Subsidy Design under Financial Frictions: Theory and Evidence from Health Insurance*

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Preliminary. Comments welcome!

Abstract

Insurers face financial frictions, i.e., they incur additional convex costs for taking on risk. Reinsurance subsidies reimburse insurers a portion of high-cost claims, alleviating insurers' costs of maintaining adequate capital, thus lowering extra charges for taking on risks. We derive theoretically how the efficiency of subsidy mechanisms varies with the degree of financial friction. We show evidence of insurers internalizing financial frictions. Health insurers purchase private reinsurance despite high markups. 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 estimate an equilibrium model where insurers choose premiums and private reinsurance purchases. Model estimates reveal reinsurance subsidies are more efficient than premium subsidies under current market conditions. Under a fixed government budget, reallocating 8% of the premium subsidies to reimburse insurers 60% of high-cost claims increases consumer surplus by $23.

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1. Introduction

Government subsidies are crucial across various markets, such as agriculture (Bergquist and Dinerstein, 2020), education (Neilson, 2013), energy (De Groote and Verboven, 2019; Springel, 2021), and health care (Decarolis et al., 2020; Finkelstein et al., 2019). Governments implement these subsidies in two main ways: demand-side subsidies that reduce the purchasing costs for consumers or supply-side subsidies that decrease production costs of firms. Both approaches aim to enhance access to specific goods and services by reducing consumer prices. This is particularly pertinent in the US health insurance market, where government subsidies play a significant role: federal insurance subsidies amounted to \$920 billion in 2021 (CBO, 2020). This considerable expenditure raises a natural but important question: which type of subsidy is more efficient?

Conventional wisdom proposes that subsidizing consumers is better than subsidizing firms in the presence of market power (Cabral et al., 2018; Einav et al., 2019). But these predictions may not hold in the presence of financial frictions. When firms' daily operations involve uncertainty, they will likely fall short of adequate capital, either being penalized by regulators or incurring additional costs of raising funds on capital markets. This increases their effective marginal costs, which we call financial frictions. Ex-post supply-side subsidy could lower the probability that firms fall behind capital requirements, thus reducing extra charges for taking on risks, bringing down prices, and raising welfare. Financial friction is especially prevalent in insurance markets, and there exist public reinsurance subsidies to reimburse insurers' costs of covering tail risk events. However, such market friction and regulation are usually ignored in the oligopolistic model of insurer competition.

This paper studies the welfare effects of financial frictions and their implications for subsidy design in health insurance. We make three conceptual and empirical contributions. First, we provide novel evidence that health insurers face and internalize financial frictions. Second, we theoretically derive how the efficiency of subsidy mechanisms varies with the degree of financial friction. Third, we develop a tractable empirical model where oligopoly insurers compete in price and private reinsurance purchases and face additional costs when their portfolio of enrollees is riskier. We use the model to quantify the effects of financial frictions and find that supply-side subsidies can be more efficient than demand-side subsidies. Our framework highlights the importance of regulating supply-side frictions and is generalizable to other markets with tail-end risks, such as property and casualty, flood, and wildfire insurance.

We begin with a theoretical model that incorporates adverse selection, market power, and financial frictions. Financial frictions are modeled as insurers facing additional convex costs for taking on risk, such that insurers pass extra risk charges to prices and behave as risk-averse. We show that, contrary to the conventional results, the pass-through of supply-side reinsurance subsidies can be greater than one due to the reduction of cost stemming from risk exposure. We further compare the efficiency of premium subsidies and reinsurance subsidies. In imperfectly competitive markets with only financial frictions and absent any selection, reinsurance subsidies are more efficient for the government: for a dollar spent on subsidies, reinsurance subsidies bring down prices more than premium subsidies. Yet when adverse selection is present, it is ambiguous which subsidy mechanism is more efficient. We show that in such a setting, the relative effectiveness of subsidies depends on two key model primitives: the degree of adverse selection and the indirect cost of financial frictions.

We then present two pieces of evidence that insurers internalize financial frictions. First, using transaction-level reinsurance purchase records from the National Association of Insurance Commissioners (NAIC), we document that 68% health insurers purchase private reinsurance policies despite having to pay high markups of 2.05 on average. Moreover, smaller, more financially constrained, and non-profit insurers are more likely to purchase private reinsurance policies, which are consistent with financial frictions driving such behaviors.

Second, we conduct an event study exploiting the initiation of state-level reinsurance programs on the individual health insurance market (hereafter, the exchange). These programs provide ex-post cost-sharing reimbursement to the insurer if an enrollee's cost exceeds some threshold. We find that reinsurance subsidies significantly decrease the health insurance premiums of exchange insurers. The estimated pass-through is 1.3 – when the government reinsures at the actuarially fair price, it is able to reduce expenditure in premiums by more than its own expenditure in reinsurance payments. Premium reductions are larger for insurers that are more financially constrained. Furthermore, insurers substitute away from purchasing private reinsurance in response to the public reinsurance subsidies. These results suggest financial frictions affect insurer pricing and private reinsurance purchase decisions.

Motivated by these stylized facts, we next develop and estimate an equilibrium model to explore optimal subsidy design under financial frictions. Consumers' demand for insurance follows a standard discrete choice model. Their key primitives are the differential price elasticities by health risks, which capture the degree of adverse selection. Insurers simultaneously choose health insurance premiums and the amount of private reinsurance to purchase. The novelty is that insurers face additional risk charges when their portfolio of enrollees is riskier, which they can mitigate by pricing to attract a pool of clients with lower variance or by purchasing reinsurance. Insurers' key primitives include the conventional marginal costs of providing insurance and their risk preferences, i.e., how the variance of their portfolio lowers total profits, which captures the degree of financial frictions.

We estimate the model in the Colorado (CO) exchange, employing their administrative records on enrollment and medical claims, as well as reinsurance purchase records from NAIC. We first calibrate reinsurance markup from transaction-level reinsurance records. We then estimate the price elasticities by health risks following the two-step estimator of Goolsbee and Petrin (2004). Finally, we estimate insurers' marginal costs and risk preferences using first-order conditions on pricing and private reinsurance purchases.

Model estimates shed light on the two key market features that are key to designing subsidy schemes. First, there exists a considerable magnitude of adverse selection on the market. Young consumers are twice more price sensitive than old consumers, while they incur a third of claims costs to that of old consumers. Second, insurers internalize financial frictions. Their average risk charge is 3.38% of health insurance premiums. Notably, small, more financially constrained regional health insurers have a higher risk charge than national insurers. Regional and national insurers' risk charges are 4.06% and 1.69% of their health insurance premiums, separately.

We use the model estimates to decompose the effects of public reinsurance subsidies that CO implemented in 2020. The reinsurance program spends an average of \$446 per consumer to share high-cost claims with insurers and lowers premiums by \$580, a 9% decrease from the baseline. This simulated pass-through is 1.3, consistent with reduced form estimates. The main driver of this result is the convexity in costs stemming from risk exposure: among the 9% premium decreases, 7% can be attributed to reductions in medical claims costs; the remaining 2% are from declines in the overall riskiness of insurers' portfolios, which lower risk charges and private reinsurance expenses. This analysis illustrates the effectiveness of alleviating financial frictions on the supply side. As a result, consumer surplus rises by $57 per member-year.

We finally compare the effectiveness of reinsurance subsidies and premium subsidies and explore optimal subsidy designs. We find that reinsurance subsidies are more efficient under the current market conditions than premium subsidies. Under a fixed government budget, reallocating 8% premium subsidies to reimburse insurers 60% high-cost claims increases consumer surplus by $23. These results demonstrate that, besides the well-known demand-side adverse selection problem, addressing supply-side frictions can effectively improve the functioning of insurance markets.

Our analysis sheds light on policy designs beyond subsidies. A key premise of the managed competition paradigm is that private insurers compete on prices to create value. However, small regional insurers, who are more financially constrained, need to raise their prices in the presence of financial frictions, which could impede the efficiency of such managed competition. Our analysis illustrates that reinsurance subsidies could effectively combat the upward pricing pressure, especially for small competitors, thus restoring competitiveness and improving welfare.

The implications of financial frictions extend beyond health insurance. Government risk-sharing could be important in markets facing systematic financial risks, such as floods, wildfires, or property and casualty insurance in general. The threat of tail risk events and associated inadequate capital reserves could force insurers out of the market or inflate premiums substantially. By similar logic, subsidizing the supply side in those markets may also be more effective in terms of lowering premiums and increasing insurance takeup than subsidizing consumer purchases. The new framework developed in this paper is generalizable for evaluating the welfare impacts of such market failures and policy solutions.

Our paper contributes to several strands of literature. First, our paper adds to studies on the financial and regulatory frictions of insurers. Recent work in life insurance (Koijen and Yogo, 2015, 2016) shows 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, whose framework we build upon. Our contribution is to document financial frictions for health insurers leveraging novel reinsurance purchase data and analyze the implications of financial frictions for subsidy designs.

Second, our paper relates to the literature on policy designs in the healthcare market. Existing papers study each policy instrument separately, such as premium subsidies (Decarolis et al., 2020; Finkelstein et al., 2019; Polyakova and Ryan, 2019; Tebaldi, 2017), risk adjustment (Brown et al., 2014; Glazer and McGuire, 2000; Geruso and Layton, 2020; Layton et al., 2018; Layton, 2017; Wynand et al., 2000), reinsurance (Polyakova et al., 2021; Drake et al., 2019; McGuire et al., 2020). All these studies treat demand-side and supply-side subsidies in isolation, and none of these papers engages in the relationship and tradeoff between them. The closest paper is Einav et al. (2019), which compares premium subsidies and ex-ante risk adjustment payments to insurers. Our paper compares premium subsidies to ex-post reinsurance payments to insurers. We provide the first theoretical and empirical analysis of the efficiency of multiple policy instruments, incorporating the underexplored financial frictions.

More broadly, our paper relates to the empirical market design literature on the choice of optimal regulation instrument. Prior work examines allocating consumer and production subsidies in electric vehicle (Springel, 2021) and solar panel industries (De Groote and Verboven, 2019), distributing consumer vouchers and entry subsidies for schools (Allende, 2019; Bodéré, 2023), or granting production, investment, and entry subsidies in shipbuilding industries (Barwick et al., 2021). Our analysis is complementary to the literature as we examine regulation designs in the new healthcare setting.

2. Empirical Setting

2.1. Institutional Background

2.1.1. Capital Adequacy Requirements Insurance regulators, like the National Association of Insurance Commissioners (NAIC), evaluate insurers' financial strength using risk-based capital and statutory capital. The risk-based capital is the required capital for insurers to cover their liabilities and is usually set as some exogenous multipler 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 company-level warning to full control of the company (NAIC, 2023b). Similarly, there exist regulations 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, namely, 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 capital regulations imply insurers must hold or raise a certain level of capital for the medical claims expenses they are assuming. When insurers fall short of the minimum capital requirement, they are either penalized by regulators or incur additional costs of raising funds on capital markets, which we call financial frictions.

2.1.2. 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 large 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).

Each individual state oversees private reinsurance through the use of credit for reinsurance laws and regulations. Reinsurers must be either licensed, accredited or trusteed 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 large catastrophic event. However, more reinsurer have started offering reinsurance in the health insurance markets, especially for smaller insurers or, in some cases, health care providers.

The market for private reinsurance contracts sold to health insurers is fairly 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).

2.1.3. Public Reinsurance. Public reinsurance is commonly observed in insurance markets with tail risk events. For example, Medicare drug coverage established its reinsurance program in 2010, the individual health insurance marketplace in 2014, and the national flood insurance program in 2012. Public reinsurance works as secondary insurance for primary insurers: they reimburse insurers' costs to cover tail risk events, with the hope 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.

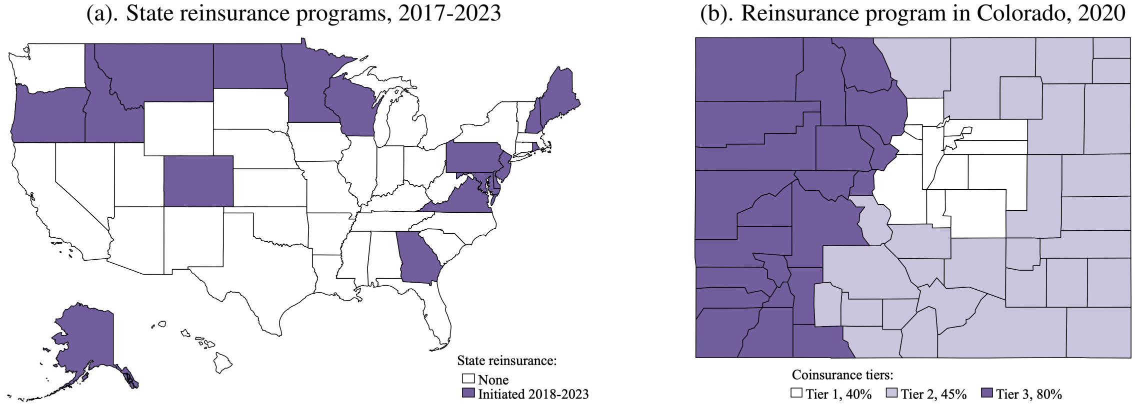
A federal reinsurance program was implemented in the exchange in 2014-2016. Since its discontinuation, 17 states initiated their own reinsurance programs as of 2023. Figure 1a depicts the distribution of these state-run programs. These programs are structured similarly: when the insurer enrolls a costly enrollee, the government shares a percentage of claims costs between a certain attachment point and a cap. Table A1 reported detailed cost-sharing parameters of each state's reinsurance program separately.

We examine state-run reinsurance programs in the exchange nationwide for motivating facts in Section 4, and in Colorado for structural exercises in Sections 5-7. Colorado initiated its reinsurance program in 2020. The program reimburses insurers for claims costs between the attachment point \$30,000 and the cap \$400,000 per consumer. As shown in Figure 1b, counties in CO are divided into three tiers, with varying government coinsurance rates between 40% and 80%. Table A2 reports the program details in CO.

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

Figure 1. 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).

2.2. Data and Summary Statistics.

2.2.1. 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.[1] We collect Schedule S reports for all insurers in the life and health line of business in 2014-2022. The data is at a unique reinsurance contract level and has information on seller identity, buyer identity, contract effective data, reinsurance premiums, and realized reinsurance claims.

We obtain information on health insurance products from the Public Use Files of 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 who sell on the individual market during our sample period.

We further extract insurers' financial solvency and capital adequacy measures using financial statements from NAIC for all insurers in the life and health line of businesses. The insurer-year-level statement includes information on insurers' statutory capital level and the authorized control level of capital.

Table 1. Sample statistics, insurers in the individual exchange market

	(1) All	(2) Has Private Reins.	(3) No Private Reins.	(4) CO Insurers
(a). Health insurance status				
Mean health insurance premium	5099	5084	5124	4582
Mean health insurance claim	4429	4417	4438	4037
Mean health insurance margin	0.117	0.111	0.128	0.098
Number of members (millions)	0.531	0.423	0.764	1.129
(b). Private reinsurance status				
Mean reinsurance premium	45	79	-	102
Mean reinsurance claim	17	28	-	34
Mean reinsurance margin	-	0.501	-	0.655
Share has private reinsurance	0.647	1	-	0.661
Reins. premium over health ins. premium (unconditional)	0.013	0.022	-	0.015
Reins. premium over health ins. premium (conditional)	-	0.022	-	0.027
(c). Insurer Characteristics				
Risk based capital (RBC) ratio	5.888	5.563	6.525	4.536
Share multi-state	0.101	0.095	0.113	0.29
Share non-profit	0.452	0.449	0.457	0.339
Share Ind. mkt. premium over all mkt. premium	0.351	0.388	0.283	0.417

Notes: This table reports the health insurance and private reinsurance status of health insurers in MLR data in 2014-2022. Column (1) reports the averages nationwide; Columns (2) and (3) report averages by whether the insurer purchases private health insurance; Column (4) restricts insurers to those operating in the CO individual exchange market. We restrict to private reinsurance contracts that are sold by a different NAIC group. The insurance product margin is calculated by one minus the ratio of claims costs over premiums and is thus conditional on purchasing. We define national insurers as those operating in more than 2 states. Mean values were calculated using a winsorized mean, capping the top and bottom 1% of values.

Table 1 reports summary statistics for health insurers in 2014-2022. Column (1) shows national averages, while columns (2)-(3) display statistics by whether the health insurer purchases private reinsurance. Column (4) focuses on insurers operating in Colorado. Panel (a) reports statistics on health insurance products. On

[1] Data Source: National Association of Insurance Commissioners, by permission. The NAIC does not endorse any analysis or conclusions based upon the use of its data.

average, insurers in our sample serve 0.53 million consumers at an operating claims margin of 0.117. They sell health insurance products at $5099 per enrollee annually and incur claims costs of $4429.

Table 1 panel (b) shows statistics on private reinsurance purchases. 64.7% of insurers purchase private reinsurance despite a high reinsurance margin of 0.501. Markups of private reinsurance are much higher than those of health insurance. This can be in part explained by the high concentration level of the private reinsurance market, as described in Section 2.1.2.

The widespread use of private reinsurance at high markups suggests that insurers face financial frictions and need to hedge against those with tools like reinsurance. The expenses on private reinsurance purchase account for about 1.3% or 2.2% of health insurance premium income, when we do or do not conditional on purchasing, separately. Transforming reinsurance to a per-enrollee basis, the mean expenses on reinsurance premium per enrollee is $79, while the mean reinsurance claims incurred is $45.

Panel (c) further compares the characteristics of insurers by their private reinsurance status. Comparing the statistics in columns (2) and (3) shows that insurers with private reinsurance tend to be smaller, and regional insurers that may have more limited capital market access. 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.

2.2.2. Consumer-Level. We obtain the universe of consumers in the Colorado exchange in 2015-2021 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 supplement the enrollment records with uninsured counts from the Small Area Health Insurance Estimates (SAHIE) in 2015-2022. These model-based estimates from the Census Bureau provide information on the uninsured rates and counts by county-age-gender-income bins. We restrict the SAHIE sample to CO consumers who satisfy the Exchanges' eligibility criteria based on age and income.

We further 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 like age, gender, zip code. 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 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 to individuals whose insurance coverage is the exchange, or uninsured but eligible for the exchange.

Table 2 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 shocks of the pandemic.

Table 2. 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.

The CO exchange has about two hundred thousand enrollees annually. Both national and regional insurers operate on CO exchange. Table A3 reports each insurer's market share: 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%, or $3,619, is paid by insurers. As shown by the standard deviation and 99th percentile of total medical expenses, the claims costs distribution has a long right tail. As shown in Figure A1, top 5% (1%) of consumers account for 68% (38%) of total medical expenses. About 2.5% of consumers have their claims costs exceeding $30,000, the reinsurance threshold where the CO government starts to reimburse insurers. If the current reinsurance program had been in place throughout, 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.

3. Theoretical Model

In this section, we present a theoretical model that incorporates adverse selection, market power, and financial frictions to analyze subsidy design.

Suppose there is a risk averse monopoly insurer that sells a single insurance plan. 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 $\tilde{c}_i^t \sim F_t$. We assume $\tilde{c}_i$ is independently distributed regardless of the individual's type. Let $c_t = E[\tilde{c}_i^t]$, and $\sigma_t^2 = \text{Var}(\tilde{c}_i^t)$. We allow for the possibility of (adverse) selection in the market by allowing F_t to be different across the two individual types.

The monopoly insurer faces the following objective function to maximize its expected profit subject to risk charges.

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

Here, we model the insurer's risk aversion behavior by the insurer incurring a risk charge from the uncertainty in its total cost. As shown in equation (1), the risk charge is the product of ρ, the coefficient of risk charge, and the variance of the total cost. ρ could be considered the risk aversion parameter where the insurer faces a CARA utility function. Given the above objective, the insurer's first order condition is

$$\underbrace{p + \frac{Q(p)}{\frac{\partial Q(p)}{\partial p}}}_{MR} = \underbrace{\Big(\lambda(p)c_\ell + (1-\lambda(p))c_h\Big)}_{MC} + \underbrace{\rho\Big(\lambda(p)\sigma_\ell^2 + (1-\lambda(p))\sigma_h^2\Big)}_{\text{marginal risk charge}}, \tag{2}$$

$$\text{where} \qquad \lambda(p) = \frac{\frac{\partial q_\ell(p)}{\partial p}}{\frac{\partial Q(p)}{\partial p}}.$$

The insurer faces 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., higher ρ or variance of cost) will charge higher prices. Let p_0^* denote the optimal price the insurer sets from equation (1).

3.1. Reinsurance Subsidies and Pass-through

We examine how reinsurance subsidies affect the insurer's pricing behavior and its associated pass-through to the consumers. Suppose the government offers stop-loss reinsurance that fully reimburses the insurer for any costs beyond the deductible θ. If an individual's ex-post cost $\tilde{c}_i > \theta$, the government fully reimburses the insurer for any cost that exceeds θ. Given such a reinsurance scheme, the insurer's ex-post cost for an individual i will be

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

Let $c_t(\theta)$ and $\sigma_t^2(\theta)$ denote the insurer's expected cost and the variance of type t individual for a reinsurance policy of θ, respectively. With reinsurance, the insurer's FOC will now be

$$p + \frac{Q(p)}{\frac{\partial Q(p)}{\partial p}} = \underbrace{\big(\lambda(p)c_\ell(\theta) + (1-\lambda(p))c_h(\theta)\big)}_{MC} + \underbrace{\rho\left(\lambda(p)\sigma_\ell^2(\theta) + (1-\lambda(p))\sigma_h^2(\theta)\right)}_{\text{marginal risk charge}}. \tag{3}$$

Equation (3) reveals reinsurance subsidies decrease the effective marginal cost in two ways. First, reinsurance decreases each individual's expected cost. Second, because reinsurance acts as insurance for the insurer, it decreases the variance of the insurer's total cost, lowering the marginal risk charge of the insurer. Given that reinsurance will unilaterally decrease the right-hand side of the insurer's effective marginal cost, it will decrease its optimal price. Let $p^*(\theta)$ denote the insurer's optimal price for reinsurance level θ, $p^*(\theta) < p_0^*$.

We further examine the pass-through rate for a given amount of reinsurance subsidy. For a risk neutral government, the cost of reinsurance subsidies is the expected amount the government is expected to reimburse the insurer. For individual of type t, this is given by $r_t(\theta) = c_t(0) - c_t(\theta)$. Then, the total expected reinsurance expenditure, as well as the average expected reinsurance cost per consumer, are

$$\begin{aligned} R(\theta) &= r_\ell(\theta)q_\ell(p) + r_h(\theta)q_h(p), \\ r(\theta) &= \underbrace{\alpha(p)r_\ell(\theta) + \big(1-\alpha(p)\big)\, r_h(\theta)}_{\text{average reinsurance cost}}, \quad \text{where} \quad \alpha(p) = \frac{q_\ell(p)}{Q(p)}. \end{aligned} \tag{4}$$

For the government, the average reinsurance cost per consumer is $r(\theta)$ in equation (4). The reinsurance pass-through rate is $(p_0 - p^*(\theta))/r(\theta)$.

Proposition 1 *If insurer is risk averse i.e. $\rho > 0$, then the reinsurance pass-through rate, $(p_0 - p^*(\theta))/r(\theta)$ can be greater than* 1.

Proposition 1 states that if the insurer is risk averse, the pass-through rate of reinsurance subsidy could be larger than 1. In a standard monopoly setting, the pass-through of cost subsidy is often smaller than one due to market power. However, when the monopoly insurer is risk averse, reinsurance not only affects its expected cost but reduces the risk that the insurer faces. This indirect effect of reinsurance for a risk averse insurer is why the pass-through rate could be greater than one. See Appendix B for proofs.

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

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

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

$$\begin{aligned} s(\theta) &= p_s^* - p_r^*(\theta) \\ &= \underbrace{\lambda(p)r_\ell(\theta) + \big(1-\lambda(p)\big)\, r_h(\theta)}_{\text{marginal reinsurance cost}} + \underbrace{\rho\left(\lambda(p)\Delta\sigma_\ell^2(\theta) + \big(1-\lambda(p)\big)\,\Delta\sigma_h^2(\theta)\right)}_{\text{marginal change in risk charge}}. \end{aligned} \tag{5}$$

where $\Delta\sigma_t^2(\theta)$ denotes the change in variance of cost for reinsurance level θ. Given the above expression for $s(\theta)$, we want to determine the relative magnitude of $r(\theta)$ vs. $s(\theta)$, 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 2 *Let adverse selection in the market be defined as $F_\ell(t) \leq F_h(t)\ \forall\, t, c_\ell < c_h,\ \sigma_\ell^2 < \sigma_h^2$. Then the relative magnitude of $r(\theta)$ and $s(\theta)$ 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 $s(\theta) = r(\theta),\ \forall\ \theta$.*

2. *With financial frictions, no selection: If the insurer is risk averse, i.e., $\rho > 0$, and there is no selection, then $s(\theta) > r(\theta),\ \forall\ \theta$.*

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 $s(\theta) < r(\theta),\ \forall\ \theta$.*

4. *With financial frictions, with adverse selection: If the insurer is risk averse, and there is adverse selection, then the relative magnitude of $s(\theta)$ and $r(\theta)$ is ambiguous.*

Proposition 2 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 B for proofs.

4. Effect of Public Reinsurance Subsidies

4.1. Evidence of Financial Frictions.

We leverage the initiation of state-level reinsurance programs to demonstrate the existence of financial frictions faced by insurers. These state-level reinsurance programs function as free reinsurance contracts with zero premiums, reducing both the expected cost and variance of cost. This, in turn, lowers the risk charges that insurers may internalize due to financial frictions. We examine the effect of public reinsurance subsidies on insurers' pricing strategies and private reinsurance purchasing behaviors using an event study framework.

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

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

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 2014-2022.[2] Standard errors are clustered at the state level. The coefficient of interest are β_n. The identifying variations of the initiation of reinsurance programs are depicted in Figure 1a.

To explore the variation in the intensity of Colorado's reinsurance program, as shown in Figure 1b, we examine its heterogeneous impacts on premiums across the state's three reinsurance tier regions. Using an event-study framework similar to that in (6), with Colorado as the sole treatment state, we estimate the following regression, allowing coefficients to vary by tier region:

$$y_{fmt} = \sum_{n \in \{-6(+), -5,..,0,1,..,4,5+\}} \sum_{r=1}^{3} \beta_{n,r} 1[t^*_{s(m)} + n = t] D^r_{mt} + \gamma_t + \gamma_{fm} + \varepsilon_{fmt}, \tag{7}$$

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

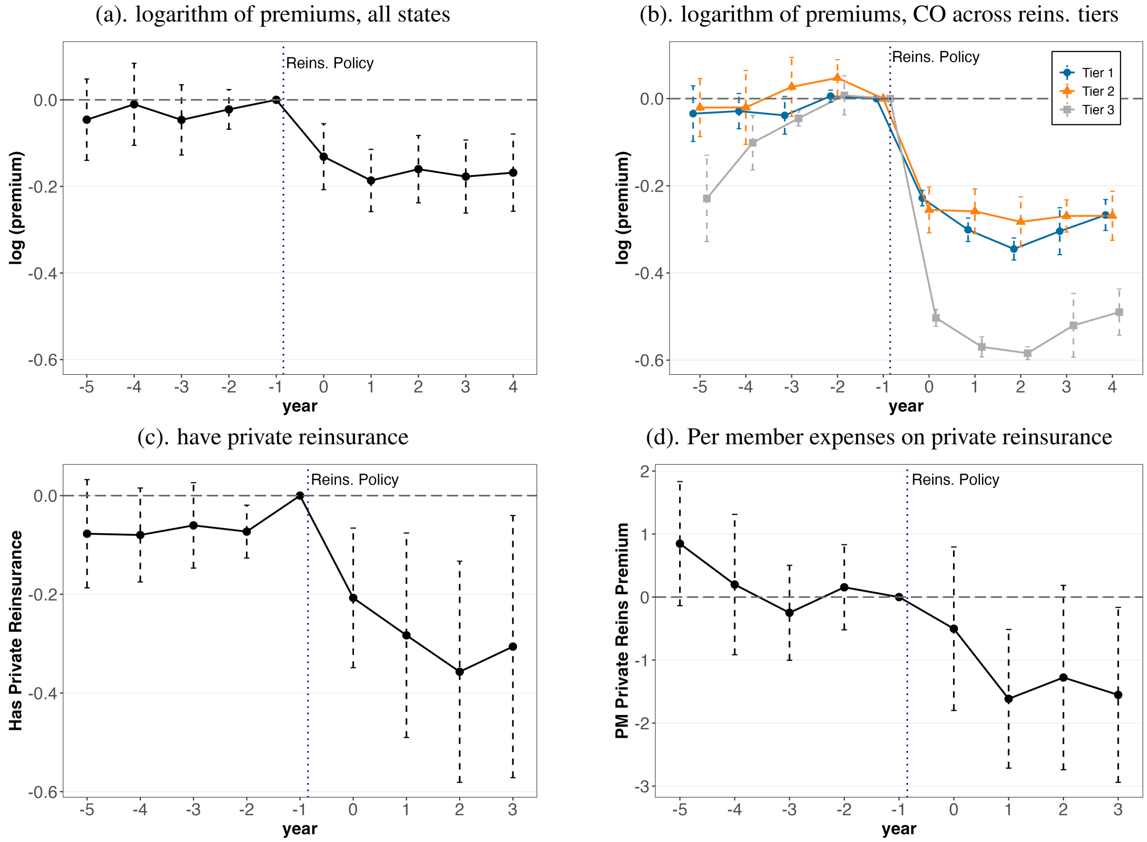
4.1.1. Reduced Health Insurance Premium, with Greater Than One Pass-Through. We begin by analyzing how public reinsurance affects insurers' pricing strategies. Figure 2a shows a large and statistically significant impact of public reinsurance on premiums. The lack of pre-trends suggests that these premium decreases are unlikely due to any heterogeneous changes occurring in states with public reinsurance. Pooling post-period coefficients from equation (6), we find that the initiation of public reinsurance programs lower premiums by around 13.7%, as is reported in Table 3 column (1).

Figure 2b presents the results of Colorado's reinsurance program, showing heterogeneous impacts across the state's reinsurance tiers. The program significantly reduced premiums, with around 27% decrease in Tiers 1 and 2, and a 46% decrease in Tier 3, which received a particularly high level of reinsurance. These

[2] The CMS HIOS issuer, i.e., firm units in premium records, and the NAIC companies, i.e., firm units in reinsurance purchasing records does not match one-to-one. We restrict the main specification to insurers which has those two records that match exactly, which covers 67% of all exchange HIOS issuers.

We rerun the analysis grouping HIOS issuers into NAIC companies as robustness in Section 4.1.4.

Figure 2. The effect of public reinsurance subsidies on premium and private reinsurance



Notes: This figure reports point estimates and 95% confidence interval of the effect of state reinsurance from the estimation of equation (6). The outcome variable is the logarithm of average premiums for age 50 in panels (a)-(b), whether the insurer has private reinsurance in panel (c), expenses on private reinsurance contracts over number of health insurance enrollees in panel (d). The regression sample includes all insurers nationwide that have positive health premium income and offer products on the individual exchange market. Panel (a), (c), (d) plot 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 that do not have reinsurance programs. The regeression is at the insurer-rating region-year level in 2014-2024 for panels (a)-(b), and insurer-state-year level in 2014-2022 for panels (c)-(d). The regression includes insurer-rating region (or insurer-state), and year fixed effects.Standard errors are clustered at the state level for all panels, except panel (b), which is clustered at the rating region level. For panels (a)-(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 are unclear in 2017-2020.

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).[3]

Using ex-post government expenditures and our event-study estimates, we calculate a back-of-the-envelope pass-through rate of 1.46: for every \$1 the Colorado government spends on reinsurance, health insurance premiums drop by \$1.46.This is in contrast to 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.

[3]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.

4.1.2. Reduced Private Reinsurance Purchases. Next, we investigate how public reinsurance programs affect insurers' private reinsurance purchases. We consider two primary outcomes: at the extensive margin, whether the insurer purchases private reinsurance, and at the intensive margin, the expenses on private reinsurance over the total number of health insurance enrollees. The intensive margin measures the amount of private reinsurance an insurer needs to insurer each enrollee.

Figures 2c and 2d 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 (6), Table 3 indicates that public reinsurance programs reduce the probability of purchasing private reinsurance by 21%, a 33% decrease from the baseline, and lower average per-member expenses on private reinsurance by \$1.23, a 41% decrease from the baseline.

4.1.3. 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 (6) with a proxy of insurer financial characteristic, x_{fmt_0}:

$$y_{fmt} = \beta_1 D_{mt} + \beta_2 x_{fmt_0} D_{mt} + \gamma_t + \gamma_{fm} + \varepsilon_{fmt}, \tag{8}$$

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,[4] 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 3. 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	-0.137^{***}	-0.135^{***}	-0.134^{***}	-0.215^{**}	-0.350^{***}	-1.228^{**}	-0.942
	(0.038)	(0.037)	(0.04)	(0.089)	(0.129)	(0.498)	(0.588)
reinsurance policy × RBC ratio below 3		-0.161^{***}			-0.207		-5.635^{*}
		(0.050)			(0.267)		(3.260)
reinsurance policy × significant private reins.			-0.207^{***}				
			(0.041)				
N	17,307	16,112	16,253	1,426	1,373	1,411	1,358
Baseline mean	634	634	634	0.646	0.646	3	3
Share of insurers w. RBC below 3		0.102			0.144		0.142
Share of insurers w. significant private reins.			0.117				

Notes: This table reports the point estimates and standard errors (in parenthesis) on the effect of reinsurance programs from the estimation of equation (8). 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 insurer-rating region-year level in 2014-2024 for Columns (1)-(3), and insurer-state-year level in 2014-2022 for Columns (4)-(7). 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.

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

Table 3 presents the results. The premium-reduction effects of government reinsurance are more pronounced for insurers that are financially constrained and those with relatively high private reinsurance expenses. Additionally, government reinsurance subsidies lead to a greater reduction in private reinsurance purchases among financially constrained insurers. These findings suggest that insurers internalize financial frictions.

4.1.4. 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).

4.2. Additional Analysis.

4.2.1. 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 (6), we assess the impact of government reinsurance on the number of insurers in a market, utilizing data at the rating region-year level. Figure A2a shows no statistically significant impact on entry in markets with public reinsurance. Given these findings, we hold market structure fixed and do not directly model insurer entry/exit decisions in the main empirical model in Section 5.

4.2.2. Effects on Private Reinsurance Markup. We investigate whether the provision of public reinsurance affects the upstream private reinsurance market. On one hand, Section 4.1.2 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, the reinsurance market is not segmented by primary health insurance business lines, and the individual exchange market, being a small share of the overall market, may not significantly impact the private reinsurance market. Since public reinsurance subsidies only affect the individual market segment, which may not be large enough to influence private reinsurers' markups, the effect may be limited.

Using the same strategy as in equation (6), 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 A2b 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 for health insurers.

In light of this empirical finding, we treat the private reinsurance market as exogenous and do not directly model the upstream market in the equilibrium model in Section 5. We do, however, perform sensitivity analyses in Section 7 to assess how varying degrees of private market responses to public reinsurance subsidies might affect welfare predictions.

4.2.3. 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. If insurers respond to the government's risk-sharing policies with fewer cost-containment activities, for example, performing less prior authorization or bargaining not as hard with medical providers, we would expect incurred medical claims to increase.

Employing detailed claims records from CO APCD, we use two empirical designs[5] 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 CO exchange, public reinsurance's cost-shares differ across counties. The identifying variations of differential cost-shares of public reinsurance are depicted in Figure 1b. The second design exploits variations across time and market segments: the public reinsurance subsidies apply to the exchange market, but not commercial markets.

Let t denote year, c denote county, m denote market segment, i denote individual. We estimate the following event-study design,

$$y_{it} = \sum_{n \in \{-4(+),-3,..,0,1,..,2,3+\}} \beta_n 1[t^* + n = t] D_{cmt} + \gamma_i + \gamma_t + \gamma X_{it} + \varepsilon_{it}, \tag{9}$$

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; γ_i, γ_t are individual, year fixed effects. 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.

Figure A3 finds a null effect of public reinsurance on monthly medical expenses per enrollee, or the probability that the enrollees' annual expenses exceeds the reimbursement threshold of the public reinsurance program. Table A6 reports analogous differences-in-differences estimates. 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.

Given this finding, we leave out insurers' cost containment efforts from the equilibrium model in Section 5,[6] and perform sensitivity analyses on how differential degrees of insurer moral hazard might affect welfare predictions in Section 7.

Nevertheless, our aggregate expense measure may mask separate responses in quantity and prices. We decompose different mecahinism of insurer moral hazard, such as gatekeeping utilization (quantity) or bargaining with providers (price), and examine whether these insurers' responses have any downstream effects on enrollee health in Kim and Li (2024).

4.2.4. 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 the existence of adverse selection in our sample. Adverse selection is a well-documented

[5]The across-state variations in initiating public reinsurance (used in Section 4.1) is no longer applicable for examining insurer moral hazard, as we only have detailed claims cost data from CO, but not other states

[6]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.

phenomenon in the individual health insurance market (Einav and Finkelstein, 2011; Saltzman, 2021).[7]

Table A5 shows that premium reductions are much larger 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. We would thus expect a larger change in premiums for higher actuarial value products as reinsurance decreases insurers' expected to cost much more for sicker enrollees.

4.3. Summary and the Need for a Model.

So far, we have provided several suggestive evidence that insurers internalize financial frictions. First, we show that health insurers purchase private reinsurance despite high markups in Section 2.2. 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.

Despite proving the existence of financial frictions, the reduced form analysis leaves open several questions. 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 empirically quantify the degree of financial frictions, adverse selection and market power with a structural model.

5. Empirical Model of Premiums and Reinsurance Purchase

The previous section confirms the existence of financial frictions and shows insurers respond in prices and private reinsurance purchases to public reinsurance subsidies. We now develop an empirical model of insurance demand, insurer pricing, and reinsurance purchasing. The goal is to quantify the magnitude of financial frictions and shed light on optimal policy design.

5.0.1. Players and Timing. Let f denote insurers, m denote counties, t denote years, $j \in J_f$ denote products of f. We divide consumers into four risk types i by age: below 18, 18-34, 34-54, and above 55. We assume consumers in the same risk type have the same preference for insurance products, and have their health risks drawn from the same distribution.

Every period, insurers first simultaneously choose premiums for products at the county level and the amount of private reinsurance coverage at the state level. Consumers then choose products after observing all product characteristics and premiums. We are interested in the Nash Equilibrium of the game.

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

5.0.2. Consumer Choices. We group plans into metal levels so that every insurer only offers three products with distinct coverage levels: Gold (80% coinsurance), Silver (70%), and 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 age rating curve. $subsidy_{\theta jmt}$ APTC 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

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

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

where X_{jmt} is other product characteristics, for example, 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, $u_{i0mt} = \epsilon_{i0mt}$.

Let s_{ijmt} denote the market share of product j among consumers of type i in market mt, $\vec{p}_{mt}$ denote the price vector charged by all insurers in market mt, $\vec{p}_t$ denote the union of price vectors across markets in year t, N_m denote the market size of county m, w_{im} denote the share of type i consumers in county m. The expected premium income of an insurer f in a year t across all markets m is a constant,

$$\Pi_{ft}(\vec{p}_t) = \sum_{m,i,j \in J_{fm}} N_m w_{im} s_{ijmt}(\vec{p}_{mt}) \iota_\theta p_{jmt}.$$

5.0.3. Insurers' Costs Without Reinsurance. Insurers' costs is a sum of claims costs paid by insurers C_{ft}, and financial costs L_{ft}. We derive these two components below one by one.

We assume health risks of risk type i, c_i, are independent and identically distributed according to a log-normal distribution with finite expected value μ_i and variance σ_i^2. We transform the health risks distribution to the claims costs distribution with an insurer-specific multiplier ψ_{fm}. ψ_{fm} captures the medical expense differences of the same individual across different health plans due to insurers' differential bargaining power. We assume the multipliers ψ_{fm} are the same within a given county across time and across all risk types. 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, who is enrolled with the plan j, is $c_{ijmt} = \psi_{fmt}\lambda_j c_i$. Following the distributional assumptions of health risks, the claims cost paid by insurers c_{ijmt} is also log-normally distributed $c_{ijmt} \sim N(\mu_i + \log(\psi_{fmt}\lambda_j), \sigma_i^2)$. We can thus derive the expectation and variance of c_{ijmt},

$$\mathbb{E}[c_{ijmt}] = \psi_{fmt}\lambda_j \exp(\mu_i + \frac{1}{2}\sigma_i^2), \quad \text{Var}[c_{ijmt}] = \sigma_i^2.$$

Summing up costs of consumers from different risk types and markets, the total claims costs of insurer f in market mt is

$$C_{ft}(\vec{p}_t) = \sum_m \sum_i \sum_{j \in J_{fm}} N_m w_{im} s_{ijmt}(\vec{p}_{mt}) c_{ijm}.$$

We apply the Lyapunov Central Limit Theorem to derive the asymptotic distribution of C_{ft},

$$C_{ft}(\vec{p}_t) \xrightarrow{d} N\bigg(\mathbb{E}[C_{ft}(\vec{p}_t)], \text{Var}[C_{ft}(\vec{p}_t)]\bigg), \quad \text{where}$$

$$\mathbb{E}[C_{ft}(\vec{p}_t)] = \sum_{m,i,j} N_m w_{im} s_{ijmt}(\vec{p}_t)\mathbb{E}[c_{ijmt}],$$

$$\text{Var}[C_{ft}(\vec{p}_t)] = \sum_{m,i,j} N_m w_{im} s_{ijmt}(\vec{p}_t)\text{Var}[c_{ijmt}].$$

Turning to the financial costs L_{ft}, we parameterize it as a loss function

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

where ρ_f is an insurer-specific risk-aversion parameter that is constant over time.

To summarize, the insurer f's total costs in a year t are the sum of claims costs $C(\vec{p}_t)$, a random variable, and financial costs $L_{ft}(\vec{p}_t)$, a constant.

5.0.4. Insurers' Costs with Private Reinsurance. Regardless of public reinsurance subsidies, insurers always have the option to purchase private reinsurance to alleviate their financial constraints. The private reinsurance contract is at the state-year level, covering all geographic markets, i.e., counties, within the state. Insurers' costs with private reinsurance, is a sum of claims costs paid by insurers C_{ft}, reinsurance costs R_{ft}, and financial costs L_{ft}. We derive these three components below one by one.

We first discuss claims costs paid by insurers C_{ft} with reinsurance. We model private reinsurance as a stop-loss contract, the most prevalent contract type observed in reality. The contract has deductible κ_{ft}, which is uniform across all counties and consumer risk types. The insurer will pay the full amount of its scheduled claims costs c_{ijmt} when c_{ijmt} is below the deductible threshold κ_{ft}. In contrast, when c_{ijmt} is above the deductible threshold κ_{ft}, the insurer will only pay κ_{ft} and the re-insurer pays for the reminder, $c_{ijmt} - \kappa_{ft}$. Let c^r_{ijmt} denote the claim costs paid by the insurer f with reinsurance coverage level κ_{ft}, for a consumer in risk type i enrolled with the plan j, is a random variable,

$$c^r_{ijmt}(\kappa_{ft}) = c_{ijmt}\mathbf{1}[c_{ijmt} < \kappa_{ft}] + \kappa_{ft}\mathbf{1}[c_{ijmt} \geq \kappa_{ft}].$$

Applying the distributional assumptions of c_{ijm}, we can derive that

$$\mathbb{E}[c^r_{ijmt}(\kappa_{ft})] < \mathbb{E}[c_{ijmt}], \quad \text{Var}[c^r_{ijmt}(\kappa_{ft})] < \text{Var}[c_{ijmt}].$$

Private reinsurance reduces both the expectation and variance of the per-member claims costs paid by insurers. Detailed expressions of $\mathbb{E}[c^r_{ijmt}(\kappa_{ft})]$, $\text{Var}[c^r_{ijmt}(\kappa_{ft})]$ are in Appendix C1.

We apply the same trick of the Lyapunov Central Limit Theorem to derive the asymptotic distribution of insurers' total claims costs C_{ft},

$$C_{ft}(\vec{p}_t, \kappa_{ft}) = \sum_{m,i,j} N_m w_{im} s_{ijmt}(\vec{p}_{mt}) c^r_{ijmt}(\kappa_{ft}) \xrightarrow{d} N\bigg(\mathbb{E}[C_{ft}(\vec{p}_t, \kappa_{ft})], \text{Var}[C_{ft}(\vec{p}_t, \kappa_{ft})]\bigg),$$

$$\mathbb{E}[C_{ft}(\vec{p}_t, \kappa_{ft})] = \sum_{m,i,j} N_m w_{im} s_{ijmt}(\vec{p}_t)\mathbb{E}[c^r_{ijmt}(\kappa_{ft})],$$

$$\text{Var}[C_{ft}(\vec{p}_t, \kappa_{ft})] = \sum_{m,i,j} N_m w_{im} s_{ijmt}(\vec{p}_t)\text{Var}[c^r_{ijmt}(\kappa_{ft})].$$

We next derive the reinsurance expenses R_{ft}. The actuarial value of the reinsurance coverage κ_{ft}, namely, the expected cost of reinsurance per individual $\mathbb{E}[r_{ijmt}(\kappa_{ft})]$. $r_{ijmt}(\kappa_{ft})$ is a random variable,

$$r_{ijmt}(\kappa_{ft}) = (c_{ijmt} - \kappa_{ft})\mathbf{1}[c_{ijmt} \geq \kappa_{ft}].$$

We assume insurers can buy reinsurance policy at some mark-up of $\tau_f \geq 1$ above the actuarial value. Insurer f's reinsurance expenses is a constant,

$$R_{ft}(\vec{p}_t, \kappa_{ft}) = \sum_{m,i,j} N_m w_{im} s_{ijmt}(\vec{p}_t)\tau_f \mathbb{E}[r_{ijmt}(\kappa_{ft})],$$

We finally derive the financial costs L_{ft}. Using the same loss function as in the previous paragraph, the

$$L_{ft}(\vec{p}_t, \kappa_{ft}) = \rho_f \text{Var}[C_{ft}(\vec{p}_t, \kappa_{ft})],$$

where ρ_f is an insurer-specific risk-aversion parameter that is constant over time.

To summarize, the insurer f's total costs in a year t are the sum of claims costs $C_{ft}(\vec{p}_t, \kappa_{ft})$, a random variable, reinsurance costs $R_{ft}(\vec{p}_t, \kappa_{ft})$, a constant, and financial costs $L_{ft}(\vec{p}_t, \kappa_{ft})$, a constant.

5.0.5. Insurers' Costs With Both Private and Public Reinsurance. Similar to the previous case with only private reinsurance, insurers' costs under both public and private reinsurance is a sum of claims costs paid by insurers C_{ft}, reinsurance costs R_{ft}, and financial costs L_{ft}. We again derive these three components below one by one.

Let κ_g denote the threshold that the government reinsurance program starts to reimburse the insurer, and θ_g denote insurers' cost-sharing part above the threshold. For simplicity, we ignore the maximum reimbursement cap. When the per-member claims costs is above both the private reinsurance threshold κ_{ft}, and public reinsurance threshold κ_g, we assume that government reimbursement comes in first and the remainder part is filled in by private reinsurance contracts.

We first derive the case where the insurer purchases a private reinsurance coverage with a deductible higher than the government threshold, $\kappa_{ft} > \kappa_g$. When the per member claims cost c_{ijmt} is below both thresholds, the insurer pays the full portion of c_{ijmt}. When the per member claims costs c_{ijmt} is higher than the government reimbursement threshold κ_g but lower than the private reinsurance deductible, the insurer pays $\kappa_g + \theta_g(c_{ijmt} - \kappa_g)$, and the government pays $(1 - \theta_g)(c_{ijmt} - \kappa_g)$. When the per member claims cost c_{ijmt} is above both thresholds, the insurer pays κ_{ft}, the government pays $(1-\theta_g)(c_{ijmt} - \kappa_g)$, and the private reinsurer pays $\theta_g(c_{ijmt} - \kappa_g) - \kappa_{ft}$. Claims costs paid by insurer, private reinsurer, and government reinsurance program are thus

$$c^r_{ijmt}(\kappa_{ft}, \kappa_g, \theta_g) = c_{ijmt}\mathbf{1}[c_{ijmt} < \kappa_g] + (\kappa_g + \theta_g(c_{ijmt} - \kappa_g))\mathbf{1}[\kappa_g \leq c_{ijmt} < \kappa_{ft}] + \kappa_{ft}\mathbf{1}[\kappa_{ft} \leq c_{ijmt}],$$

$$r_{ijmt}(\kappa_{ft}, \kappa_g, \theta_g) = \big(\kappa_g + \theta_g(c_{ijmt} - \kappa_g) - \kappa_{ft}\big)\,\mathbf{1}[\kappa_{ft} \leq c_{ijmt}],$$

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

We then derive the case where the insurer purchase a private reinsurance coverage with the deductible higher than the government threshold, $\kappa_{ft} \leq \kappa_g$. When the per member claims cost c_{ijmt} is below both thresholds, the insurer pays the full portion of c_{ijmt}. When the per member claims costs c_{ijmt} is higher than the private reinsurance deductible but lower than the government reimbursement threshold κ_{ft}, the insurer pays κ_{ft}, and the insurer pays $c_{ijmt} - \kappa_{ft}$. When the per member claims cost c_{ijmt} is above both thresholds, the insurer pays κ_{ft}, the government pays $(1-\theta_g)(c_{ijmt} - \kappa_g)$, and the private reinsurer pays $\theta_g c_{ijmt} + (1-\theta_g)\kappa_g - \kappa_{ft}$.Claims costs paid by insurer, private reinsurer, and government reinsurance program are thus

$$
\begin{aligned}
c^r_{ijmt}(\kappa_{ft}, \kappa_g, \theta_g) &= c_{ijmt}\mathbf{1}[c_{ijmt} < \kappa_{ft}] + \kappa_{ft}\mathbf{1}[\kappa_{ft} \le c_{ijmt} < \kappa_g], \\
r_{ijmt}(\kappa_{ft}, \kappa_g, \theta_g) &= (c_{ijmt} - \kappa_{ft})\mathbf{1}[\kappa_{ft} \le c_{ijmt} \le \kappa_g] + (\theta_g c_{ijmt} + (1-\theta_g)\kappa_g - \kappa_{ft})\mathbf{1}[\kappa_g < c_{ijmt}] \\
g_{ijmt}(\kappa_g) &= (1-\theta_g)(c_{ijmt} - \kappa_g)\mathbf{1}[\kappa_g < c_{ijmt}].
\end{aligned}
$$

Applying the distributional assumptions of c_{ijm}, we can derive that

$$
\mathbb{E}[c^r_{ijmt}(\kappa_{ft}, \kappa_g, \theta_g)] < \mathbb{E}[c_{ijmt}], \quad \text{Var}[c^r_{ijmt}(\kappa_{ft}, \kappa_g, \theta_g)] < \text{Var}[c_{ijmt}].
$$

Private and public reinsurance together reduce the expectation and variance of the per member claims costs paid by insurers. Detailed expressions of $\mathbb{E}[c^r_{ijmt}(\kappa_{ft}, \kappa_g, \theta_g)]$ and $\text{Var}[c^r_{ijmt}(\kappa_{ft}, \kappa_g, \theta_g)]$ are in Appendix C1.

The formulas for claims costs $C_{ft}(\vec{p}_t, \kappa_{ft}, \kappa_g, \theta_g)$, a random variable, reinsurance costs $R_{ft}(\vec{p}_t, \kappa_{ft}, \kappa_g, \theta_g)$, a constant, and financial costs $L_{ft}(\vec{p}_t, \kappa_{ft}, \kappa_g, \theta_g)$, a constant, are similar to the previous case.

$$
\begin{aligned}
C_{ft}(\vec{p}_t, \kappa_{ft}, \kappa_g, \theta_g) &= \sum_{m,i,j} N_m w_{im} s_{ijmt}(\vec{p}_{mt}) c^r_{ijmt}(\kappa_{ft}, \kappa_g, \theta_g), \\
C_{ft}(\vec{p}_t, \kappa_{ft}, \kappa_g, \theta_g) &\xrightarrow{d} N\Big(\mathbb{E}[C_{ft}(\vec{p}_t, \kappa_{ft}, \kappa_g, \theta_g)], \text{Var}[C_{ft}(\vec{p}_t, \kappa_{ft}, \kappa_g, \theta_g)]\Big), \\
\mathbb{E}[C_{ft}(\vec{p}_t, \kappa_{ft}, \kappa_g, \theta_g)] &= \sum_{m,i,j} N_m w_{im} s_{ijmt}(\vec{p}_t) \mathbb{E}[c^r_{ijmt}(\kappa_{ft}, \kappa_g, \theta_g)], \\
\text{Var}[C_{ft}(\vec{p}_t, \kappa_{ft}, \kappa_g, \theta_g)] &= \sum_{m,i,j} N_m w_{im} s_{ijmt}(\vec{p}_t) \text{Var}[c^r_{ijmt}(\kappa_{ft}, \kappa_g, \theta_g)]. \\
R_{ft}(\vec{p}_t, \kappa_{ft}, \kappa_g, \theta_g) &= \sum_{m,i,j} N_m w_{im} s_{ijmt}(\vec{p}_t) \tau_f \mathbb{E}[r_{ijmt}(\kappa_{ft}, \kappa_g, \theta_g)], \\
L_{ft}(\vec{p}_t, \kappa_{ft}, \kappa_g, \theta_g) &= \rho_f \text{Var}[C_{ft}(\vec{p}_t, \kappa_{ft}, \kappa_g, \theta_g)].
\end{aligned}
$$

5.0.6. Insurers' Strategies. Putting together the premium income, claims costs, reinsurance costs, and financial costs, we derive insurers' objective function is

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

where, claims costs $C_{ft}(\vec{p}_t, \kappa_{ft}; \vec{p}_{-ft})$ are random variables; revenue income $\Pi(\vec{p}_{ft}; \vec{p}_{-ft})$, reinsurance costs $R_{ft}(\vec{p}_t, \kappa_{ft}; \vec{p}_{-ft})$, and risk charge $L_{ft}(\vec{p}_t, \kappa_{ft}; \vec{p}_{-ft})$ are deterministic.

Insurer's first order condition of prices p_{km} is

$$
\sum_i \frac{\partial p_{ikm}}{\partial p_{km}} D_{ijm} + \sum_{j \in J_{fm}} \sum_i \Big(p_{ijm} - E[c_{ijm}] - E[r_{ijm}] - \text{Var}[c^r_{ijm}]\Big) \frac{\partial D_{ijm}}{\partial p_{km}} = 0
$$

When choosing private reinsurance, the insurer tradeoffs, for one more extra unit of private reinsurance coverage, the increased costs of private reinsurance, and the decreased claims costs and financial costs. Insurer's first order condition with respect to reinsurance thresholds κ_f is

$$-\sum_{m}\sum_{j\in J_{fm}}\sum_{i}\left(\frac{\partial \mathbb{E}[r_{ijm}(\kappa_f,\kappa_g,\theta_g)]}{\partial \kappa_f}+\rho_f\frac{\partial \text{Var}[c^r_{ijm}(\kappa_f,\kappa_g,\theta_g)]}{\partial \kappa_f}\right)D_{ijm}(\vec{p}_m)=0$$

6. Estimation

This section describes how we estimate the empirical model described in Section 5. We outline estimation methods and identification in Section 6.1. We present model estimates in Section 6.2.

6.1. Estimation and Identification

The model outlined in the previous section has four sets of primitives to be estimated. The first primitive is heterogeneity in price elasticity by consumer risk types, α_i. The second primitive is the marginal claims costs of insurers. We calibrate the baseline consumer health risks parameters μ_i, σ_i^2 from MEPS so that the remaining marginal costs parameter to be estimated is the insurer-specific medical expenses multiplier ψ_{fm}. The third primitive is insurers' risk preferences, ρ_f. The fourth primitive is the reinsurance markup, τ_f.

We calibrate the fourth primitive, reinsurance markups τ_f, from the NAIC reinsurance records, using the averages of the ratio of reinsurance premiums over reinsurance costs. We describe how we estimate the remaining primitives below.

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

$$u_{ijmt}=\delta_{\theta jmt}-(\alpha_r+\nu_i)(p_{jmt}\iota_\theta-subsidy_{\theta jmt})+\epsilon_{ijmt}, \tag{12}$$

$$\delta_{\theta jmt}=\alpha_\theta(p_{jmt}\iota_\theta-subsidy_{\theta jmt})+\beta_\theta X_{jmt}+\xi_{jmt}+\xi_{\theta jm}+\xi_{\theta jmt}. \tag{13}$$

The first step uses the individual-year panels of enrollment records to recover preference heterogeneity and uses aggregate market shares to pin down common utility components. It is a constrained maximum likelihood estimation with parameters outlined in equation (12): heterogeneity in price preference 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 observed and predicted market shares match.

The differential correlations between premiums and choice patterns by consumers with different health risks identify differences in price sensitivity α_r by risk bins. The differential substitution patterns across consumers of the same demographics in the same market identify the standard deviation of random coefficient, σ. 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 (13), projecting the estimated common utility $\delta_{\theta jmt}$ onto its components. This step recovers mean preferences for premium α_θ and other financial characteristics β_θ. Correlations between product characteristics and choice patterns identify these mean preferences. 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 key identifying variation comes from the age rating regulation in the exchange (Tebaldi, 2017): 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-product-year fixed effects ξ_{jmt}.

6.1.2. Marginal Cost Multiplier and Risk Aversion. We estimate the supply-side parameters, marginal cost multiplier ψ_{fmt}, and risk preference parameter ρ_f with a generalized method of moments estimator, using insurers' first order conditions as moments. As we do not observe the reinsurance deductible, but instead observe private reinsurnce premiums, we match model-implied reinsurance premium to that of observed in the data:

$$\sum_m \sum_{j \in J_{fm}} \sum_i \left(\underbrace{E[c_{ijm} - c^r_{ijm} | (\kappa_f, \kappa_g, \theta_g)]}_{\text{AV of reins}} + \mathbb{E}[r_{ijm}(\kappa_f, \kappa_g, \theta_g)] \right) D_{ijm}(\vec{p}_m) = \underbrace{p_f^{\text{reins}} D_f}_{\text{reinsurance premium}}$$

Risk preferences ρ_{ft} are primarily identified by the correlation between aggregate cost variance and private reinsurance coverage. Intuitively, for a given amount of cost variance increase, the magnitude of the associated increase in private reinsurance purchase pins down the degree of financial frictions.

Marginal cost multipliers ψ_{fmt} are primarily identified by the premium levels. 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 premiums and financial costs from the total marginal costs gives an estimate of the claims costs for a certain age group under a certain product. The ratio between product-specific claims costs and the baseline health risks from MEPS pins down marginal cost multipliers.

6.2. Model Estimates

6.2.1. Calibrated Parameters. We calibrate the mean and standard deviations of the lognormal claims costs distribution by each age group from the MEPS data. These parameters are reported in Table A7.

We calibrate reinsurance markup using the averages of the ratio of reinsurance premiums over reinsurance costs, from the NAIC reinsurance records. The markup is calibrated to be 1.62. NAIC records show that the mean share of reinsurance premiums over health insurance premium income is 3.23%. The share is 4.50% and 0.04%, respectively, for regional and national health insurers.

6.2.2. Consumer Preference Estimates. Table 4a reports consumer preference estimates. These estimates imply that the average enrollment-weighted own-premium semi-elasticity is -4.0 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 4b panel (a) reports the own-premium semi-elasticity for each age, risk bin. Our estimates confirm adverse selection: sicker consumers in risk bin 4 are less price elastic than healthier consumers in risk bin 1. The price elasticity decreases in absolute magnitude as consumers age. Table 4b panel (b) reports the extensive margin sensitivity, measured as the percentage drop in the probability of purchasing marketplace coverage if the annual posted premiums increase by $100. Such price increases would reduce the insured rate by 3-5% for the Colorado exchange, consistent with 4% (Tebaldi, 2017) of the California exchange.

Table 4. Consumer preferences estimates

(a). Parameter estimates

	Coefficient	Standard error
(a). Demand estimation, first step MLE estimates		
Coefficient on premium (in $1,000), risk bin 1	-0.493	(0.002)
Coefficient on premium (in $1,000), risk bin 2	-0.323	(0.002)
Coefficient on premium (in $1,000), risk bin 3	-0.112	(0.002)
Standard deviation of random coefficient	0.332	(0.001)
(b). Demand estimation, second step OLS estimates		
Coefficient on premium (in $1,000), age below 34	-2.098	(0.071)
Coefficient on premium (in $1,000), age between 35-54	-1.480	(0.052)
Coefficient on premium (in $1,000), age above 55	-0.857	(0.033)

(b). Derived elasticities

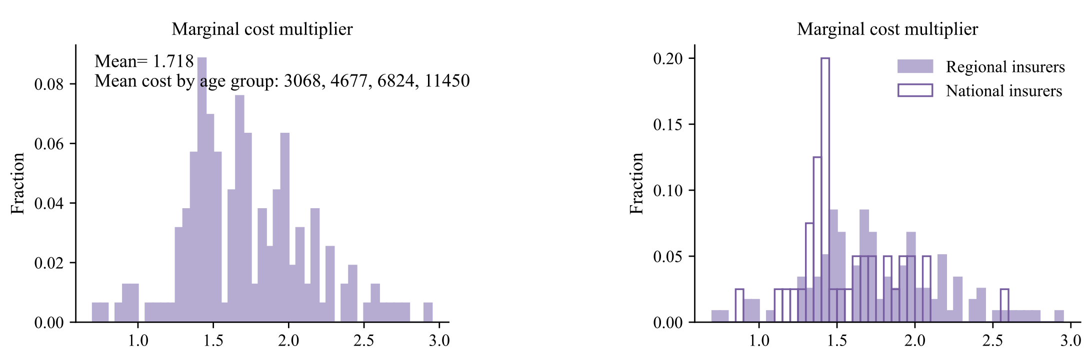
	(a). Semi-elasticity to own premiums				(b). Changes in insured rate if all annual posted premiums increase by $100			
	Risk bin 1	Risk bin 2	Risk bin 3	Risk bin 4	Risk bin 1	Risk bin 2	Risk bin 3	Risk bin 4
Age below 34	-6.54	-6.16	-5.68	-5.46	-4.23%	-5.18%	-5.82%	-5.76%
Age 35-54	-4.22	-3.93	-3.57	-3.40	-4.03%	-4.66%	-4.89%	-4.69%
Age above 54	-2.22	-2.04	-1.81	-1.69	-4.57%	-4.33%	-3.56%	-3.06%

Notes: Standard errors (in parenthesis) are derived using the delta method. Statistics in panel (b) are enrollment-weighted means.

6.2.3. Marginal Claims Costs Estimates. Figure 3a plots the distribution of marginal cost multiplier by insurer-year-market. Overall, insurer-specific medical expenses are 1.78 times the baseline health risks. This could be caused by the fact that consumers on Colorado Exchanges are less healthy than the average consumer in Exchanges nationwide or by the fact the insurers in Colorado have a disadvantaged bargaining position. There also exist considerable variations in marginal costs across insurers and markets. Figure 3b plots the marginal cost multiplier by insurer types. National insurers have lower marginal costs than regional insurers for individuals of the same risk types.

Figure 3. Marginal Claims Cost Estimates

(a). Marginal costs multiplier (b). Marginal costs multiplier, by insurer type



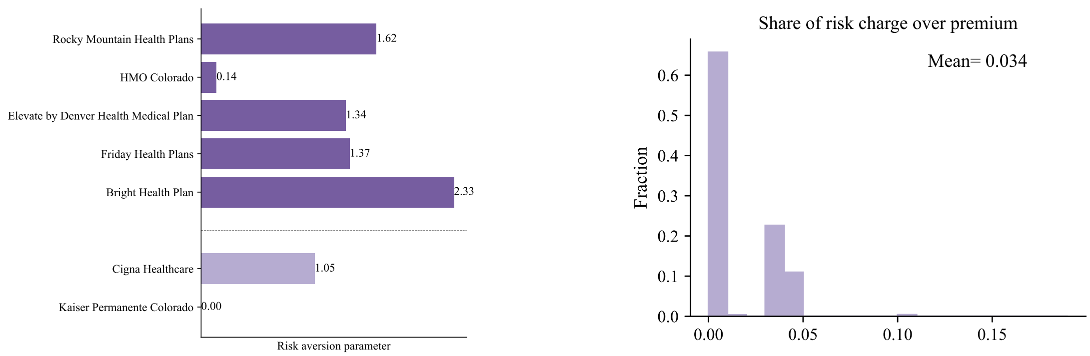
Notes: Panel (a) plots the estimated marginal costs multiplier relative to the population in MEPS at the insurer-county-year level. Panel (b) plots the estimates further by regional and national insurers.

Applying the marginal cost multiplier to the claims cost distribution, we find the mean costs for each age group are \$3068, \$4677, \$6878, \$11450 for consumers aged below 18, 18-34, 35-54, and above 55. The correlation between claims costs and premium elasticities confirms the adverse selection pattern that healthy consumers are more price-elastic than sick consumers.

6.2.4. Risk Preferences Estimates. Figure 4a plots the estimated risk preferences for each insurer. The upper panel dark bar plots the risk preferences for regional insurers, while the lower panel light bar plots those for national insurers. Regional insurers behave more like risk averse than national insurers. This is as expected, as national insurers tend to have more access to financial capital, thus having lower capital costs.

Figure 4. Rick charge estimates

(a). Risk preference, by insurer type (b). Risk charge



Notes: Panel (a) plots the estimated risk preference at the insurer-year level from the inversion of insurers' first order condition of private reinsurance purchases. Panel (b) plots the derived risk charges per enrollee implied by risk preference estimates.

Figure 4b plots risk charge as a share of health insurance premiums at the insurer-year level. The mean risk charge is 3.38% of the \$5,935 health insurance premiums. This is consistent with actuarial documents that insurers' risk charges are usually 2-4% of their premiums (Kim, 2022). The share of risk charge over health insurance premium income is 4.06% and 1.69% for regional and national insurers, separately.

7. Subsidy Design in the Presence of Financial Frictions

In this section, we use our model to evaluate the effects of public reinsurance on insurers' pricing, private reinsurance purchases, and overall welfare.[8] We start by simulating Colorado's reinsurance subsidies under several scenarios that isolate different economic forces. We then study optimal policy design and compare the relative effectiveness of demand-side consumer subsidies and supply-side reinsurance subsidies.

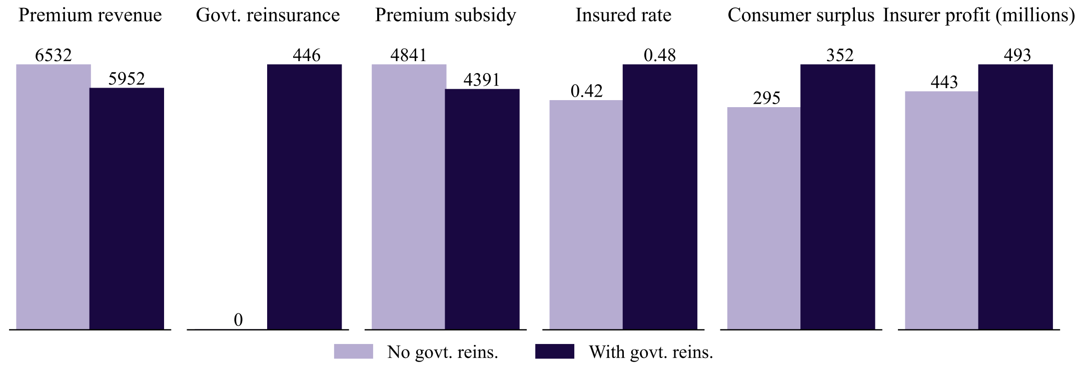
7.1. Equilibrium Effect of Public Reinsurance Subsidies

We first simulate the effects of Colorado's reinsurance policies on consumer choices, insurers' pricing and private reinsurance purchase decisions, and consumer welfare. Figure 5 reports the simulated equilibrium outcomes before and after the reinsurance programs.

The reinsurance program spends an average of \$446 per consumer to share high-cost claims with insurers and lowers premiums by \$580, an 8.8% decrease from the baseline. This simulated pass-through is 1.3, consistent with reduced form estimates in Section 4. As the public reinsurance subsidies lower both the

[8] Our current counterfactual results are based on a demand specification without random coefficients. We will incorporate the results with random coefficients in the next version of the draft.

Figure 5. Equilibrium statistics, with and without 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. All objects except insurer profit and insured rate are measured per member year.

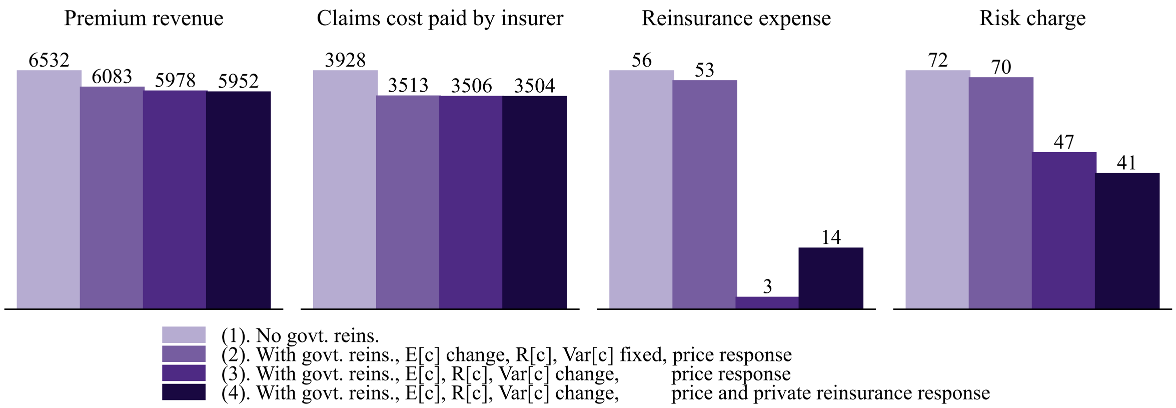
mean and variance of insurers' claims expenses, insurers reduce their private reinsurance expenses from \$56 per enrollee to \$14 per enrollee, and risk charges decrease from \$72 per enrollee to \$41 per enrollee.

The insured rate rises by 6%, and premium subsidies per enrollee fall by \$450 along with premiums drops. Annual consumer surplus raise by \$57 per member, a 19% increase from the baseline. Total insurers' profits rise by 50 million due to decreased claims costs, reinsurance expenses, and risk charges.

To disentangle the roles of different economic forces, we run four counterfactuals. The first counterfactual, denoted by (0), *no intervention*, corresponds to the case in which no policy is in place. To isolate the effect of public reinsurance on insurers' expected claims, we compare the no-intervention benchmark with a situation in which the reinsurance policy affects only the expected claims costs terms, but not the reinsurance costs or risk charges in insurers' profit functions. We allow insurers to optimally choose prices but not private reinsurance purchases in response to this interim profit function. We denote this counterfactual by (1), *claims cost only*. We then compute counterfactual (2), *premium only*, in which the reinsurance policy affects all of the expected claims costs, reinsurance costs, and risk charges terms in insurers' profit functions, but we allow insurers to respond by only changing price but not private reinsurance purchase. Finally, we compute counterfactual (3), *equilibrium*, the reinsurance policy affects all of the expected claims costs, reinsurance costs, and risk charges terms in insurers' profit functions. We allow insurers to choose both price and private reinsurance purchases in response optimally. This corresponds to the equilibrium model in Section 5.

We present changes in insurers' premiums, claims expenses, reinsurance expenses, and risk charges under different counterfactuals in Figure 6. As reinsurance subsidies lower the expected claims costs paid by insurers, moving from a counterfactual with no intervention, (0), to one in which insurers' expected claims costs decrease, (1), reduces average insurers' claims expenses by \$415 per member. Because insurers' expected claims costs per member decrease, the probability that an enrollee's expenditure will exceed a given reinsurance reimbursement threshold also decreases, leading to a \$3 reduction in reinsurance expenses. Furthermore, by reimbursing the tail risks of claims costs, the variance of total claims costs also drops, leading to a \$2 reduction in risk charge. These forces together result in insurers lowering the premium by \$449 on average.

Figure 6. Equilibrium statistics, with and without public reinsurance subsidies



Notes: This figure plots the simulated equilibrium objects in different scenarios. All objects are measured per member year. The first bar corresponds to the case in which no policy is in place. The second bar plots the case where reinsurance policy affects only the expected claims costs terms but not the reinsurance costs or risk charges in insurers' profit functions. We allow insurers to optimally choose prices but not private reinsurance purchases in response to this interim profit function. The third bar plots the case where the reinsurance policy affects all of the expected claims costs, reinsurance costs, and risk charges terms in insurers' profit functions, but we allow insurers to respond by only changing price but not private reinsurance purchase. The fourth bar plots the case where the reinsurance policy affects all of the expected claims costs, reinsurance costs, and risk charges terms in insurers' profit functions. We allow insurers to choose both price and private reinsurance purchases in response optimally.

We then change both the insurers' expected claims costs and their expenses related to financial frictions by simulating counterfactual (2). By reimbursing tail risks for insurers, public reinsurance subsidies decrease both the expected claims costs paid by insurers and the variance of the distribution of aggregate claims costs. We find that insurers lower average premiums by \$105 more following the decrease in private reinsurance expenses and risk charges. The decreases in premiums in counterfactual (2) attract price-elastic healthy consumers to enroll given the adverse selection feature, which further reduces claims costs paid by insurers by \$7. As the newly enrolled healthy consumers have a smaller variance of claims costs and a smaller probability to exceed the reinsurance reimbursement threshold, reinsurance expenses further fall by \$7, and risk charge falls by \$23.

Under counterfactual (3), insurers not only choose prices but also adjust private reinsurance purchases. Public reinsurance makes insuring the tail risks cheaper in the private reinsurance market. Insurers thus purchase more private reinsurance coverage in response to the decrease in private reinsurance prices and per member reinsurance expense increase slightly by \$7 from counterfactual (2) to counterfactual (3). However, note that the aggregate private reinsurance purchase still decreases by \$42 from the no policy counterfactual (0) to with policy counterfactual (3) since public reinsurance subsidies reduce insurers' need for using private reinsurance to stabilize their risk profiles. The rise in private reinsurance coverage further decreases the expected mean and variance of aggregate cost distribution, making per member claims costs payment and risk charge decrease by \$2 and \$3 separately. The net effect of an increase in private reinsurance expenditure and a decrease in claims costs and risk charges together reduces premiums by \$26.

Taken together, this decomposition exercise suggests that reductions in claims costs and risk charges from public reinsurance subsidies each account for 77% and 23% of premium decreases. This indicates that financial frictions can be an essential distortion that drives up premiums in the health insurance market.

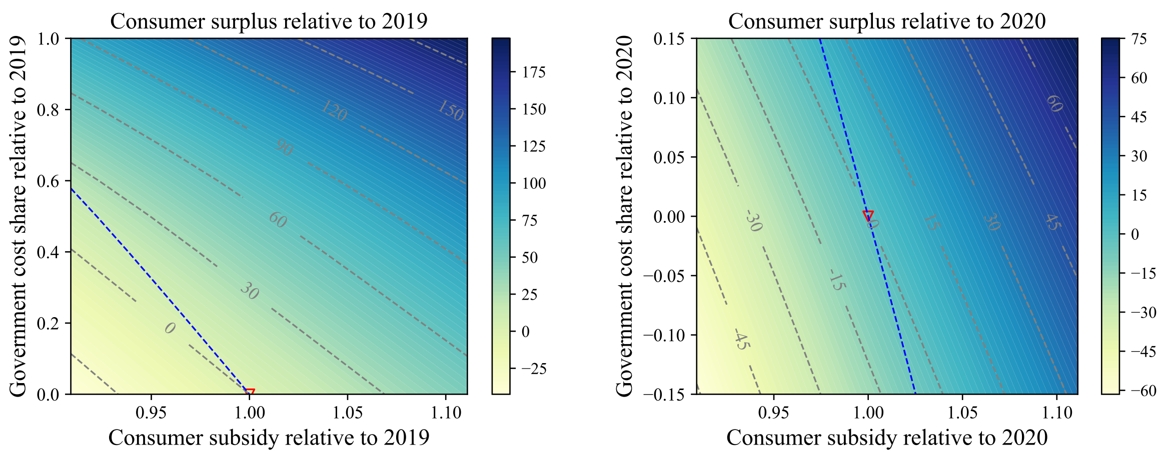
7.2. Allocating Premium and Reinsurance Subsidies

We now study the design of subsidy policies. The theoretical model in Section 3 predicts that the effectiveness of premium and reinsurance subsidies depends on the relative magnitude of adverse selection and financial frictions. We thus perturb subsidy allocation between consumers and insurers under a fixed government budget.

Figure 7 reports the average consumer surplus under different subsidy regimes. The horizontal and vertical axes represent different premium and reinsurance subsidies relative to the status quo. 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.

Figure 7. 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.

Figure 7a corresponds to the subsidy allocations scenario in the year 2019, where there is no reinsurance program in place. Moving along the blue curve to increase reinsurance subsidies, consumer surplus increases, consistent with the results in Section 7.1. Figure 7a corresponds to the subsidy allocations scenario in 2020, where the reinsurance program was implemented. Our simulations reveal that 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 simulation exercises show that reinsurance subsidies are more efficient than premium subsidies under the current market conditions.

To summarize, simulations in this section demonstrate that, besides the well-known demand-side adverse selection problem, addressing supply-side frictions can effectively improve insurance market functioning.

8. Discussion and Conclusion

Government subsidy plays a major role in the US health insurance markets. Given the large magnitude of fiscal spending in the area, it is crucial to utilize an efficient subsidy mechanism to deliver affordable insurance coverage. This paper examines the efficiency of two widely used subsidy mechanisms in the individual health insurance market: government reinsurance and direct-to-consumer premium subsidy. Reinsurance subsidizes the insurers by ex-post covering some of the high-cost enrollee's costs, leading insurers to decrease their premiums. On the other hand, premium subsidy directly subsidizes the purchase of insurance for consumers, lowering the effective enrollee premium.

By building a theoretical model in which insurers face financial frictions in the adverse selection market, we show that both forces play an essential role in determining the efficiency of the two subsidy mechanisms. With financial frictions, reinsurance not only decreases the expected cost of insurers but lowers insurer's risk charges stemming from financial frictions. With adverse selection, the cost of a marginal enrollee tends to be smaller than the cost of an average enrollee. Because consumer subsidy targets the marginal enrollee, whereas reinsurance targets the average enrollee, it may be a more efficient mechanism without financial frictions. However, with both forces in the market, it is unclear which subsidy mechanism will be more efficient for the government.

Using state-level reinsurance policies, we show empirical evidence that both frictions exist in the market. We then estimate an equilibrium model of consumers' insurance demand and insurers' premium and private reinsurance decisions to separately quantify the effect of financial frictions and adverse selection and explore optimal subsidy designs. We find that reinsurance subsidies are more efficient than premium subsidies under current market conditions. Under a fixed government budget, reallocating premium subsidies to reimburse insurers for high-cost claims could increase consumer surplus. Our results demonstrate that, besides the well-known demand-side adverse selection problem, addressing supply-side frictions can be an important factor to a well-functioning insurance market.

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Appendix

A. Supplementary Tables and Figures

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
(a). Demographics				
Below 34	45.8%	45.2%	45.8%	44.8%
35-54	35.3%	34.9%	34.8%	35.4%
Above 55	18.9%	19.9%	19.4%	19.8%
(b). Market share				
Kaiser	22.6%	18.6%	14.3%	10.4%
Bright	2.4%	4.6%	4.9%	5.2%
United	0.5%	-	-	-
Cigna	8.2%	6.1%	4.9%	5.2%
Friday	1.8%	1.0%	1.3%	1.9%
Elevate	0.2%	0.2%	0.1%	0.2%
HMO CO	1.2%	6.4%	11.4%	12.8%
Rocky Mountain	0.7%	0.3%	0.3%	0.4%
Uninsured	62.4%	62.7%	62.9%	63.8%

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)	−0.214	(0.068)	−1.228	(0.498)
(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			−0.188	(0.054)	−2.314	(0.886)
(7) Alternative estimator: Callaway and Sant'Anna (2021)	−0.191	(0.096)	−0.250	(0.103)	−1.847	(0.960)
(8) Alternative estimator: Borusyak et al. (2024)	−0.136	(0.024)	−0.238	(0.080)	−1.208	(0.486)

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 3, 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

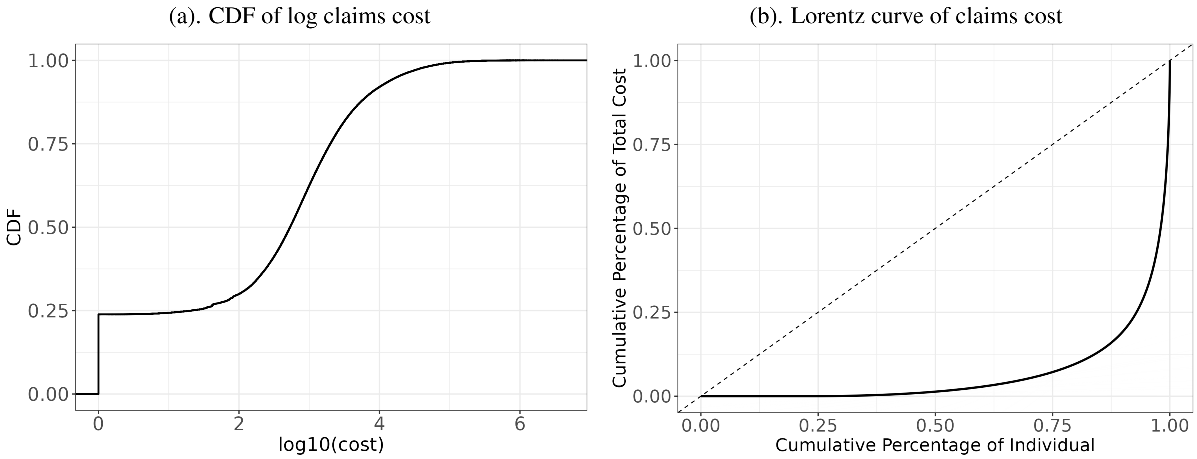
Notes: This table reports the point estimates and standard errors (in parenthesis) on the effect of reinsurance programs from the estimation of differences-in-differences version of equation (7), and (9). The regeression is at the insurer-rating region-year level in 2014-2024 for Columns (1)-(2), and 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 2b. For columns (3)-(6), the regression sample and specification is the same as that of Figure A3. 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. Claim costs distribution by age group

Claim costs	Age below 18	Age 18-34	Age 35-54	Age above 55
Claims cost distribution, statistics				
Mean costs	1889	1429	2443	5105
Probability of zero costs	0.26	0.44	0.35	0.21
1st percentile	0	0	0.0	0
25th percentile	0	0	0	76
50th percentile	250	84	225	891
75th percentile	831	687	1355	3603
99th percentile	23975	20306	36330	67990
Approximated log-normal distribution, parameters				
Means (μ_i)	5.986	6.526	6.972	7.500
Standard deviations (σ_i)	3.003	2.766	2.629	2.609

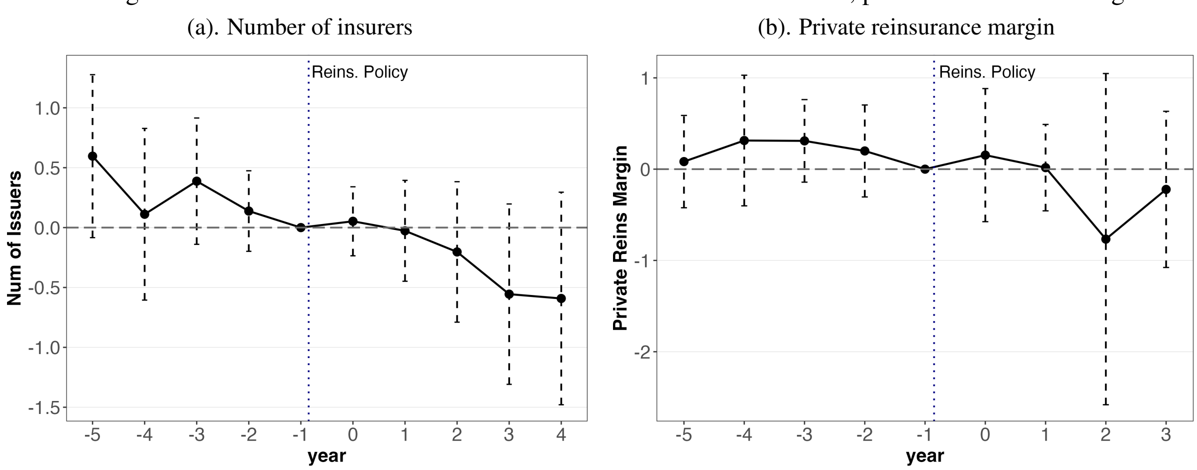
Notes: Data comes from MEPS 2014-2019 for individuals whose self-reported insurance coverage is Exchanges market or uninsured but eligible for the Exchanges. The measurement unit of the approximated log-normal distribution is in thousands.

Figure A1. Distribution of total medical expenses



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.

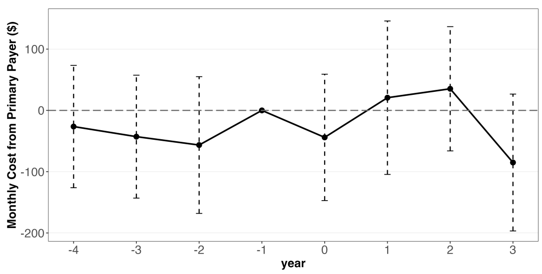
Figure A2. Effect of state reinsurance subsidies on number of insurers, private reinsurance margin



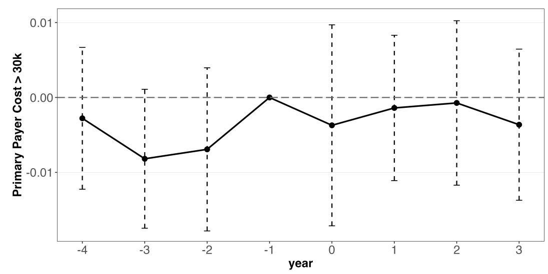
Notes: This figure reports point estimates and 95% confidence interval of the effect of state reinsurance from the estimation of equation (6). The outcome variable is the number of insurers in a rating region in panel (a), and private reinsurance margin, defined as difference in premiums to claims over 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 A3. Effect of public reinsurance subsidies on medical expenses

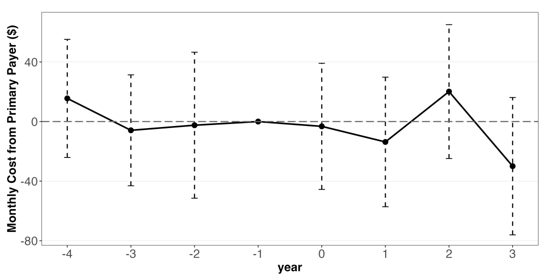
(a). Monthly expenses, across reinsurance tiers



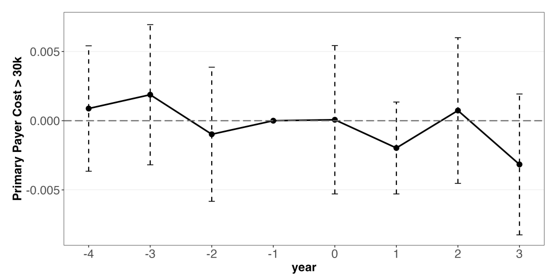
(b). Total expenses above threshold, across reinsurance tiers



(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 (9). The outcome variable is monthly medical expenses per enrollee in panels (a) and (c), and whether the enrollees' annual expenses exceeds 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.

B. Derivations for the Theoretical Model

Proof to Proposition 1

Without loss of generality, we provide a simple example with linear demand and symmetric individual types to illustrate that pass-through rate of greater than one can be achieved to prove Proposition 1. Suppose that individual of type t's cost is identically distributed i.e. $F_\ell = F_h$, meaning $c_\ell = c_h, \sigma_\ell^2 = \sigma_h^2$. Suppose that the monopoly insurer faces an aggregate linear demand of $Q(p) = a - bp$. Then the insurer's first order condition can be re-written in the following way:

$$p^*(\theta) = \frac{1}{2}\left(c(\theta) + \rho\sigma^2(\theta) + \frac{a}{b}\right)$$

Without reinsurance, $p_0^* = c + \rho\sigma^2 + a/b$. When the government provides reinsurance of level θ, then it will decrease the insurer's expected cost by $r(\theta) = c - c(\theta)$. So the corresponding pass-through rate will be

$$\frac{p^*(\theta) - p_0^*}{r(\theta)} = \frac{1}{2} + \frac{1}{2}\frac{\rho\overbrace{(\sigma^2(\theta) - \sigma^2)}^{\Delta\sigma^2(\theta)}}{r(\theta)}$$

As a result, as long as the decrease in the risk charge, $\rho\Delta\sigma^2(\theta)$ is larger than the expected reinsurance cost of $r(\theta)$, the pass-through could be greater than one.

Proof to Proposition 2

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 $c_\ell = c_h, \sigma_\ell^2 = \sigma_h^2$.

Then the expected average reinsurance cost for given θ is

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

The expected per-enrollee subsidy will be $s(\theta) = r(\theta)$. 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

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

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

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

The expected per-enrollee subsidy is

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

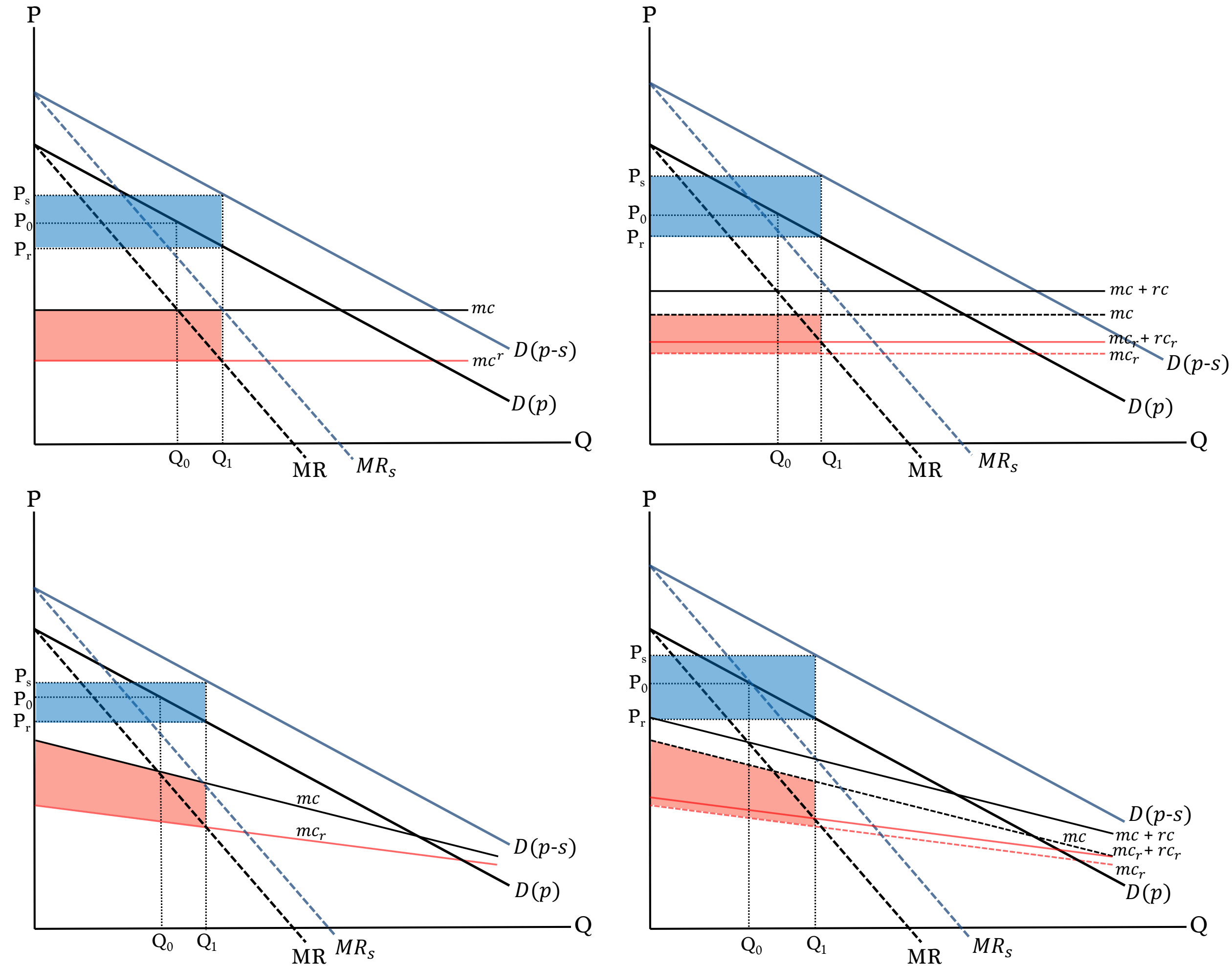
Under adverse selection, $F_h(t) < F_\ell(t)\ \forall\, t$. This directly implies that $r_\ell(\theta) < r_h(\theta)$. We now show that the marginal reinsurance cost is smaller than the average reinsurance cost. Given that $r_\ell(\theta) < r_h(\theta)$, if $\alpha(p) < \lambda(p)$ then $r(\theta) > s(\theta)$ as the average reinsurance cost uses $\alpha(p)$ as the weight for the type ℓ individual whereas the marginal reinsurance cost uses $\lambda(p)$.

$$\begin{aligned}
\lambda(p) &= \frac{\frac{\partial q_\ell(p)}{\partial p}}{\frac{\partial q_\ell(p)}{\partial p} + \frac{\partial q_h(p)}{\partial p}} \\
&= \frac{\frac{\partial q_\ell(p)}{\partial p}\frac{p}{q_\ell}}{\frac{\partial q_\ell(p)}{\partial p}\frac{p}{q_\ell} + \frac{\partial q_h(p)}{\partial p}\frac{p}{q_\ell}} \\
&= \frac{\varepsilon_\ell(p)}{\varepsilon_\ell(p) + \varepsilon_\ell(p)\frac{q_h}{q_\ell}} \\
&= \frac{q_\ell \varepsilon_\ell(p)}{q_\ell \varepsilon_\ell(p) + \varepsilon_\ell(p) q_h} \\
&= \frac{q_\ell}{q_\ell + q_h \underbrace{\frac{\varepsilon_p(p)}{\varepsilon_\ell(p)}}_{<1}} \\
&> \frac{q_\ell}{q_\ell + q_h} = \alpha(p)
\end{aligned}$$

where the last inequality comes from the assumption that type ℓ's demand is more elastic than type h's. Hence $s(\theta) < r(\theta)$ 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.

Figure A4. Reinsurance vs. Demand Subsidy



C. Additional Details on Estimation

C1. Derivations

This subsection derives detailed expressions for key objects in Section 5, including the expectation and variance of claims costs with only private reinsurance $\mathbb{E}[c^r_{ijmt}(\kappa_{ft})]$, $\text{Var}[c^r_{ijmt}(\kappa_{ft})]$, the expectation of private reinsurance premiums with only private reinsurance $\mathbb{E}[r_{ijmt}(\kappa_{ft})]$, the expectation and variance of claims costs with both private and public reinsurance $\mathbb{E}[c^r_{ijmt}(\kappa_{ft}, \kappa_g, \theta_g)]$, $\text{Var}[c^r_{ijmt}(\kappa_{ft}, \kappa_g, \theta_g)]$, and the private reinsurance premiums with both private and public reinsurance $\mathbb{E}[r_{ijmt}(\kappa_{ft}, \kappa_g, \theta_g)]$.

Before proceeding to the detailed expression, we first present two formulas that the derivations rely heavily on. Let a be an arbitrary number. The distribution assumptions in Section 5 state the baseline health risks c_i are log-normally distributed, $\log(c_i) \sim N(\mu_i, \sigma_i)$. Applying the distributional assumptions, we get

$$\begin{aligned}
\int_{-\infty}^{a} c_i f(c_i) dc_i &= \int_{-\infty}^{a} c_i \frac{1}{c_i \sigma_i \sqrt{2\pi}} \exp\left(-\frac{(\ln(c_i) - \mu_i)^2}{2\sigma^2}\right) dc_i \\
&= \int_{-\infty}^{\frac{\ln(a)-\mu_i}{\sigma_i}} \frac{1}{\sqrt{2\pi}} \exp(-\frac{1}{2} y_i^2 + \sigma_i y_i + \mu_i)) dy_i \\
&= \exp(\mu_i + \frac{1}{2}\sigma_i^2) \int_{-\infty}^{\frac{\ln(a)-\mu_i}{\sigma_i}} \frac{1}{\sqrt{2\pi}} \exp(-\frac{1}{2}(y_i - \sigma_i)^2) dy_i \\
&= \exp(\mu_i + \frac{1}{2}\sigma_i^2) \Phi\left[\frac{\ln(a) - \mu_i - \sigma_i^2}{\sigma_i}\right].
\end{aligned}$$

The first equality plugs in the log-normal probability density functions. The second equality uses changes of variables, $y_i = \frac{\ln c_i - \mu_i}{\sigma_i}$ and $dc_i = \sigma_i \exp(\sigma_i y_i + \mu_i))$. The fourth equality uses changes of variables $z_i = y_i - \sigma_i$ and $dz_i = dy_i$.

$$\begin{aligned}
\int_{-\infty}^{a} c_i^2 f(c_i) dc_i &= \int_{-\infty}^{a} c_i^2 \frac{1}{c_i \sigma_i \sqrt{2\pi}} \exp\left(-\frac{(\ln(c_i) - \mu)^2}{2\sigma^2}\right) dc_i \\
&= \int_{-\infty}^{\frac{\ln(a)-\mu_i}{\sigma_i}} \frac{1}{\sqrt{2\pi}} \exp(2\sigma_i y_i + 2\mu_i - \frac{1}{2} y_i^2) dy_i \\
&= \exp(2\mu_i + 2\sigma_i^2) \int_{-\infty}^{\frac{\ln(a)-\mu_i}{\sigma_i}} \frac{1}{\sqrt{2\pi}} \exp(-\frac{1}{2}(y_i - 2\sigma_i)^2) dy_i \\
&= \exp(2\mu_i + 2\sigma_i^2) \Phi\left[\frac{\ln(a) - \mu_i - 2\sigma_i^2}{\sigma_i}\right].
\end{aligned}$$

The first equality plugs in the log-normal probability density functions. The second equality uses changes of variables, $y_i = \frac{\ln c_i - \mu_i}{\sigma_i}$ and $dc_i = \sigma_i \exp(\sigma_i y_i + \mu_i))$. The fourth equality uses changes of variables $z_i = y_i - \sigma_i$ and $dz_i = dy_i$.

We now derive the expectation and variance of claims costs, and the expectation of private reinsurance premiums under the scenario with only private reinsurance. For simplicity, we omit the subscript t, and note that the equations applies to all time periods. Given the private reinsurance coverage κ_f, insurer f's cost is

$$\begin{aligned}
c_{ijm}^r(\kappa_f, \theta_f) &= c_{ijm} \mathbf{1}[c_{ijm} < \kappa_f] + \kappa_f \mathbf{1}[c_{ijm} \geq \kappa_f] \\
&= \psi_{fm} \lambda_j c_i \mathbf{1}[c_i < \frac{\kappa_f}{\psi_{fm}\lambda_j}] + \kappa_f \mathbf{1}[c_i \geq \frac{\kappa_f}{\psi_{fm}\lambda_j}].
\end{aligned}$$

Taking expectations we have

$$\begin{aligned}\mathbb{E}[c^r_{ijm}] &= \psi_{fm}\lambda_j \int_{-\infty}^{\frac{\kappa_f}{\psi_{fm}\lambda_j}} c_i f(c_i) dc_i + \kappa_f \int_{\frac{\kappa_f}{\psi_{fm}\lambda_j}}^{\infty} f(c_i) dc_i \\ &= \psi_{fm}\lambda_j \exp(\mu_i + \frac{1}{2}\sigma_i^2)\Phi\left[\frac{\ln\kappa_f - \ln\left(\psi_{fm}\lambda_j\right) - \mu_i - \sigma_i^2}{\sigma_i}\right] \\ &+ \kappa_f \Phi\left[\frac{\mu_i - \ln(\kappa_f) + \ln\left(\psi_{fm}\lambda_j\right)}{\sigma_i}\right].\end{aligned}$$

$$\begin{aligned}\text{Var}[c^r_{ijm}] = &\int_{-\infty}^{\frac{\kappa_f}{\psi_{fm}\lambda_j}} (\psi_{fm}\lambda_j c_i - \mathbb{E}[c^r_{ijm}])^2 f(c_i) dc_i + \int_{\frac{\kappa_f}{\psi_{fm}\lambda_j}}^{\infty} (\kappa_f - \mathbb{E}[c^r_{ijm}])^2 f(c_i) dc_i \\ =&\psi_{fm}^2\lambda_j^2 \exp(2\mu_i + 2\sigma_i^2)\Phi\left[\frac{\ln\kappa_f - \ln\left(\psi_{fm}\lambda_j\right) - \mu_i - 2\sigma_i^2}{\sigma_i}\right] \\ &-2\psi_{fm}\lambda_j \mathbb{E}[c^r_{ijm}] \exp(\mu_i + \frac{1}{2}\sigma_i^2)\Phi\left[\frac{\ln\kappa_f - \ln\left(\psi_{fm}\lambda_j\right) - \mu_i - \sigma_i^2}{\sigma_i}\right] \\ &+\mathbb{E}[c^r_{ijm}]^2 \Phi\left[\frac{\ln(\kappa_f) - \ln\left(\psi_{fm}\lambda_j\right) - \mu_i}{\sigma_i}\right] \\ &+(\kappa_f - \mathbb{E}[c^r_{ijm}])^2 \Phi\left[\frac{\mu_i - \ln(\kappa_f) + \ln\left(\psi_{fm}\lambda_j\right)}{\sigma_i}\right].\end{aligned}$$

The reinsurance cost is

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

Taking expectations we have

$$\begin{aligned}\mathbb{E}[r_{ijm}] =&\psi_{fm}\lambda_j \int_{\frac{\kappa_f}{\psi_{fm}\lambda_j}}^{\infty} c_i f(c_i) dc_i - \kappa_f \int_{\frac{\kappa_f}{\psi_{fm}\lambda_j}}^{\infty} f(c_i) dc_i \\ =&\psi_{fm}\lambda_j \exp(\mu_i + \frac{1}{2}\sigma_i^2)\Phi\left[\frac{-\ln\kappa_f + \ln\left(\psi_{fm}\lambda_j\right) + \mu_i + \sigma_i^2}{\sigma_i}\right] \\ &-\kappa_f \Phi\left[\frac{\mu_i - \ln(\kappa_f) + \ln\left(\psi_{fm}\lambda_j\right)}{\sigma_i}\right].\end{aligned}$$

We proceed to derive the expectation and variance of claims costs, and the expectation of private reinsurance premiums under the scenario with both private and public reinsurance. We again omit the subscript t for simplicity. We first consider the case where $\kappa_f > \kappa_g$. Given private reinsurance coverage κ_f and public reinsurance coverage κ_g, θ_g, insurer f's cost is

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

Taking expectations we have

$$
\begin{aligned}
&\mathbb{E}[c_{ijm}^r] \\
=&\psi_{fm}\lambda_j \int_{-\infty}^{\frac{\kappa_g}{\psi_{fm}\lambda_j}} c_i f(c_i) dc_i + \theta_g \psi_{fm}\lambda_j \int_{\frac{\kappa_g}{\psi_{fm}\lambda_j}}^{\frac{\kappa_f}{\psi_{fm}\lambda_j}} c_i f(c_i) dc_i \\
+&(\kappa_g - \theta_g \kappa_g) \int_{\frac{\kappa_g}{\psi_{fm}\lambda_j}}^{\frac{\kappa_f}{\psi_{fm}\lambda_j}} f(c_i) dc_i + \kappa_f \int_{\frac{\kappa_f}{\psi_{fm}\lambda_j}}^{\infty} f(c_i) dc_i \\
=&\psi_{fm}\lambda_j \exp(\mu_i + \frac{1}{2}\sigma_i^2) \Phi \left[\frac{\ln \kappa_g - \ln\left(\psi_{fm}\lambda_j\right) - \mu_i - \sigma_i^2}{\sigma_i} \right] \\
+&\theta_g \psi_{fm}\lambda_j \exp(\mu_i + \frac{1}{2}\sigma_i^2) \\
&\times \left(\Phi \left[\frac{\ln \kappa_f - \ln\left(\psi_{fm}\lambda_j\right) - \mu_i - \sigma_i^2}{\sigma_i} \right] - \Phi \left[\frac{\ln \kappa_g - \ln\left(\psi_{fm}\lambda_j\right) - \mu_i - \sigma_i^2}{\sigma_i} \right] \right) \\
+&(\kappa_g - \theta_g \kappa_g) \left(\Phi \left[\frac{\ln(\kappa_f) - \ln\left(\psi_{fm}\lambda_j\right) - \mu_i}{\sigma_i} \right] - \Phi \left[\frac{\ln(\kappa_g) - \ln\left(\psi_{fm}\lambda_j\right) - \mu_i}{\sigma_i} \right] \right) \\
+&\kappa_f \Phi \left[\frac{\mu_i - \ln(\kappa_f) + \ln\left(\psi_{fm}\lambda_j\right)}{\sigma_i} \right].
\end{aligned}
$$

$$
\begin{aligned}
&\mathrm{Var}[c^r_{ijm}] \\
=&\int_{-\infty}^{\frac{\kappa_g}{\psi_{fm}}}(\psi_{fm}\lambda_j c_i-\mathbb{E}[c^r_{ijm}])^2 f(c_i)dc_i+\int_{\frac{\kappa_g}{\psi_{fm}}}^{\frac{\kappa_f}{\psi_{fm}}}(\theta_g\psi_{fm}\lambda_j c_i+\kappa_g-\theta_g\kappa_g-\mathbb{E}[c^r_{ijm}])^2 f(c_i)dc_i \\
+&\int_{\frac{\kappa_f}{\psi_{fm}}}^{\infty}(\kappa_f-\mathbb{E}[c^r_{ijm}])^2 f(c_i)dc_i \\
=&\psi_{fm}^2\lambda_j^2\exp(2\mu_i+2\sigma_i^2)\Phi\left[\frac{\ln\kappa_g-\ln\left(\psi_{fm}\lambda_j\right)-\mu_i-2\sigma_i^2}{\sigma_i}\right] \\
+&\theta_g^2\psi_{fm}^2\lambda_j^2\exp(2\mu_i+2\sigma_i^2) \\
&\times\left(\Phi\left[\frac{\ln\kappa_f-\ln\left(\psi_{fm}\lambda_j\right)-\mu_i-2\sigma_i^2}{\sigma_i}\right]-\Phi\left[\frac{\ln\kappa_g-\ln\left(\psi_{fm}\lambda_j\right)-\mu_i-2\sigma_i^2}{\sigma_i}\right]\right) \\
-&2\psi_{fm}\lambda_j\bar{c}\exp(\mu_i+\frac{1}{2}\sigma_i^2)\Phi\left[\frac{\ln\kappa_g-\ln\left(\psi_{fm}\lambda_j\right)-\mu_i-\sigma_i^2}{\sigma_i}\right] \\
+&2\theta_g\psi_{fm}\lambda_j(\kappa_g-\theta_g\kappa_g-\bar{c})\exp(\mu_i+\frac{1}{2}\sigma_i^2) \\
&\times\left(\Phi\left[\frac{\ln\kappa_f-\ln\left(\psi_{fm}\lambda_j\right)-\mu_i-\sigma_i^2}{\sigma_i}\right]-\Phi\left[\frac{\ln\kappa_g-\ln\left(\psi_{fm}\lambda_j\right)-\mu_i-\sigma_i^2}{\sigma_i}\right]\right) \\
+&\mathbb{E}[c^r_{ijm}]^2\Phi\left[\frac{\ln(\kappa_g)-\ln\left(\psi_{fm}\lambda_j\right)-\mu_i}{\sigma_i}\right] \\
+&(\kappa_g-\theta_g\kappa_g-\mathbb{E}[c^r_{ijm}])^2\left(\Phi\left[\frac{\ln(\kappa_f)-\ln\left(\psi_{fm}\lambda_j\right)-\mu_i}{\sigma_i}]\right]-\Phi\left[\frac{\ln(\kappa_g)-\ln\left(\psi_{fm}\lambda_j\right)-\mu_i}{\sigma_i}\right]\right) \\
+&(\kappa_f-\mathbb{E}[c^r_{ijm}])^2\Phi\left[\frac{\mu_i-\ln(\kappa_f)+\ln\left(\psi_{fm}\lambda_j\right)}{\sigma_i}\right].
\end{aligned}
$$

The private reinsurance cost is

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

Taking expectations we have

$$
\begin{aligned}
\mathbb{E}[r_{ijm}]=&\theta_g\psi_{fm}\lambda_j\int_{\frac{\kappa_f}{\psi_{fm}}}^{\infty}c_i f(c_i)dc_i+(\kappa_g-\theta_g\kappa_g-\kappa_f)\int_{\frac{\kappa_f}{\psi_{fm}}}^{\infty}f(c_i)dc_i \\
=&\theta_g\psi_{fm}\lambda_j\exp(\mu_i+\frac{1}{2}\sigma_i^2)\Phi\left[\frac{-\ln\kappa_f+\ln\left(\psi_{fm}\lambda_j\right)+\mu_i+\sigma_i^2}{\sigma_i}\right] \\
&+(\kappa_g-\theta_g\kappa_g-\kappa_f)\Phi\left[\frac{\mu_i-\ln(\kappa_f)+\ln\left(\psi_{fm}\lambda_j\right)}{\sigma_i}\right].
\end{aligned}
$$

Government reinsurance expenditure is

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

Taking the expectations we have

$$\begin{aligned}
\mathbb{E}[g_{ijm}] = &(1-\theta_g)\psi_{fm}\lambda_j \int_{\frac{\kappa_g}{\psi_{fm}}}^{\infty} c_i f(c_i) dc_i + (\theta_g\kappa_g - \kappa_g) \int_{\frac{\kappa_g}{\psi_{fm}}}^{\infty} f(c_i) dc_i \\
=&(1-\theta_g)\psi_{fm}\lambda_j \exp(\mu_i + \frac{1}{2}\sigma_i^2)\Phi\left[\frac{-\ln\kappa_g + \ln\left(\psi_{fm}\lambda_j\right) + \mu_i + \sigma_i^2}{\sigma_i}\right] \\
&+(\theta_g\kappa_g - \kappa_g)\Phi\left[\frac{\mu_i - \ln(\kappa_g) + \ln\left(\psi_{fm}\lambda_j\right)}{\sigma_i}\right].
\end{aligned}$$