}[c_{ijm}]$ and $\text{Var}[c_{ijm}]$ are derived in equations (A22),(A23). The $\mathbb{E}[C_f(\vec{p})]$ term is the expected claims costs used in the insurer's objective function (equation (13)).

We finally derive the risk charge term L_f, a scalar that equals the total variation of enrollee claims times insurers' risk preferences ρ_f.

$$L_f(\vec{p}, \kappa_f) = \rho_f \sqrt{\text{Var}[C_f(\vec{p})]}.$$

For tractability, in the empirical model (equation (16)), we use the asymptotic variance of aggregate claims to calculate risk charges, but not the exact analytic expression. Simulations reveal that asymptotic statistics approximate the realized aggregate variance well.

E2. Baseline Model With Private Reinsurance.

When private reinsurance is present, insurers' total costs include their claims liabilities C_f, reinsurance costs R_f, and risk charges L_f.

We first translate the cost-sharing arrangement between the insurer and the reinsurer, as written in equation (14), into words. The insurer pays the full amount of its scheduled claims costs c_{ijm} when c_{ijm} is below

the deductible threshold κ_f. In contrast, when c_{ijm} is above the deductible threshold κ_f, the insurer will only pay κ_f and the reinsurer pays for the reminder, $c_{ijm} - \kappa_f$. Let c^r_{ijm} denote the claim costs paid by the insurer f with reinsurance coverage level κ_f, for a consumer in risk type i enrolled with the plan j:

$$c^r_{ijm}(\kappa_f) = c_{ijm}\mathbf{1}[c_{ijm} < \kappa_f] + \kappa_f \mathbf{1}[c_{ijm} \geq \kappa_f]. \tag{A26}$$

The actuarial value of reinsurance per insured r_{ijm} is

$$r_{ijm}(\kappa_f) = \mathbb{E}[c_{ijm}] - \mathbb{E}[c^r_{ijm}] = \mathbb{E}[(c_{ijm} - \kappa_f)\mathbf{1}[c_{ijm} \geq \kappa_f]]. \tag{A27}$$

Equation (A26) indicates that insurers' liabilities per insured c^r_{ijm} is a random variable that depends on the ex-post realization of an enrollee's health state and the generosity of reinsurance contracts. Applying the distributional assumptions of c_{ijm}, we derive

$$\mathbb{E}[c^r_{ijm}(\kappa_f)] = \int_{-\infty}^{\frac{\kappa_f}{\psi_{jm}\lambda_j}} \psi_{jm}\lambda_j c_i f(c_i) dc_i + \int_{\frac{\kappa_f}{\psi_{jm}\lambda_j}}^{\infty} \kappa_f f(c_i) dc_i. \tag{A28}$$

$$\text{Var}[c^r_{ijm}(\kappa_f)] = \int_{-\infty}^{\frac{\kappa_f}{\psi_{jm}\lambda_j}} (\psi_{jm}\lambda_j c_i - \mathbb{E}[c^r_{ijm}(\kappa_f)])^2 f(c_i) dc_i + \int_{\frac{\kappa_f}{\psi_{jm}\lambda_j}}^{\infty} (\kappa_f - \mathbb{E}[c^r_{ijm}(\kappa_f)])^2 f(c_i) dc_i. \tag{A29}$$

$f(c_i)$ is the probability density function (pdf) of the standard log-normal distribution. The analytical expressions for $\mathbb{E}[c^r_{ijm}(\kappa_f)]$ and $\text{Var}[c^r_{ijm}(\kappa_f)]$ are available due to the log-normal distributional assumptions. We omit them here to save space.

Note that private reinsurance reduces both the expectation and variance of the per-member claims costs paid by insurers:

$$\mathbb{E}[c^r_{ijm}(\kappa_f)] < \mathbb{E}[c_{ijm}], \quad \text{Var}[c^r_{ijm}(\kappa_f)] < \text{Var}[c_{ijm}],$$

where $\mathbb{E}[c_{ijm}]$ and $\text{Var}[c_{ijm}]$ are moments without any reinsurance in equations (A22), (A23).

We now apply the same trick of the Lyapunov Central Limit Theorem to derive the asymptotic distribution of insurers' total claims costs C_f,

$$C_f(\vec{p}, \kappa_f) = \sum_{m,i,j} N_m w_{im} s_{ijm}(\vec{p}_m) c^r_{ijm}(\kappa_f) \xrightarrow{d} N\Big(\mathbb{E}[C_f(\vec{p}, \kappa_f)], \text{Var}[C_f(\vec{p}, \kappa_f)]\Big),$$

$$\mathbb{E}[C_f(\vec{p}, \kappa_f)] = \sum_{m,i,j} N_m w_{im} s_{ijm}(\vec{p}) \mathbb{E}[c^r_{ijm}(\kappa_f)],$$

$$\text{Var}[C_f(\vec{p}, \kappa_f)] = \sum_{m,i,j} N_m w_{im} s_{ijm}(\vec{p}) \text{Var}[c^r_{ijm}(\kappa_f)],$$

where $\mathbb{E}[c^r_{ijm}(\kappa_f)]$ and $\text{Var}[c^r_{ijm}(\kappa_f)]$ is detailed in equations (A28) and (A29). The $\mathbb{E}[c^r_{ijm}(\kappa_f)]$ term is the expected claims costs used in the insurer's objective function (equation (13)).

We next derive the reinsurance expenses R_f. Note that the expected reinsurance expense per insured is

a scalar that integrates over all possible health states of a consumer, as shown in equation (A27). We apply the exogenous reinsurance markup $\tau_f \geq 1$ above the actuarial value, and aggregate across consumers to derive total reinsurance expenses.

$$R_f(\vec{p}, \kappa_f) = \sum_{m,i,j} N_m w_{im} s_{ijm}(\vec{p}) \tau_f r_{ijm}(\kappa_f),$$

$$r_{ijm}(\kappa_f) = \int_{\frac{\kappa_f}{\psi_{jm}\lambda_j}}^{\infty} (\psi_{jm}\lambda_j c_i - \kappa_f) f(c_i) dc_i.$$

We again use the asymptotic variance of aggregate claims to calculate risk charges:

$$L_f(\vec{p}, \kappa_f) = \rho_f \sqrt{\text{Var}[C_f(\vec{p}, \kappa_f)]}.$$

E3. Baseline Model With Private and Public Reinsurance.

When both public and private reinsurance are present, insurers' total costs include their claims liabilities C_f, reinsurance costs R_f, and risk charges L_f.

Similar to the prior case, we translate cost-shares between the insurer, the reinsurer, and the government, as written in equation (15), into words. We first consider the case where the private reinsurance deductible is higher than the government threshold, $\kappa_f > \kappa_g$. When the per-member claims cost c_{ijm} is below both thresholds, the insurer pays the entire portion of c_{ijm}. When the per member claims costs c_{ijm} is higher than the government reimbursement threshold κ_g but lower than the private reinsurance deductible κ_f, the insurer pays the public deductible amount plus its cost shares above deductible, $\kappa_g + \theta_g(c_{ijm} - \kappa_g)$, and the government pays the reminder, $(1 - \theta_g)(c_{ijm} - \kappa_g)$. When the per-member claims cost c_{ijm} is above both thresholds, we assume that government reimbursement comes in first, and the remainder is filled by private reinsurers. Namely the insurer pays up to the private deductible amount κ_f, the government pays for its cost-share above the public deductible, $(1 - \theta_g)(c_{ijm} - \kappa_g)$, while the private reinsurer pays the reminder $\theta_g(c_{ijm} - \kappa_g) - \kappa_f$. Let c^r_{ijm} denote the claim costs paid by the insurer f with reinsurance coverage level κ_f, for a consumer in risk type i enrolled with the plan j:

$$\begin{aligned} c^r_{ijm}(\kappa_f, \kappa_g, \theta_g) = c_{ijm}\mathbf{1}[c_{ijm} < \kappa_g] + (\kappa_g + \theta_g(c_{ijm} - \kappa_g))\mathbf{1}[\kappa_g \leq c_{ijm} < \kappa_f] \\ + (\theta_g \kappa_f + (1 - \theta_g)\kappa_g)\mathbf{1}[\kappa_f \leq c_{ijm}]. \end{aligned} \tag{A30}$$

The actuarial value of reinsurance per insured r_{ijm} is

$$r_{ijm}(\kappa_f, \kappa_g, \theta_g) = \mathbb{E}[\big(\theta_g(c_{ijm} - \kappa_g) - \kappa_f\big)\, \mathbf{1}[c_{ijm} \geq \kappa_f]]. \tag{A31}$$

The public reinsurance expenses per insured r_{ijm} is

$$g_{ijm}(\kappa_g) = (1 - \theta_g)(c_{ijm} - \kappa_g)\mathbf{1}[\kappa_g \leq c_{ijm}]. \tag{A32}$$

Equation (A30) indicates that insurers' liabilities per insured c^r_{ijm} is a random variable that depends on

the ex-post realization of an enrollee's health state and the generosity of reinsurance contracts. Applying the distributional assumptions of c_{ijm}, we derive

$$\mathbb{E}[c^r_{ijm}(\kappa_f,\kappa_g,\theta_g)] = \int_{-\infty}^{\frac{\kappa_g}{\psi_{jm}\lambda_j}} \psi_{jm}\lambda_j c_i f(c_i)dc_i + \int_{\frac{\kappa_g}{\psi_{jm}\lambda_j}}^{\frac{\kappa_f}{\psi_{jm}\lambda_j}} (\theta_g\psi_{jm}\lambda_j c_i + \kappa_g - \theta_g\kappa_g)f(c_i)dc_i + \int_{\frac{\kappa_f}{\psi_{jm}\lambda_j}}^{\infty} \kappa_f f(c_i)dc_i. \tag{A33}$$

$$\begin{aligned}\text{Var}[c^r_{ijm}(\kappa_f,\kappa_g,\theta_g)] = &\int_{-\infty}^{\frac{\kappa_g}{\psi_{jm}}\lambda_j} (\psi_{jm}\lambda_j c_i - \mathbb{E}[c^r_{ijm}(\kappa_f,\kappa_g,\theta_g)])^2 f(c_i)dc_i \\ &+ \int_{\frac{\kappa_g}{\psi_{jm}\lambda_j}}^{\frac{\kappa_f}{\psi_{jm}\lambda_j}} (\theta_g\psi_{jm}\lambda_j c_i + \kappa_g - \theta_g\kappa_g - \mathbb{E}[c^r_{ijm}(\kappa_f,\kappa_g,\theta_g)])^2 f(c_i)dc_i \\ &+ \int_{\frac{\kappa_f}{\psi_{jm}\lambda_j}}^{\infty} (\kappa_f - \mathbb{E}[c^r_{ijm}(\kappa_f,\kappa_g,\theta_g)])^2 f(c_i)dc_i.\end{aligned} \tag{A34}$$

$f(c_i)$ is the probability density function (pdf) of the standard log-normal distribution. The analytical expressions for $\mathbb{E}[c^r_{ijm}(\kappa_f,\kappa_g,\theta_g)]$ and $\text{Var}[c^r_{ijm}(\kappa_f,\kappa_g,\theta_g)]$ are available due to the log-normal distributional assumptions. We omit them here to save space.

Equations (A33) and (A34) reveal that reinsurance reduces the expectation and variance of the insurers' claims liabilities per enrollee. All else equal, the public option reduces the means and dispersions of claims distribution, compared to the case where no public reinsurance is available.

$$\mathbb{E}[c^r_{ijm}(\kappa_f,\kappa_g,\theta_g)] < \mathbb{E}[c^r_{ijm}(\kappa_f)] < \mathbb{E}[c_{ijm}],$$

$$\text{Var}[c^r_{ijm}(\kappa_f,\kappa_g,\theta_g)] < \text{Var}[c^r_{ijm}(\kappa_f)] < \text{Var}[c_{ijm}],$$

where $\mathbb{E}[c_{ijm}]$ and $\text{Var}[c_{ijm}]$ are moments without any reinsurance in equations (A22), (A23); $\mathbb{E}[c^r_{ijm}(\kappa_f)]$ and $\text{Var}[c^r_{ijm}(\kappa_f)]$ are moments with only private reinsurance in equations (A28), (A29).

With the mean and variance of claims derived at the enrollee level, we apply the central limit theorem as in the prior case to derive the formulas for insurers' total claims. $C_f(\vec{p},\kappa_f,\kappa_g,\theta_g)$ is a random variable:

$$C_f(\vec{p},\kappa_f,\kappa_g,\theta_g) = \sum_{m,i,j} N_m w_{im} s_{ijm}(\vec{p}_m) c^r_{ijm}(\kappa_f,\kappa_g,\theta_g),$$

$$C_f(\vec{p},\kappa_f,\kappa_g,\theta_g) \xrightarrow{d} N\Big(\mathbb{E}[C_f(\vec{p},\kappa_f,\kappa_g,\theta_g)], \text{Var}[C_f(\vec{p},\kappa_f,\kappa_g,\theta_g)]\Big),$$

$$\mathbb{E}[C_f(\vec{p},\kappa_f,\kappa_g,\theta_g)] = \sum_{m,i,j} N_m w_{im} s_{ijm}(\vec{p}) \mathbb{E}[c^r_{ijm}(\kappa_f,\kappa_g,\theta_g)],$$

$$\text{Var}[C_f(\vec{p},\kappa_f,\kappa_g,\theta_g)] = \sum_{m,i,j} N_m w_{im} s_{ijm}(\vec{p}) \text{Var}[c^r_{ijm}(\kappa_f,\kappa_g,\theta_g)].$$

$\mathbb{E}[C_f(\vec{p}, \kappa_f, \kappa_g, \theta_g)]$ is the expected claims costs used in the insurer's objective function (equation (13)).

Equations (A31) and (A32) further reveal that the availability of public reinsurance reduces the actuarial value of private reinsurance, thus lowering total expenditure on private contracts.

$$\mathbb{E}[c_{ijm}] - \mathbb{E}[c^r_{ijm}] = r_{ijm}(\kappa_f, \kappa_g, \theta_g) + \mathbb{E}[g_{ijm}] > r_{ijm}(\kappa_f),$$

where $r_{ijm}(\kappa_f)$ is defined in equation (A27), where no public option is available.

The total expense on private reinsurance is a scalar that equals the exogenous markup times the actuarial value of reinsurance contracts.

$$R_f(\vec{p}, \kappa_f, \kappa_g, \theta_g) = \sum_{m,i,j} N_m w_{im} s_{ijm}(\vec{p}) \tau_f r_{ijm}(\kappa_f, \kappa_g, \theta_g),$$

$$r_{ijm}(\kappa_f, \kappa_g, \theta_g) = \int_{\frac{\kappa_f}{\psi_{jm}\lambda_j}}^{\infty} (\theta_g \psi_{jm} \lambda_j c_i + \kappa_g - \theta_g \kappa_g - \kappa_f) f(c_i) dc_i.$$

We again use the asymptotic variance of aggregate claims to calculate risk charges, which is a scalar:

$$L_f(\vec{p}, \kappa_f, \kappa_g, \theta_g) = \rho_f \sqrt{\text{Var}[C_f(\vec{p}, \kappa_f, \kappa_g, \theta_g)]}.$$

We finally derive ex-post reinsurance expenses of the government, which is also a random variable that depends on consumers' health status realizations:

$$G(\vec{p}, \kappa_g, \theta_g) = \sum_{m,i,j,f} N_m w_{im} s_{ijm}(\vec{p}_m) g_{ijm}(\kappa_g, \theta_g).$$

Unlike previous aggregate variables, government transfers do not depend on the design of private reinsurance contracts κ_f, and aggregates across all players f on the market. The asymptotic distribution is

$$G(\vec{p}, \kappa_g, \theta_g) \xrightarrow{d} N\Big(\mathbb{E}[G(\vec{p}, \kappa_f, \kappa_g, \theta_g)], \text{Var}[G(\vec{p}, \kappa_f, \kappa_g, \theta_g)]\Big),$$

$$\mathbb{E}[G(\vec{p}, \kappa_g, \theta_g)] = \sum_{m,i,j,f} N_m w_{im} s_{ijm}(\vec{p}) \mathbb{E}[g_{ijm}(\kappa_f, \kappa_g, \theta_g)],$$

$$\text{Var}[G(\vec{p}, \kappa_g, \theta_g)] = \sum_{m,i,j,f} N_m w_{im} s_{ijm}(\vec{p}) \text{Var}[g_{ijm}(\kappa_f, \kappa_g, \theta_g)].$$

$$\mathbb{E}[g_{ijm}(\kappa_g, \theta_g)] = \int_{\frac{\kappa_g}{\psi_{jm}\lambda_j}}^{\infty} (1 - \theta_g)(\theta_g \psi_{jm} \lambda_j c_i - \kappa_g) f(c_i) dc_i.$$

$$\text{Var}[g_{ijm}(\kappa_g, \theta_g)] = \int_{\frac{\kappa_g}{\psi_{jm}\lambda_j}}^{\infty} ((1 - \theta_g)(\theta_g \psi_{jm} \lambda_j c_i - \kappa_g) - \mathbb{E}[g_{ijm}(\kappa_g, \theta_g)])^2 f(c_i) dc_i.$$

In addition, we consider the opposite case where the insurer purchases a private reinsurance coverage with the deductible lower than the government threshold, $\kappa_f \leq \kappa_g$. In this scenario, the cost shares between

parties are as follows. When the per-member claims cost c_{ijm} is below both thresholds, the insurer pays the full portion of c_{ijm}. When the per-member claims cost is higher than the private reinsurance deductible but lower than the government reimbursement threshold, the insurer pays κ_f, and the reinsurer pays $c_{ijm} - \kappa_f$. When the per member claims cost c_{ijm} is above both thresholds, the insurer pays κ_f, the government pays $(1-\theta_g)(c_{ijm}-\kappa_g)$, and the reinsurer pays $\theta_g c_{ijm}+(1-\theta_g)\kappa_g-\kappa_f$. Claims costs paid by insurer, reinsurer, and government reinsurance program are thus

$$c^r_{ijm}(\kappa_f,\kappa_g,\theta_g) = c_{ijm}\mathbf{1}[c_{ijm}<\kappa_f] + \kappa_f\mathbf{1}[\kappa_f \le c_{ijm}],$$

$$r_{ijm}(\kappa_f,\kappa_g,\theta_g) = (c_{ijm}-\kappa_f)\mathbf{1}[\kappa_f \le c_{ijm} \le \kappa_g] + (\theta_g c_{ijm} + (1-\theta_g)\kappa_g - \kappa_f)\mathbf{1}[\kappa_g < c_{ijm}]$$

$$g_{ijm}(\kappa_g) = (1-\theta_g)(c_{ijm}-\kappa_g)\mathbf{1}[\kappa_g < c_{ijm}].$$

Derivations of total claims, reinsurance expenses, and risk charges follow the same techniques as before.

E4. Accomodating Correlated Cost Shocks.

We show how to extend our framework to incorporate correlated cost shocks. Suppose the claims costs per enrollee paid by insurers $\tilde{c}_{ijm}$ are now the sum of a log-normally distributed iid cost c_{ijm} as before, and a common cost term $\log(x) \sim N(\mu_x, \sigma_x^2)$ that is independent of c_{ijm}.

$$\mathbb{E}[x] = \exp(\mu_x + \frac{1}{2}\sigma_x^2), \text{Var}[x] = \exp(\sigma_x^2 - 1)\exp(2\mu_x + \sigma_x^2). \tag{A35}$$

Applying the Fenton-Wilkinson approximation, we can use a lognormal distribution to approximate the distribution of $\tilde{c}_{ijm}$.

$$\tilde{c}_{ijm} = c_{ijm} + x,\ \log(\tilde{c}_{ijm}) \to N(\tilde{\mu}_i, \tilde{\sigma}_i),$$

where $\tilde{\mu}_i$, $\tilde{\sigma}_i$ satisfies

$$\exp(\tilde{\mu}_i + \frac{1}{2}\tilde{\sigma_i}^2) = \psi_{jm}\lambda_j \exp(\mu_i + \frac{1}{2}\sigma_i^2) + \exp(\mu_x + \frac{1}{2}\sigma_x^2),$$

$$\exp(\tilde{\sigma}_i^2 - 1)\exp 2(\tilde{\mu}_i + \sigma_i^2) = \exp(\sigma_i^2 - 1)\exp(2(\mu_i + \log(\psi_{jm}\lambda_j)) + \sigma_i^2) + \exp(\tilde{\sigma}_x^2 - 1)\exp(2\mu_x + \sigma_x^2).$$

Summing up the claims across consumers i and market m, the total claims costs of insurer f is

$$\tilde{C}_f(\vec{p}) = \underbrace{\sum_m \sum_i \sum_{j\in J_{fm}} N_m w_{im} s_{ijm}(\vec{p}_m) c_{ijm}}_{C_f(\vec{p}) \text{ as in equation (A24)}} + \underbrace{\sum_m \sum_i \sum_{j\in J_{fm}} N_m w_{im} s_{ijm} x}_{N_f(\vec{p})x}, \tag{A36}$$

$$\xrightarrow{d} N\Big(\mathbb{E}[C_f(\vec{p})] + N_f(\vec{p})\mathbb{E}[x], \text{Var}[C_f(\vec{p})] + N_f^2(\vec{p})\text{Var}[x]\Big), \text{ where}$$

$$N_f(\vec{p}) = \sum_{m,i,j} N_m w_{im} s_{ijm}(\vec{p}); \tag{A37}$$

$\mathbb{E}[C_f(\vec{p})]$ and $\text{Var}[C_f(\vec{p})]$ are derived in equation (A25); $\mathbb{E}[x]$ and $\text{Var}[x]$ are derived in equation (A35).

The rest of the derivations are the same as in Section E1-E3: we use the asymptotic (or approximated) distribution of $\tilde{C}_f$ (or $\tilde{c}_{ijm}$) to calculate total claims, reinsurance expenses, and risk charges.

E5. Accomodating Quota-Share Reinsurance.

We now consider a quota-share reinsurance with a deductible κ_f and cost-share $1-\theta_f$. The insurer pays the full amount of its scheduled claims costs c_{ijm} when c_{ijm} is below the deductible threshold κ_f. In contrast, when c_{ijm} is above the deductible threshold κ_f, the insurer pays $\kappa_f + \theta_f(c_{ijm} - \kappa_f)$ and the reinsurer pays for the reminder, $(1-\theta_f)(c_{ijm} - \kappa_f)$. Let c^r_{ijm} denote the claim costs paid by the insurer f for a consumer in risk type i enrolled with the plan j, r_{ijm} denote the actuarial value of reinsurance per insured:

$$c^r_{ijm}(\kappa_f, \theta_f) = c_{ijm}\mathbf{1}[c_{ijm} < \kappa_f] + (\kappa_f + \theta_f(c_{ijm} - \kappa_f))\mathbf{1}[c_{ijm} \geq \kappa_f].$$

$$r_{ijm}(\kappa_f, \theta_f) = \mathbb{E}[c_{ijm}] - \mathbb{E}[c^r_{ijm}] = \mathbb{E}[(1-\theta_f)(c_{ijm} - \kappa_f)\mathbf{1}[c_{ijm} \geq \kappa_f]].$$

Note that for each quota-share contract with deductible κ_f and cost share θ_f, we can find another stop-loss reinsurance contract κ'_f that delivers the same actuarial fair value. In other words, for each (κ_f, θ_f) combination, there is always a $\kappa'_f > \kappa_f$ that satisfies

$$\mathbb{E}[(1-\theta_f)(c_{ijm} - \kappa_f)\mathbf{1}[c_{ijm} \geq \kappa_f]] = \mathbb{E}[(c_{ijm} - \kappa'_f)\mathbf{1}[c_{ijm} \geq \kappa'_f]].$$

We only observe the total amount of private reinsurance premiums, but not the exact contract details, such as deductibles per enrollee or cost shares. Since both reinsurance formats could deliver the same results, our modelling assumption is innocuous in terms of matching the observed reinsurance expenses.

Recall that the level of private reinsurance expenses identifies risk preferences. Since we can construct different formats of reinsurance contracts of the same actuarial value, the remaining piece to examine is how different contracts affect the variance of claims. We rewrite the FOC to reflect the identification intuition:

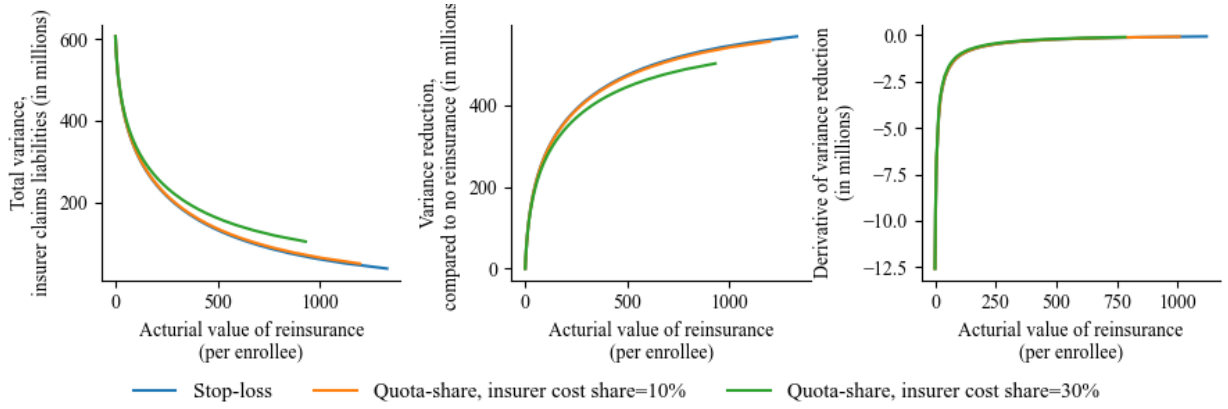
$$\underbrace{-(\tau - 1)}_{\text{markup over acturial value}} = \underbrace{\rho_f \frac{1}{N_f} \frac{\partial \text{Std}[C_f]}{\partial r_f}}_{\text{risk charge reduction}}, \tag{A38}$$

where r_{ft} is the actuarial value of reinsurance that the health insurer purchases. If in reality the reinsurance contract is quote-share with parameters (κ_f, θ_f) but we assume a stop-loss format with κ'_f of equilvalent actuarial value, the estimated risk charge reduction will be different.

To compare risk reduction under quota-share reinsurance and stop-loss reinsurance, we simulate $\frac{\partial \text{Std}[C_{ft}]}{\partial r_{ft}(\kappa_f, \theta_f)}$ and $\frac{\partial \text{Std}[C_{ft}]}{\partial r_{ft}(\kappa'_f)}$ under different contract arrangements. We take the empirical claims distribution from CO APCD, construct reinsurance contracts with various deductibles and cost shares, and compute the expected claims reduction (contract actuarial value), expected variance reduction, and the derivative of the variance of claims with respect to contract actuarial value (right-hand side of equation (A38)). Figure A8 displays the results.

At the same actuarial value, or reinsurance expenses per enrollee, stop-loss contracts overstate decreases in total variance compared to quota-share contracts. Our modeling assumption of stop-loss contracts thereby

Figure A8. Effect of reinsurance under different contract formats



Notes: This figure plots the effect of reinsurance under different contract formats. We take the empirical claims distribution from CO APCD, construct reinsurance contracts with various deductibles and cost shares, and compute the following statistics. The horizontal axis is the expected claims reduction, i.e., the actuarial value of reinsurance. The vertical axis displays the total variances of insurers' claims liabilities per enrollee in the left panel; the variance reduced by the reinsurance contract compared to the no reinsurance case in the middle panel; the derivative of variances of insurers' claims liabilities with respect to the actuarial value of reinsurance in the right panel.

overstates the marginal risk charge reduction from reinsurance coverage. The estimated risk preferences are a lower bound of the true risk preference parameters.

However, at the observed reinsurance expenses (around $200 annually per enrollee, as reported in Table 1, A8), the difference between each contract arrangement, especially the derivative of variance with respect to reinsurance coverage, is fairly small. This implies that the estimated risk preferences will not differ too much when we use different assumptions on contracting arrangements.

E6. Accomodating Group-Based Reinsurance.

We show how to extend our empirical model to accommodate reinsurance contracts that have a deductible for the sum of individual costs, but not separately for each individual. Apply the private reinsurance with a deductible κ_f, we write out the first two moments of the aggregate claims C_f:

$$\mathbb{E}[C_f(\vec{p},\kappa_f)] = \mathbb{E}[C_f(\vec{p})|C_f(\vec{p}) \leq \kappa_f] + \kappa_f \Pr[C_f(\vec{p}) > \kappa_f],$$

$$\text{Var}[C_f(\vec{p},\kappa_f)] = \mathbb{E}[(C_f(\vec{p}) - \mathbb{E}[C_f(\vec{p},\kappa_f)])^2|C_f(\vec{p}) \leq \kappa_f] + (\kappa_f - \mathbb{E}[C_f(\vec{p},\kappa_f)])^2 \Pr[C_f(\vec{p}) > \kappa_f].$$

Equation (A25) shows that C_f has a normal distribution asymptotically when each consumer's health risk is independent and identically distributed. We could thus use the asymptotic distribution to approximate C_f's distribution and compute the above terms. The effect of private reinsurance is the same as in the baseline model, that it reduces both the mean and the variance of total costs. The rest of the derivations are the same as in Section E1-E3: we use the asymptotic distribution of $\tilde{C}_f$ to calculate total claims, reinsurance expenses, and risk charges.

For each group-based stop-loss contract with deductible κ_f, we can find another individual-based stop-loss reinsurance contract κ_f' that delivers the same actuarial fair value. In other words, for each κ_f, there is

always a κ'_f that satisfies

$$\mathbb{E}[(C_f(\vec{p}) - \kappa_f)\mathbf{1}[C_f(\vec{p}) \geq \kappa_f]] = N_f(\vec{p})\mathbb{E}[(c_{ijm} - \kappa'_f)\mathbf{1}[c_{ijm} \geq \kappa'_f]] = R_f^{obs},$$

where $N_f(\vec{p})$ is defined in equation (A37). Both reinsurance arrangements could match the observed reinsurance expenses.

We further examine how group-based or individual-based contracts affect the variance of total claims, for the same amount of total reinsurance expenses. If, in reality, the reinsurance contract is group-based, but our modeling assumption is individual-based, we will overestimate the variance reduction for contracts with the same actuarial value, because individual-level risks could offset each other when calculating aggregate costs. In that scenario, we underestimate risk preferences from equation (A38).