The Design of Public Reinsurance *

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Abstract

We study the effectiveness and design of pubic reinsurance. Reinsurance takes the form of ex-post payments from either private reinsurers or the government to insurers for incurring high-cost enrollees. We argue that reinsurance reduces insurers' cost of financial friction, i.e., additional costs incurred for taking on risk. We show evidence of health insurers internalizing financial frictions with their private reinsurance purchases. In response to public reinsurance subsidies, insurers purchase less private reinsurance and lower health insurance premiums, with an estimated pass-through of 1.3. We develop and estimate an equilibrium model to decompose the pass-through of reinsurance subsidies into three components: a reduction in expected costs, a reduction in insurer risk, and competitive effects. Counterfactuals further reveal that supply-side reinsurance subsidies can be more efficient than demand-side premium subsidies in reducing consumer prices. Our results highlight the importance of addressing supply-side frictions to foster effective competition.

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1. Introduction

Government risk sharing plays a central role in many markets. In credit markets, public programs guarantee various loans, including small business, student, and mortgage loans, shielding private lenders from default risk (Bachas et al., 2021; Stillerman, 2024). In financial markets, deposit insurance and central bank liquidity facilities protect intermediaries from solvency and liquidity shocks (Diamond and Dybvig, 1983). In insurance markets, public reinsurance helps share the financial burden for insurers covering catastrophic losses related to natural disasters or health shocks (Froot, 2001; Swartz, 2003). In the absence of such policies, increased risk exposure could lead firms to raise prices, reduce coverage, or exit altogether, ultimately limiting consumer access. However, despite their prevalence, the mechanisms through which government risk sharing shapes market outcomes remain understudied, particularly in health insurance, where public involvement is extensive and complex.

This paper examines the effectiveness and design of reinsurance as a public risk-sharing tool in health insurance. Reinsurance provides ex-post payments, from the government or private reinsurers, to insurers that incur large, adverse claims. We argue that public reinsurance impacts insurers' behavior through two distinct mechanisms. The first is a *cost subsidy*: by reimbursing a portion of high-cost claims without charging an actuarially fair premium in advance, public reinsurance lowers the insurer's expected cost of coverage. This reduction in marginal cost can translate into lower premiums and expanded consumer access, provided insurers pass through the cost savings. Yet in markets with imperfect competition or if reinsurance mitigates adverse selection, such pass-through may be limited (Cabral et al., 2018; Einav et al., 2019).

The second, often-overlooked mechanism is *risk protection*. Insurers face convex costs of bearing risk, as they are penalized by regulators, credit markets, and rating agencies when their portfolios become riskier or their financial condition weakens. We characterize these extra indirect costs of bearing risk as insurers' cost of financial frictions, stemming from volatility in claims, capital constraints, or regulatory oversight. By shielding insurers from adverse cost realizations, reinsurance diminishes the need for costly risk management activites, such as maintaining excess capital or purchasing private reinsurance. These savings can be substantial in the presence of financial frictions. Public reinsurance, then, does more than shift expected costs: it alleviates the burden of operating under uncertainty, relaxing insurers' capital constraints and mitigating the implicit costs associated with risk-bearing.

This paper makes two contributions. First, we provide novel evidence that insurers internalize financial frictions. Second, we develop a tractable empirical model to examine when and how reinsurance influences insurer behavior and improves market outcomes. In the model, oligopoly insurers choose price and private reinsurance purchases and face additional costs when their portfolio of enrollees is riskier, which captures financial frictions. We derive how the efficiency of public reinsurance varies with the degree of financial friction and find that the pass-through rate of public reinsurance subsidies to consumer prices exceeds unity. Aligned with it, we find ex-post reinsurance subsidies to insurers can be more efficient than uniform premium subsidies to consumers in reducing prices and expanding access. Our framework highlights the importance of regulating supply-side distortions and applies to markets with uncertain cost structures, such as property and casualty or climate insurance.

We focus on health insurance, which is attractive for several reasons. First, this market offers exceptionally rich and high-quality data compared to other insurance contexts. Granular individual-level panels of medical claims provide detailed insights into population risk distributions and realized costs in the downstream product market. At the same time, transaction-level records of reinsurance purchases offer a clear view of insurers' risk-offloading behavior in the upstream market. Second, several states have implemented public reinsurance programs in the individual exchange market, which reimburse insurers for a portion of high-cost claims once an enrollee's expenses exceed a predefined threshold. These quasi-experimental variations create a unique opportunity to study how insurers respond when public reinsurance exogenously alters their risk exposure. We use this setting to examine how financial frictions affect insurer behaviors.

We begin with a stylized model of a monopoly insurer's pricing behavior in the presence of financial frictions. These frictions are modeled as convex costs of bearing risk (Jean-Baptiste and Santomero, 2000), which cause insurers to behave as if they are risk-averse and to incorporate additional risk charges into prices. Our main theoretical result is that the pass-through of reinsurance subsidies to consumer prices can exceed one when financial frictions are present. This result is driven by reinsurance's dual role in reducing both expected costs and risk exposure. In addition to acting as a direct cost subsidy, reinsurance reduces the extra costs insurers face when taking on risk, which are ultimately passed through to consumer prices.

We next present several pieces of evidence that health insurers are exposed to cost uncertainty and internalize the financial frictions 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 demonstrate that the distribution of claims costs has a long right tail. Both simulations and observed cost-to-price realizations indicate that insurers indeed face significant fluctuations in costs. To manage this risk, insurers may either incur additional capital costs to raise funds (Masson, 1972) or purchase private reinsurance to transfer liabilities (Koijen and Yogo, 2015).

Second, to illustrate that insurers engage in such risk-management behavior, 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 the fact that financial frictions play a key role in shaping these decisions.

Third, we conduct an event study exploiting the staggered initiation of state-level public reinsurance programs on the exchange market. We find that reinsurance subsidies significantly reduce health insurance premiums by around 15%. 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 insurers' expected claims and risk exposure, thereby lowering the cost of financial frictions for insurers. Furthermore, insurers substitute away from purchasing private reinsurance in response to public reinsurance subsidies. These responses in premiums and private reinsurance are more pronounced for insurers that are more financially constrained. We find no evidence that public reinsurance affects insurers' entry or exit, the overall cost of care (moral hazard), or the private reinsurance markups they face. Taken together, these results suggest that financial frictions influence both insurer pricing and private reinsurance purchases.

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

Motivated by these facts, we develop an equilibrium model to quantify the impacts of financial frictions and explore optimal government risk-sharing design. Consumers' demand for insurance follows a standard discrete choice model (Berry et al., 1995). Their key primitives are heterogeneous price elasticities by age and health risks, capturing rich demand curvatures and flexible selection patterns. Insurers simultaneously choose health insurance premiums 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, which they can mitigate by purchasing reinsurance. Insurers' key primitives include standard marginal costs of coverage and their risk preferences, i.e., the extent to which the riskiness of their 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 reveal that small regional insurers behave as if they are more risk-averse than their larger counterparts. On average, regional insurers spend 1.6-3.8% of their health insurance premiums to purchase reinsurance from private third parties, whereas most national insurers on the CO exchange do not. The estimated risk charges, i.e., the incremental cost associated with holding a riskier enrollee portfolio and embedded in price setting, range from 2.7% to 4% of premiums for regional insurers. Combining expenditures on private reinsurance and internal risk charges, the effective marginal cost faced by financially constrained regional insurers is approximately 7% higher than that of their less-constrained national counterparts. These findings suggest financial frictions meaningfully impede the pricing competitiveness of smaller insurers.

We use the model to decompose the more-than-unity pass-through of public reinsurance into three channels: claims reduction, risk reduction, and competitive effects. First, public reinsurance covers a portion of high-cost claims, reducing insurers' claims expenses by 16%. This accounts for 74% of observed reductions in premiums. Second, by shielding insurers from extreme adverse shocks, public reinsurance lowers risk charges and private reinsurance expenditures. The risk mitigation explains 11% of premium declines. Third, public reinsurance relaxes financial constraints for smaller regional insurers, allowing them to compete more effectively. The resulting increase in market competition generates downward pricing pressure, contributing an additional 15% to price reductions. Moreover, the first two channels reinforce each other: by ceding tail risks of high-cost enrollees, public reinsurance lowers risk charges and insurance prices, attracting price-sensitive healthy consumers with less-dispersed claims distributions. This further suppress the riskiness of the enrollee portfolio and financial costs per insured. Taken together, beyond its role as direct cost subsidies, public reinsurance improves market efficiency due to enhanced risk-sharing and stronger competition, resulting in greater reductions in consumer premiums than the government's reinsurance expenses.

We further examine the optimal degree of government risk-sharing when designing public reinsurance, which depends on two countervailing factors. First, reinsurance provides cost subsidies and risk offloading. As public reinsurance becomes more generous, distortions from financial frictions diminish towards zero. Reduced costs and risk charges are passed through to prices, benefiting consumers. Second, reinsurance mitigates adverse selection by compressing variation in expected claims across risk types. This raises markup, as the positive profit gap between the marginal and average consumer shrinks, relieving the downward pricing pressure from adverse selection. Increased markup could offset cost cuts, harming consumers.

When the generosity of reinsurance increases, distortions from financial frictions attenuate, but harms from market power amplify. Accounting for the cost of public funds, we find that a 40% government risk-sharing maximizes social surplus, precisely the status quo design in CO. Our framework, therefore, highlights that the optimal risk-sharing design hinges on the shape of both supply and demand curves, which govern the degree of financial frictions, adverse selection, and pricing power.

Lastly, we explore optimal subsidy allocations, comparing the effectiveness of supply-side reinsurance subsidies and demand-side premium subsidies under a fixed government budget. We find that reinsurance subsidies are more efficient under current market conditions than uniform premium subsidies in bringing down prices. This result is again driven by the relative effect of risk reduction and markup inflation. On the one hand, reinsurance provides risk protection, shifting down marginal cost curves more than premium subsidies, which leaves insurers' risk dispersions unaffected. On the other hand, reinsurance flattens marginal cost curves and raises markup, whereas premium subsidies do not rotate cost curves. As the degree of financial frictions is considerable concurrently, the risk reduction effect dominates. These results underscore that addressing supply-side distortions can effectively improve the functioning of insurance markets.

The implications of financial frictions extend beyond health insurance. Government risk-sharing may play a critical role in markets exposed to increasingly large 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 insurers to substantially raise premiums or, in some cases, exit the market entirely. By similar logic, government risk-sharing through policies like reinsurance can help firms manage risk more effectively, resulting in lower premiums and increased insurance take-up. Our framework thus informs ongoing policy debates about the appropriate scope and scale of public reinsurance in other contexts, including wildfire insurance (Araullo, 2025) and Medicare Part D drug insurance (Medicare Payment Advisory Commission, 2020).

Our analysis offers insights into policy designs that promote effective competition. A key premise of the managed competition paradigm is that private insurers create value by competing on price. However, small regional insurers that are more financially constrained may be forced to raise premiums in the presence of financial frictions, undermining the efficiency of this model. We show that reinsurance subsidies can alleviate these upward pricing pressures, especially for smaller insurers, thereby enhancing competition and improving market welfare. These findings highlight the importance of addressing supply-side frictions to foster effective competition.

Related Literature. First, our paper adds to studies on the financial and regulatory frictions facing insurers. Seminal work by Koijen and Yogo (2015, 2016) shows that life insurers pass financial frictions to the pricing of insurance contracts. Kim (2022) estimates a model of risk-averse health insurers to study risk-sharing policies in Medicare Part D. More broadly, we build on the literature that examines how financial frictions from imperfect capital markets can induce risk aversion preferences (Masson, 1972; Froot and Stein, 1998; Hakansson, 1970). Our contribution is to document financial frictions for health insurers, leveraging novel reinsurance purchase data, and to analyze the implications of financial frictions for policy designs.

Second, our paper contributes to the empirical market design literature on the choice of optimal regulatory instruments. Prior work has examined the allocation of consumer and production subsidies in sectors such as electric vehicles (Springel, 2021) and solar panels (De Groote and Verboven, 2019), the distribution of consumer vouchers and school entry subsidies in education (Allende, 2019; Bodéré, 2023), and the granting of production, investment and entry subsidies in shipbuilding (Barwick et al., 2021). In health care, most studies examine policy instruments in isolation and focuses on demand-side frictions only.[2,3]. One notable exception is Einav et al. (2019), which compares premium subsidies to ex-ante risk adjustment transfers. In contrast, we compare consumer premium subsidies and ex-post reinsurance payments to insurers, emphasizing that ex-post transfers reduce not only expected costs but also cost *dispersion*, which in turn affects insurers' pricing strategies when they internalize financial risk.[4] We provide the first theoretical and empirical analysis of the efficiency of multiple policy instruments in health insurance that incorporates the often-overlooked financial frictions that insurers face.

Third, our paper relates to studies on pass-through and efficiency of government subsidies. Existing papers (Farrell and Shapiro, 2010; Mahoney and Weyl, 2017; Miravete et al., 2018; Weyl and Fabinger, 2013) show that pass-through rates under risk-neutral oligopoly competition depend on demand curvature. We additionally document the role of supply curvature, especially the risk-preferences induced cost components, in affecting the pass-through of government subsidies to the supply side. While most papers find less than complete pass-through rates (Cabral et al., 2018; Koujianou Goldberg and Hellerstein, 2013; Nakamura and Zerom, 2010), some studies also find over-shifting, for example, analyses of solar subsidies (Pless and Van Benthem, 2019), soda taxes (Dubois et al., 2020), or alcohol taxes (Kenkel, 2005). We document more-than-complete pass-through with a novel underlying mechanism, where we show that the existence of financial frictions makes subsidy efficacy ambiguous in insurance.

2. Institutional Background

Capital Adequacy Requirements Insurance regulators, like the National Association of Insurance Commissioners (NAIC), evaluate insurers' financial strength using risk-based and statutory 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. The risk-based capital (RBC) ratio, calculated as the ratio of capital surplus, i.e., asset 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). Similarly, regulations exist on minimum statutory capital, measured by the amount of capital surplus the insurer has above the risk-based capital required.

Most health insurers' liability stems from their underwriting risk: their enrollees' claims cost. Their RBC ratio is an ex-post solvency measure of how much extra capital insurers have in relation to their claims liability. The RBC regulations imply insurers must hold or raise a certain level of capital for the medical

[2] For example, premium subsidies (Decarolis et al., 2020; Finkelstein et al., 2019; Polyakova and Ryan, 2019; Tebaldi, 2025), risk adjustment (Brown et al., 2014; Glazer and McGuire, 2000; Geruso and Layton, 2020; Layton et al., 2018), and the design of health insurance exchanges (Azevedo and Gottlieb, 2017; Handel et al., 2015). See Handel and Ho (2021) for a review.

[3] Notably, existing literature on reinsurance are descriptive (Polyakova et al., 2021; Drake et al., 2019; McGuire et al., 2020) We contribute by pointing out the novel mechanism of financial frictions through which reinsurance affects insurers' behaviors. We also develop a quantitative framework to examine optimal policy design.

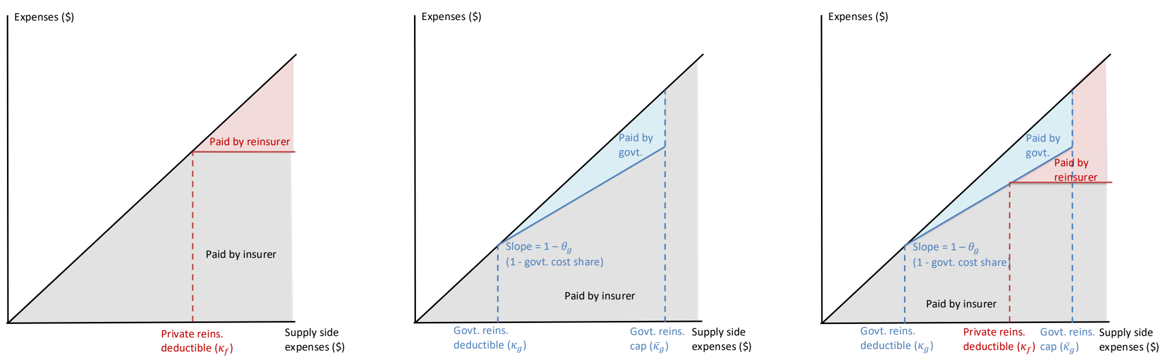
[4] Although both risk adjustment and reinsurance are payments to insurers that change the means of an enrollee's expected costs, a significant difference is that ex-ante risk adjustment does not change the *variance* of the enrollee's cost distribution while ex-post reinsurance does. The *dispersion* of cost distribution is an essential source of financial friction that we focus on in this paper.

claims expenses they are assuming.

Private Reinsurance. Given the risk-based capital regulation and financial frictions, primary insurers often purchase private reinsurance from third parties to increase their underwriting ability without raising additional capital. At the basic level, 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. Illustration of Reinsurance

(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.[5] 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% (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.

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

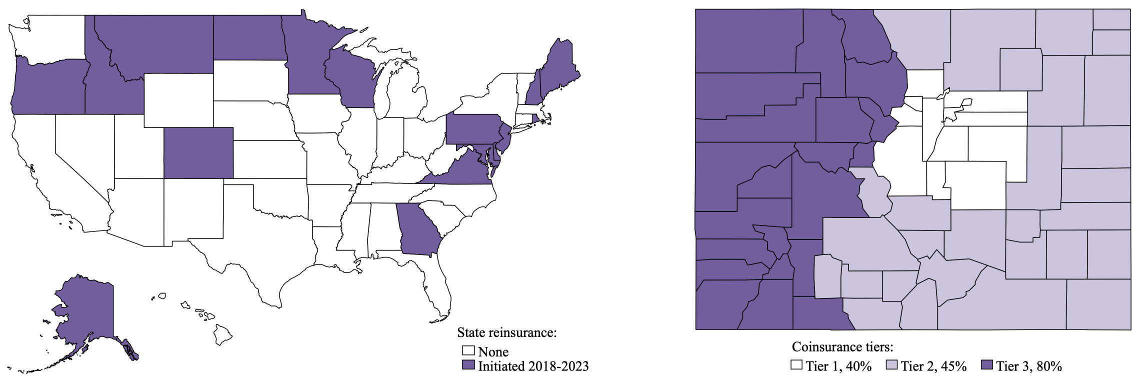
[5] In 2023, Swiss Re, the world’s largest reinsurer, collected 10% of its premiums from the health segment (A.M. Best, 2024).

cover tail risk events, hoping that cost savings can be passed through to consumers with lower insurance premiums (Lueck, 2019).

We study public reinsurance in the individual health insurance market (hereafter, the exchange). Private health insurers offer various coverage options on the exchange. 3% of the US population who are not eligible for Medicaid or Medicare and without employer-sponsored insurance purchase exchange products. Products are offered at the county level and follow standardized cost-shares and age-rating schedules. Health insurers cannot reject enrollees or price-discriminate based on health status. Appendix B describes additional institutional details.

Figure 2. 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 2018-2023. Panel (b) plots the differential cost-shares within the Coloratio reinsurance program, which started in 2020. Source: CMS (2024).

A federal reinsurance program existed in the exchange market nationwide from 2014 to 2016. However, since its discontinuation, 18 states have implemented their own reinsurance programs as of 2023. 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 reinsurance subsidies.

3. Stylized Framework

This section outlines a stylized model to illustrate how financial frictions interact with government risk-sharing to affect insurance pricing.

Effect of Financial Frictions on Insurance Pricing. Suppose there is a monopoly insurer selling a single insurance plan. We assume that the insurer cannot distinguish consumers' risk type ex-ante, and charges all consumers the same price. There are two types of individuals in the market with $t \in \{\ell, h\}$. The insurer faces an elastic demand of $q_t(p)$ for individuals of type t. We assume that type $t = \ell$ individuals have more elastic demand i.e. $\varepsilon_\ell(p) \geq \varepsilon_h(p), \forall\, p$ where $\varepsilon(p)$ is the price elasticity of demand. For each individual i of type t, the insurer faces a random marginal cost $\tilde{c}_i^t \sim F_t$, $\tilde{c}_i^t \in [0, \infty)$. We assume $\tilde{c}_i$ is independently distributed regardless of the individual's type. We allow for the possibility of selection by allowing F_t to be different across individual types. Let $c_t = E[\tilde{c}_i^t]$, and $\sigma_t^2 = \text{Var}(\tilde{c}_i^t)$.

The monopoly insurer behaves "as if risk averse" (Froot and Stein, 1998), and maximizes the following mean-variance objective function, where it trades off expected profit and risk, measured by the variance of claim costs (Jean-Baptiste and Santomero, 2000).

$$\max_p \quad \underbrace{p\overbrace{\left(q_\ell(p) + q_h(p)\right)}^{Q(p)}}_{\text{premium revenue}} - \underbrace{\left(c_\ell q_\ell(p) + c_h q_h(p)\right)}_{\text{expected cost}} - \underbrace{\rho \overbrace{\left(\sigma_\ell^2 q_\ell(p) + \sigma_h^2 q_h(p)\right)}^{\text{total variance}}}_{\text{risk charge}}. \tag{1}$$

We model the insurer's induced risk aversion behavior by incurring a risk charge from the uncertainty in its total cost. The risk charge is the risk preference coefficient ρ times the variance of the total cost. ρ can be interpreted as the induced risk aversion parameter where the insurer faces a CARA utility function, as the mean-variance utility is also equivalent to maximizing expected utility under an exponential utility function and normally distributed aggregate costs (Kim, 2022). We use a mean-variance utility since it allows us to flexibly account for potential frictions without specifying a particular financial or regulatory mechanism. Section 4-5 provides empirical evidence to confirm insurers' induced-risk-aversion from financial frictions.

The insurer's first-order condition is

$$\underbrace{p + \frac{Q(p)}{Q'(p)}}_{\text{marginal revenue}} = \underbrace{\left(\lambda(p)c_\ell + (1-\lambda(p))c_h\right)}_{\text{marginal claims}} + \underbrace{\rho\left(\lambda(p)\sigma_\ell^2 + (1-\lambda(p))\sigma_h^2\right)}_{\text{marginal risk charge}}, \text{ where } \lambda(p) = \frac{q_\ell'(p)}{Q'(p)}. \tag{2}$$

The insurer has an effective marginal cost that is the sum of its marginal cost and marginal risk charge. All else equal, insurers facing heightened financial frictions, i.e., having higher risk preferences ρ or facing larger cost variance, will charge higher prices. Let p_0^* denote the optimal price from equation (2).

Effect of Public Reinsurance on Insurance Pricing. We examine how public reinsurance affects the insurer's pricing behavior and its associated pass-through to the consumers. For simplicity, suppose the government offers stop-loss reinsurance that fully reimburses the insurer for any costs beyond the deductible κ_g. If an individual's ex-post cost $\tilde{c}_i > \kappa_g$, the government fully reimburses the insurer for any cost that exceeds κ_g. So, the amount of reinsurance is decreasing in κ_g, where $\kappa_g = 0$ implies full reinsurance, and $\kappa_g = \infty$ implies no reinsurance. Given such a reinsurance scheme, the insurer's ex-post cost for an individual i is

$$\tilde{c}_i(\kappa_g) = \begin{cases} \tilde{c}_i & \text{if } \tilde{c}_i \leq \kappa_g \\ \kappa_g & \text{if } \tilde{c}_i > \kappa_g. \end{cases} \tag{3}$$

Let $c_t(\kappa_g)$ and $\sigma_t^2(\kappa_g)$ denote the insurer's expected cost and the variance under a reinsurance policy with deductible κ_g, respectively. Equation (3) suggests that public reinsurance lowers both the expected cost and the variance of each individual's cost.

$$c_t(\kappa_g) = \mathbb{E}[\tilde{c}_i^t(\kappa_g)] < c_t = \mathbb{E}[\tilde{c}_i^t], \quad \sigma_t^2(\kappa_g) = \text{Var}[\tilde{c}_i^t(\kappa_g)] < \sigma_t^2 = \text{Var}(\tilde{c}_i^t).$$

Therefore, reinsurance impacts the insurer's effective marginal cost in two ways. First, it shares claims costs with the insurer, acting as a cost subsidy. Second, it is insurance for the insurer and provides certainty to the insurer's profit across different enrollees' health realizations, acting as a risk subsidy. It reduces the variance of the insurer's total cost, lowering the marginal risk charge.

The insurer's first-order condition is

$$\underbrace{p + \frac{Q(p)}{Q'(p)}}_{\text{marginal revenue}} = \underbrace{\left(\lambda(p)c_\ell(\kappa_g) + (1-\lambda(p))c_h(\kappa_g)\right)}_{\text{marginal claims}} + \underbrace{\rho\left(\lambda(p)\sigma_\ell^2(\kappa_g) + (1-\lambda(p))\sigma_h^2(\kappa_g)\right)}_{\text{marginal risk charge}}, \quad (4)$$

where $\lambda(p)$ is defined the same as in equation (2). Since reinsurance unilaterally decreases the right-hand side of Equation (4), it reduces the insurer's optimal price. Let $p^*(\kappa_g)$ denote optimal price under reinsurance with deductible κ_g, $p^*(\kappa_g) < p_0^* = p^*(\infty)$.

Pass-through of Reinsurance Subsidies. For a risk-neutral government, reinsurance subsidies that it expects to reimburse the insurer are: $r_t(\kappa_g) = \Delta c_t(\kappa_g) = c_t(\infty) - c_t(\kappa_g)$. Under public reinsurance with deductible κ_g, the average expected reinsurance cost per consumer $r(\kappa_g)$ is

$$r(\kappa_g) = \underbrace{\alpha(p)r_\ell(\kappa_g) + \left(1-\alpha(p)\right) r_h(\kappa_g)}_{\text{average reinsurance cost}} = \underbrace{\alpha(p)\Delta c_\ell(\kappa_g) + \left(1-\alpha(p)\right) \Delta c_h(\kappa_g)}_{\text{average claims reduction}}, \quad \text{where} \quad \alpha(p) = \frac{q_\ell(p)}{Q(p)}.$$

The reinsurance pass-through rate is $(p_0^* - p^*(\kappa_g))/r(\kappa_g)$.

Proposition 1 *(i) If insurer is subject to financial frictions, i.e. $\rho > 0$, the pass-through rate of reinsurance subsidies to insurance price can be greater than 1. All else equal, the larger the financial friction is, the larger the pass-through rate is. (ii) The more alleviation of adverse selection from reinsurance, the smaller the pass-through rate is.*

Appendix C1 provides a proof. The intuition for Proposition 1(i) is that reinsurance affects risk portfolios and thus risk charges when the insurer is subject to financial frictions. When the insurer bears additional costs for taking risks, drops in risk charges bring extra decreases in marginal costs, which are embedded into price setting. The extra changes in risk charges reduce effective marginal costs more than claims liabilities, which equals government expenses for reinsurance. The more considerable financial frictions the insurer faces, the more significant drops in risk charges it experiences, and the more likely more-than-complete pass-through rates are. Figure A1 displays a visual example for this intuition.

In other words, public reinsurance creates surplus for the insurer by smoothing out profits across different realizations of enrollee health states. This intuition is similar to how insurance enhances consumer surplus by equalizing wealth across different health statuses. Absent financial frictions in a standard monopoly setting, the pass-through of cost subsidies is often smaller than one due to market power (Miravete et al., 2018; Weyl and Fabinger, 2013). Accounting for the costs of insuring a risky portfolio could flip the conventional prediction, as public reinsurance serves as both a cost and a risk subsidy.[6] Empirical exercises in Section 5 confirm this theoretical prediction.

The intuition behind Proposition 1(ii) is how reinsurance changes pricing power through shifting selection patterns. Since sicker consumers are more likely to have claims realizations exceed the reinsurance reimbursement threshold and experience larger reductions in expected claims, the stop-loss reinsurance mitigates selection by rotating the marginal cost curve. This relieves the downward pricing pressure for the insurer because the positive profit gap between the marginal and average consumer shrinks. Without reinsurance flattening marginal costs, insurers are more reluctant to increase premiums because the marginal buyers they would lose are relatively cheaper and more attractive to retain. The flattening of marginal cost curves could increase markup and partly offset the price drop from risk reduction, making it less likely to achieve more-than-complete pass-through rates.

To sum up, the pass-through of public reinsurance depends on the relative magnitude of risk reduction from alleviated financial frictions and markup increase from mitigated adverse selection, and the degree of insurers' market power. In Appendix C2, we isolate the role of financial frictions, adverse selection, and market power, and compare our results to the pass-through propositions in the literature. The efficiency of public reinsurance is an empirical question that hinges on the shape of both supply and demand curves.

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 include 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.

[6]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).

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 household panel with information on health insurance coverage and total and out-of-pocket 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 year of 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 CVOID pandemic on the health insurance claims.

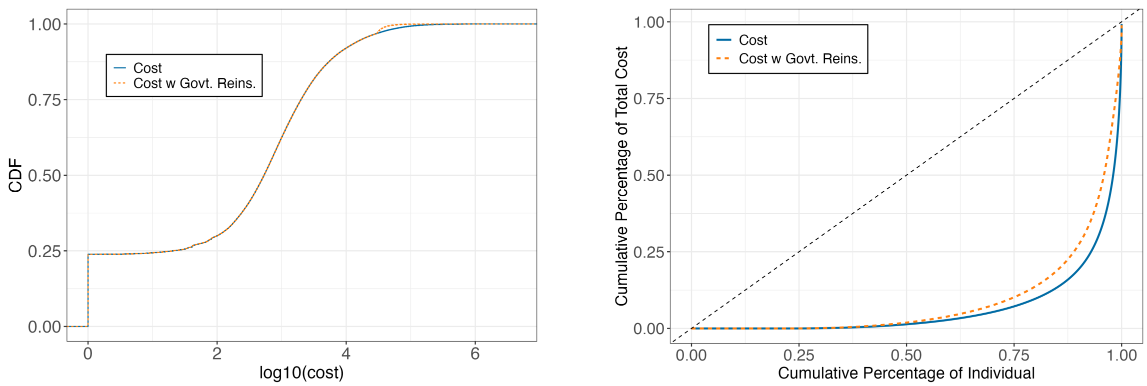
The CO exchange has about two hundred thousand enrollees annually. Both national and regional insurers operate on the CO exchange. The mean insured rate is 37%. An average of 4 insurers sell products per county. The average annual out-of-pocket premium after premium subsidy is \$3,697, while the average 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.

The distribution of consumer claims costs has a long right tail. This can be seen in Figure 3, which shows 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 subsidies.

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 cost. 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.

4.3. Sources of Cost Fluctuations and Financial Risks.

Two sources of financial risk may lead insurers to financial distress: tail-end risk and aggregate risk. We describe these two cost fluctuations 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% (5%) is approximately 32% (7.4%). 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.

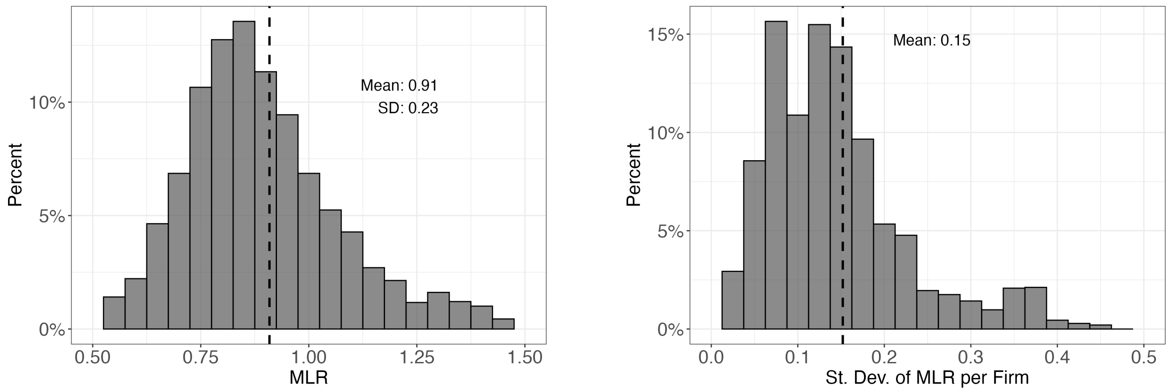
Because exchange insurers tend to be smaller and often do not operate in other markets, the probability that their claims exceed premium income is significant. This is evident in Figures 4a and 4b, which show a long-tailed empirical distribution of claims costs relative to premium income. In over 24% 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.

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 C4, we explore both sources of financial risk and discuss how systematic cost shocks could be incorporated.

Either tail-end or aggregate risk can lead to cost fluctuations that generate adverse shocks to insurers' capital reserves. In response, insurers may need to raise or borrow additional capital (Masson, 1972) or

Figure 4. Illustration of cost-fluctuations

(a). Empirical distribution of MLR (b). Within firm Std. of MLR



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.

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. We refer to these additional costs driven by cost uncertainty as "financial frictions".

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

Given the uncertainty in costs and its implications for financial frictions, 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 nonaffiliate reinsurers.[7] Column (1) reports national averages, while Columns (2)-(3) present statistics separately for insurers that do and do not purchase private reinsurance.

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 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 2.

The widespread use of private reinsurance at high markups suggests that insurers face meaningful financial frictions 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 claims payments.

Panel (c) further compares the characteristics of insurers by their private reinsurance status. Comparing

[7] 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.

Table 1. Sample statistics, insurers on the exchange

	(1) All	(2) Has Reins.	(3) No Reins.
(a). Health insurance status			
Mean health insurance premium	5,160	5,087	5,279
Mean health insurance claim	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	28	67	-
Mean reinsurance claim	12	25	-
Mean reinsurance margin	-	0.544	-
Share has private reinsurance	0.623	1	-
Reins. premium over health ins. premium (unconditional)	0.021	0.033	-
Reins. premium over health ins. premium (conditional)	0.033	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.

the statistics in columns (2) and (3) shows that insurers with private reinsurance tend to be smaller insurers in 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 financial frictions 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. Effect of Public Reinsurance Subsidies

5.1. Impact on Premiums and Evidence of Financial Frictions.

We leverage the introduction of state-level reinsurance programs to examine their impact on insurance premiums and provide evidence of the financial frictions faced by insurers. 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 financial frictions. Using an event study framework, we examine the effect of public reinsurance subsidies 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,

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

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 5-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.[8] Standard errors are clustered at the state level. The coefficient of interest is β_n. The identifying variations of the initiation of reinsurance programs are depicted in Figure 2a.

To explore the variation in the intensity of Colorado's reinsurance program, as shown in Figure 2b, we examine its heterogeneous impacts on premiums across the state's three reinsurance tier regions. Using an event-study framework similar to that in equation (5), with Colorado as the sole treatment state, we estimate the following regression, allowing coefficients to vary by tier region:

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

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

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 (5), we find that the initiation of public reinsurance programs lowered premiums by around 14.5%, as is reported in Table 2 column (1).

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 or slightly exceed 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).[9]

Using ex-post 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.

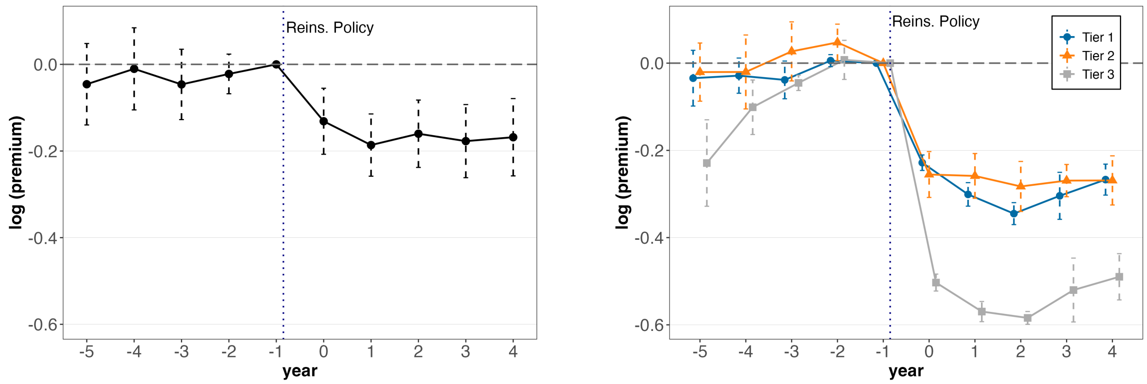
This contrasts the typical pass-through rate of less than one in an imperfectly competitive market (Cabral et al., 2018). Given that firms likely have some degree of market power in this market, this finding aligns with our theoretical model, suggesting that insurers face financial frictions.

[8] 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.

[9] 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.

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

(a). logarithm of premiums, all states (b). logarithm of premiums, CO across reins. tiers

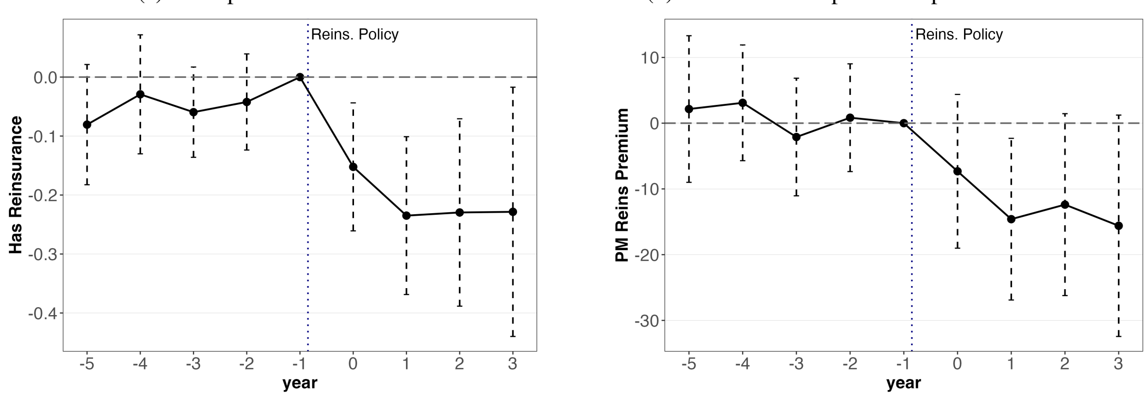


Notes: This figure reports point estimates and 95% confidence interval of the effect of state reinsurance from the estimation of equation (5). The outcome variable is the logarithm of average premiums for age 50. The regression sample includes all insurers nationwide with positive health premium income 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 6 states (DC, IL, IN, MS, TX, WV) whose silver loading policies were unclear in 2017-2020.

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.[10]

Figure 6. The effect of public reinsurance subsidies on private reinsurance

(a). have private reinsurance (b). Per member expenses on private reinsurance



Notes: This figure reports point estimates and 95% confidence interval of the effect of state reinsurance from the estimation of equation (5). The outcome variable is whether the insurer has private reinsurance in panel (a), expenses on private reinsurance contracts over 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.

[10]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.

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 (5), 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 (5) with a proxy of insurer financial characteristic, x_{fmt_0}:

$$y_{fmt} = \beta_1 D_{mt} + \beta_2 x_{fmt_0} D_{mt} + \gamma_t + \gamma_{fm} + \varepsilon_{fmt}, \tag{7}$$

where D_{mt} is an indicator of whether market m has reinsurance policies in year t. For x_{fmt_0}, we use an indicator for whether an insurer's RBC ratio falls below 3 as a proxy for financial distress,[11] along with a measure 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 × RBC ratio below 3		-0.161^{***}			-0.347		-108.754^{**}
		(0.050)			(0.243)		(43.639)
reinsurance policy × significant private reins.			-0.187^{***}				
			(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 (7). 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 the staggered implementation of reinsurance across states and years. The premium-reduction effects of government reinsurance are more pronounced for financially constrained insurers and those with higher private reinsurance expenses.

[11] 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).

Furthermore, public reinsurance subsidies lead to a more substantial reduction in private reinsurance purchases among financially constrained insurers. These findings suggest that insurers internalize financial frictions.

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 subsidies lead to a more significant reduction in private reinsurance purchases among financially constrained insurers. These findings suggest insurers internalize financial frictions.

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 (5), 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 (5), 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.

On the one hand, Section 5.1.2 shows that health insurers substitute between public and private reinsurance. Public reinsurance subsidies 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 even more adversely selected, having a less solvent financial status and being more inelastic than the average firm before the law change. These two offsetting effects together could explain the null results.

5.2.3. No Significant Effects on Total Medical Expenses. We examine whether insurers' moral hazard interacts with public reinsurance subsidies 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[12] 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: the public reinsurance subsidies apply 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 subsidies.[13] 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 subsidies varies across different types of insurance products in different actuarial values to provide suggestive evidence for adverse selection in our sample. Adverse selection is a well-documented phenomenon in the individual health insurance market (Einav and Finkelstein, 2011; Saltzman, 2021).[14]

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 financial frictions in Section 4 and 5.1. First, we show that health insurers purchase private reinsurance despite high markups. Second, we show that the pass-through of public reinsurance subsidies to health insurance premiums is more than one, indicating cost reductions include claims and capital costs. 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.

[12]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

[13]If insurers inflate medical expenses and exhibit moral hazard in response to public reinsurance, our estimated degree of financial friction would be a lower bar of the true parameter.

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

Empirical findings in Section 5.2 further inform modelling choices. In our primary specification, we hold market structures of health insurance fixed and do not model insurers' entry or exit decisions. We treat private reinsurance markets as exogenous and do not model reinsurers' pricing decisions. We also leave out insurers' efforts in cost containment or price negotiation with medical providers. We perform sensitivity analyses to assess how varying degrees of insurer entry, exit, moral hazard, and private market markup responses might affect welfare predictions in Section 8.

Although the reduced-form analysis proves the existence of financial frictions, 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 financial frictions remain unanswered. To further examine optimal subsidy allocation in this context and explore how consumers in different demographics benefit differentially from reinsurance subsidies, we need to use a structural model to empirically quantify the degree of financial frictions, adverse selection, and market power.

6. Empirical Model of Premiums and Reinsurance Purchase

In the previous sections, we documented empirical evidence on insurers' financial frictions and their responses to public reinsurance subsidies—both in pricing and in private reinsurance purchases. Building on these findings, we now develop an empirical model of insurance demand, insurer pricing, and reinsurance purchasing behavior using data from Colorado. The goal is to quantify the magnitude of insurers' financial frictions, and to shed light on the design of optimal reinsurance subsidies 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.

6.1. Consumer Choices.

Let f denote insurers, m denote counties, t denote years, $j \in J_f$ denote products of f. We divide consumers into bins based on their age and risk scores predicted using previous years' claims. We assume consumers in the same age-risk 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 above 55, 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 in age bin θ, quartile risk bin r, county m and year t is

$$u_{ijmt} = -\alpha_i(p_{jmt}\iota_\theta - subsidy_{\theta jmt}) + \beta_i X_{jmt} + \xi_{\theta jmt} + \epsilon_{ijmt},\ j \neq 0;, \tag{8}$$

$$\alpha_i = \alpha_\theta + \alpha_r + \nu_i,\ \log(\nu_i) \sim N(0, \sigma_1^2). \tag{9}$$

$$\beta_i = \beta_\theta + \beta_r. \tag{10}$$

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 regulations, such as premium subsidies.

There are two canonical ways to model health insurance choices: one where consumers in 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 age and risk types in equation (8). Therefore, our framework is able to characterize a fairly flexible distribution of risk preferences for the population.[15]

6.2. *Insurers' Strategies.*

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:

$$\max_{\kappa_{ft}, \vec{p}_{ft}} = \underbrace{\Pi(\vec{p}_{ft}; \vec{p}_{-ft})}_{\text{premium income}} - \underbrace{\mathbb{E}[C_{ft}(\vec{p}_t, \kappa_{ft}; \vec{p}_{-ft})]}_{\text{claims costs}} - \underbrace{R_{ft}(\vec{p}_t, \kappa_{ft}; \vec{p}_{-ft})}_{\text{reinsurance costs}} - \underbrace{L_{ft}(\vec{p}_t, \kappa_{ft}; \vec{p}_{-ft})}_{\text{risk charge}}. \tag{11}$$

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

Insurers' expected premium income $\Pi_{ft}(\vec{p}_t)$, is the sum of revenue income 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}.[16]

Turning to expected claims costs, we assume health risks of risk type i, c_i, are independent and identically distributed[17] 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 medical expense differences of the same individual across different health plans due to insurers' differential bargaining power. Let λ_j denote the cost-sharing feature of a given insurance product. Without any reinsurance policy, the claim costs paid by the insurer f for a consumer in risk type i

[15] The estimation and counterfactual results are robust to adding a random coefficient to preferences of financial attributes, β_i.

[16] Note that an insurer's premium revenue does not directly depend on consumer types, except for exogenous adjustments based on an individual's age, reflecting the regulatory age-rating curve. While, in reality, insurers' premiums are also influenced by risk-adjustment transfers, our primary specification does not explicitly incorporate these transfers. As a robustness check, we are in the process of extending the model to include risk-adjustment transfers, where an insurer's premiums are adjusted—either partially or fully—according to an individual's health risk bin.

[17] 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.

enrolled in plan j, is $c_{ijmt} = \psi_{jmt}\lambda_j c_i$. Following the distributional assumption of health risks, claims cost paid by insurers c_{ijmt} are 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.[18,19] 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 r_{ijmt} denote the reinsurers' payments, c^r_{ijmt} denote the insurers' liabilities after reinsurance policy:

$$c^r_{ijmt} = \begin{cases} c_{ijmt} \\ \kappa_{ft} \end{cases} ; \; r_{ijmt} = \begin{cases} 0 & \text{if } c_{ijmt} \leq \kappa_{ft} \\ c_{ijmt} - \kappa_{ft} & \text{if } c_{ijmt} > \kappa_{ft}. \end{cases} \tag{12}$$

Summing across all insured individuals gives us the total claims expenses of the insurer $C_{ft}(\kappa_{ft})$, a random variable. See Appendix E for expressions of its asymptotic distribution.

We assume insurers can buy private reinsurance policies at some exogenous markup of $\tau_f \geq 1$ above the actuarial value. This is reasonable as most exchange insurers are small. Instead of bargaining with the third-party reinsurer, it is plausible that they are price-takers for private reinsurance coverages. The actuarial value per insured is the expected cost of reinsurer, $\mathbb{E}[r_{ijmt}]$, where r_{ijmt} is distributed according to equation (12). Total reinsurance expenses $R_{ft}(\kappa_{ft})$ aggregate across all insured; see Appendix E2 for the 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.[20] 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.[21] Let g_{ijmt} denote the public reinsuruance payments,

$$c^r_{ijmt} = \begin{cases} c_{ijmt} \\ \kappa_g + \theta_g(c_{ijmt} - \kappa_g) \\ \kappa_{ft} \end{cases} ; \; r_{ijmt} = \begin{cases} 0 \\ 0 \\ \kappa_g + \theta_g(c_{ijmt} - \kappa_g) - \kappa_{ft} \end{cases} ; \; g_{ijmt} = \begin{cases} 0 & \text{if } c_{ijmt} \leq \kappa_g \\ (1-\theta_g)(c_{ijmt} - \kappa_g) & \text{if } \kappa_g < c_{ijmt} \leq \kappa_{ft}. \\ (1-\theta_g)(c_{ijmt} - \kappa_g) & \text{if } c_{ijmt} > \kappa_{ft} \end{cases} \tag{13}$$

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.

[18] 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.

[19] 85% of premiums of comprehensive major medical reinsurance in CO exchange are based on individual claims c_{ijmt}, rather than aggregate claims $\sum_{i,j,m} c_{ijmt}$. Appendix E6 extends the model to accommodate group-based reinsurance.

[20] 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.

[21] Empirically, it is always the case that $\kappa_{ft} < \kappa_g$, i.e., the threshold that the public reinsurance starts to reimburse insurers is lower than the private reinsurance deductible. We analyze the opposite case in Appendix E3.

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

$$L_{ft}(\vec{p}_t) = \rho_{ft}\text{Var}[C_{ft}], \tag{14}$$

where ρ_{ft} is insurers' 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 it to vary by time as a function of insurers' capital reserves. Risk charges $L_{ft}(\vec{p}_t)$ capture the incremental costs associated with holding a riskier enrollee portfolio and are embedded into price setting. Consistent with the theoretical model in Section 3, we adopt a mean-variance functional form that captures insurers' financial frictions and endogenizes their private reinsurance purchases without requiring specific assumptions about the underlying financial or regulatory mechanisms (Jean-Baptiste and Santomero, 2000). This formulation is also isomorphic to insurers maximizing exponential utility under normally distributed aggregate costs, a structure that effectively captures their induced risk aversion. Although higher-order moments of the distribution could be considered, we focus on the second-order moment for tractability.

Putting together premium revenue and the three cost terms, equation (15) 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 financial frictions, factored into price setting.

$$\underbrace{p_{jmt} + \frac{Q(\vec{p}_t)}{Q'(\vec{p}_t)}}_{\text{marginal revenue}} = \underbrace{\frac{\partial E[C_{ft}]}{\partial p_{jmt}}}_{\text{marginal claims costs}} + \underbrace{\tau\frac{\partial E[R_{ft}]}{\partial p_{jmt}}}_{\text{marginal reins. costs}} + \underbrace{\rho_{ft}\frac{\partial \text{Var}[C_{ft}]}{\partial p_{jmt}}}_{\text{marginal risk charge}} \tag{15}$$

Equation (16) 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 (12) and (13), 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 frictions. When choosing deductibles of private reinsurance contract κ_{ft}, insurers trade off the increased reinsurance expenses versus the decreased claims and financial costs,

$$\underbrace{-\tau\frac{\partial E[R_{ft}]}{\partial \kappa_{ft}}}_{\text{reins. expenses}} = \underbrace{\frac{\partial E[C_{ft}]}{\partial \kappa_{ft}}}_{\text{claims reduction}} + \underbrace{\rho_{ft}\frac{\partial \text{Var}[C_{ft}]}{\partial \kappa_{ft}}}_{\text{risk charge reduction}} \tag{16}$$

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 (8)) as the sum of common utility terms $\delta_{\theta jmt}$

and idiosyncratic terms:

$$u_{ijmt} = \delta_{\theta jmt} + (\alpha_r + \nu_i)(p_{jmt}\iota_\theta - subsidy_{\theta jmt}) + \theta_r X_{jmt} + \epsilon_{ijmt}, \tag{17}$$

$$\delta_{\theta jmt} = \alpha_\theta(p_{jmt}\iota_\theta - subsidy_{\theta jmt}) + \beta_\theta X_{jmt} + \xi_{jmt} + \xi_{\theta mt} + \xi_{\theta jmt}. \tag{18}$$

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 (17): 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 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 (18), 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 demographics 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 A8 reports consumer preference estimates. While Column (2) is our preferred one, the implied elasticities are reassuringly robust across different specifications. Preference estimates across risk bins are as expected: healthy consumers prefer less about the insured option, and are more sensitive to out-of-pocket expenses.

These estimates imply that the average enrollment-weighted own-premium semi-elasticity (elasticity) is -4.37 (-7.63) 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 exchange.

Table 3 panel (a) reports the average own-premium semi-elasticity for each age-risk bin. Figure A6 displays the distribution of estimated elasticities by consumer types. Our estimates confirm adverse selection: Elderly consumers, or those in risk bin 4 who are relatively sicker, are less price elastic than young consumers or those in risk bin 1 who are relatively healthier. Panel (b) reports 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 4.7% for the Colorado exchange, consistent with 4% (Tebaldi, 2025) of the California exchange.

Table 3. Derived demand elasticities by consumer types

	Risk bin 1	Risk bin 2	Risk bin 3	Risk bin 4
(a). Semi-elasticity to own premiums				
Age below 34	-7.35	-6.850	-6.442	-6.161
Age 35-54	-4.405	-4.010	-3.750	-3.506
Age above 55	-2.043	-1.785	-1.647	-1.467
(b). Drop in insured rate if all annual posted prices increase by $100				
Age below 34	5.09%	5.94%	6.77%	6.74%
Age 35-54	4.15%	4.68%	4.55%	4.78%
Age above 55	3.65%	3.41%	2.03%	2.37%

Notes: The table summarizes the enrollment-weighted averages of sensitivity to premiums conditioning on different age-risk bins. Risk bins are four quartiles based on the predicted risk scores using claims from previous years. The statistics reported are functions of the demand parameters reported in Table A8.

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 preferences, ρ_f. The third primitive is the markup of private reinsurance, τ_f.

7.2.1. Calibration and Estimation. We calibrate the baseline health risk parameters from CO APCD. We use log-normals to approximate the distribution of realized health risks. Corresponding parameters, i.e. mean and variance, μ_i, σ_i^2, are reported in Table A7. Figure A5 shows our parameterized distribution aligns well with the realized data. We then use an insurer-product specific multiplier ψ_{fm} to transform the health risks distribution into claims costs distribution.

We calibrate private reinsurance markup using the averages of the ratio of private reinsurance premiums over private reinsurance claims from the NAIC reinsurance records. This is reasonable given our analysis in Section 5.2.2: the markup of private reinsurance is not affected by government reinsurance policy. We calibrate the markup to be 1.66 and hold it constant for the estimation and counterfactual exercises.

We estimate the remaining supply-side parameters, marginal cost multiplier ψ_{fmt}, and risk preference parameter ρ_f with a generalized method of moments estimator. The moments are insurers' first-order conditions of health insurance prices (equation (15)) and how much private reinsurance to purchase (equation (15)). Note that we do not observe the deductible of each private reinsurance contract; instead, we observe private reinsurance premiums. 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:

$$\sum_{i,m,j \in J_{fm}} \Big(\underbrace{\tau}_{\text{markup of reinsurance}} \underbrace{E[c_{ijmt} - c^r_{ijmt}(\kappa_{ft})]}_{\text{AV of reinsurance}} \Big) D_{ijmt} = \underbrace{R^{\text{obs}}_{ft}}_{\text{observed reinsurance expense}}, \tag{19}$$

where c^r_{ijmt} is the insurers' share of claims expenses under private reinsurance, with a deductible κ_f.

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 (16) suggests that insurers pay a markup over claims cost reduction for the gains of reduced variance of total costs.

$$\underbrace{-(\tau-1)\frac{\partial E[R_{ft}]}{\partial \kappa_{ft}}}_{\text{markup over claims reduction}} = \underbrace{\rho_{ft}\frac{\partial \text{Var}[C_{ft}]}{\partial \kappa_{ft}}}_{\text{risk charge reduction}} . \tag{20}$$

Equation (20) reveals that the correlation between aggregate cost variance and private reinsurance coverage identifies risk preferences ρ_{ft}. For a given amount of cost variance increase, the magnitude of the associated increase in private reinsurance purchase pins down the degree of financial friction. In other words, holding fixed underlying cost distributions, the more reinsurance coverage the insurer buys, the larger its risk preferences. Figure A7 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 A9 reports the marginal cost multiplier within each insurer. Figure A8 plots the estimated marginal cost distribution by insurers. Overall, insurer-specific medical expenses are 1.788 times the baseline health risks. This could be because consumers on the Colorado exchange are less healthy than the average consumer statewide, or insurers in the exchange have a disadvantaged bargaining position. It can also be explained by the fact that our estimated marginal costs of a specific product include both claims payments to providers and plan administrative costs.

Marginal cost multipliers vary across insurers and markets. National insurers, on average, have lower marginal costs than regional insurers for individuals of the same risk types. 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).

The mean claims costs are estimated to be \$3,873, \$6,579, \$10,855 for consumers aged below 34, 35-54, and above 55; and \$5,927, \$6,885, \$7,648, \$7,797 for each risk bin quartiles. The correlation between claims costs and premium elasticities confirms the adverse selection pattern that healthy consumers are more price-elastic than sick consumers.

Table 4 Columns (1)–(2) report the estimated private reinsurance coverage thresholds and risk preference parameters. The monotonic relationship between private reinsurance purchases and risk preferences 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 risk-averse, with strictly positive risk charge coefficient and induced risk preference terms. Regional insurers are estimated to behave more risk-averse 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.[22]

Column (5) displays the corresponding private reinsurance expenses per insured, which match the ob-

[22]We are in the process of expanding the supply estimation to include full sample years. We will examine the relationship between estimated risk preferences (ρ) and insurer solvency by correlating ρ with RBC ratios, or capital reserves.

Table 4. Estimates of private reinsurance deductible and risk preferences

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Private	Induced	Mean per member price/cost				Share over total premium		
Insurer	reins. deductible	Risk pref. estimates	Premium	Medical claims	Private reins.	Risk charge	Medical Claims	Private reins.	Risk charge
Kaiser	-	0.000	7,004	6,475	0	0	92.44%	0%	0%
HMO CO	-	0.000	9,316	8,455	0	0	90.75%	0%	0%
Rocky Mountain	-	0.000	10,184	9,649	0	0	94.75%	0%	0%
Cigna	12.02	0.027	7,369	6,815	37	4	92.64%	0.06%	0.50%
Friday	1.65	0.201	7,656	6,886	206	121	90.13%	1.59%	2.70%
Elevate	0.80	0.419	7,311	6,331	293	275	86.78%	3.77%	4.02%
Bright	0.78	0.425	6,092	5,274	221	185	86.70%	3.04%	3.63%

Notes: This table reports insurers' estimated private reinsurance deductible and risk preferences in 2019. We assume private reinsurance is in a stop-loss format, and the deductible reported 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.

served values exactly, as required by the moment conditions. Most large national insurers do not purchase non-affiliate private reinsurance.[23] In contrast, regional insurers — Friday, Elevate, and Bright — spend approximately $173 per insured on reinsurance coverage, equivalent to 2.7% of their health insurance premium 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 $219 per member or 3.3% of their health insurance premium. This is consistent with actuarial documents that insurers' risk charges are usually 2-4% of their premiums (Kim, 2022).

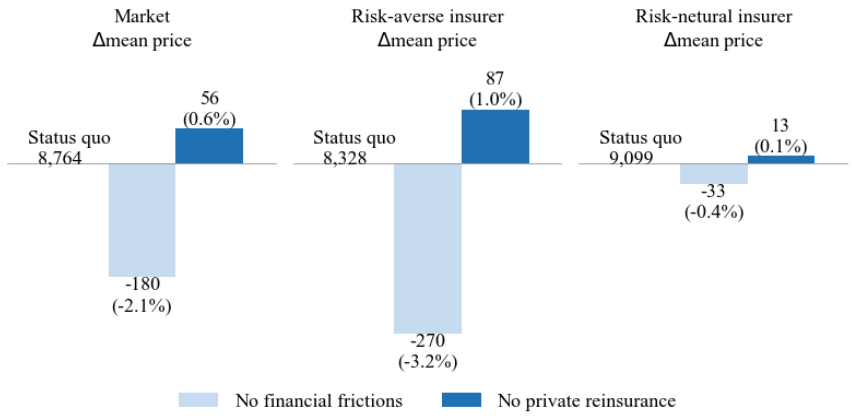
7.2.4. Implications of Financial Frictions. Summing reinsurance expenses and risk charges in Table 4, our estimates imply that risk-averse regional insurers face, on average, 6% higher costs than risk-neutral national insurers. Financial frictions lead smaller insurers to incur risk charges and spend more on private reinsurance, inflating their total costs. These additional costs are passed through to prices, hindering smaller insurers' ability to compete effectively with larger, more capitalized insurers.

To further quantify how financial frictions affect equilibrium prices, we simulate a counterfactual in which all insurers behave as risk-neutral and thereby insurers do not purchase any private reinsurance—i.e., medical claims are the only cost and there are no risk charges. The light bars in Figure 7 how equilibrium prices change relative to the status quo. Eliminating financial frictions lowers total costs for the originally risk-averse insurers by 3.5%, yielding a 3.2% price drop, or $270 per consumer. Competitive spillovers also reduce prices for the originally risk-neutral insurers by 0.4%. Taken together, when there are no financial frictions, the mean market price drops by 2.1%, or $180 per consumer.

Next, we examine the role of private reinsurance under existing financial frictions. To do so, we simulate a scenario, in which private reinsurance market is shut down but insurers' degree of financial friction remain the same as the status quo. The dark bars in Figure 7 illustrate the resulting equilibrium. Insurers save on private reinsurance expenses but lose the ability to offload risk, leading to higher overall risk charges.

[23] National insurers on the Colorado exchange do purchase affiliate reinsurance from their parent companies. As a result, the estimated risk preference parameters for these insurers may be interpreted as a lower bound.

Figure 7. Effects of financial frictions on equilibrium prices



Notes: This figure plots changes in equilibrium prices compared to the status quo in 2019. We focus on the markets in the reinsurance policy tier 1 as it is where most risk-averse insurers operate. The light bars plot the scenario without financial friction. The dark bars plot the scenario where we shut down the private reinsurance market. The averages reported are enrollment-weighted means. We group insurers into risk-averse and risk-neutral based on whether they have positive risk preference estimates, as is reported in Table 4.

The latter effect dominates, causing risk-averse insurers to raise prices by 1%, or $87 per consumer-year. This, in turn, reduces competitive pressure on risk-neutral insurers, who also increase their prices. The average market premium rises by 0.6%, or $56 per insured. These results suggest that the availability of the private reinsurance market benefits consumers by reducing financial costs for smaller, risk-averse insurers and thereby enhancing market competition.

In addition, Figure A9 explores how pricing power in upstream private reinsurance markets affects downstream health insurance prices. We simulate equilibria under varying reinsurance markups. As reinsurance becomes more affordable, risk-averse insurers increase their purchases and achieve more effective risk offloading. The resulting reductions in claims costs and risk charges more than offset the rise in reinsurance expenses. For instance, under a scenario where private reinsurers are subject to a regulated 20% claims margin, risk-averse insurers would spend an additional $161 per enrollee on private reinsurance, but would see claims costs and risk charges fall by $172 and $44, respectively. As a result, consumers face a 0.5% lower health insurance premium in the re-simulated equilibrium compared to the status quo.

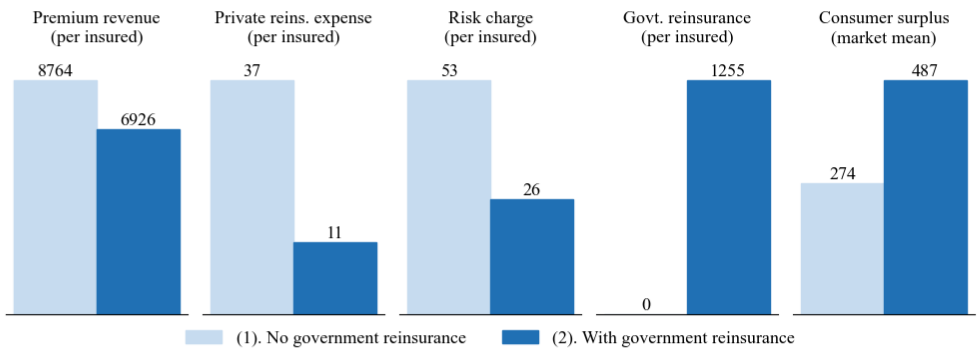
8. Optimal Reinsurance Policy Designs

In this section, we use our model to evaluate the effects of public reinsurance on insurers' pricing, private reinsurance purchases, and overall welfare. We start by simulating Colorado's reinsurance subsidies under several scenarios that isolate different economic forces. We then study optimal reinsurance design and compare the relative effectiveness of demand-side consumer subsidies and supply-side reinsurance subsidies.

8.1. Equilibrium Effect of Public Reinsurance Subsidies

8.1.1. Simulated Policy Impacts. We first simulate the effects of Colorado's public reinsurance subsidy on consumer choices, insurers' pricing and private reinsurance purchase decisions, and consumer welfare. Figure 8 reports key simulated outcomes before and after the reinsurance program, using the estimated model primitives in 2019. Table A10 reports all equilibrium objects. Our main analysis focuses on the markets in Tier 1 reinsurance region (i.e., the white areas in Figure 2b), which represents the most populous region in CO where most risk-averse insurers operate. The results for markets in other policy tiers are reported in Table A10.

Figure 8. Effect of public reinsurance subsidies



Notes: This figure plots the simulated equilibrium objects in the scenario with (in dark bars) and without (in light bars) government reinsurance subsidies for markets in reinsurance tier 1. We simulate the equilibrium using market primitives in 2019. The per-insured measure is averaged across all insurers, regardless of whether the insurer is risk-averse or risk-neutral.

The reinsurance program reduces premiums by $1,835 per enrollee, representing a 20% decline from the baseline. This simulated price decreases closely aligns with our reduced-form estimates in Figure 5b and Table A6, which show that CO's reinsurance program led to a 27.6% drop in premiums. On average, the government spends $1,255 per enrollee to share high-cost claims with insurers. The simulated pass-through rate is 1.2 across markets in all policy tiers, consistent with the greater-than-one pass-through estimates documented in Section 5.1.1.

As public reinsurance reduces not only the expected cost but also the variance of claims cost, insurers lower their risk charges and substitute away from private reinsurance for risk-offloading. Consequently, private reinsurance expenses fall from $37 to $11 per enrollee.[24] This simulated shift in insurer behavior aligns with the reduced-form estimates in Figure 6b: initiating public reinsurance reduces insurers' private reinsurance expenses by $25 per member on average. Focusing just on risk-averse insurers, private reinsurance expenses decline from $84 to $26 per enrollee, and risk charges drop from $121 to $61 per enrollee. The combined effects of lower claims costs, reduced risk exposure, and expanded enrollment increase insurers' profits by $44 million.

Consumers' out-of-pocket expenses on insurance premiums drop by about 12%; their insured rate rises by 22% consequently. Premium decreases attract price-elastic healthy consumers to enroll, stabilizing the risk pool and further lowering market prices. After the implementation of public reinsurance, annual consumer surplus increases by $213 per member, or $63 million in the aggregate - a 78% increase from the baseline.

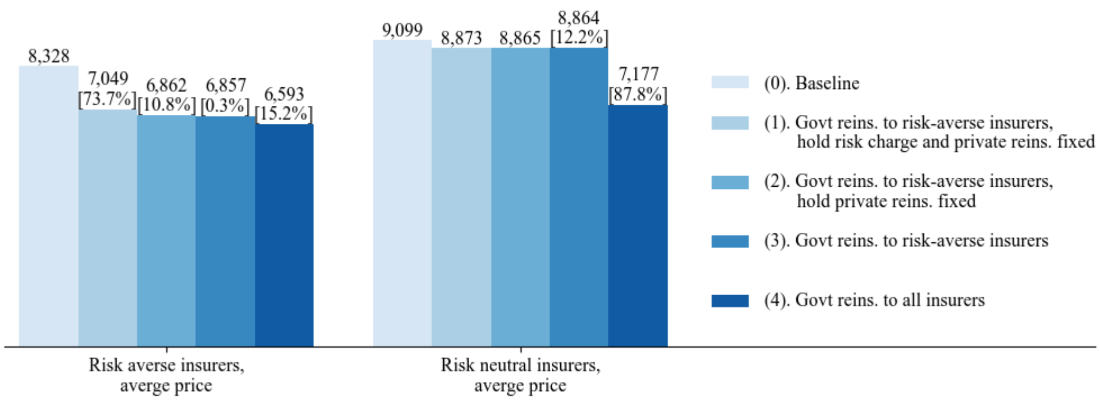
We find that public reinsurance generates social surplus gains, assuming equal weights on consumer surplus, insurer profits, reinsurer profits, and government expenses. These net gains primarily stem from market expansion: as public reinsurance shifts down the effective marginal cost curves, more consumers

[24]Note that the sum of the decrease in claims costs paid by insurers and private reinsurance expenses is larger than the increase in public reinsurance expenses because there is a markup in private reinsurance.

enroll in insurance and extract gains from trade.

8.1.2. Decompose Price Reduction. Public reinsurance lowers equilibrium prices through multiple channels. First, it reduces insurers' expected costs by directly subsidizing high claims expenses. Second, it mitigates risk exposure by shielding insurers from cost fluctuations—captured by the variance of costs in the model—and thereby reduces both risk charges and private reinsurance expenses. Third, it enhances competition by easing financial frictions faced by risk-averse insurers, enabling them to compete more effectively and exert greater downward pressure on market prices. We design a series of counterfactuals to disentagle the roles of the above economic mechanisms.

Figure 9. Decompose the effect of public reinsurance subsidies on equilibrium prices



Notes: This figure plots simulated enrollment-weighted average prices in each counterfactual equilibrium (described in Section 8.1.2). The numbers in brackets denote the percentage of price reduction resulting from a particular scenario compared to the total price changes with and without government reinsurance. We group insurers into risk-averse and risk-neutral based on whether they have positive risk preference estimates, as is reported in Table 4.

Figure 9 reports resimulated premiums under each counterfactual equilibrium. Table A11 reports the complete set of equilibrium statistics, including cost components and welfare changes. The first counterfactual, denoted by (0), corresponds to the case where no policy exists. The remaining counterfactuals apply public reinsurance sequentially to risk-averse and risk-neutral insurers to separately quantify the expected cost reduction effect, which applies to all insurers, and the risk reduction effect, which applies only to risk-averse insurers.

Our counterfactual (1) isolates effect of public reinsurance subsidy on risk-averse insurers' expected claims. We compare the no-intervention benchmark with a situation in which the reinsurance policy affects *only expected claims costs of risk-averse insurers*, but not the private reinsurance expenses or risk charges in insurers' profit functions, nor the claims costs of risk-neutral insurers. We allow insurers to *optimally choose prices* but not private reinsurance purchases in response to this interim profit function. Reinsurance subsidies lower the expected claims costs paid by risk-averse insurers by \$1,224 per member. Moving from counterfactual (0) to (1), risk-averse insurers lower their premium by \$1,279, which accounts for 73.7% of the premium decreases of risk-averse 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 costs components of risk-averse insurers*, including expected claims costs, private reinsurance expenses, and risk charges terms. We allow insurers to respond by *only changing price* 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 \$23 reduction in private reinsurance expenses. Furthermore, by reimbursing the tail risks of claims costs, the variance of total claims costs also drops, leading to a \$66 reduction in risk charge. Together, these forces lead to an extra 10.8% of premium reduction of risk-averse insurers, or \$187 per insured. Given adverse selection in the market, the decreases in premiums in counterfactual (2) attract more price-elastic, healthy consumers to enroll, which further reduces claims costs paid by insurers by \$38.

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 risk-averse insurers*, and we allow insurers to optimally *choose both price and private reinsurance purchases* in response. Since public reinsurance subsidies reduce insurers' need for using the private option to lower their risk level, expenses on private reinsurance further drop by \$32 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 \$19 and \$9 due to reduced risk-offloading. The combined effect of reduced private reinsurance expenditures and increased claims costs and risk charges lowers premiums by \$4 per consumer, or 0.3% for risk-averse insurers.

Notably, even without receiving any reinsurance subsidies, risk-neutral insurers' premiums decline by 12.2% from the baseline under scenario (3). This underscores how public reinsurance intensifies competition by reducing the costs faced by risk-averse insurers.

Finally, we compute counterfactual (4) to shed light on 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 counterfactual (3) and (4) highlights the effect of public reinsurance on expected claims of risk-neutral insurers. Similar to the change from counterfactual (0) to (1), public reinsurance reduces average claims expenses by \$1,570 per member for risk-neutral insurers. Consequently, risk-neutral insurers lower prices by \$1,687 per insured, which accounts for 87.8% of their premium decreases. The intensified competition, in turn, pushes down prices of risk-averse insurers by \$264, accounting for 15.2% of premium decreases.

To summarize, this decomposition excercise suggests that, upon the intiation of public reinsurance subsidies, reductions in expected claims costs, risk mitigation, and competitive effects account for 73.7%, 11.1%, and 15.2% of premium decreases, respectively, for risk-averse insurers. For risk-neutral insurers, expected claims cost reduction and competitive effects explain 87.8% and 12.2% of the price reduction. Our findings indicate that financial frictions can be a significant distortion driving up premiums for smaller market participants. Addressing these supply-side frictions could therefore be an effective strategy for fostering competition and providing affordable insurance to consumers.

A unique feature of public reinsurance is that its two price-lowering mechanisms, i.e., expected claims cost and risk reduction, reinforce each other. Public reinsurance cuts the tail of claims distribution for sicker consumers, which decreases risk charges and effective marginal costs. Consequently, reduced premiums attract price-sensitive healthy consumers with less-dispersed claims distributions, further suppressing average financial costs. The processes continue such that alleviating financial frictions and adverse selection stimulate each other, lowering equilibrium prices and increasing the efficacy of supply-side subsidies.

To further separate the role of adverse selection and financial frictions in the more-than-complete pass-through, Table A12 compares the effect of public reinsurance when different market frictions are present. It is expected that in an imperfectly competitive market without selection or financial frictions, the pass-through of subsidies is less than 1. The presence of either friction increases the pass-through rate of subsidies, whereas the presence of both gives the highest pass-through rates. The additional risk reduction and its interaction with selection patterns could explain the remarkably high efficiency of reinsurance subsidies.

8.1.3. Distributional Analysis. We examine consumer surplus gains from public reinsurance by age group in Table A13. The deductible cutoff in public reinsurance subsidies barely changes insurers' claims costs for young consumers, while cost reduction is the largest for the elderly age groups. Insurers' claims expenses decrease by \$305 (7.8%), \$728 (10.8%), \$1,903 (17.1%), for those aged below 34, 35-54, and above 54, separately. Price drops are the most significant for older adults in absolute and percentage terms. On the other hand, the young age group, which is most elastic, experiences the largest gains in insured rates. Consumer welfare increases for all age groups. Per member, consumer surplus increases by \$121 (288%), \$202 (183%), \$563 (40%) for the age groups from the youngest to the oldest.

Table A14 displays heterogeneous effects of public reinsurance by risk bins. The takeaways are similar: the sickest consumers are most affected by the policy and experience the largest surplus gains.

8.1.4. Sensitivity Analysis. We inspect the sensitivity of model predictions to various primitives fixed in the baseline analysis: insurer moral hazard, markup of private reinsurance, and insurer 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 subsidies 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 A10 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 will shrink by 36%; consumer (social) surplus gains will shrink by 40% (29%).

Next, we consider possible interactions between the public and private reinsurance. The public option could make the demand for private reinsurance more elastic, potentially lowering the markup on private reinsurance contracts. In that case, we expect insurers' financial costs to decrease more than the baseline, as they would purchase more private coverage at lower prices, which in turn provide better risk-offloading and further reduce insurers' risk charges. Figure A11 plots how equilibrium statistics change with the markup of private reinsurance after the policy implementation. If public reinsurance lowers private reinsurance markup by 10%, the baseline analysis will understate consumer (social) surplus gains by 0.6% (0.7%).

We also consider how public reinsurance might affect health insurers' entry and exit patterns. As analyzed in Section 8.1.1, insurers' profits increase along with reduced effective costs and expanded enrollment.

This could induce more players, especially small regional insurers, to enter the market. Additional players could heighten competition and further push down equilibrium prices. We are working on simulating scenarios with hypothetical insurer entries to determine how much baseline analyses understate welfare gains.

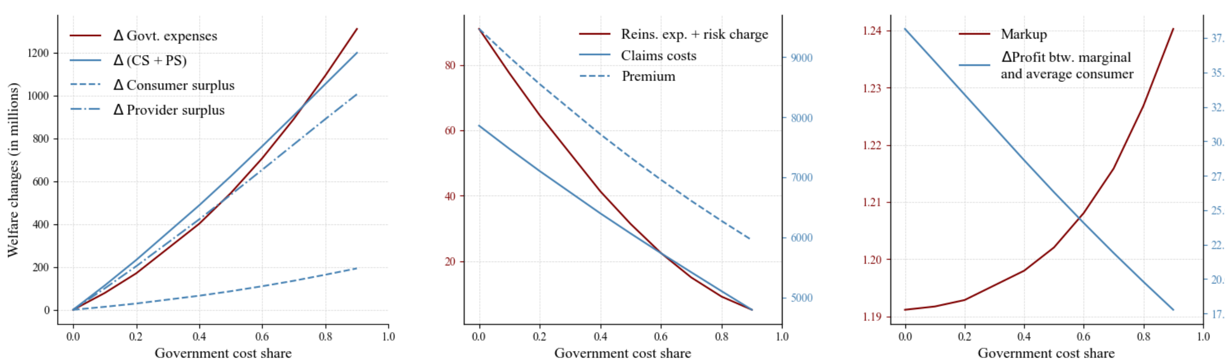
Finally, we are working on examining how ex-ante risk adjustment interacts with ex-post reinsurance subsidies. We implement risk-adjustment by setting the expected costs for each age-risk bin to a weighted average of its own and the population average, while keeping the dispersion of claims costs unchanged. We will report this sensitivity test in the next version of the draft.

8.2. Optimal Policy Design Under Financial Frictions

8.2.1. Degree of Government Risk-Sharing. Beyond public reinsurance programs in the individual health exchange, there are also policy discussions on whether and how much public reinsurance to provide, such as in wildfire (Araullo, 2025), or Medicare Part D program (Medicare Payment Advisory Commission, 2020) We examine the optimal degree of risk-sharing in public reinsurance. The government balances the fiscal cost of public funds against the benefits of enhanced risk protection. Insurers gain from lower expected claims costs and risk-offloading; consumers benefit through more stable and affordable access to coverage.

Figure 10. Effect of public reinsurance subsidies, alternative government cost shares

(a). Aggregrate welfare (b). Risk and cost reduction (c). Selection mitigation



Notes: This figure plots simulated welfare changes compared to the status quo no public reinsurance scenario using the 2019 market primitives. We hold the deductible of public reinsurance the same as the status quo and apply the same government cost shares across all counties in CO. We simulate the equilibrium under alternative public reinsurance designs and report welfare changes across all markets in CO. Government expenses include both premium subsidies and reinsurance subsidies. Providers include insurers, reinsurers, and medical providers. Medical expenses for the uninsured, i.e., medical providers' profit losses, are calibrated from Medical Expenditure Panel Surveys in 2017-2019. The cost of public funds is set to 10 cents per dollar spent by the government.

The optimal degree of government cost shares depends on two countervailing factors. First, reinsurance provides risk offloading. Figure 10b shows as public reinsurance becomes more generous, the extra costs induced by financial frictions attenuate towards zero. Reduced costs and risk charges are passed through to prices, benefiting consumers. Second, reinsurance mitigates adverse selection by compressing variation in expected claims across risk types. As shown in Figure 10c, the positive profit gap between the marginal and average consumer shrinks, relieving the downward pricing pressure from adverse selection. Consequently, markup in equilibrium raises, which partly could offset cost cuts, harming consumers.

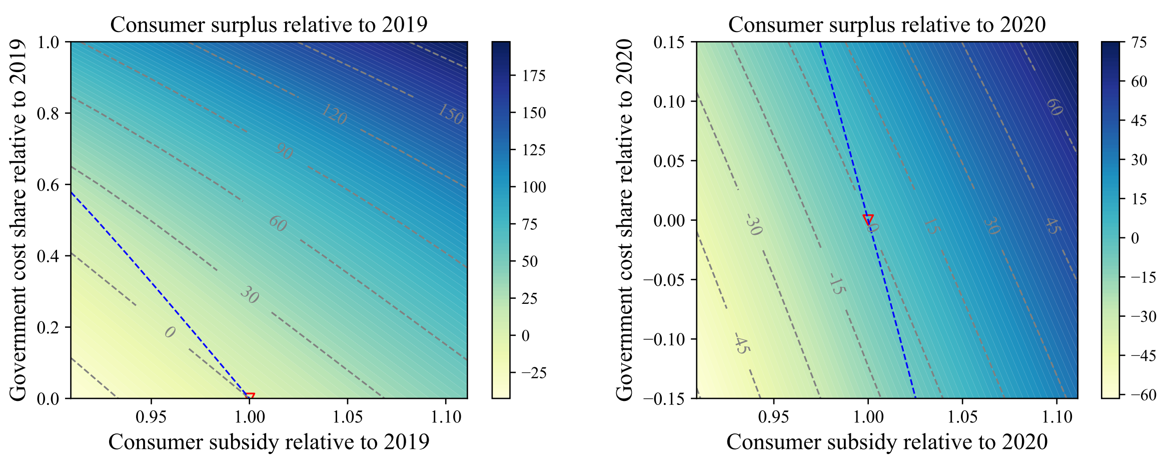
Putting together the above two channels, Figure 10a displays how social welfare changes with government cost shares in CO, keeping the deductible of public reinsurance fixed. When the generosity of reinsurance increases, the distortion from financial frictions attenuates, but the harm from market power amplifies. Since the risk reduction mechanism first outweighs and then falls behind the markup inflation mechanism, the social surplus gains are a concave function of public cost shares. Accounting for the cost of public funds, the net benefit of subsidizing the supply side eventually diminishes to zero when cost shares reach 80%. The optimal public risk-sharing is about 40%, precisely the status quo design in CO's first two policy regions.

There are a couple of benefits that public risk-sharing might bring that our model does not capture. For example, protecting insurers from insolvency could limit costly market exits and price volatility, and strengthens insurers' willingness in underwriting policies for high-risk consumers or areas.The public backstop also prevents unpaid claims and shields consumers from unexpected out-of-pocket costs. In that sense, we are our model underestimates gains from public reinsurance, and the optimal level of government cost share should be higher.

8.2.2. Allocating Premium and Reinsurance Subsidies. We now explore optimal subsidy allocation between consumers and insurers under a fixed government budget. The incidence of public reinsurance and allocation of subsidies have been the subject of intense policy debate (Colorado Division of Insurance, 2025; Liebling, 2017), and there are direct concerns about the low pass-through of transfers to insurers compared to that of consumers.

Figure 11. Consumer surplus under alternative subsidy allocation scheme

(a). Year 2019 (b). Year 2020



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

Holding the government budget fixed, we perturb supply-side subsidies by varying the government's cost-sharing ratio in the reinsurance program and perturb demand-side subsidies by changing the proportion of consumer premiums relative to the status quo. Figure 11a corresponds to the subsidy allocations scenario in the year 2019, where there is no reinsurance program in place. Moving along the iso-cost (blue) curve to increase reinsurance subsidies, consumer surplus increases to higher levels of the iso-utility (grey) curves, consistent with the results in Section 8.1. Figure 11b corresponds to the subsidy allocations scenario in

2020, where the reinsurance program was implemented. Under the current government budget, building on the existing reinsurance subsidy schemes and further reallocating 8% premium subsidies to reimburse insurers 60% high-cost claims increases consumer surplus by $23.

These results are driven by two countervailing forces: cost reduction and selection mitigation. 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 subsidies 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 markup, as documented in (Starc, 2014; Mahoney and Weyl, 2017). With adverse selection, the marginal consumer is cheaper than the average consumer and is 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.

Therefore, the relative efficiency of supply-side versus demand-side subsidies is ultimately an empirical question, shaped by the curvature of both demand and cost curves. Under current market conditions, distortions from financial frictions, or the extra costs from risk bearing, dominate, such that allocating transfers to insurers ex-post is more efficient than transfers to consumers.[25] In Appendix C3, we formalize a theoretical model that formalizes how the degree of financial frictions and selection affect subsidy efficiency.

To summarize, these simulations demonstrate that addressing supply-side frictions can effectively improve the functioning of the insurance market, in addition to the well-known demand-side adverse selection.

8.2.3. Further Analysis. We plan to consider additional counterfactual exercises in future work. First, we will simulate a scenario where the government charges an actuarially fair price for public reinsurance. Second, we will explore the generalizability of our framework to other insurance market contexts. By substituting the underlying risk distributions to reflect those found in climate or property and casualty insurance markets, we will resimulate the impact of public reinsurance. These exercises could help inform ongoing policy discussions about the potential role of public reinsurance in other segments of the insurance market.

9. Discussion and Conclusion

Government risk-sharing plays a critical role in markets characterized by uncertain operational costs. We study the design and effectiveness of public risk-sharing scheme in health insurance markets, reinsurance, an ex-post risk-sharing mechanism in which private reinsurers or the government reimburse insurers for incurring high-cost claims. Besides mitigating adverse selection, we argue that it also lowers insurers' effective marginal costs when they face convex costs of bearing risk. Traditional supply-side models of

[25] One caveat is that our model does not explicitly incorporate risk-adjustment transfers. However, to the extent that omitting such transfers overestimates the selection insurers face, we interpret our results as conservative estimates, as shown in Section C3.

health insurance typically abstract away from these financial frictions. However, we document that 62% of health insurance companies purchase private reinsurance despite having to pay high markups, highlighting their willingness to pay to reduce financial risk.

Our differences-in-differences estimates show that Colorado's public reinsurance program achieves a pass-through rate of 1.3; for every dollar the government spends on actuarially fair reinsurance, premiums fall by more than a dollar. Our equilibrium framework further highlights that public reinsurance not only acts as a direct cost subsidy but also enhances market efficiency by improving risk-sharing and intensifying insurer competition. These forces together generate more-than-unitary pass-through rates public reinsurance. Consistent with this mechanism, we find that reinsurance subsidies are more cost-effective than uniform demand-side subsidies in improving insurance affordability.

The implications of financial frictions in insurance markets extend beyond health coverage. Many insurance sectors, including those covering floods, hurricanes, wildfires, and other catastrophic events, are increasingly exposed to large, volatile financial risks. In these contexts, the threat of tail events combined with limited capital reserves can drive insurers to substantially increase premiums or exit the market entirely. These dynamics raise growing policy concerns around insurance affordability and market stability, particularly in property and casualty lines. Our analysis offers a framework for understanding how government risk-sharing mechanisms, such as reinsurance, can mitigate these pressures by allowing insurers to offload risk. Although we focus on health insurance, the insights from our study are directly relevant to ongoing policy debates in markets such as wildfire coverage (Araullo, 2025) and Medicare Part D drug insurance (Medicare Payment Advisory Commission, 2020).

In addition to informing the scope of public intervention, our framework also contributes to understanding how risk-sharing policies affect market structure. A central tenet of managed competition is that private insurers deliver value by competing on price. Yet, when financial frictions constrain insurers' ability to bear risk, especially among smaller or regional carriers, these firms may raise premiums or withdraw from somee markets. We show that public reinsurance can ease these supply-side frictions, improving healthy competition in the market and improving welfare. By addressing financial frictions directly, such policies not only improve affordability but also promote a more competitive and efficient insurance market.

References

Vermont Legislative Joint Fiscal Office , "Surplus and Risk-Based Capital for Health Insurance Companies," 2017.

Allende, Claudia, "Competition under Social Interactions and the Design of Education Policies," *Job Market Paper*, 2019.

A.M. Best, "Changing Trends Continue To Push Up Demand for Health Reinsurance," *Best's Market Segment Report*, 2024.

Araullo, Kenneth, "Colorado lawmakers debate loss ratio limits and wildfire re/insurance reform," 2025. link, Accessed: 2025/3/18.

Azevedo, Eduardo and Daniel Gottlieb, "Perfect Competition in Markets with Adverse Selection," *Econometrica*, 2017, *85* (1), 67–105.

Bachas, Natalie, Olivia S Kim, and Constantine Yannelis, "Loan Guarantees and Credit Supply," *Journal of Financial Economics*, 2021, *139* (3), 872–894.

Barwick, Panle Jia, Myrto Kalouptsidi, and Nahim Bin Zahur, *Industrial Policy Implementation: Empirical Evidence from China's Shipbuilding Industry*, Cato Institute, 2021.

Berry, Steven, "Estimating Discrete-Choice Models of Product Differentiation," *RAND Journal of Economics*, 1994, pp. 242–262.

—, James Levinsohn, and Ariel Pakes, "Automobile Prices in Market Equilibrium," *Econometrica*, 1995, *63* (4), 841–890.

Bodéré, Pierre, "Dynamic Spatial Competition in Early Education: An Equilibrium Analysis of the Preschool Market in Pennsylvania," *Job Market Paper*, 2023.

Borusyak, Kirill, Xavier Jaravel, and Jann Spiess, "Revisiting Event-Study Designs: Robust and Efficient Estimation," *Review of Economic Studies*, 2024, p. rdae007.

Brown, Jason, Mark Duggan, Ilyana Kuziemko, and William Woolston, "How does risk selection respond to risk adjustment? New evidence from the Medicare Advantage Program," *American Economic Review*, 2014, *104* (10), 3335–64.

Cabral, Marika, Michael Geruso, and Neale Mahoney, "Do Larger Health Insurance Subsidies Benefit Patients or Producers? Evidence from Medicare Advantage," *American Economic Review*, 2018, *108* (8), 2048–2087.

Callaway, Brantly and Pedro Sant'Anna, "Difference-in-differences with Multiple Time Periods," *Journal of Econometrics*, 2021, *225* (2), 200–230.

Cicala, Steve, Ethan Lieber, and Victoria Marone, "Regulating Markups in US Health Insurance," *American Economic Journal: Applied Economics*, 2019, *11* (4), 71–104.

CMS, "State Innovation Waivers: State-Based Reinsurance Programs," 2024. link, Accessed: 2024/11/28.

Colorado Department of Regulatory Agency, "Colorado Reinsurance 2020 Program Update," 2020. .

Colorado Division of Insurance, "Reinsurance Programs," 2025. link, Accessed: 2025/4/3.

Curto, Vilsa, Liran Einav, Jonathan Levin, and Jay Bhattacharya, "Can Health Insurance Competition Work? Evidence from Medicare Advantage," *Journal of Political Economy*, 2021, *129* (2), 570–606.

Decarolis, Francesco, Maria Polyakova, and Stephen P Ryan, "Subsidy Design in Privately Provided Social Insurance: Lessons from Medicare Part D," *Journal of Political Economy*, 2020, *128* (5), 1712–1752.

Diamond, Douglas and Philip Dybvig, "Bank runs, deposit insurance, and liquidity," *Journal of Political Economy*, 1983, *91* (3), 401–419.

Drake, Coleman, "What Are Consumers Willing to Pay for a Broad Network Health Plan?: Evidence from Covered California," *Journal of Health Economics*, 2019, *65*, 63–77.

—, Brett Fried, and Lynn A Blewett, "Estimated Costs of a Reinsurance Program to Stabilize the Individual Health Insurance Market: National-and State-Level Estimates," *INQUIRY: The Journal of Health Care Organization, Provision, and Financing*, 2019, *56*, 0046958019836060.

Dube, Jean-Pierre, Jeremy T Fox, and Che-Lin Su, "Improving the Numerical Performance of Static and Dynamic Aggregate Discrete Choice Random Coefficients Demand Estimation," *Econometrica*, 2012, *80* (5), 2231–2267.

Dubois, Pierre, Rachel Griffith, and Martin O'Connell, "How Well Targeted are Soda Taxes?," *American Economic Review*, 2020, *110* (11), 3661–3704.

Einav, Liran, Amy Finkelstein, and Pietro Tebaldi, "Market design in regulated health insurance markets: Risk adjustment vs. subsidies," *Unpublished mimeo, Stanford University, MIT, and University of Chicago*, 2019, *7*, 32.

— and — , "Selection in Insurance Markets: Theory and Empirics in Pictures," *Journal of Economic perspectives*, 2011, *25* (1), 115–138.

Fang, Hanming and Ami Ko, "Partial Rating Area Offering in the ACA Marketplaces: Facts, Theory and Evidence," 2018.

Farrell, Joseph and Carl Shapiro, "Antitrust Evaluation of Horizontal Mergers: An Economic Alternative to Market Definition," *The BE Journal of Theoretical Economics*, 2010, *10* (1).

Fiedler, Matthew, "How did the ACA's Individual Mandate Affect Insurance Coverage? Evidence from Coverage Decisions by Higher Income People," *USC-Brookings Schaeffer Initiative on Health Policy*, 2018.

Finkelstein, Amy, Nathaniel Hendren, and Mark Shepard, "Subsidizing Health Insurance for Low-Income Adults: Evidence from Massachusetts," *American Economic Review*, 2019, *109* (4), 1530–1567.

Froot, Kenneth, "The Market for Catastrophe Risk: a Clinical Examination," *Journal of Financial Economics*, 2001, *60* (2-3), 529–571.

Froot, Kenneth A. and Jeremy C. Stein, "Risk management, capital budgeting, and capital structure policy for financial institutions: an integrated approach," *Journal of Financial Economics*, 1998, *47*, 55–82.

Geddes, Eilidh, "The Effects of Price Regulation in Markets with Strategic Entry: Evidence from Health Insurance Markets," 2022.

Geruso, Michael and Timothy Layton, "Upcoding: Evidence from Medicare on Squishy Risk Adjustment," *Journal of Political Economy*, 2020, *128* (3), 984–1026.

— , — , and Daniel Prinz, "Screening in Contract Design: Evidence from the ACA Health Insurance Exchanges," *American Economic Journal: Economic Policy*, 2019, *11* (2), 64–107.

Glazer, Jacob and Thomas McGuire, "Optimal Risk Adjustment in Markets with Adverse Selection: An Application to Managed Care," *American Economic Review*, 2000, *90* (4), 1055–1071.

Goldberg, Pinelopi Koujianou and Rebecca Hellerstein, "A Structural Approach to Identifying the Sources of Local Currency Price Stability," *Review of Economic Studies*, 2013, *80* (1), 175–210.

Goolsbee, Austan and Amil Petrin, "The Consumer Gains from Direct Broadcast Satellites and the Competition with Cable TV," *Econometrica*, 2004, *72* (2), 351–381.

Groote, Olivier De and Frank Verboven, "Subsidies and time discounting in new technology adoption: Evidence from solar photovoltaic systems," *American Economic Review*, 2019, *109* (6), 2137–72.

Hakansson, Nils H., "Friedman-Savage Utility Functions Consistent with Risk Aversion," *Quarterly Journal of Economics*, 1970, *84*, 472–487.

Handel, Ben, Igal Hendel, and Michael D Whinston, "Equilibria in health exchanges: Adverse selection versus reclassification risk," *Econometrica*, 2015, *83* (4), 1261–1313.

Handel, Benjamin, "Adverse Selection and Inertia in Health Insurance Markets: When Nudging Hurts," *American Economic Review*, 2013, *103* (7), 2643–82.

— and Kate Ho, "The Industrial Organization of Health Care Markets," in "Handbook of Industrial Organization," Vol. 5, Elsevier, 2021, pp. 521–614.

Jean-Baptiste, Eslyn L. and Anthony M. Santomero, "The Design of Private Reinsurance Contracts," *Journal of Financial Intermediation*, 2000, *9*, 274–297.

Jenkin, Fleeming, "On the Principles which Regulate the Incidence of Taxes," *Proceedings of the Royal Society of Edinburgh*, 1872, *7*, 618–631.

Kautter, John, Gregory Pope, Melvin Ingber, Sara Freeman, Lindsey Patterson, Michael Cohen, and Patricia Keenan, "The HHS-HCC Risk Adjustment Model for Individual and Small Group Markets under the Affordable Care Act," *Medicare & Medicaid Research Review*, 2014, *4* (3).

Keith, Katie, "More Insurers Win Lawsuits Seeking Cost-Sharing Reduction Payments," *Health Affairs*, 2019, *10.*

Kenkel, Donald, "Are Alcohol Tax Hikes Fully Passed Through to Prices? Evidence from Alaska," *American Economic Review*, 2005, *95* (2), 273–277.

Kim, Paul and Anran Li, "Do Insurers Exhibit Moral Hazard: Evidence From Public Reinsurance Programs.," 2024.

Kim, Paul HS, "Risk-Corridors in Medicare Part D: Financial Risk-Sharing or Profit-Limiting Mechanism?," *Working Paper*, 2022.

Koijen, Ralph and Motohiro Yogo, "The Cost of Financial Frictions for Life Insurers," *American Economic Review*, 2015, *105* (1), 445–75.

Koijen, Ralph S.J. and Motohiro Yogo, "Shadow Insurance," *Econometrica*, 2016, *84* (3), 1265–1287.

Layton, Timothy, "Imperfect Risk Adjustment, Risk Preferences, and Sorting in Competitive Health Insurance Markets," *Journal of Health Economics*, 2017, *56*, 259–280.

— **, Thomas McGuire, and Richard Van Kleef**, "Deriving Risk Adjustment Payment Weights to Maximize Efficiency of Health Insurance Markets," *Journal of Health Economics*, 2018, *61*, 93–110.

Li, Anran, "Commitment, Competition, and Preventive Care Provision," 2024.

Liebling, Tina, "Rep. Liebling statement on House GOP "reinsurance" proposal," 2017. link, Accessed: 2025/4/3.

Lueck, Sarah, "Reinsurance Basics: Considerations as States Look to Reduce Private Market Premiums," 2019. link, Accessed: 2023/10/23.

Lurie, Ithai, Daniel Sacks, and Bradley Heim, "Does the Individual Mandate Affect Insurance Coverage? Evidence from Tax Returns," *American Economic Journal: Economic Policy*, 2021, *13* (2), 378–407.

Mahoney, Neale and E Glen Weyl, "Imperfect Competition in Selection Markets," *Review of Economics and Statistics*, 2017, *99* (4), 637–651.

Masson, Robert Tempest, "The Creation of Risk Aversion by Imperfect Capital Markets," *American Economic Review*, 1972, *62*, 77–86.

McGuire, Thomas G, Sonja Schillo, and Richard C Van Kleef, "Reinsurance, repayments, and risk adjustment in individual health insurance: Germany, the Netherlands, and the US marketplaces," *American Journal of Health Economics*, 2020, *6* (1), 139–168.

Medicare Payment Advisory Commission, "Report to the Congress: Medicare and the Health Care Delivery System, Realigning incentives in Medicare Part D," 2020. link, Accessed: 2025/4/3.

Miravete, Eugenio, Katja Seim, and Jeff Thurk, "Market Power and the Laffer Curve," *Econometrica*, 2018, *86* (5), 1651–1687.

NAIC, "Reinsuance," 2023. .

— , "Risk-Based Capital," 2023. link, Accessed: 2023/10/23.

Nakamura, Emi and Dawit Zerom, "Accounting for Incomplete Pass-through," *The Review of Economic Studies*, 2010, *77* (3), 1192–1230.

Pless, Jacquelyn and Arthur A Van Benthem, "Pass-through as A Test for Market Power: An Application to Solar Subsidies," *American Economic Journal: Applied Economics*, 2019, *11* (4), 367–401.

Polyakova, Maria and Stephen P Ryan, "Subsidy targeting with market power," Technical Report, National Bureau of Economic Research 2019.

— **, Vinayak Bhatia, and M Kate Bundorf**, "Analysis of publicly funded reinsurance—government spending and insurer risk exposure," in "JAMA Health Forum," Vol. 2 American Medical Association 2021, pp. e211992–e211992.

Saltzman, Evan, "Demand for Health Insurance: Evidence from the California and Washington ACA Exchanges," *Journal of Health Economics*, 2019, *63*, 197–222.

— , "Managing Adverse Selection: Underinsurance Versus Underenrollment," *The RAND Journal of Economics*, 2021, *52* (2), 359–381.

Shepard, Mark, "Hospital Network Competition and Adverse Selection: Evidence from the Massachusetts Health Insurance Exchange," *American Economic Review*, 2022, *112* (2), 578–615.

Springel, Katalin, "Network externality and subsidy structure in two-sided markets: Evidence from electric vehicle incentives," *American Economic Journal: Economic Policy*, 2021, *13* (4), 393–432.

Starc, Amanda, "Insurer Pricing and Consumer Welfare: Evidence from Medigap," *The RAND Journal of Economics*, 2014, *45* (1), 198–220.

Stillerman, David, "Loan guarantees and incentives for information acquisition," *Available at SSRN 4411553*, 2024.

Su, Che-Lin and Kenneth L Judd, "Constrained Optimization Approaches to Estimation of Structural Models," *Econometrica*, 2012, *80* (5), 2213–2230.

Swartz, Katherine, "Reducing Risk to Increase Access to Health Insurance," *American Economic Review*, 2003, *93* (2), 283–287.

Tebaldi, Pietro, "Estimating equilibrium in health insurance exchanges: Price competition and subsidy design under the aca," *Review of Economic Studies*, 2025, *92* (1), 586–620.

Weyl, E Glen and Michal Fabinger, "Pass-Through as an Economic Tool: Principles of Incidence under Imperfect Competition," *Journal of Political Economy*, 2013, *121* (3), 528–583.

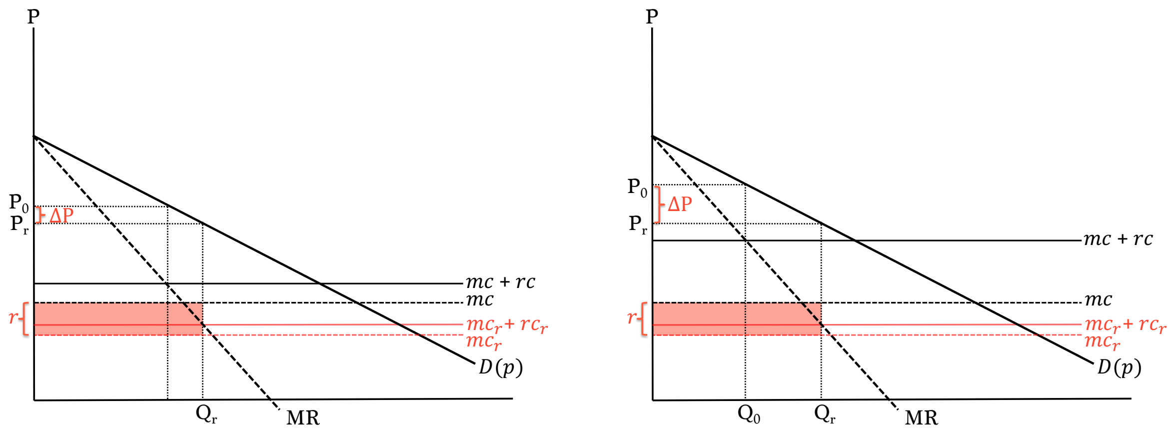
Appendix

Contents

A. Supplementary Figures and Tables

Figure A1. Pass-through of Reinsurance

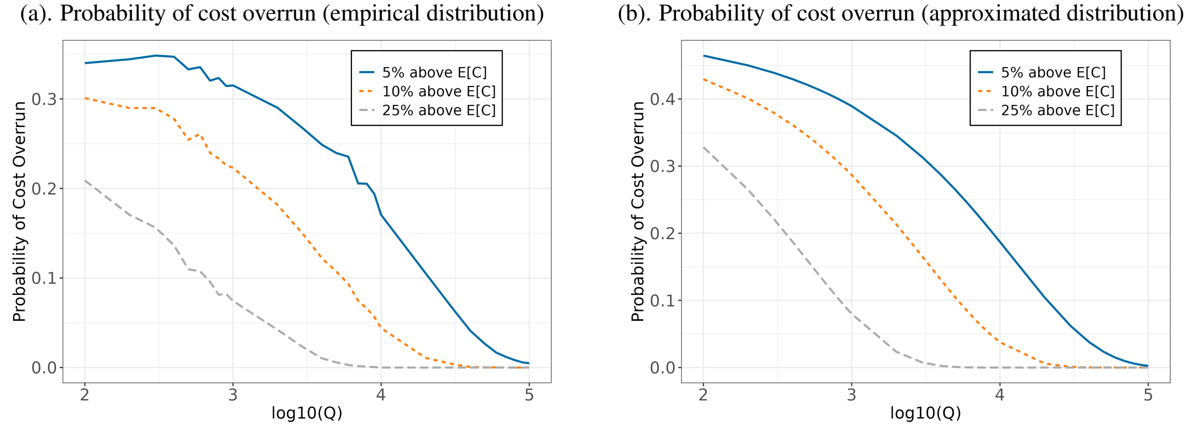
(a). Small Change in Risk Charge (b). Large Change in Risk Charge



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

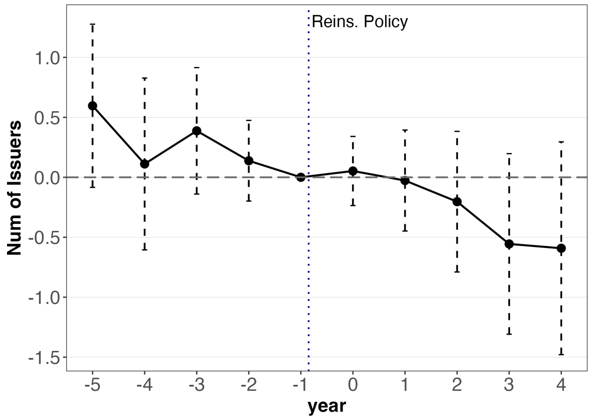
(a). Probability of cost overrun (empirical distribution) (b). Probability of cost overrun (approximated distribution)



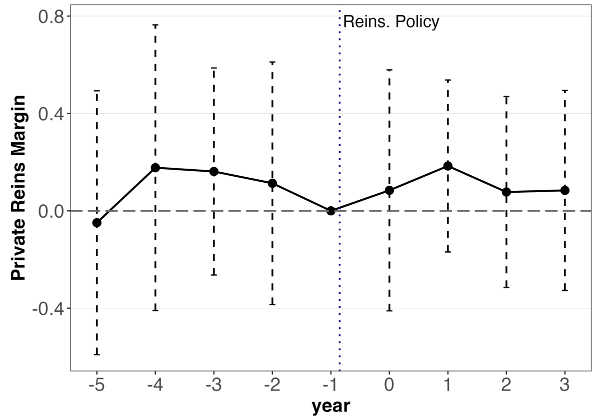
Notes: This figure shows the probability that realized claims exceed a given percentage of expected costs by enrollee size. We sample the number of enrollees (x-axis) from the empirical distribution of realized claims for panel (a) or the normal approximated distribution of total realized claims for 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



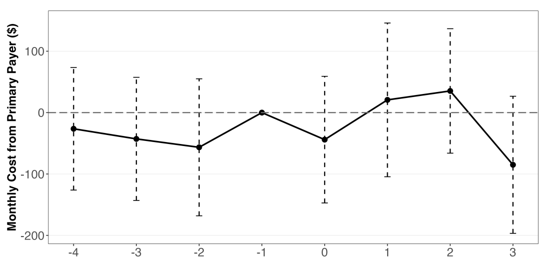
(b). Private reinsurance margin



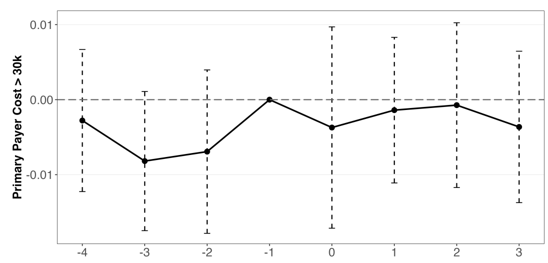
Notes: This figure reports point estimates and 95% confidence interval of the effect of state reinsurance from the estimation of equation (5). The outcome variable is the number of insurers in a rating region in panel (a), and private reinsurance margin, defined as difference in premiums to claims over 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

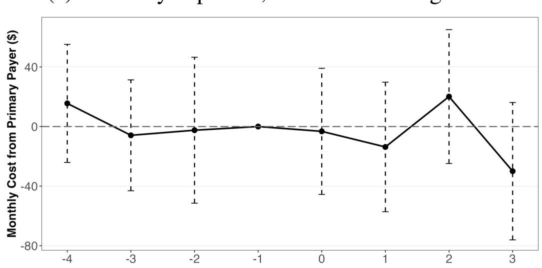
(a). Monthly expenses, across reinsurance tiers



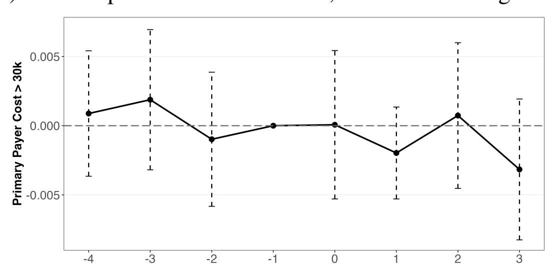
(b). Total expenses above threshold, across reinsurance tiers



(c). Monthly expenses, across market segments



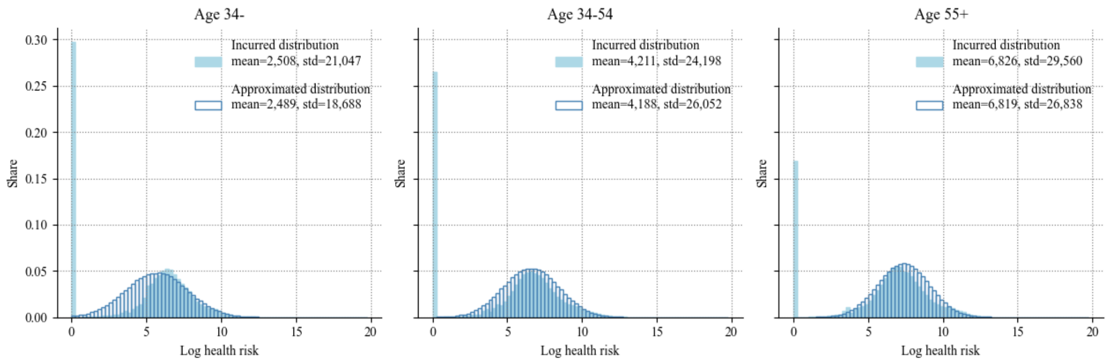
(d). Total expenses above threshold, across market segments



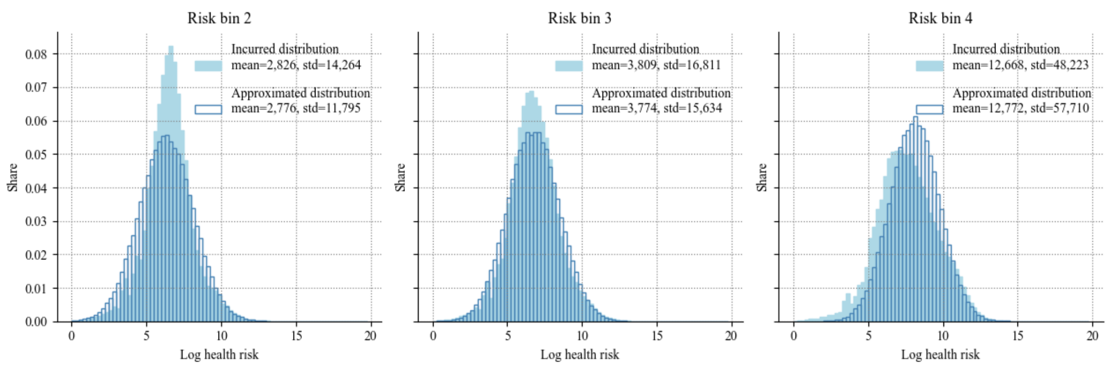
Notes: This figure reports point estimates and 95% confidence interval of the effect of state reinsurance on medical expenses from the estimation of equation (A8). The outcome variable is monthly medical expenses per enrollee in panels (a) and (c), and whether the enrollees' annual expenses exceed the 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. Simulated versus realized health risk distribution

(a). By Age bins

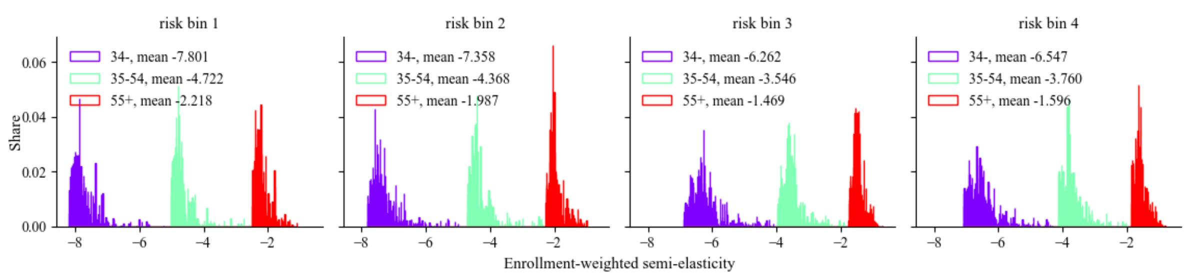


(b). By risk bins



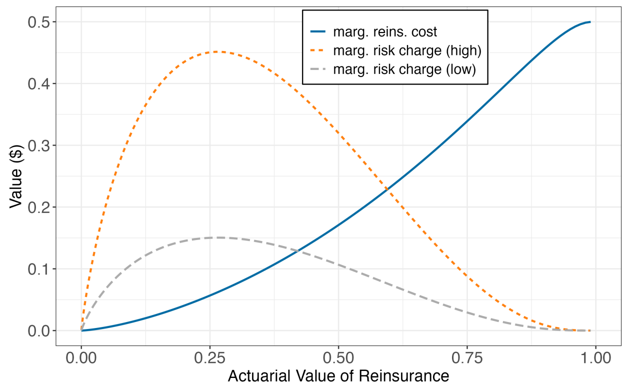
Notes: This figure plots the realized risk score distributions versus the our log-normal approximation, by age and risk bins. Risk scores are predicted using the previous year's claims records, and then divided into four quartiles. The risk bin 1 does not incur any claims records. The parameters of the approximated distribution are reported in Table A7.

Figure A6. Estimated distribution of own-premium semi-elasticity



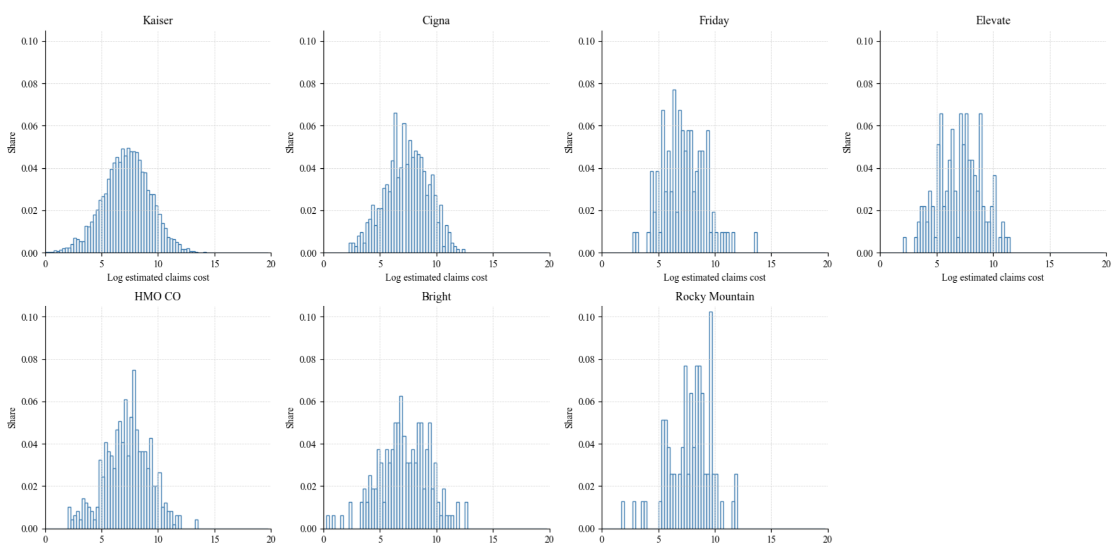
Notes: The table summarizes the enrollment-weighted averages of sensitivity to premiums conditioning on different age-risk bins. Risk bins are four quartiles based on the predicted risk scores using claims from previous years. The statistics reported are functions of the demand parameters reported in Table A8.

Figure A7. Identification of risk preference parameter



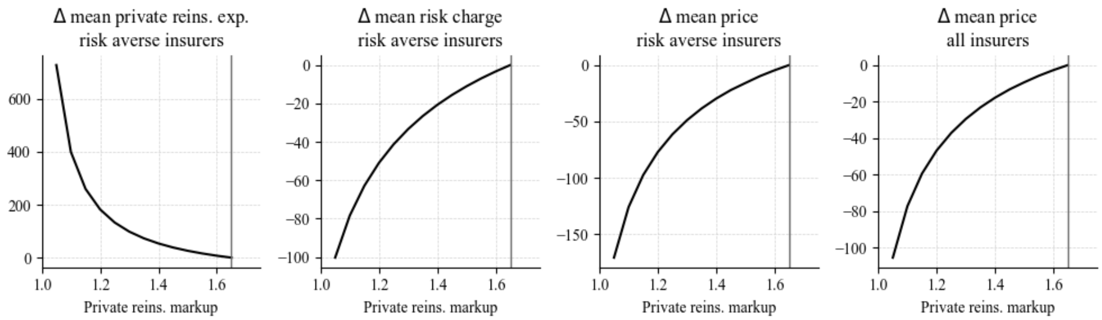
Notes: This figure illustrates the identification of risk preferences parameters ρ_{ft}. The horizontal axis converts the reinsurance deductible κ_{ft} into the actuarial value of reinsurance contracts, or the claims reduction brought by the reinsurance contracts. The lines displayed are simulated marginal 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 (20), 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 A8. Estimated claims cost distribution by insurers



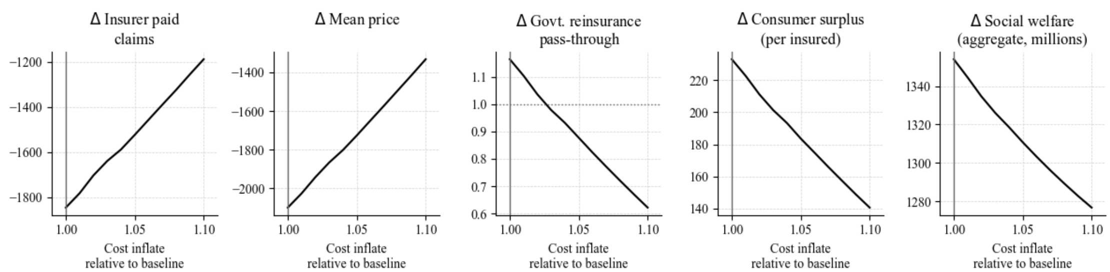
Notes: This figure plots each insurer's estimated claims cost distribution (before applying insurers' cost shares) in 2019. The sample size plotted corresponds to the realized enrollment numbers for that insurer.

Figure A9. Effect of private reinsurance markup on equilibrium pricing strategies



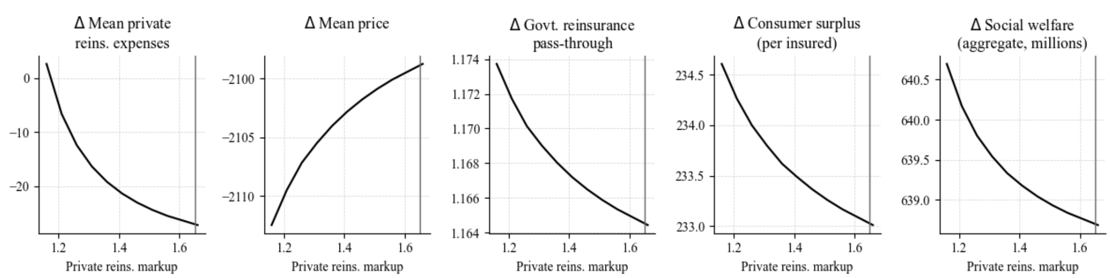
Notes: This figure plots simulated equilibrium prices under different reinsurance markup, using market primitives estimated in 2019. The simulation sample and specifications other than markup are the same as Figure 7. The averages are enrollment-weighted. The vertical dashed line denotes the status quo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

Figure A10. 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 8. The averages are enrollment-weighted. The vertical dashed line denotes the status quo degree of moral hazard.

Figure A11. Effect of public reinsurance subsidies, sensitivity to private reinsurance markup



Notes: This figure plots simulated equilibrium prices under different reinsurance markup, using market primitives estimated in 2019. The simulation sample and specifications other than markup are the same as Figure 8. The averages are enrollment-weighted. The vertical dashed line denotes the status quo markup.

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 subsidies, 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 subsidies 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 × Tier 2		-0.0003				
		(0.027)				
reinsurance policy × Tier 3		-0.199^{***}				
		(0.028)				
reinsurance policy × 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 (6), and (A8). 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. Health risk distribution

Consumer type	Means (μ_i)	Square of Std. (σ_i^2)	Consumer type	Means (μ_i)	Square of Std. (σ_i^2)
Risk bin 1, 34-	0	0	Risk bin 2, 34-	6.126	3.120
Risk bin 1, 35-54	0	0	Risk bin 2, 35-54	6.326	3.157
Risk bin 1, 55+	0	0	Risk bin 2, 55+	6.605	3.284
Risk bin 3, 34-	6.338	3.032	Risk bin 4, 34-	7.305	3.611
Risk bin 3, 35-54	6.651	3.072	Risk bin 4, 35-54	7.949	2.797
Risk bin 3, 55+	7.141	2.846	Risk bin 4, 55+	8.480	2.335

Notes: Data comes from CO APCD 2017-2020. The parameters reported are of the approximated log-normal distribution for each specific group. Risk bins are four quartiles based on the predicted risk scores using claims from previous years. For computational purposes, we use an arbitrary small number to the standard deviations of the risk bin 1.

Table A8. Consumer preferences parameter estimates

	(1)	(2)	(3)
(a). Demand estimation, first step MLE estimates			
Coefficient on premium (in $1,000), risk bin 1	-0.754 (0.003)	-0.564 (0.003)	-0.682 (0.003)
Coefficient on premium (in $1,000), risk bin 2	-0.507 (0.003)	-0.323 (0.003)	-0.410 (0.003)
Coefficient on premium (in $1,000), risk bin 3	-0.049 (0.004)	-0.235 (0.004)	-0.230 (0.004)
Coefficient on deductible (in $1,000), risk bin 1		-0.093 (0.003)	
Coefficient on deductible (in $1,000), risk bin 2		-0.116 (0.003)	
Coefficient on deductible (in $1,000), risk bin 3		0.025 (0.003)	
Coefficient on maximum out-of-pocket (in $1,000), risk bin 1			-0.155 (0.003)
Coefficient on maximum out-of-pocket (in $1,000), risk bin 2			-0.742 (0.003)
Coefficient on maximum out-of-pocket (in $1,000), risk bin 3			-0.263 (0.002)
Coefficient on insured option, risk bin 1		-0.723 (0.007)	-1.157 (0.007)
Coefficient on insured option, risk bin 2		-0.858 (0.008)	-5.540 (0.008)
Coefficient on insured option, risk bin 3		0.807 (0.009)	2.566 (0.010)
Standard deviation of random coefficient on price	0.634 (0.002)	0.523 (0.002)	0.550 (0.002)
(b). Demand estimation, second step OLS estimates			
Coefficient on premium (in $1,000), age below 34	-3.054 (0.110)	-2.619 (0.097)	-2.670 (0.101)
Coefficient on premium (in $1,000), age between 35-54	-1.932 (0.080)	-1.608 (0.071)	-1.658 (0.074)
Coefficient on premium (in $1,000), age above 55	-0.768 (0.051)	-0.572 (0.045)	-0.590 (0.047)
(c). Implied mean semi-elasticity to own premium			
Age below 34, risk bin 1	-8.536	-7.345	-7.708
Age below 34, risk bin 2	-8.009	-6.850	-7.146
Age below 34, risk bin 3	-7.057	-6.442	-6.585
Age below 34, risk bin 4	-7.000	-6.161	-6.321
Age 35-54, risk bin 1	-5.186	-4.405	-4.652
Age 35-54, risk bin 2	-4.776	-4.010	-4.210
Age 35-54, risk bin 3	-4.062	-3.750	-3.817
Age 35-54, risk bin 4	-4.015	-3.506	-3.590
Age above 55, risk bin 1	-2.453	-2.043	-2.183
Age above 55, risk bin 2	-2.188	-1.785	-1.893
Age above 55, risk bin 3	-1.741	-1.647	-1.670
Age above 55, risk bin 4	-1.707	-1.467	-1.499

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 coefficient on insured option, deductible, and maximum out-of-pocket in the second step is absorbed by the fixed effects, 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 A9. Estimated marginal cost multiplier

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Across all markets					By reins. policy tier		
	Weighted					weighted mean		
Insurer	mean	Mean	Std.	Min	Max	tier 1	tier 2	tier 3
Kaiser	1.412	1.586	(0.330)	1.167	2.753	1.357	1.560	1.694
Bright	2.009	2.243	(0.321)	1.825	3.129	1.987	-	2.700
Cigna	2.291	2.422	(0.214)	2.195	2.795	2.291	-	-
Friday	2.514	2.726	(0.656)	1.439	3.779	2.204	2.925	3.357
Elevate	2.308	2.311	(0.226)	2.124	2.647	2.308	-	-
HMO CO	1.813	1.917	(0.290)	1.432	2.920	1.638	1.718	2.002
Rocky Mountain	2.256	2.327	(0.268)	2.051	2.690	-	-	2.256

Notes: This table reports the summary statistics of the estimated marginal costs multiplier by insurer in 2019. The marginal cost multiplier is estimated at 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, which is described in Figure 2b. Columns (1) and (6)-(8) report enrollment weighted means. Dashed line means the insurer does not operate in the policy tier regions.

Table A10. Effect of public reinsurance subsidies

	(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	9,498	7,399	8,764	6,926	12,242	8,581	15,724	8,717
Claims costs	7,886	6,039	7,346	5,826	9,906	6,936	12,458	6,383
Private reinsurance expenses	37	9	37	11	54	9	13	2
Risk charge	54	22	53	26	94	28	19	2
Public reinsurance expenses	0	1,802	0	1,255	0	1,847	0	4,227
Premium subsidy expenses	5,632	3,981	5,142	3,723	7,590	4,863	9,595	4,536
(b). Market mean (per consumer)								
Consumer surplus	221	454	274	487	111	252	116	568
Insured rate	0.20	0.42	0.25	0.45	0.10	0.25	0.09	0.49
Total number of insured	87,808	185,517	74,565	134,900	7,951	20,531	5,292	30,087
Total number of consumers	443,017	443,017	298,487	298,487	82,926	82,926	61,604	61,604
(c). Aggregate welfare (total, in millions)								
Consumer surplus	98	201	121	216	49	112	51	252
Insurer profit, including risk charges	134	246	99	143	17	33	17	70
Insurer profit, excluding risk charges	138	251	103	147	18	34	17	70
Reinsurer profit	1.28	0.70	1.08	0.61	0.17	0.07	0.03	0.02
Public reinsurance expenses	0	334	0	169	0	38	0	127
Premium subsidy expenses	495	739	383	502	60	100	51	136
Charitable care expenses for uninsured	1,070	610	656	391	234	153	180	65

Notes: This table reports simulated equilibrium statistics before and after government reinsurance subsidies. We simulate the equilibrium using market primitives in 2019. Averages in the table are enrollment-weighted.

Table A11. Decompose the effect of public reinsurance subsidies

	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	8,328	7,049	6,862	6,857	6,593	8,763	7,381	7,175	7,169	6,894
Claims costs	6,879	5,654	5,617	5,635	5,530	7,169	5,828	5,795	5,815	5,728
Private reins. expenses	84	91	61	28	26	93	107	63	29	27
Risk charge	121	126	55	65	61	138	149	57	67	65
(b). Risk-neutral insurers (average per insured)										
Price	9,099	8,873	8,865	8,864	7,177	9,976	9,940	9,956	9,957	7,668
Claims costs	7,705	7,618	7,620	7,620	6,050	8,351	8,403	8,421	8,422	6,204
Private reins. expenses	-	-	-	-	-	-	-	-	-	-
Risk charge	-	-	-	-	-	-	-	-	-	-
(c). Market mean (per insured)										
Price	8,764	7,602	7,404	7,398	6,926	9,498	8,272	8,042	8,036	7,399
Claims costs	7,346	6,250	6,158	6,170	5,826	7,886	6,724	6,614	6,626	6,039
Private reinsurance expenses	37	63	44	21	11	37	70	44	20	9
Risk charge	53	88	40	47	26	54	97	39	46	22
Public reinsurance expenses	0	830	865	866	1,255	0	883	951	952	1,802
Premium subsidy expenses	5,142	4,253	4,108	4,104	3,723	5,632	4,708	4,540	4,535	3,981
(d). Market mean (per consumer)										
Consumer surplus	274	361	378	379	487	221	289	304	304	454
Insured rate	0.25	0.34	0.36	0.36	0.45	0.20	0.27	0.28	0.28	0.42
(e). Aggregate welfare (total, in millions)										
Consumer surplus	82	108	113	113	145	98	128	135	135	201
Insurer profit, including risk charges	99	122	124	124	143	134	164	170	170	246
Insurer profit, excluding risk charges	103	131	129	130	147	138	176	174	175	251
Reinsurer profit	1.08	2.56	1.89	0.88	0.61	1.28	3.30	2.18	0.99	0.70
Public reinsurance expenses	0	84	93	93	169	0	105	120	120	334
Premium subsidy expenses	383	433	440	440	502	495	560	572	572	739
Charitable care expenses for uninsured	656	574	558	558	391	1,070	974	952	952	610

Notes: This table reports simulated equilibrium statistics under various counterfactual scenarios. We simulate the equilibrium using market primitives in 2019. 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 compute social welfare assuming that the planner puts an equal weight on consumer surplus, insurer profits, reinsurer profits, and government expenses. 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 4. 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.

Table A12. Compare the effect of financial frictions and adverse selection

Adverse selection	Financial friction	Δ price	Δ public reins. expenses	Pass-through
Yes	Yes	1280	1046	1.22
Yes	No	1204	1054	1.14
No	Yes	1156	1159	0.97
No	No	1092	1193	0.91

Notes: This table reports the changes in equilibrium statistics with and without public reinsurance subsidies. Statistics reported are enrollment-weighted, per consumer, per year. We remove adverse selection by allowing all consumers to have the same claims costs distribution. We remove financial frictions by setting all insurers' risk preferences to zero and banning private reinsurance.

Table A13. Effect of public reinsurance subsidies, by age bins

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	All consumers		Age below 34		Age 35-54		Age above 55	
	Before	After	Before	After	Before	After	Before	After
(a). Market mean (per insured)								
Price	9,498	7,399	4,945	4,537	7,587	6,842	13,631	11,745
Claims costs	7,886	6,039	3,929	3,624	6,729	6,001	11,125	9,222
Private reinsurance expenses	37	9	30	8	37	10	41	10
Risk charge	54	22	33	14	51	24	70	31
Public reinsurance expenses	0	1,802	0	992	0	1,729	0	2,938
Premium subsidy expenses	5,632	3,981	2,198	1,897	4,086	3,473	8,823	7,259
(b). Market mean (per consumer)								
Consumer surplus	912	942	184	340	414	628	1,708	2,076
Insured rate	0.20	0.42	0.11	0.34	0.17	0.40	0.45	0.64
Total number of insured	87,808	185,517	23,341	70,568	26,502	60,686	37,966	54,264
Total number of consumers	443,017	443,017	205,535	205,535	153,007	153,007	84,475	84,475

Notes: This table reports simulated equilibrium statistics before and after government reinsurance subsidies. We simulate the equilibrium using market primitives in 2019. Averages in the table are enrollment-weighted.

Table A14. Effect of public reinsurance subsidies, by risk bins

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Risk bin 1		Risk bin 2		Risk bin 3		Risk bin 4	
	Before	After	Before	After	Before	After	Before	After
(a). Market mean (per insured)								
Price	7,790	6,372	9,138	7,324	10,193	7,971	10,268	8,125
Claims costs	6,438	5,228	7,541	5,957	8,489	6,494	8,563	6,641
Private reinsurance expenses	33	9	35	9	38	9	39	10
Risk charge	49	21	54	22	55	23	58	24
Public reinsurance expenses	0	1,495	0	1,755	0	1,977	0	2,050
Premium subsidy expenses	4,651	3,348	5,597	4,006	5,901	4,262	6,053	4,407
(b). Market mean (per consumer)								
Consumer surplus	287	380	558	668	1,394	1,554	1,145	1,318
Insured rate	0.09	0.28	0.17	0.40	0.39	0.64	0.33	0.58
Total number of insured	15,667	47,586	23,652	55,163	27,468	45,439	21,021	37,330
Total number of consumers	171,364	171,364	137,300	137,300	70,528	70,528	63,825	63,825

Notes: This table reports simulated equilibrium statistics before and after government reinsurance subsidies. We simulate the equilibrium using market primitives in 2019. Averages in the table are enrollment-weighted.

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

Without loss of generality, we again provide a simple example with linear demand $q_t(p) = a - b_t p$, $b_l < b_h$. In this case, the insurer's first order condition is:

$$p^*(\kappa_g) = \frac{1}{2}\left(\big(\lambda(p)c_\ell(\kappa_g) + (1-\lambda(p))c_h(\kappa_g)\big) + \rho\left(\lambda(p)\sigma_\ell^2(\kappa_g) + (1-\lambda(p))\sigma_h^2(\kappa_g)\right) + \frac{2a}{b_l + b_h}\right).$$

Without reinsurance, $p_0^* = p^*(\infty)$. So the corresponding pass-through is

$$\frac{p^*(\infty) - p^*(\kappa_g)}{r(\kappa_g)} = \frac{1}{2}\left(\frac{\overbrace{\lambda(p)\Delta c_\ell(\kappa_g) + (1-\lambda(p))\Delta c_h(\kappa_g)}^{\text{marginal claims reduction}}}{\underbrace{\alpha(p)\Delta c_\ell(\kappa_g) + \left(1-\alpha(p)\right)\Delta c_h(\kappa_g)}_{\text{average claims reduction}}} + \frac{\overbrace{\rho\left(\lambda(p)\Delta\sigma_\ell^2(\kappa_g) + (1-\lambda(p))\Delta\sigma_h^2(\kappa_g)\right)}^{\text{marginal risk charge reduction}}}{\underbrace{\alpha(p)\Delta c_\ell(\kappa_g) + \left(1-\alpha(p)\right)\Delta c_h(\kappa_g)}_{\text{average claims reduction}}} \right). \tag{A1}$$

If financial frictions are severe enough (ρ or $\Delta\sigma^2$ is large), it is possible that the second term on the right-hand side of equation (A1) is very large, which drives the pass-through to become greater than 1. The intuition is the same as stated in Section 3: When the insurer bears additional costs for taking risks, drops in risk charges bring extra decreases in marginal costs, which are embedded into price setting. The more considerable financial frictions the insurer faces, the more significant drops in risk charges it experiences, and the more likely more-than-complete pass-through rates are. This risk reduction effect is uniform across consumers of all risk types.

We now analyze additional features that selection brings, which correspond to the second part of Proposition 1. In an adverse selection market, healthy consumers are more price elastic: if $b_l < b_h$, F_h first order stochastically dominates F_ℓ. In this scenario, reinsurance reduces the expected costs and variance more for consumer type h than consumer type l

$$c_\ell < c_h, \sigma_\ell^2 < \sigma_h^2, \Delta c_\ell(\kappa_g) < \Delta c_h(\kappa_g), \Delta\sigma_\ell^2(\kappa_g) < \Delta\sigma_h^2(\kappa_g).$$

This means that reinsurance not only shifts down the marginal cost curves, but also flattens the cost curves by compressing variation in expected claims across risk types. Note that

$$\frac{\lambda(p)}{\alpha(p)} = \frac{q_\ell'/Q'}{q_\ell/Q} = \frac{\epsilon_\ell}{\epsilon} > 1.$$

This implies that the first term on the right hand side of equation (A1) is less than 1.

$$\frac{\lambda(p)\Delta c_\ell(\kappa_g) + (1-\lambda(p))\Delta c_h(\kappa_g)}{\alpha(p)\Delta c_\ell(\kappa_g) + \left(1-\alpha(p)\right)\Delta c_h(\kappa_g)} < 1. \tag{A2}$$

All else equal, the presence of adverse selection makes it less likely to achieve more-than-unity pass-through than the no-selection case. The key driver behind equation (A2) is that reinsurance reduces claims cost more for the high-risk consumers than low-risk consumers $\Delta c_h(\kappa_g) > \Delta c_l(\kappa_g)$. When we reduce the degree of selection and shrink the gap between two health status distributions, the difference between cost reductions, or the claims cost of the average and the marginal consumers, decreases. In the extreme case without selection, $\Delta c_h(\kappa_g) = \Delta c_l(\kappa_g)$, equation (A2) equals one, giving the largest possible pass-through.

The intuition behind this result is how reinsurance changes pricing power through shifting selection patterns. Since sicker consumers are more likely to have claims realizations exceed the reinsurance reimbursement threshold and experience larger reductions in expected claims, the stop-loss reinsurance mitigates selection by rotating the marginal cost curve. This relieves the downward pricing pressure for the insurer because the positive profit gap between the marginal and average consumer shrinks. Without reinsurance flattening marginal costs, insurers are more reluctant to increase premiums because the marginal buyers they would lose are relatively cheaper and more attractive to retain. The flattening of marginal cost curves could increase markup and partly offset the price drop from risk reduction, making it less likely to achieve more-than-complete pass-through rates.

C2. The Role of Each Market Imperfection

We compare the pass-throughs of supply-side subsidies in Table A15, to isolate the role of market power, financial frictions, and adverse selection.

Table A15. Comparison of pass-through results under different assumptions

Scenario	Market power	Financial frictions	Adverse selection	Pass-through of ex-post S subsidy compared to 1	Efficiency, D subsidiy compared to S subsidiy
(1)	✗	✗	✗	$\leq$	=
(2)	✓	✗	✗	ambiguous	ambiguous
(3)	✗	✓	✗	ambiguous	$<$
(4)	✓	✓	✗	ambiguous	ambiguous
(5)	✗	✗	✓	$>$	=
(6)	✓	✗	✓	ambiguous	ambiguous
(7)	✗	✓	✓	$>$	$<$
(8)	✓	✓	✓	ambiguous	ambiguous

Scenarios (1) correspond to the canonical case with perfect competition. Jenkin (1872) derives that the pass-through of a tax or subsidy to the prices consumers face is $1/(1+\frac{\epsilon_D}{\epsilon_S})$, where ϵ_D, ϵ_S are the elasticity of demand and supply curves, respectively. Pass-through in perfectly competitive markets is bounded between 0 and 100 percent and determined entirely by the relative elasticity of supply and demand. Complete pass-through occurs when demand is perfectly inelastic or supply is perfectly elastic. In this scenario, whether the government subsidizes demand or supply is immaterial.

Scenario (2) incorporates market power. Weyl and Fabinger (2013) derives that pass-through under a monopoly is $1/(1+\frac{\epsilon_D-1}{\epsilon_S}+\frac{1}{\epsilon_{ms}})$, where $ms = -p'q$, the marginal consumer surplus, is what consumers earn when quantity expands; $\epsilon_{ms} = ms/ms'q$ is the elasticity of the inverse marginal surplus function. Pless and Van Benthem (2019) shows when demand is log-concave, $\frac{1}{\epsilon_{ms}} > 0$, and the pass-through of a tax or subsidy is less than one. In contrast, when demand is log-convex, $\frac{1}{\epsilon_{ms}} < 0$, it is possible that the pass-through for a monopoly with constant marginal costs facing log-convex demand is larger than one. In this scenario, the efficiency of demand versus supply side subsidies is ambiguous and depends on the relative elasticities of supply and demand, as well as the shape of the demand curve.

Scenario (3)-(4) add financial frictions to canonical cases. Considering insurers who behave as if they are risk-averse makes ex-post transfers to the supply side both cost and risk subsidies. As shown in Proposition 1, the extra downward shifts in the marginal cost curve, due to risk reductions, make it likely that the pass-through of supply subsidies exceeds one. Aligned with this result, the relative degree of pricing power, i.e., the markup effect, and financial frictions, i.e., extra cost reduction, determine relative efficiencies of demand versus supply subsidies.

Scenario (5)-(6) add adverse selection to canonical cases. Standard analyses assume diminishing returns to inputs, or increasing marginal costs, $\epsilon_S > 0$. In industries with strong returns to scale or adverse selection, the marginal cost function is decreasing, $\epsilon_S < 0$. Applying the above pass-through formula, it is natural to see that in perfectly competitive markets with adverse selection, the pass-through of subsidies is greater than 1. In imperfectly competitive markets with adverse selection, the pass-through of subsidies is ambiguous and depends on the shape of both demand and supply curves.

Scenario (7)-(8) considers combinations of market imperfections, which mimic reality and integrate the effects of each force outlined before. The extra risk reduction from relieving financial frictions enhances the pass-through of ex-post supply subsidies. The downward-sloping marginal costs from adverse selection amplify that effect. But the markup effect from market power hampers the pass-through of supply subsidies to consumer prices. The efficiency of public reinsurance is an empirical question that depends on the shape of both supply and demand curves.

C3. Efficiency of Reinsurance versus Premium Subsidies

Our previous analysis shows reinsurance as an ex-post cost subsidy can lead to a pass-through of greater than one. We proceed to compare such a subsidy to a more straightforward direct-to-consumer premium subsidy. In particular, we examine the role of adverse selection and the insurer's financial frictions in determining the efficiency of each subsidy mechanism and their relative pass-through rates.

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

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

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

$$\begin{aligned} s(\kappa_g) &= p_s^* - p_r^*(\kappa_g) \\ &= \underbrace{\lambda(p) r_\ell(\kappa_g) + \big(1 - \lambda(p)\big)\, r_h(\kappa_g)}_{\text{marginal reinsurance cost}} + \underbrace{\rho\left(\lambda(p)\Delta\sigma_\ell^2(\kappa_g) + \big(1-\lambda(p)\big)\,\Delta\sigma_h^2(\kappa_g)\right)}_{\text{marginal change in risk charge}}. \end{aligned} \tag{A3}$$

where $\Delta\sigma_t^2(\kappa_g)$ denotes the change in variance of cost for reinsurance level κ_g. Given the above expression for $s(\kappa_g)$, we want to determine the relative magnitude of $r(\kappa_g)$ vs. $s(\kappa_g)$, 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 financial frictions.

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

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

Proposition A1 states that the pass-through rate of reinsurance and premium subsidy is the same without any financial frictions 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 frictions, 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 $c_\ell = c_h, \sigma^2_\ell = \sigma^2_h$.

Then the expected average reinsurance cost for given κ_g is

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

The expected per-enrollee subsidy will be $s(\kappa_g) = r(\kappa_g)$. That is, under no financial frictions 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

$$s(\kappa_g) = r(\kappa_g) + \underbrace{\rho\Delta\sigma^2(\kappa_g)}_{>0} > r(\kappa_g)$$

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

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

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

The expected per-enrollee subsidy is

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

Under adverse selection, $F_h(t) < F_\ell(t)\ \forall t$. This directly implies that $r_\ell(\kappa_g) < r_h(\kappa_g)$. We now show that the marginal reinsurance cost is smaller than the average reinsurance cost. Given that $r_\ell(\kappa_g) < r_h(\kappa_g)$, if $\alpha(p) < \lambda(p)$ then $r(\kappa_g) > s(\kappa_g)$ 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 $s(\kappa_g) < r(\kappa_g)$ 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 frictions 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 frictions dominate, then reinsurance might be more efficient. The results for a linear demand setting are illustrated in Figure A12.

C4. 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 a similar setting to the theoretical model in Section 3 and C1. Suppose now that there is a perfectly correlated aggregate cost shock common to all individuals, $x \sim N(1, \sigma_x^2)$. So, each individual's ex-post cost is now given by $y_i^t = x\tilde{c}_i^t$.[1] Then, the insurer's mean-variance utility will be given by

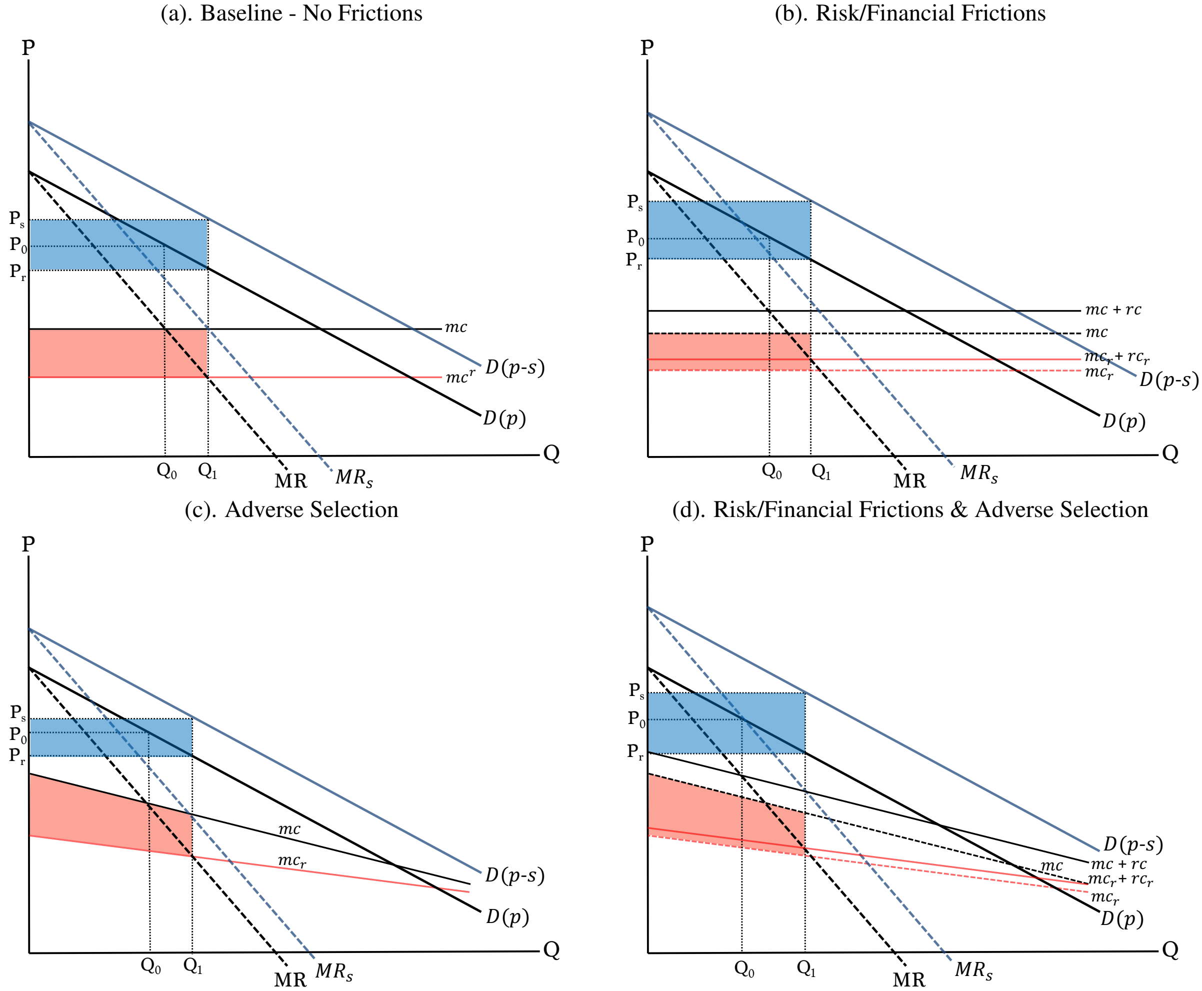
$$\max_p \quad p\underbrace{\big(q_\ell(p)+q_h(p)\big)}_{Q(p)} - \underbrace{\big(c_\ell q_\ell(p)+c_h q_h(p)\big)}_{\mu_c(p)} - \rho\overbrace{\left[(1+\sigma_x^2)\underbrace{\Big(\sigma_\ell^2 q_\ell(p)+\sigma_h^2 q_h(p)\Big)}_{\sigma_c^2(p)} + \sigma_x^2\mu_c^2(p)\right]}^{\text{total variance}}. \tag{A4}$$

Then, the corresponding FOC will be:

$$\underbrace{p+\frac{Q(p)}{\frac{\partial Q(p)}{\partial p}}}_{MR} = \underbrace{\big(\lambda(p)c_\ell+(1-\lambda(p))c_h\big)}_{MC(p)} + \underbrace{\rho\overbrace{\left[(1+\sigma_x^2)\Big(\lambda(p)\sigma_\ell^2+(1-\lambda(p))\sigma_h^2\Big)+2\sigma_x^2\mu_c(p)MC(p)\right]}^{\text{marginal variance, } MV(p)}}_{\text{marginal risk charge, } MRC(p)} \tag{A5}$$

[1] We can think of such aggregate cost shock coming from uncertainty in cost parameters, insurer-level shock to its cost factors such as provider price negotiations, or an extreme event such as COVID-19 pandemic.

Figure A12. 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.

Note that the FOC in (A5) is similar to the main theoretical model, except that the marginal risk charge is composed of other variance and co-variance terms related to the aggregate cost shocks. So, the larger the variance of the individual-level cost shock, or the aggregate cost shock, the larger the risk charge will be.

We re-examine how reinsurance subsidies affect insurer's cost, risk and associated pricing beahivour. Given government reinsurance that reimburses all costs beyond some deductible κ_g, insurer's ex-post cost for each individual i will be

$$y_i(\kappa_g) = \begin{cases} y_i & \text{if } y_i \leq \kappa_g \\ \kappa_g & \text{if } y_i > \kappa_g. \end{cases}$$

Such reinsurance will decrease both the MC and the marginal risk charge, as a result the new FOC will be

$$\underbrace{p + \frac{Q(p)}{\frac{\partial Q(p)}{\partial p}}}_{MR} = \underbrace{\big(\lambda(p)c_\ell(\kappa_g) + (1-\lambda(p))c_h(\kappa_g)\big)}_{MC(p;\kappa_g)} + \rho\, MV(p;\kappa_g) \tag{A6}$$

where both the marginal cost, $MC(p;\kappa_g)$, and the marginal variance, $MV(p;\kappa_g)$, are strictly increasing in κ_g, or decreasing in the amount of reinsurance. Hence, any level of reinsurance would decrease both the marginal cost and the marginal risk charge, leading to a decrease in the equilibrium price.

As before, we can now directly compare the cost of implementing such reinsurance versus providing a direct consumer subsidy that would yield the same effective consumer premiums. For any level of κ_g, the equivalent subsidy, $s(\kappa_g)$, will be:

$$\begin{aligned} s(\kappa_g) &= p_s^* - p_r^*(\kappa_g) \\ &= \underbrace{\lambda(p)r_\ell(\kappa_g) + \big(1-\lambda(p)\big)\, r_h(\kappa_g)}_{\text{marginal reinsurance cost}} + \underbrace{\rho\, \overbrace{\big(MV(p;0) - MV(p;\kappa_g)\big)}^{>0}}_{\text{marginal change in risk charge}}. \end{aligned} \tag{A7}$$

As long as reinsurance decreases the insurer's marginal variance and thereby decreases the insurer's marginal risk charge, our main theoretical results will remain the same. That is, with both adverse selection and financial frictions, the efficiency of reinsurance versus consumer subsidy is ambiguous.

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,

$$y_{it} = \sum_{n \in \{-4(+),-3,..,0,1,..,2,3+\}} \beta_n 1[t^* + n = t] D_{cmt} + \gamma_i + \gamma_t + \gamma X_{it} + \varepsilon_{it}, \tag{A8}$$

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 (A8) 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 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

$$\mathbb{E}[c_{ijm}] = \psi_{jm}\lambda_j \exp(\mu_i + \frac{1}{2}\sigma_i^2). \tag{A9}$$

$$\text{Var}[c_{ijm}] = \exp(\sigma_i^2 - 1)\exp(2(\mu_i + \log(\psi_{jm}\lambda_j)) + \sigma_i^2). \tag{A10}$$

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

$$C_f(\vec{p}) = \sum_m \sum_i \sum_{j \in J_{fm}} N_m w_{im} s_{ijm}(\vec{p}_m) c_{ijm}, \tag{A11}$$

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,

$$C_f(\vec{p}) \xrightarrow{d} N\Bigg(\mathbb{E}[C_f(\vec{p})], \text{Var}[C_f(\vec{p})]\Bigg), \text{ where} \tag{A12}$$

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

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

$\mathbb{E}[c_{ijm}]$ and $\text{Var}[c_{ijm}]$ are derived in equations (A9),(A10). The $\mathbb{E}[C_f(\vec{p})]$ term is the expected claims costs used in the insurer's objective function (equation (11)).

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.

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

For tractability, in the empirical model (equation (14)), 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 (12), 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:

$$c^r_{ijm}(\kappa_f) = c_{ijm}\mathbf{1}[c_{ijm} < \kappa_f] + \kappa_f \mathbf{1}[c_{ijm} \geq \kappa_f]. \tag{A13}$$

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

$$r_{ijm}(\kappa_f) = \mathbb{E}[c_{ijm}] - \mathbb{E}[c^r_{ijm}] = \mathbb{E}[(c_{ijm} - \kappa_f)\mathbf{1}[c_{ijm} \geq \kappa_f]]. \tag{A14}$$

Equation (A13) 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

$$\mathbb{E}[c^r_{ijm}(\kappa_f)] = \int_{-\infty}^{\frac{\kappa_f}{\psi_{jm}\lambda_j}} \psi_{jm}\lambda_j c_i f(c_i) dc_i + \int_{\frac{\kappa_f}{\psi_{jm}\lambda_j}}^{\infty} \kappa_f f(c_i) dc_i. \tag{A15}$$

$$\text{Var}[c^r_{ijm}(\kappa_f)] = \int_{-\infty}^{\frac{\kappa_f}{\psi_{jm}\lambda_j}} (\psi_{jm}\lambda_j c_i - \mathbb{E}[c^r_{ijm}(\kappa_f)])^2 f(c_i) dc_i + \int_{\frac{\kappa_f}{\psi_{jm}\lambda_j}}^{\infty} (\kappa_f - \mathbb{E}[c^r_{ijm}(\kappa_f)])^2 f(c_i) dc_i. \tag{A16}$$

$f(c_i)$ 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 (A9), (A10).

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

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

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

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

where $\mathbb{E}[c^r_{ijm}(\kappa_f)]$ and $\text{Var}[c^r_{ijm}(\kappa_f)]$ is detailed in equations (A15) and (A16). The $\mathbb{E}[c^r_{ijm}(\kappa_f)]$ term is the expected claims costs used in the insurer's objective function (equation (11)).

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 (A14). 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:

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

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 (13), 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:

$$c^r_{ijm}(\kappa_f, \kappa_g, \theta_g) = c_{ijm}\mathbf{1}[c_{ijm} < \kappa_g] + (\kappa_g + \theta_g(c_{ijm} - \kappa_g))\mathbf{1}[\kappa_g \leq c_{ijm} < \kappa_f] \\ + (\theta_g\kappa_f + (1-\theta_g)\kappa_g)\mathbf{1}[\kappa_f \leq c_{ijm}]. \tag{A17}$$

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

$$r_{ijm}(\kappa_f, \kappa_g, \theta_g) = \mathbb{E}[\big(\theta_g(c_{ijm} - \kappa_g) - \kappa_f\big)\, \mathbf{1}[c_{ijm} \geq \kappa_f]]. \tag{A18}$$

The public reinsurance expenses per insured r_{ijm} is

$$g_{ijm}(\kappa_g) = (1-\theta_g)(c_{ijm} - \kappa_g)\mathbf{1}[\kappa_g \leq c_{ijm}]. \tag{A19}$$

Equation (A17) 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

$$\mathbb{E}[c^r_{ijm}(\kappa_f, \kappa_g, \theta_g)] = \int_{-\infty}^{\frac{\kappa_g}{\psi_{jm}\lambda_j}} \psi_{jm}\lambda_j c_i f(c_i)dc_i + \int_{\frac{\kappa_g}{\psi_{jm}\lambda_j}}^{\frac{\kappa_f}{\psi_{jm}\lambda_j}} (\theta_g\psi_{jm}\lambda_j c_i + \kappa_g - \theta_g\kappa_g)f(c_i)dc_i \\ + \int_{\frac{\kappa_f}{\psi_{jm}\lambda_j}}^{\infty} \kappa_f f(c_i)dc_i. \tag{A20}$$

$$\text{Var}[c^r_{ijm}(\kappa_f, \kappa_g, \theta_g)] = \int_{-\infty}^{\frac{\kappa_g}{\psi_{jm}}\lambda_j} (\psi_{jm}\lambda_j c_i - \mathbb{E}[c^r_{ijm}(\kappa_f, \kappa_g, \theta_g)])^2 f(c_i)dc_i \\ + \int_{\frac{\kappa_g}{\psi_{jm}\lambda_j}}^{\frac{\kappa_f}{\psi_{jm}\lambda_j}} (\theta_g\psi_{jm}\lambda_j c_i + \kappa_g - \theta_g\kappa_g - \mathbb{E}[c^r_{ijm}(\kappa_f, \kappa_g, \theta_g)])^2 f(c_i)dc_i \\ + \int_{\frac{\kappa_f}{\psi_{jm}\lambda_j}}^{\infty} (\kappa_f - \mathbb{E}[c^r_{ijm}(\kappa_f, \kappa_g, \theta_g)])^2 f(c_i)dc_i. \tag{A21}$$

$f(c_i)$ 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 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 (A20) and (A21) 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 (A9), (A10); $\mathbb{E}[c^r_{ijm}(\kappa_f)]$ and $\text{Var}[c^r_{ijm}(\kappa_f)]$ are moments with only private reinsurance in equations (A15), (A16).

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:

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

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

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

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

$\mathbb{E}[C_f(\vec{p}, \kappa_f, \kappa_g, \theta_g)]$ is the expected claims costs used in the insurer's objective function (equation (11)).

Equations (A18) and (A19) 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 (A14), 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:

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

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

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

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

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

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

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

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

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

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

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

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}.

$$\mathbb{E}[x] = \exp(\mu_x + \frac{1}{2}\sigma_x^2), \text{Var}[x] = \exp(\sigma_x^2 - 1)\exp(2\mu_x + \sigma_x^2). \tag{A22}$$

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

$$\tilde{C}_f(\vec{p}) = \underbrace{\sum_m \sum_i \sum_{j \in J_{fm}} N_m w_{im} s_{ijm}(\vec{p}_m) c_{ijm}}_{C_f(\vec{p}) \text{ as in equation (A11)}} + \underbrace{\sum_m \sum_i \sum_{j \in J_{fm}} N_m w_{im} s_{ijm} x}_{N_f(\vec{p})x}, \tag{A23}$$

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

$$N_f(\vec{p}) = \sum_{m,i,j} N_m w_{im} s_{ijm}(\vec{p}); \tag{A24}$$

$\mathbb{E}[C_f(\vec{p})]$ and Var$[C_f(\vec{p})]$ are derived in equation (A12); $\mathbb{E}[x]$ and Var$[x]$ are derived in equation (A22).

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.

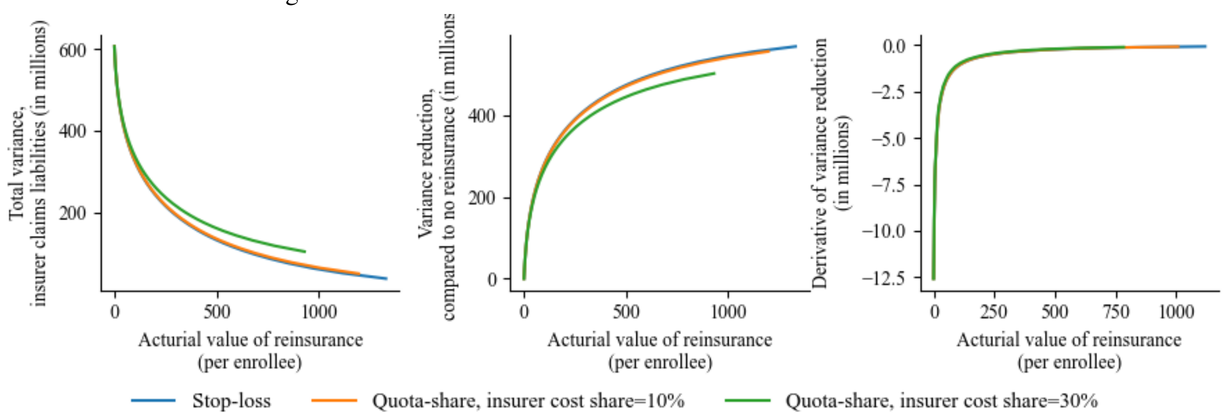
Recall that the level of private reinsurance expenses identifies risk preferences. Since we can construct different formats of reinsurance contracts of the same actuarial value, the remaining piece to examine is how different contracts affect the variance of claims. We rewrite the FOC to reflect the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

$$\underbrace{-(\tau - 1)}_{\text{markup over acturial value}} = \underbrace{\rho_f \frac{1}{N_f} \frac{\partial \text{Var}[C_f]}{\partial r_f}}_{\text{risk charge reduction}}, \tag{A25}$$

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 $\frac{\partial \text{Var}[C_{ft}]}{\partial r_{ft}(\kappa_f, \theta_f)}$ and $\frac{\partial \text{Var}[C_{ft}]}{\partial r_{ft}(\kappa'_f)}$ 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 (A25)). Figure A13 displays the results.

Figure A13. 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.

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 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, A9), 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 (A12) 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 (A24). 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 (A25).