Reinsurance, Financial Frictions, and Subsidy Efficiency: Evidence from Health Insurance *

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Abstract

This paper studies the effects of insurers' financial frictions and their implications for subsidy design in the health insurance market. 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 financial frictions and lowering their extra risk charges. We show evidence of insurers internalizing financial frictions with their private reinsurance purchases. In response to public reinsurance subsidies, insurers purchase less private reinsurance and lower health insurance premiums, with an estimated pass-through of 1.3. We estimate an equilibrium model to decompose the pass-through into claims reduction, financial friction alleviation, and competitive effects. Simulations reveal supply-side reinsurance subsidies can be more efficient than demand-side premium subsidies in reducing equilibrium prices and enhancing market competition. Our results highlight the importance of addressing supply-side frictions to foster effective competition.

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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 present several 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 65% health insurers purchase private reinsurance coverage despite paying high markups of 1.66 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, using the individual-level medical claims panel from Colorado All Payer Claims Data (APCD), we demonstrate that the claims costs distribution has a long right tail. We use simulations to show that these tail-end risks expose insurers to a considerable probability of cost overrun. This inflates insurers' effective marginal costs as they need to incur additional capital costs to raise funds or purchase private reinsurance to transfer liabilities in the case of these tail-end adverse events.

Third, we conduct an event study exploiting the initiation of state-level public 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, by around 20% from the baseline. 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. Furthermore, insurers substitute away from purchasing private reinsurance in response to the public reinsurance subsidies. The extensive margin probability of purchasing reinsurance drop by 35% and intensive margin expenses on private reinsurance coverage drop by $25 per insured-year. Responses in premium and private reinsurance strategies are larger for insurers that are more financially constrained. 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 estimate price elasticities by health risks following the two-step estimator of Goolsbee and Petrin (2004). We estimate insurers' marginal costs and risk preferences using first-order conditions on pricing and private reinsurance purchases.

Model estimates reveal that insurers, on average, spend 2%-4% of their health insurance premiums to purchase private reinsurance. Their average risk charge, i.e., the additional costs due to risky enrollee portfolio that is factored into insurance prices, 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. Accounting for expenses on private reinsurance and risk charges, the total effective marginal costs for regional insurers that are more financially constrained is about 7% higher than those of less-constrained national insurers. Financial frictions thus hinder small insurers' ability to compete more effectively in prices.

We use the model and its estimates to analyze the effects of public reinsurance subsidies and examine optimal subsidy design under private reinsurance. Our simulation reveals that the public reinsurance subsidies reduce equilibrium prices by 20%, and private reinsurance expenses drop by $25 per insured. This is reassuringly consistent with reduced form estimates. The ratio of total price reduction over government reinsurance expenses is 1.2, which aligns with the greater than one pass-through result.

We decompose the price effects of public reinsurance into three channels: claims cost reduction, risk reduction, and competition effects. First, public reinsurance shares high-cost claims with insurers and lowers insurers' claims costs by 16% from the baseline, which in turn accounts for 74% of total price reduction. Second, public reinsurance shields insurers from tail-end risk, thus lowering the risk charge and private reinsurance expenses. As risk exposure makes insurers' effective marginal costs convex, risk reduction additionally accounts for 11% of total price reduction. The third channel is the competitive effect, i.e., alleviating the financial frictions of small regional insurers makes them more effective competitors, which pushes down equilibrium further by 15%. Hence, in addition to the conventional cost subsidy, risk reduction and competitive effects increase the efficiency of public reinsurance, making it possible to reduce expenditure in premiums by more than the government's expenditure in reinsurance payments. This analysis illustrates the effectiveness of alleviating financial frictions on the supply side.

We further examine the optimal degree of government risk-sharing when designing public reinsurance subsidies. The government trades off the cost of public funds versus the increased surplus of market participants: insurers benefit from reduced claims costs and risk-offloading, and consumers benefit from decreased prices and increased insurance participation. As the degree of reinsurance cost-share increases, the distortion from financial frictions is attenuated and gradually reduced to zero, but the harm from market power persists. Eventually, the net benefit of subsidizing the supply side, especially alleviating extra financial costs, will diminish to zero. We find that the optimal government cost-shares is about 40%, which is precisely the status quo reinsurance design in CO.

We finally compare the effectiveness of reinsurance and premium subsidies and explore optimal subsidy allocations. We find that reinsurance subsidies are more efficient under the current market conditions than premium subsidies, due to the existence of financial frictions. 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. We thereby highlight the importance of addressing supply-side frictions to foster effective competition.

The implications of financial frictions extend beyond health insurance. Government risk-sharing could be important in markets facing financial risks, such as floods, hurricanes, 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. Similar logic suggests that subsidizing the supply side in those markets may also be more effective in lowering premiums and increasing insurance takeup than subsidizing consumer purchases. The 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 faced by insurers. Recent work in life insurance (Koijen and Yogo, 2015, 2016) shows that life insurers pass financial frictions to the pricing of insurance contracts. Kim (2022) estimates a model of risk-averse health insurers to study risk-sharing policies in Medicare Part D, whose framework we build upon. More broadly, we build on the literature that examines how financial frictions from imperfect capital markets can induce risk aversion preferences (Masson, 1972; Froot and Stein, 1998; Hakansson, 1970). Our contribution is to document financial frictions for health insurers leveraging novel reinsurance purchase data and to analyze the implications of financial frictions for subsidy designs by modeling insurer risk preferences induced by financial frictions.

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 consider demand-side and supply-side subsidies in isolation, with few papers examining the relationship or trade-offs between them. The closest work is Einav et al. (2019), which compares premium subsidies and ex-ante risk adjustment transfers to insurers. In contrast, our paper compares premium subsidies and ex-post reinsurance payments to insurers, emphasizing how ex-post transfers differ from ex-ante transfers when insurers internalize the amount of risk they face.[1] We provide the first theoretical and empirical analysis of the efficiency of multiple policy instruments, explicitly accounting for the often-overlooked 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.

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

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 and statutory capital. Risk-based capital is the required capital for insurers to cover their liabilities and is usually set as an exogenous multiplier of the liabilities. The risk-based capital (RBC) ratio, calculated as the ratio of capital surplus, i.e., asset minus liabilities, to the required risk-based capital, indicates the solvency status of the insurer. NAIC scrutinizes companies with RBC ratios below 200% and takes various actions ranging from a company-level warning to full control of the company (NAIC, 2023b). Similarly, regulations exist on minimum statutory capital, measured by the amount of capital surplus the insurer has above the risk-based capital required.

Most health insurers' liability stems from their underwriting risk: their enrollees' claims cost. Their RBC ratio is an ex-post solvency measure of how much extra capital insurers have in relation to their claims liability. The 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 significant losses. Private reinsurance usually takes the form of "stop-loss" contracts, which aid primary insurers in stabilizing underwriting results and provide catastrophe protection (NAIC, 2023a). Figure 1a displays a stylized example of the division of medical claims payment between a primary health insurer and a third-party reinsurer.

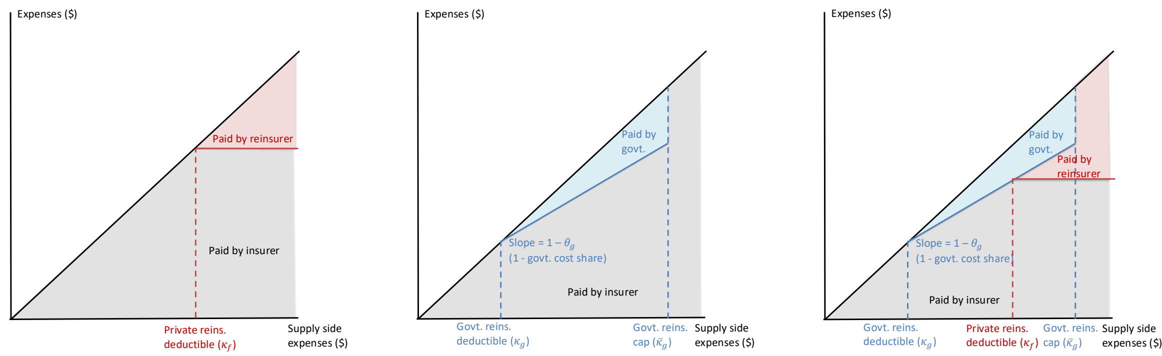
Each state oversees private reinsurance through the use of credit for reinsurance laws and regulations. Reinsurers must be either licensed, accredited, or trusted in a health insurer's state of domicile in order for the health insurer to take credit for the liabilities transferred to reinsurers. Historically, reinsurance policies have been widely used in property and casualty insurance, where primary insurers face the risk of a small probability of a catastrophic event. However, while health reinsurance still represents a small share of the overall reinsurance market, it has been experiencing notable growth in recent years.[2] In 2023, primary health insurers collectively ceded around 4% of their premiums to private reinsurance, reflecting an increasing reliance on reinsurance to manage financial risks in the health insurance sector (A.M. Best, 2024).

Despite growth in the health reinsurance market, the market for private reinsurance contracts sold to health insurers remains relatively concentrated. In 2023, the largest four (ten) reinsurers account for 63% (88%) of the total contracting amount. The mean (standard deviation) of the number of health insurers a reinsurer sells to annually is 3.6 (6.7).

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

Figure 1. Illustration of Reinsurance

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



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

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

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

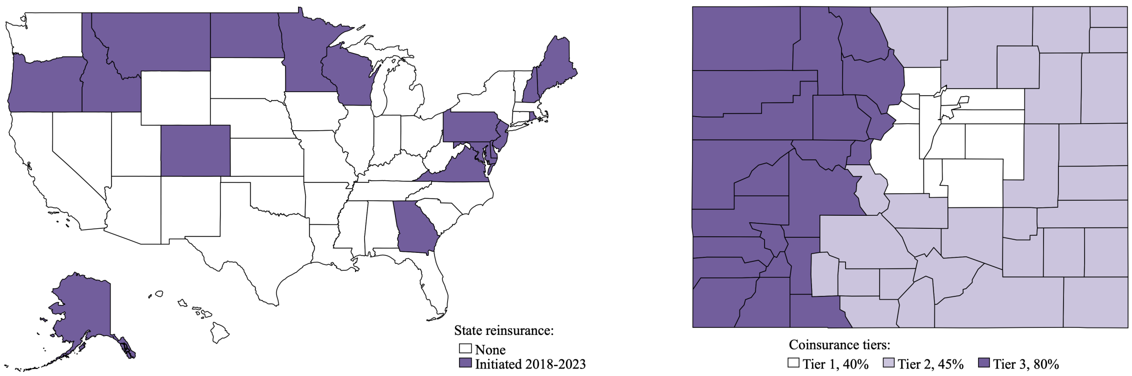
A federal reinsurance program was implemented in the exchange in 2014-2016. Since its discontinuation, 18 states initiated their own reinsurance programs as of 2023. Figure 2a depicts the geographic distribution of these state-run programs. These programs are structured similarly: when the insurer enrolls 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. Figure 1b displays a stylized example of the division of medical claims payment between a primary health insurer and the government as the reinsurer.

We examine state-run reinsurance programs in the exchange nationwide for motivating facts in Section 5, and in Colorado for structural exercises in Sections 6-8. 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 2b, 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 2. Public reinsurance programs

(a). State reinsurance programs, 2017-2023 (b). Reinsurance program in Colorado, 2020



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

2.2. *Data.*

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.[3] We collect Schedule S reports for all insurers in the life and health lines of business from 2014 to 2022. The data is at the unique reinsurance contract level and includes information on seller identity, buyer identity, contract effective date, reinsurance premiums, and realized reinsurance claims.

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

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

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

We supplement the enrollment records with uninsured counts from the Small Area Health Insurance Estimates (SAHIE) for 2015-2022. These model-based estimates from the Census Bureau provide information

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

on uninsured rates and counts by county, age, gender, and 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, and 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 the sample to individuals whose insurance coverage is the exchange or who are uninsured but eligible for the exchange.

3. Descriptive Patterns

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

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 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 partly be 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 with 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.

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.

3.2. Medical Claims Distributions Has a Long Right Tail.

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

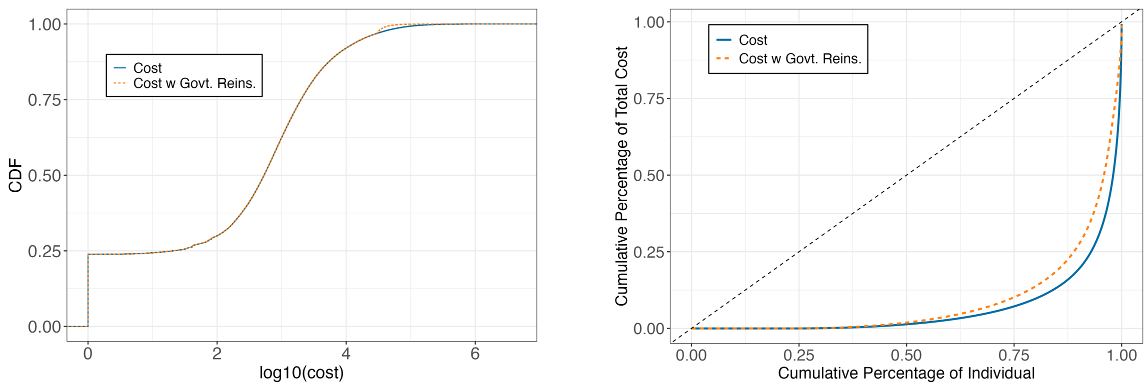
The CO exchange has about two hundred thousand enrollees annually. Both national and regional insurers operate on the CO exchange. The mean insured rate is 37%. An average of 4 insurers sell products per county. The average annual out-of-pocket premium after premium subsidy is $3,697, while the average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

Consumers' claims costs distribution has a long right tail. This can be seen from Figure 3, which plots the cumulative distribution and the Lorentz curve of the logarithm of consumers' claims costs. The top 5% (1%) of consumers account for 68% (38%) of total medical expenses. The large standard deviation and 99th percentile of total medical expenses in Table A3 also echoes this.

About 2.5% of consumers have their claims costs exceeding $30,000, the reinsurance threshold where the CO government starts to share costs with insurers. If the current reinsurance program had been in place throughout, 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'

Figure 3. Distribution of total medical expenses

(a). CDF of log claims cost (b). Lorentz curve of claims cost



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

expenses in scenarios with and without public reinsurance subsidies.

3.3. *Sources of Cost Fluctuations and Financial Risks.*

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

Tail-end risk is the uncertainty of extreme medical bills occurring at the end of a distribution of claims costs. It is particularly relevant for small insurers, even when consumer costs are independent. To illustrate how uncertainties in consumer cost draw affect insurers, Figure A1 simulates the probability that realized claims exceed a given percentage of expected costs as a function of enrollee size. Insurers need at least 100k consumers to mitigate tail-end risks. With only 1k enrollees, the probability that realized claims exceed 25% (5%) of expected claims is around 32% (7.4%). Even with 10k enrollees, there remains a 17% chance that claims exceed expected costs by 5%. Notably, 3 (7) out of 7 insurers in the CO exchange have fewer than 10k (100k) enrollees, exposing them all to tail-end cost fluctuations.

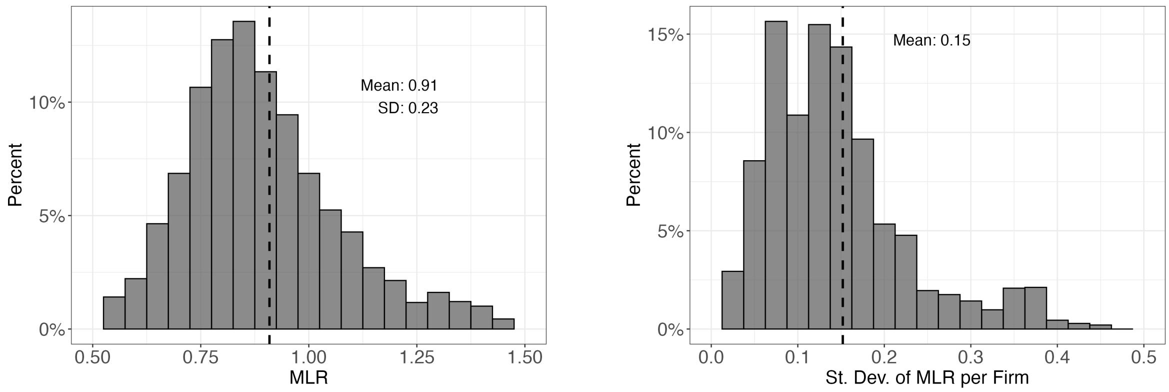
Since exchange insurers tend to be smaller and many do not operate in other markets, the probability that their claims exceed premium income is significant. This is evident in Figures 4a and 4b, which show a long-tailed empirical distribution of claims costs relative to premium income. Over 24% of insurer-year pairs have premiums that fall short of ex-post claims payments. The within-firm standard deviation of the claims-to-premium ratio is 0.16, indicating substantial uncertainty in aggregate costs.

Aggregate risk can arise when individual risks are correlated or when uncertainties in the cost distribution affect all enrollees. Examples include systematic shocks, such as a pandemic, or local health shocks, like flu breakouts. There are no evident systematic shocks impacting the exchange market during our sample period. Therefore, our main empirical model does not formally model correlated risks. In Appendix B2, we explore both sources of financial risk and discuss how systematic cost shocks could be incorporated.

Either tail-end or aggregate risks can lead to cost fluctuations, causing adverse shocks to insurers' capital reserves. In response, insurers must raise or borrow additional capital (Masson, 1972) or purchase additional reinsurance policies to transfer liabilities (Koijen and Yogo, 2015), both of which can be costly due to capital

Figure 4. Illustration of cost-fluctuations

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



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

market imperfections or the concentrated private reinsurance market. We refer to these added capital costs driven by cost fluctuations as "financial frictions".

4. 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 monopoly insurer that behaves "as if risk averse" (Froot and Stein, 1998). The insurer 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 $\tilde{c}_i^t \sim F_t$, $\tilde{c}_i^t \in [0, \infty)$. 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 individual types.

The monopoly insurer maximizes the following mean-variance objective function, where it trades off expected profit and risk, measured by the variance of claim costs.

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

Here, we model insurers' induced risk aversion in a reduced-form way using a mean-variance utility. This approach allows us to flexibly account for potential frictions without specifying a particular financial or regulatory mechanism. The mean-variance utility is also equivalent to maximizing expected utility under an exponential utility function and normally distributed aggregate costs (Kim, 2022). Although higher-order moments of the distribution could be considered, we focus on the second-order moment for computational tractability in our empirical model.

We model the insurer's induced 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 induced risk aversion parameter where the insurer faces a CARA utility function. Given the above objective, the insurer's first-order condition is

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

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).

4.1. 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. So, the amount of reinsurance is decreasing in θ, where $\theta = 0$ implies full government reinsurance, and $\theta = \infty$ implies no government reinsurance. Given such a reinsurance scheme, the insurer's ex-post cost for an individual i will be

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

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

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

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 deductible level θ, $p^*(\theta) < p_0^*$.[4]

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 $r_t(\theta) = c_t(\infty) - c_t(\theta)$. Then, the total expected

[4]The optimal price without any reinsurance, p_0^*, is equivalent to optimal price where the reinsurance deductible is infinite, $p^*(\infty)$.

reinsurance expenditure, as well as the average expected reinsurance cost per consumer, are

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

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 (Miravete et al., 2018; Weyl and Fabinger, 2013). 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.

4.2. 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.

5. Effect of Public Reinsurance Subsidies

5.1. 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. Using an event study framework, we examine the effect of public reinsurance subsidies on insurers' pricing strategies and private reinsurance purchasing behaviors.

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

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

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

To explore the variation in the intensity of Colorado's reinsurance program, as shown in Figure 2b, we examine its heterogeneous impacts on premiums across the state's three reinsurance tier regions. Using an event-study framework similar to that in (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.

5.1.1. Reduced Health Insurance Premium, with Greater Than One Pass-Through. We begin by analyzing how public reinsurance affects insurers' pricing strategies. Figure 5a shows a large and statistically significant impact of public reinsurance on premiums. The lack of pre-trends suggests that these premium decreases are unlikely due to any heterogeneous changes occurring in states with public reinsurance. Pooling post-period coefficients from equation (6), we find that the initiation of public reinsurance programs lowers premiums by around 13.7%, as is reported in Table 2 column (1).

Figure 5b presents the results of Colorado's reinsurance program, showing heterogeneous impacts across the state's reinsurance tiers. The program significantly reduced premiums, with around a 27% decrease in Tiers 1 and 2 and a 46% decrease in Tier 3, which received a particularly high level of reinsurance. We report equivalent post-period coefficients in Table A6. These reductions align with or slightly exceed the regulator's targets of lowering premiums by 18-25%, 25-30%, and 38-44% in Tiers 1, 2, and 3, respectively (Colorado Department of Regulatory Agency, 2020).[6]

Using ex-post government expenditures, the premium expenses in the baseline year, and our event-study estimates, we calculate a back-of-the-envelope pass-through rate of 1.34. The p-value is 0.037 of a one-sided t-test on whether this estimated pass-through is greater than 1. For every \$1 the Colorado government spends on reinsurance, expenses on health insurance premiums drop by \$1.34. This contrasts the typical pass-through rate of less than one in an imperfectly competitive market (Cabral et al., 2018). Given that firms likely have some degree of market power in this market, this finding aligns with our theoretical model, suggesting that insurers face financial frictions.

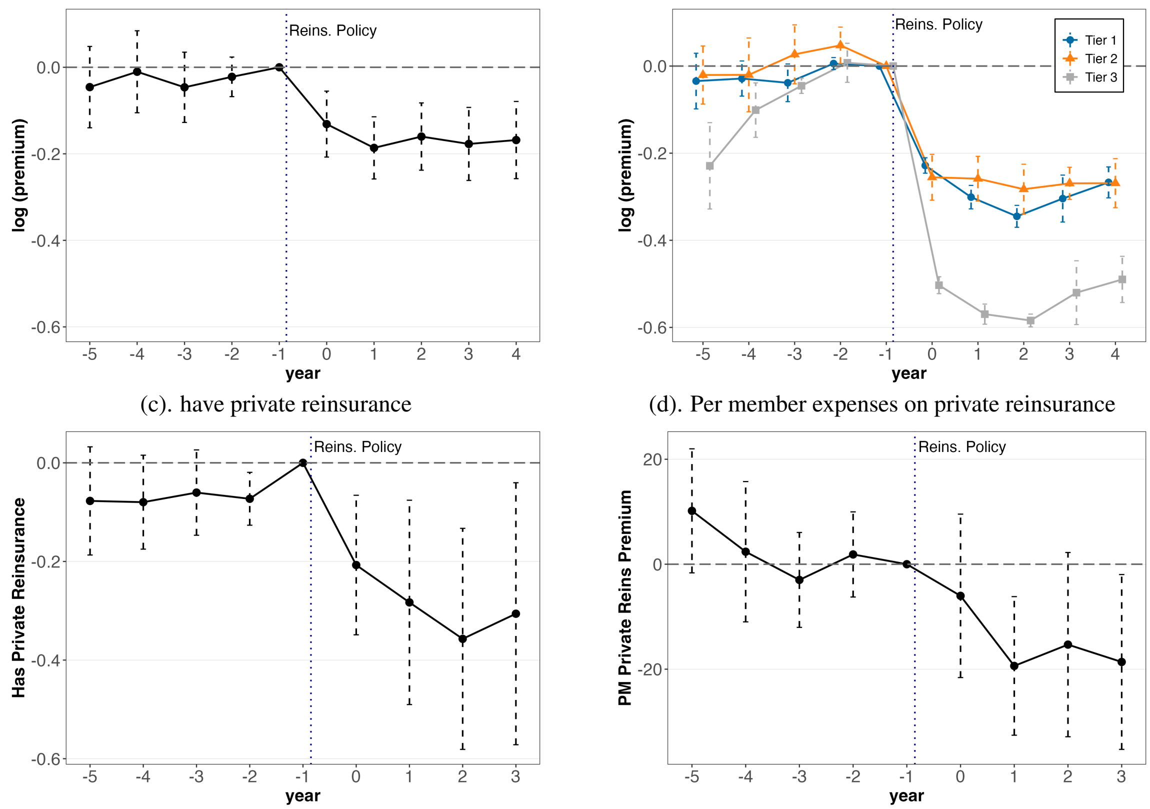
[5]The CMS HIOS issuer, i.e., firm units in premium records, and the NAIC companies, i.e., firm units in reinsurance purchasing records, do not match one-to-one. We restrict the main specification to insurers with those two records that match exactly, covering 67% of all exchange HIOS issuers. We rerun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

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

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

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

(c). have private reinsurance (d). Per member expenses on private reinsurance



Notes: This figure reports point estimates and 95% confidence interval of the effect of state reinsurance from the estimation of equation (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 with positive health premium income and offering products on the individual exchange market. Panel (a), (c), and (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 without 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. We do not analyze the CO-specific impact on reinsurance purchases and expenses due to a limited number of observations, which restricts the power of our analysis.

5.1.2. 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 for each enrollee.[7]

Figures 5c and 5d 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

[7]We do not estimate the private reinsurance regression with CO as the only treatment state because such state-year level analysis is underpowered. In contrast, regressions with premiums as outcomes are at the more granular insurer-rating region level, facilitating such exercise.

coefficients from equation (6), Table 2 indicates that public reinsurance programs reduce the probability of purchasing private reinsurance by 38%, a 60% decrease from the baseline, and lower average per-member expenses on private reinsurance by $25, a 65% decrease from the baseline.

5.1.3. Larger Responses from Financially-Constrained Insurers. We further examine whether insurers' responses to public reinsurance differ by the degree of financial constraints. We interact the event dummies in equation (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,[8] along with a measure of whether the insurer incurs significant private reinsurance expenses. Insurer's financial characteristics are assessed based on the year preceding the implementation of the given state's reinsurance policy.

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

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
		logarithm of premiums		Probability of purchasing private reinsurance		Per member reinsurance expenses	
reinsurance policy	-0.137^{***}	-0.135^{***}	-0.134^{***}	-0.383^{***}	-0.351^{**}	-24.9^{***}	-15.0^{*}
	(0.038)	(0.037)	(0.04)	(0.110)	(0.132)	(9.0)	(7.6)
reinsurance policy × RBC ratio below 3		-0.161^{***}			-0.250		-77.5^{*}
		(0.050)			(0.260)		(40.2)
reinsurance policy × significant private reins.			-0.207^{***}				
			(0.041)				
N	17,307	16,112	16,253	1,525	1,525	1,508	1,508
Baseline mean	634	634	634	0.634	0.634	36.7	36.7
Share of insurers w. RBC below 3		0.102			0.15		0.148
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 with positive health premium income and offering products on the individual exchange market. The regression is at the insurer-rating region-year level in 2014-2024 for Columns (1)-(3) and the insurer-state-year level in 2014-2022 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.

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

5.1.4. Robustness. Table A4 probes the robustness of our findings. First, our results hold across different outcome measures, including benchmark premiums for the rating region and average premiums of Silver

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

plans. Second, our estimates remain robust when aggregating at different insurer levels or running regressions at the market-year level. Third, our estimates are robust to corrections for staggered treatments in difference-in-differences designs, such as those proposed by Callaway and Sant'Anna (2021) and Borusyak et al. (2024).

5.2. Additional Analysis.

5.2.1. 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 market entry with public reinsurance. Given these findings, we hold the market structure fixed and do not directly model insurer entry/exit decisions in the main empirical model in Section 6.

5.2.2. Effects on Private Reinsurance Markup. We investigate whether the provision of public reinsurance affects the upstream private reinsurance market. On the one hand, Section 5.1.2 shows that health insurers substitute between public and private reinsurance. Public reinsurance subsidies could make private reinsurance demand more elastic, potentially lowering the markup on private reinsurance contracts. On the other hand, 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.

Given 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 6. However, we perform sensitivity analyses in Section 8 to assess how varying degrees of private market responses to public reinsurance subsidies might affect welfare predictions.

5.2.3. 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. Suppose insurers respond to the government's risk-sharing policies with fewer cost-containment activities, such as performing less prior authorization or exerting less effort to bargain with medical providers. In that case, we expect the medical claims to increase.

Employing detailed claims records from CO APCD, we use two empirical designs[9] to investigate the effect of public reinsurance subsidies on the realized medical costs before reinsurance payments. The first

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

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 2b. 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 exceed 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 6,[10] and perform sensitivity analyses on how differential degrees of insurer moral hazard might affect welfare predictions in Section 8.

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

5.2.4. Evidence of Adverse Selection. We finally examine whether the impact of public reinsurance subsidies varies across different types of insurance products in different actuarial values to provide suggestive evidence for adverse selection in our sample. Adverse selection is a well-documented phenomenon in the individual health insurance market (Einav and Finkelstein, 2011; Saltzman, 2021).[11]

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

[10] 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.

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

5.3. *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.

Although the reduced-form analysis proves the existence of financial frictions, it leaves several questions open. First, the magnitude of the underlying mechanisms is unclear. To disentangle how marginal cost reductions and risk charge reductions separately contribute to changes in insurers' strategies, we need to formally model how insurers respond to the differential riskiness of their portfolios. Second, the welfare and policy implications of financial frictions remain unanswered. To further examine optimal subsidy allocation in this context and explore how consumers in different demographics benefit differentially from reinsurance subsidies, we need to use a structural model to empirically quantify the degree of financial frictions, adverse selection, and market power.

6. Empirical Model of Premiums and Reinsurance Purchase

The previous section confirms the existence of financial frictions and shows insurers' response 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 subsidy designs.

Consumers of different ages and with varying health risks choose insurance products based on heterogeneous preferences for premiums. Insurers simultaneously choose premiums for products at the county level and private reinsurance coverage at the state level, considering the uncertain realization of claims costs. Every period, insurers move first to set prices; consumers then make product choices. We are interested in the Nash Equilibrium of the game.

6.1. *Consumer Choices.*

Let f denote insurers, m denote counties, t denote years, $j \in J_f$ denote products of f. We divide consumers into 12 bins based on age (below 18, 18-34, 34-54, and above 55) and risk bin (four risk quartiles predicted using previous years' claims). We assume consumers in the same age-risk type have the same preference for insurance products and have their health risks drawn from the same distribution.

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

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

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

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, $u_{i0mt} = \epsilon_{i0mt}$.

Insurers' expected premium income $\Pi_{ft}(\vec{p}_t)$, is the sum of revenue income across markets and consumer types, which equals the price of each specific product for a particular consumer type $p_{jt}\iota_\theta$, times the market share of product j among consumers of type i in market mt, s_{ijmt}.[12]

6.2. Insurers' Strategies.

We first describe insurers' cost components and then discuss insurers' optimal strategies for pricing and private reinsurance deductibles. Insurers' total effective marginal costs is a sum of claims costs paid by insurers C_{ft}, reinsurance costs R_{ft}, and financial costs L_{ft}.

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 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 $c_{ijmt} \sim N(\mu_i + \log(\psi_{fmt}\lambda_j), \sigma_i^2)$.

Regardless of whether public reinsurance is available, 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. We model private reinsurance as a stop-loss contract, the most prevalent contract type observed in reality. The ductible κ_{ft} of the contract 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, $c_{ijmt} - \kappa_{ft}$. Summing across all insured individuals gives us the total claims expenses of the insurer C_{ft}. See Figure 1a for an illustration of cost shares between parties, and Appendix C for detailed derivations and expressions.

We assume insurers can buy private reinsurance policies at some exogenous markup of $\tau_f \geq 1$ above the actuarial value. The actuarial value of reinsurance policies with deductible κ_{ft}, namely, the expected cost of reinsurance per insured, is $\mathbb{E}[r_{ijmt}(\kappa_{ft})] = \mathbb{E}[(c_{ijmt} - \kappa_{ft})\mathbf{1}[c_{ijmt} \geq \kappa_{ft}]]$. Appendix C2 contains the

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

detailed expression for R_{ft}, which aggregates expenses of private reinsurance across all insured consumers.

Our framework also allows for public reinsurance. 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 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 κ_{ft},[13] 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, we assume that government reimbursement comes in first and the remainder part is filled in by private reinsurance contracts. Namely the insurer pays κ_{ft}, the government pays $(1 - \theta_g)(c_{ijmt} - \kappa_g)$, and the private reinsurer pays $\theta_g(c_{ijmt} - \kappa_g) - \kappa_{ft}$. See Figure 1c for an illustration of cost shares between parties. Derivations for C_{ft}, R_{ft} in this scenario can be found in Appendix C3.

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

$$L_{ft}(\vec{p}_t) = \rho_f \text{Var}[C_{ft}], \tag{12}$$

where ρ_f is an insurer-specific risk-aversion parameter constant over time. The loss function terms capture insurers' induced risk aversion. Like the theoretical model in Section 4, the mean-variance utility is a reduced-form way of modeling financial friction, allowing us to flexibly account for potential frictions without specifying a particular financial or regulatory mechanism. The mean-variance utility is also equivalent to maximizing expected utility under an exponential utility function and normally distributed aggregate costs (Kim, 2022). Although higher-order moments of the distribution could be considered, we focus on the second-order moment for computational tractability.

Putting together premium revenue, claims costs, reinsurance costs, and financial costs, insurer f in year t chooses a price vector $\vec{p}_{ft}$ across markets and a scalar of private reinsurance deductible κ_{ft} to maximize the following objective functions

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

Equation (14) writes out insurers' first-order condition of prices. In addition to the conventional marginal revenue and marginal cost terms, we see two extra terms: marginal reinsurance expenses and marginal risk charge. These are the extra costs induced by financial frictions.

$$\underbrace{p_{jmt} + \frac{Q(\vec{p}_t)}{Q'(\vec{p}_t)}}_{\text{marginal revenue}} = \underbrace{\frac{\partial E[C_{ft}]}{\partial p_{jmt}}}_{\text{marginal claims costs}} + \underbrace{\frac{\partial \tau E[R_{ft}]}{\partial p_{jmt}}}_{\text{marginal reins. costs}} + \underbrace{\frac{\partial \rho_f \text{Var}[C_{ft}]}{\partial p_{jmt}}}_{\text{marginal risk charge}} \tag{14}$$

Equation (15) displays insurers' first-order condition of private reinsurance coverages. The insurer trades off for one more unit of private reinsurance coverage, the increased costs of private reinsurance, and the

[13] In our empirical setting, it is always the case that $\kappa_{ft} < \kappa_g$, i.e., the threshold that the public reinsurance starts to reimburse insurers are lower than the private reinsurance deductible. We analyze the opposite case in Appendix C3.

decreased claims and financial costs.

$$\underbrace{-\tau\frac{\partial E[R_{ft}]}{\partial\kappa_{ft}}}_{\text{reins. expenses}} = \underbrace{\frac{\partial E[C_{ft}]}{\partial\kappa_{ft}}}_{\text{claims reduction}} + \underbrace{\frac{\partial\rho_f \mathrm{Var}[C_{ft}]}{\partial\kappa_{ft}}}_{\text{risk charge reduction}} \tag{15}$$

7. Estimation and Identification

7.1. Consumer Primitives.

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

$$u_{ijmt} = \delta_{\theta jmt} - (\alpha_r + \nu_i)(p_{jmt}\iota_\theta - subsidy_{\theta jmt}) + \epsilon_{ijmt}, \tag{16}$$

$$\delta_{\theta jmt} = \alpha_\theta(p_{jmt}\iota_\theta - subsidy_{\theta jmt}) + \beta_\theta X_{jmt} + \xi_{jmt} + \xi_{\theta mt} + \xi_{\theta jmt}. \tag{17}$$

The first step uses the individual-year panel of enrollment records to recover preference heterogeneity and uses aggregate market shares to pin down common utility terms. It is a constrained maximum likelihood estimation with parameters outlined in equation (16): 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 that 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 the 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 (17), 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.

7.1.2. Identification. 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(county-year)-product (insurer-metal) fixed effects ξ_{jmt}.

7.1.3. Results. Table A8 reports consumer preference estimates. These estimates imply that the average enrollment-weighted own-premium semi-elasticity (elasticity) is -4.37 (-7.63) in the Colorado exchange, similar to -3.2 to -4.5 (Geddes, 2022), -5.2 (Drake, 2019), -5.5 (Li, 2024), and -7.2 (Saltzman, 2019) for the Oregon, California, Utah, and Washington exchange.

Table 3 panel (a) reports the average own-premium semi-elasticity for each age-risk bin. Figure A5 displays the distribution of estimated elasticities by consumer types. Our estimates confirm adverse selection:

Elderly consumers, or those in risk bin 4 who are relatively sicker, are less price elastic than young consumers or those in risk bin 1 who are relatively healthier. Panel (b) reports the extensive margin sensitivity, measured as the percentage drop in the probability of purchasing marketplace coverage if annual posted prices of all products increase by \$100. Such price increases would reduce the insured rate by 4.7% for the Colorado exchange, consistent with 4% (Tebaldi, 2017) of the California exchange.

Table 3. Derived demand elasticities by consumer types

	Risk bin 1	Risk bin 2	Risk bin 3	Risk bin 4
(a). Semi-elasticity to own premiums				
Age below 34	-7.80	-7.36	-6.26	-6.55
Age 35-54	-4.72	-4.37	-3.55	-3.76
Age above 55	-2.22	-1.99	-1.47	-1.60
(b). Drop in insured rate if all annual posted prices increase by \$100				
Age below 34	5.09%	5.94%	6.77%	6.74%
Age 35-54	4.15%	4.68%	4.55%	4.78%
Age above 55	3.65%	3.41%	2.03%	2.37%

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

7.2. Insurer Primitives.

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

7.2.1. Calibration and Estimation. We calibrate the baseline health risk parameters from CO APCD. We use log-normals to approximate the distribution of realized health risks. Corresponding parameters, i.e. mean and variance, μ_i, σ_i^2, are reported in Table A7. Figure A4 shows our parameterized distribution aligns well with the realized data. We then use an insurer-product specific multiplier ψ_{fm} to transform the health risks distribution into claims costs distribution.

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

We estimate the remaining supply-side parameters, marginal cost multiplier ψ_{fmt}, and risk preference parameter ρ_f with a generalized method of moments estimator. The moments are insurers' first-order conditions of health insurance prices (equation (14)) and how much private reinsurance to purchase (equation (14)). Note that we do not observe the deductible of each private reinsurance contract; instead, we observe private reinsurance premiums. To address this issue, we exploit the one-to-one mapping between coverage levels and premiums of private reinsurance given the stop-loss contract design. We thus add a moment that matches model-implied reinsurance premium to that of observed data:

$$\sum_{i,m,j\in J_{fm}} \Bigg(\underbrace{\tau}_{\text{markup of reins.}} \underbrace{E[c_{ijm} - c^r_{ijm} | (\kappa_f, \kappa_g, \theta_g)]}_{\text{AV of reins.}} \Bigg) D_{ijm} = \underbrace{R^{\text{obs}}_{ft}}_{\text{observed reinsurance expense}} , \quad (18)$$

where c^r_{ijm} is the insurers' share of claims expenses under private reinsurance deductible κ_f and government reinsurance deductible and cost shares κ_g, θ_g.

7.2.2. Identification. The correlation between aggregate cost variance and private reinsurance coverage primarily identifies risk preferences ρ_{ft}. Intuitively, the magnitude of the associated increase in private reinsurance purchase pins down the degree of financial friction for a given amount of cost variance increase.

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

7.2.3. Results. Table A9 reports the marginal cost multiplier within each insurer. Figure A6 plots the estimated marginal cost distribution by insurers. Overall, insurer-specific medical expenses are 1.788 times the baseline health risks. This could be because consumers on the Colorado exchange are less healthy than the average consumer statewide, or insurers in the exchange have a disadvantaged bargaining position. It can also be explained by the fact that our estimated marginal costs of a specific product include both claims payments to providers and plan administrative costs.

Marginal cost multipliers vary across insurers and markets. National insurers, on average, have lower marginal costs than regional insurers for individuals of the same risk types. Marginal costs in the Denver metropolitan areas (the tier 1 reinsurance policy regions) are lower than those in the mountain areas (the remaining policy regions).

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

Table 4. Estimates of private reinsurance deductible and risk preferences

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

Notes: This table reports insurers' estimated private reinsurance deductible and risk preferences in 2019. We assume private reinsurance is in a stop-loss format, and the deductible reported is in millions. Columns (1)-(2) are parameter estimates; Column (3) is observed data; and Columns (4)-(9) are derived statistics. The averages reported are enrollment-weighted. The reinsurance deductible in Column (1) is reported in millions.

Table 4 Columns (1)-(2) report estimated private reinsurance coverage thresholds and risk preferences parameters for each insurer. The monotone mapping between private reinsurance purchases and risk preferences implies that those without private reinsurance behave as risk-neutral, i.e., have an estimated risk preference of zero. Those with positive private reinsurance purchases behave as risk-averse, i.e., have a positive risk preference and risk charge terms. Regional insurers are estimated to behave more risk-averse than national insurers. This is expected, as national insurers tend to have more access to financial capital and lower capital costs. This lowers their need for extra risk charges to shield themselves from tail-end risks.

Column (5) displays corresponding private reinsurance expenses per insured, which match the observed records precisely as required by the moment conditions. Most large national insurers do not purchase private reinsurance, whereas regional insurers, Friday, Elevate, and Bright, spend $173 per insured for reinsurance coverage. This is equivalent to 2.7% of the revenue income of their health insurance products.

We further compute the model-implied per-member risk charge in Column (6). While national insurers' risk charges are close to zero, average risk charges for regional insurers are $219 per member or 3.3% of their health insurance premium. This is consistent with actuarial documents that insurers' risk charges are usually 2-4% of their premiums (Kim, 2022).

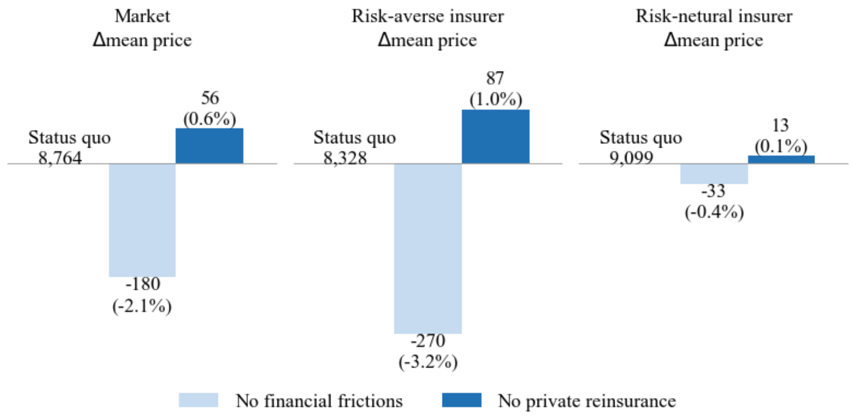
7.2.4. Implications of Financial Frictions. Summing up reinsurance expenses and risk charges in Table 4, our estimates imply that risk-averse regional insurers have an average 6% higher cost than risk-neutral national insurers. Financial frictions make small insurers incur risk charges and extra expenses on private reinsurance purchases, inflating their total costs. These additional costs are passed through to prices, hindering the small players' ability to compete effectively with large insurers.

To further quantify how financial frictions affect equilibrium prices, we simulate the equilibrium, taking medical claims as the only cost component. Namely, we shut down the private reinsurance markets and assume every insurer is risk-neutral without incurring risk charges. The light bar in Figure 6 reports how equilibrium prices change relative to the status quo. Removing financial frictions lowers total costs for the originally risk-averse insurers by 3.5%, leading to a 3.2% reduction in their prices, or $270 per consumer. The competitive effects also reduce the prices for the originally risk-neutral insurers by 0.4%. Taken together, when there are no financial frictions, the mean market price drops by 2.1%, or $180 per consumer.

We proceed to examine the roles of private reinsurance in the presence of financial frictions. To do so, we simulate a scenario where we shut down the private reinsurance market but keep the degree of financial friction the same as the status quo. The dark bar in Figure 6 shows the re-simulated equilibrium. Insurers save on their expenses to purchase reinsurance coverage but, in the meantime, lose access to offload their risks to a third party and need to raise risk charges. The latter effect dominates the former, resulting in risk-averse insurers raising their prices by 1%, or $87 per consumer-year. This loosens competitive pressure for risk-neutral insurers, allowing them to increase their price by 0.1%. The average premium on the market rises by 0.6%, or $56 per insured. This indicates that the availability of the private reinsurance market could benefit consumers with the risk-offloading mechanism, both lowering financial costs for small regional insurers and also making them more effective competitors.

In addition, Figure A7 investigates how upstream reinsurance markets' pricing power affects the downstream health insurance pricing. We re-simulate the equilibrium under different private reinsurance markups. Risk-averse insurers purchase more and obtain more effective risk offloading as reinsurance becomes cheaper. The consequent decrease in claims costs and risk charges outweighs the increased expenses of reinsurance

Figure 6. Effects of financial frictions on equilibrium prices



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

coverage. If private reinsurers are subject to a regulated margin of 20%, risk-averse insurers' expenses on private reinsurance would increase by \$161 per enrollee, while their claims expenses and risk charges would decrease by \$172 and \$44, respectively. Consumers face a 0.5% lower health insurance price in the re-simulated equilibrium than the status quo.

8. 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. 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.

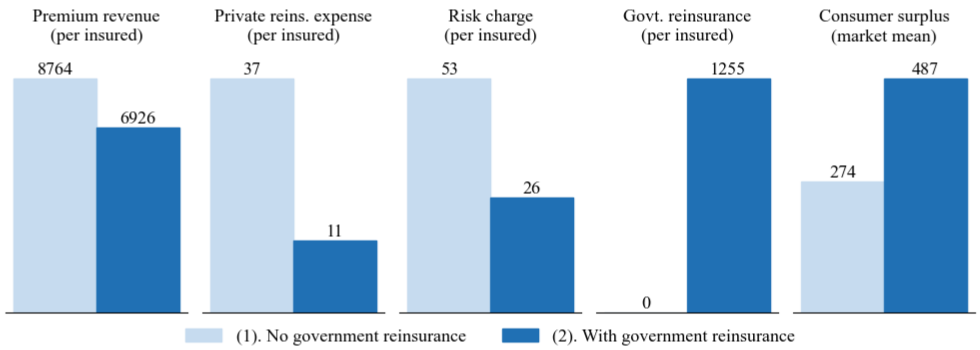
8.1. Equilibrium Effect of Public Reinsurance Subsidies

8.1.1. Simulated policy impacts. We first simulate the effects of Colorado's reinsurance policies on consumer choices, insurers' pricing and private reinsurance purchase decisions, and consumer welfare. Figure 7 reports key simulated outcomes before and after the reinsurance programs, using market primitives in 2019. Table A10 reports all equilibrium objects. The main text focuses on the markets in tier 1 reinsurance (i.e., the white areas in Figure 2b), the most populous regions in CO where most risk-averse insurers operate. The effects of markets in other policy tiers are reported in Table A10.

The reinsurance program lowers premiums by \$1835 per consumer, a 20% decrease from the baseline. This simulated price decrease aligns well with reduced form estimates in Figure 5b and Table A6 that CO reinsurance program results in a 27.6% drop in premiums. The government spends an average of \$1255 per insured to share high-cost claims with insurers. The simulated pass-through is 1.2 in markets across all policy tiers, consistent with greater-than-one pass-through estimates in Section 5.1.1.

As public reinsurance lowers not only averages but also variances of claims expenses, insurers reduce their risk charge and substitute away from private options to public options for risk-offloading — the ex-

Figure 7. Effect of public reinsurance subsidies



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

penses on private reinsurance decrease from \$37 to \$11 per enrollee.[14] The simulated strategy in private reinsurance reassuringly aligns with reduced form estimates in Figure 5d: initiating public reinsurance, on average, reduces insurers' private reinsurance expenses by \$25 per member. If we instead focus on risk-averse insurers, the reduction in private reinsurance expenses changes from \$84 to \$26 per enrollee, and risk charges decrease from \$121 to \$61 per enrollee. The combined effects of claims reduction, risk reduction, and expanded enrollment make insurers' profits rise by 44 million.

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

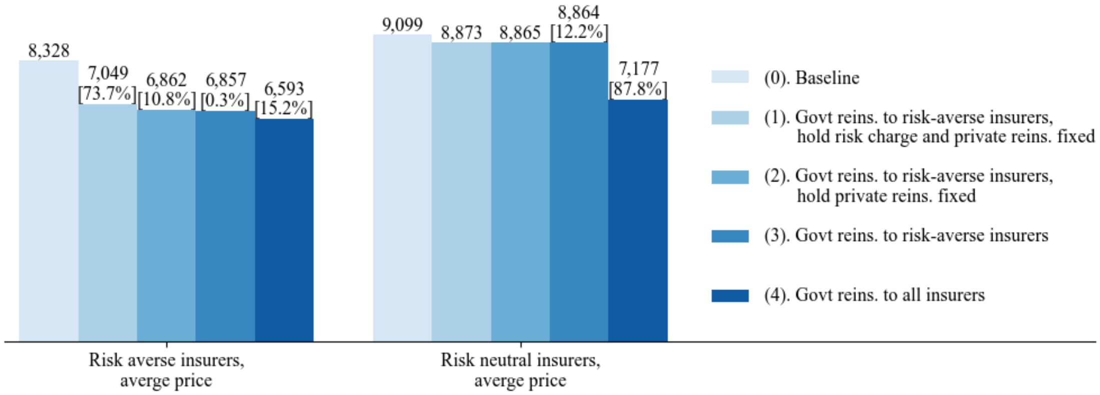
We find public reinsurance generates social surplus gains, assuming equal weights on consumer surplus, insurer profits, reinsurer profits, and government expenses. This net gain mostly comes from market expansion: as public reinsurance shifts down effective marginal cost curves, more consumers enroll in insurance and extract gains from trade.

8.1.2. Decompose Price Reduction. Public reinsurance brings down equilibrium prices through several components. The first is cost reduction, as public reinsurance directly subsidizes insurers for the claims costs incurred. The second is risk reduction, which shields insurers from tail-end risk, thus lowering the risk charge and private reinsurance expenses. The third is the competitive effect, i.e., alleviating the financial frictions of risk-averse insurers makes them more effective competitors, which puts downward pressure on equilibrium prices. We design several counterfactuals to disentangle the roles of the above economic forces.

Figure 8 reports resimulated premiums under each counterfactual equilibrium. Table A11 reports the complete set of equilibrium statistics, including cost components and welfare changes. The first counterfactual, denoted by (0), corresponds to the case where no policy exists. The remaining counterfactuals apply public reinsurance sequentially to risk-averse and risk-neutral insurers to separately quantify the cost reduction effect, which applies to all insurers, and the risk reduction effect, which applies only to risk-averse

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

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



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

insurers.

Our counterfactual (1) isolates public reinsurance's effect on risk-averse insurers' expected claims. We compare the no-intervention benchmark with a situation in which the reinsurance policy affects *only expected claims costs of risk-averse insurers*, but not the reinsurance costs or risk charges in insurers' profit functions, nor the claims costs of risk-neutral insurers. We allow insurers to *optimally choose prices* but not private reinsurance purchases in response to this interim profit function. Reinsurance subsidies lower the expected claims costs paid by risk-averse insurers by $1,224 per member. Moving from counterfactual (0) to (1), risk-averse insurers lower their premium by $1,279, which accounts for 73.7% of the premium decreases of risk-averse insurers.

We then compute counterfactual (2), quantifying how public reinsurance lowers prices through alleviating financial frictions. We simulate a scenario where public reinsurance affects *all costs components of risk-averse insurers*, including expected claims costs, private reinsurance expenses, and risk charges terms. We allow insurers to respond by *only changing price* but not private reinsurance deductibles. Government risk-sharing lowers the probability that an enrollee's expenditure exceeds a given reinsurance reimbursement threshold, making insuring the tail risks cheaper in the private reinsurance market. This leads to a $23 reduction in private reinsurance expenses. Furthermore, by reimbursing the tail risks of claims costs, the variance of total claims costs also drops, leading to a $66 reduction in risk charge. Together, these forces lead to an extra 10.8% of premium reduction of risk-averse insurers, or $187 per insured. 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 $38.

We next compute counterfactual (3), measuring how adjustments in private reinsurance expenses from alleviated financial frictions affect prices. We simulate a scenario where public reinsurance affects *all cost components of risk-averse insurers*, and we allow insurers to *choose both price and private reinsurance purchases* in response optimally. Since public reinsurance subsidies reduce insurers' need for using the private option to stabilize their risk profiles, expenses on private reinsurance further drop by $32 per consumer from counterfactual (2) to (3). However, substituting away from private coverage also leads to an offsetting effect, where per-member claims costs and risk charges rise slightly by \$19 and \$9 due to reduced risk-offloading. The net effect of drops in private reinsurance expenditure and rises in claims costs and risk charges together reduces premiums by \$4 per consumer, or 0.3% for the risk-averse insurers.

Notably, even if they do not receive any reinsurance subsidies, the premium of risk-neutral insurers drops by 12.2% from the baseline by the end of the scenario (3). This result highlights how public reinsurance intensifies competition by lowering the costs of risk-averse insurers.

Finally, we compute counterfactual (4) to shed light on competitive effects. This scenario corresponds to the equilibrium model in Section 6, where the reinsurance policy affects cost components of *all insurers*, and insurers choose both price and private reinsurance purchases in response optimally. The difference between counterfactual (3) and (4) highlights the effect of public reinsurance on expected claims of risk-neutral insurers. Similar to the change from counterfactual (0) to (1), public reinsurance reduces average claims expenses by \$1,570 per member for risk-neutral insurers. Consequently, risk-neutral insurers lower prices by \$1,687 per insured, which accounts for 87.8% of their premium decreases. The intensified competition, in turn, pushes down prices of risk-averse insurers by \$2,64, accounting for 15.2% of premium decreases.

To sum up, this decomposition exercise suggests that, upon the initiation of public reinsurance subsidies, claims costs reduction, risk reduction, and competitive effects each account for 73.7%, 11.1%, and 15.2% of price decreases for risk-averse insurers. The first and last effects explain 87.8% and 12.2% of price reduction for risk-neutral insurers. Our results indicate that financial frictions can be an essential distortion driving up premiums for small players in the healthcare market. Addressing supply-side frictions could be an effective way to foster competition and provide affordable insurance to consumers.

8.1.3. Distributional Analysis. We examine consumer surplus gains from public reinsurance by age group in Table A12. The deductible cutoff in public reinsurance subsidies barely changes insurers' claims costs for young consumers, while cost reduction is the largest for the elderly age groups. Insurers' claims expenses decrease by \$305 (7.8%), \$728 (10.8%), \$1,903 (17.1%), for those aged below 34, 35-54, and above 54, separately. Price drops are the most significant for older adults in absolute and percentage terms. On the other hand, the young age group, which is most elastic, experiences the largest gains in insured rates. Consumer welfare increases for all age groups. Per member, consumer surplus increases by \$121 (288%), \$202 (183%), \$563 (40%) for the age groups from the youngest to the oldest.

From an efficiency standpoint, the pass-through of public reinsurance is highest for young consumers. This is because the premium age gradient must follow a pre-specified regulatory age curve. If insurers only incur claims costs, the price reduction gradient would be almost the same as the pre-specified age pricing gradient. However, as insurers face financial frictions and elderly consumers have a cost distribution with longer tails, public reinsurance induces larger reductions in financial costs for the elderly than the young. If insurers could charge different prices to consumers in different age groups, older adults would experience more significant price decreases that factor in alleviated financial frictions. In contrast, younger adults would experience smaller price decreases until pass-through is equalized across age groups.

Table A13 displays heterogeneous effects of public reinsurance by risk bins. The takeaways are similar to those by age group: the sickest consumers are most affected by the policy and experience the largest surplus gains. At the same time, the pass-through is highest for the healthiest consumers due to the pricing regulation, which states that insurers cannot price discriminate based on enrollee health.

8.1.4. Sensitivity Analysis. We inspect the sensitivity of model predictions to various primitives fixed in the baseline analysis: insurer moral hazard, markup of private reinsurance, and insurer entry.

We begin by allowing insurers to respond to the government's risk-sharing policies in cost-containment activities. Suppose the initiation of public reinsurance subsidies makes insurers perform fewer utilization controls or exert less effort to bargain with medical providers. In that case, we expect total claims for consumers in the same risk type to increase after implementing the policy. Hence, insurers' moral hazard mitigates the claims reduction effect of public reinsurance and the risk reduction effect due to extended tails. Welfare gains from public reinsurance are attenuated. Figure A8 plots how equilibrium statistics change with the degree of cost inflation. If insurers inflate costs by 2.5%, the greater-than-one pass-through will flip. If insurers inflate costs by 10%, reductions in equilibrium price will shrink by 36%; consumer (social) surplus gains will shrink by 40% (29%).

Next, we consider possible interactions between the public and private reinsurance. The public option could make the demand for private reinsurance more elastic, potentially lowering the markup on private reinsurance contracts. In that case, we expect insurers' financial costs to decrease more than the baseline, as they would purchase more private coverage at lower prices, which in turn provide better risk-offloading and further reduce insurers' risk charges. Figure A9 plots how equilibrium statistics change with the markup of private reinsurance after the policy implementation. If public reinsurance lowers private reinsurance markup by 10%, the baseline analysis will understate consumer (social) surplus gains by 0.6% (0.7%).

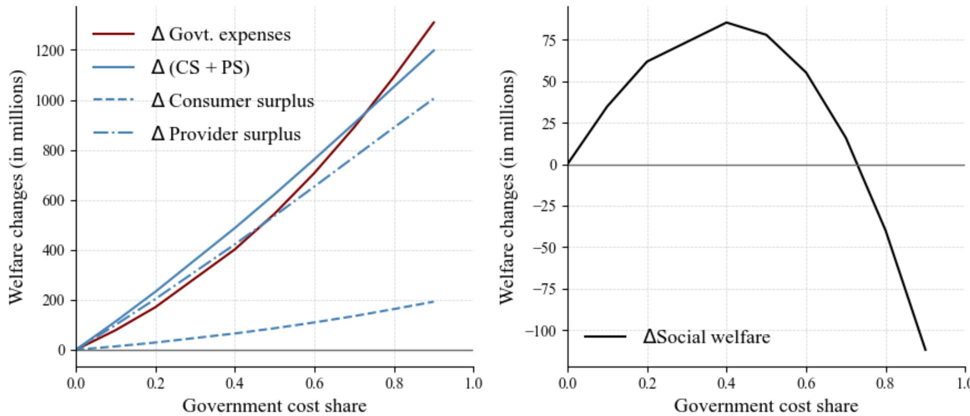
We also consider how public reinsurance might affect health insurers' entry and exit patterns. As analyzed in Section 8.1.1, insurers' profits increase along with reduced effective costs and expanded enrollment. This could induce more players, especially small regional insurers, to enter the market. Additional players could heighten competition and further push down equilibrium prices. We are working on simulating the scenario with hypothetical insurer entries to determine how much the baseline analysis might understate welfare gains.

8.2. *Optimal Policy Design Under Financial Frictions*

8.2.1. Degree of Government Risk-Sharing. We examine the optimal degree of government risk-sharing when designing public reinsurance subsidies. We keep the deductible of public reinsurance the same as the status quo and apply the same government cost shares across all counties in CO. As the generosity of reinsurance subsidies increases, the government trades off the cost of public funds versus the increased surplus of market participants: insurers benefit from reduced claims costs and risk-offloading, consumers benefit from decreased prices, and medical providers benefit from reduced uninsured rates.

Figure 9 displays how social welfare changes with government cost shares. As the degree of reinsurance cost-share increases, the distortion from financial frictions is attenuated and gradually reduced to zero, but the harm from market power persists. Eventually, the net benefit of subsidizing the supply side, especially alleviating extra financial costs, will diminish to zero. We find that the optimal government cost-shares is about 40%, which is precisely the status quo reinsurance design in CO's first two policy regions.

Figure 9. Effect of public reinsurance subsidies, alternative government cost shares



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

8.2.2. Allocating Premium and Reinsurance Subsidies. We now explore optimal subsidy allocation between consumers and insurers under a fixed government budget. The theoretical model in Section 4 predicts that the effectiveness of premium and reinsurance subsidies depends on the relative magnitude of adverse selection and financial frictions. We perturb supply-side subsidies by varying the government's cost-sharing ratio in the reinsurance program and perturb demand-side subsidies by changing the proportion of consumer premiums relative to the status quo.

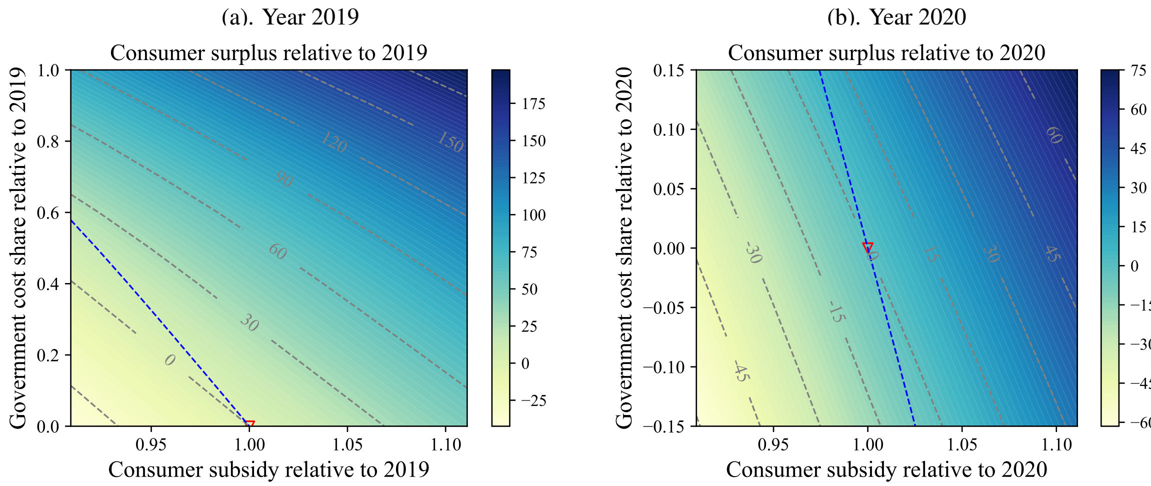
Figure 10 reports the average consumer surplus under different subsidy regimes. The horizontal and vertical axes represent different premium and reinsurance subsidies relative to the status quo. A darker color denotes higher consumer surplus relative to the status quo, labeled as the red triangle. Grey 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 10a 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 8.1. Figure 10b 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.[15]

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

[15]One caveat is that our model does not explicitly incorporate risk-adjustment transfers. However, to the extent that omitting such transfers overestimates the selection insurers face, we interpret our results as conservative estimates, as shown in Section 4.

Figure 10. Consumer surplus under alternative subsidy allocation scheme



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.

adverse selection problem.

9. Discussion and Conclusion

Government subsidy plays a major role in the US health insurance markets. Given the enormous 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 subsidies directly subsidize consumers' insurance purchase, 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 also lowers insurers' 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. 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 essential factor in a well-functioning insurance market.

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Appendix

Contents

A. Supplementary Tables and Figures

A1. Tables

Table A1. State reinsurance programs

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

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

Table A2. Structure of the CO Reinsurance Program

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

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

Table A3. Sample statistics, consumers in CO exchange

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

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

Table A4. Effects of public reinsurance subsidies, robustness

	Logarithm of premiums		Prob. having private reins.		Per member expense private reins.	
	Coeff	Std	Coeff	Std	Coeff	Std
(1) Baseline	−0.137	(0.038)	−0.214	(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 2, except for the tweaks specified in each row.

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

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

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

Table A6. Effect of public reinsurance subsidies in CO

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

Notes: This table reports the point estimates and standard errors (in parenthesis) on the effect of reinsurance programs from the estimation of differences-in-differences version of equation (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 5b. 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. Health risk distribution

Consumer type	Means (μ_i)	Square of Std. (σ_i^2)	Consumer type	Means (μ_i)	Square of Std. (σ_i^2)
Risk bin 1, 34-	0	0	Risk bin 2, 34-	6.126	3.120
Risk bin 1, 35-54	0	0	Risk bin 2, 35-54	6.326	3.157
Risk bin 1, 55+	0	0	Risk bin 2, 55+	6.605	3.284
Risk bin 3, 34-	6.338	3.032	Risk bin 4, 34-	7.305	3.611
Risk bin 3, 35-54	6.651	3.072	Risk bin 4, 35-54	7.9491	2.797
Risk bin 3, 55+	7.141	2.846	Risk bin 4, 55+	8.480	2.335

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

Table A8. Consumer preferences parameter estimates

	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)

Notes: Standard errors (in parenthesis) are derived using the delta method. The second stage demand estimation controls for market(county-year)-product(insurer-metal) fixed effects and market-age fixed effects.

Table A9. Estimated marginal cost multiplier

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

Notes: This table reports the summary statistics of the estimated marginal costs multiplier by insurer in 2019. The marginal cost multiplier is estimated at insurer-product (county-year-metal) level, and we summarize those estimates into moment statistics for ease of reporting. Columns (1)-(5) report statistics across all markets, while columns (6)-(8) report statistics for each reinsurance policy tier, which is described in Figure 2b. Columns (1) and (6)-(8) report enrollment weighted means. Dashed line means the insurer does not operate in the policy tier regions.

Table A10. Effect of public reinsurance subsidies

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

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

Table A11. Decompose the effect of public reinsurance subsidies

	Policy tier 1, Counterfactual					All markets, Counterfactual				
	(0)	(1)	(2)	(3)	(4)	(0)	(1)	(2)	(3)	(4)
(a). Risk-averse insurers (average per insured)										
Price	8,328	7,049	6,862	6,857	6,593	8,763	7,381	7,175	7,169	6,894
Claims costs	6,879	5,654	5,617	5,635	5,530	7,169	5,828	5,795	5,815	5,728
Private reins. expenses	84	91	61	28	26	93	107	63	29	27
Risk charge	121	126	55	65	61	138	149	57	67	65
(b). Risk-neutral insurers (average per insured)										
Price	9,099	8,873	8,865	8,864	7,177	9,976	9,940	9,956	9,957	7,668
Claims costs	7,705	7,618	7,620	7,620	6,050	8,351	8,403	8,421	8,422	6,204
Private reins. expenses	-	-	-	-	-	-	-	-	-	-
Risk charge	-	-	-	-	-	-	-	-	-	-
(c). Market mean (per insured)										
Price	8,764	7,602	7,404	7,398	6,926	9,498	8,272	8,042	8,036	7,399
Claims costs	7,346	6,250	6,158	6,170	5,826	7,886	6,724	6,614	6,626	6,039
Private reinsurance expenses	37	63	44	21	11	37	70	44	20	9
Risk charge	53	88	40	47	26	54	97	39	46	22
Public reinsurance expenses	0	830	865	866	1,255	0	883	951	952	1,802
Premium subsidy expenses	5,142	4,253	4,108	4,104	3,723	5,632	4,708	4,540	4,535	3,981
(d). Market mean (per consumer)										
Consumer surplus	274	361	378	379	487	221	289	304	304	454
Insured rate	0.25	0.34	0.36	0.36	0.45	0.20	0.27	0.28	0.28	0.42
(e). Aggregate welfare (total, in millions)										
Consumer surplus	82	108	113	113	145	98	128	135	135	201
Insurer profit, including risk charges	99	122	124	124	143	134	164	170	170	246
Insurer profit, excluding risk charges	103	131	129	130	147	138	176	174	175	251
Reinsurer profit	1.08	2.56	1.89	0.88	0.61	1.28	3.30	2.18	0.99	0.70
Public reinsurance expenses	0	84	93	93	169	0	105	120	120	334
Premium subsidy expenses	383	433	440	440	502	495	560	572	572	739
Charitable care expenses for uninsured	656	574	558	558	391	1,070	974	952	952	610

Notes: This table reports simulated equilibrium statistics under various counterfactual scenarios. We simulate the equilibrium using market primitives in 2019. Panel (I) reports statistics for markets in reinsurance tier 1, while panel (II) reports statistics for all markets. Averages in the table are enrollment-weighted. We compute social welfare assuming that the planner puts an equal weight on consumer surplus, insurer profits, reinsurer profits, and government expenses. We group insurers into risk-averse and risk-neutral in panels (a) and (b) based on whether they have positive risk preferences estimates, as is reported in Table 4. Counterfactual (0) corresponds to the case without pubic reinsurance policy. Counterfactual (1) simulates a scenario where the reinsurance policy affects only expected claims costs of risk-averse insurers, but not the reinsurance costs or risk charges in insurers' profit functions, nor the claims costs of risk-neutral insurers. We allow insurers to choose prices optimally but not private reinsurance purchases in response to this interim profit function. Counterfactual (2) simulates a scenario where public reinsurance affects all costs components of risk averse insurers, including expected claims costs, private reinsurance expenses, and risk charges terms. We allow insurers to respond by changing only the price but not private reinsurance deductibles. Counterfactual (3) simulates a scenario where public reinsurance affects all costs components of risk-averse insurers, and we allow insurers to choose both price and private reinsurance purchases in response optimally. Counterfactual (4) simulates a scenario where the reinsurance policy affects cost components of all insurers, and insurers choose both price and private reinsurance purchases in response optimally. It is the targeted outcome after the public reinsurance policy is initiated.

Table A12. Effect of public reinsurance subsidies, by age bins

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

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

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

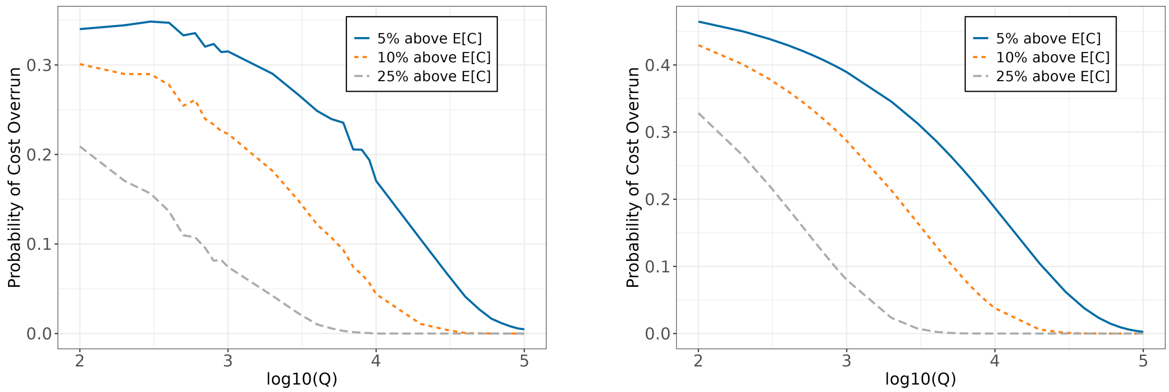
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	All consumers		Risk bin 1		Risk bin 2		Risk bin 3		Risk bin 4	
	Before	After	Before	After	Before	After	Before	After	Before	After
(a). Market mean (per insured)										
Price	9,498	7,399	7,790	6,372	9,138	7,324	10,193	7,971	10,268	8,125
Claims costs	7,886	6,039	6,438	5,228	7,541	5,957	8,489	6,494	8,563	6,641
Private reinsurance expenses	37	9	33	9	35	9	38	9	39	10
Risk charge	54	22	49	21	54	22	55	23	58	24
Public reinsurance expenses	0	1,802	0	1,495	0	1,755	0	1,977	0	2,050
Premium subsidy expenses	5,632	3,981	4,651	3,348	5,597	4,006	5,901	4,262	6,053	4,407
(b). Market mean (per consumer)										
Consumer surplus	912	942	287	380	558	668	1,394	1,554	1,145	1,318
Insured rate	0.20	0.42	0.09	0.28	0.17	0.40	0.39	0.64	0.33	0.58
Total number of insured	87,808	185,517	15,667	47,586	23,652	55,163	27,468	45,439	21,021	37,330
Total number of consumers	443,017	443,017	171,364	171,364	137,300	137,300	70,528	70,528	63,825	63,825

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

A2. *Figures*

Figure A1. Illustration of tail-end risks

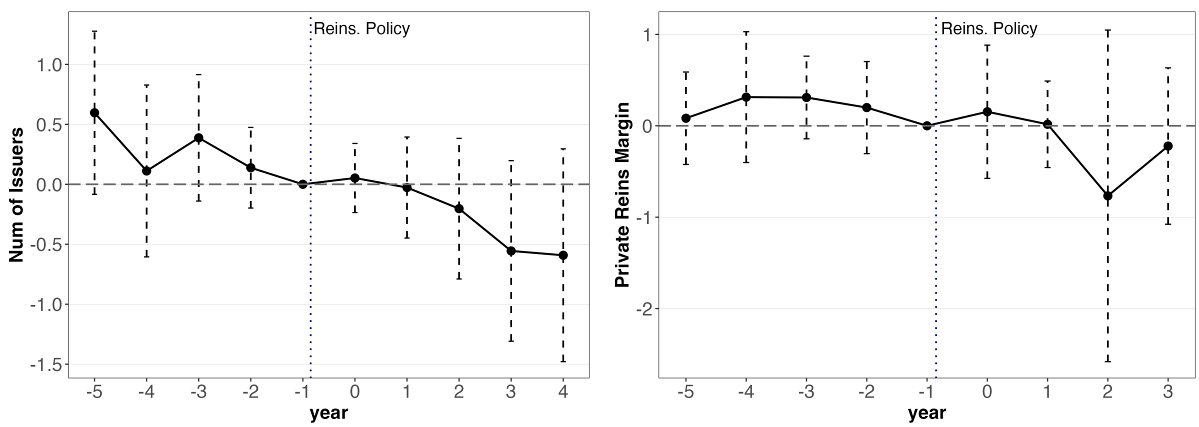
(a). Probability of cost overrun (empirical distribution) (b). Probability of cost overrun (approximated distribution)



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

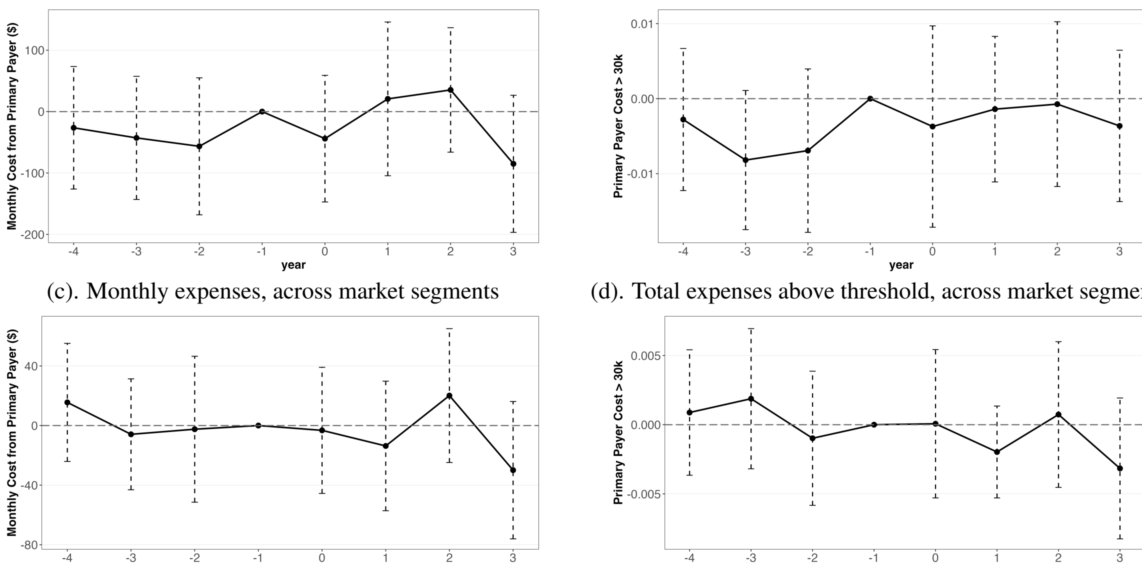
Figure A2. Effect of state reinsurance subsidies on number of insurers, private reinsurance margin

(a). Number of insurers (b). Private reinsurance margin



Notes: This figure reports point estimates and 95% confidence interval of the effect of state reinsurance from the estimation of equation (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

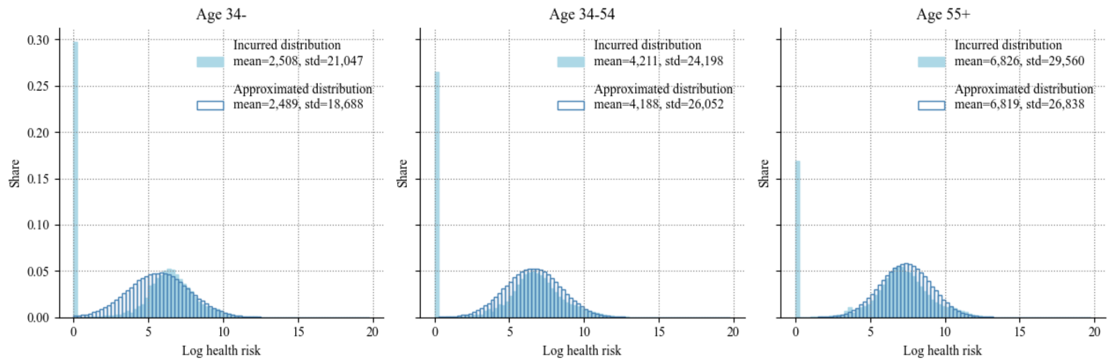
(c). Monthly expenses, across market segments

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

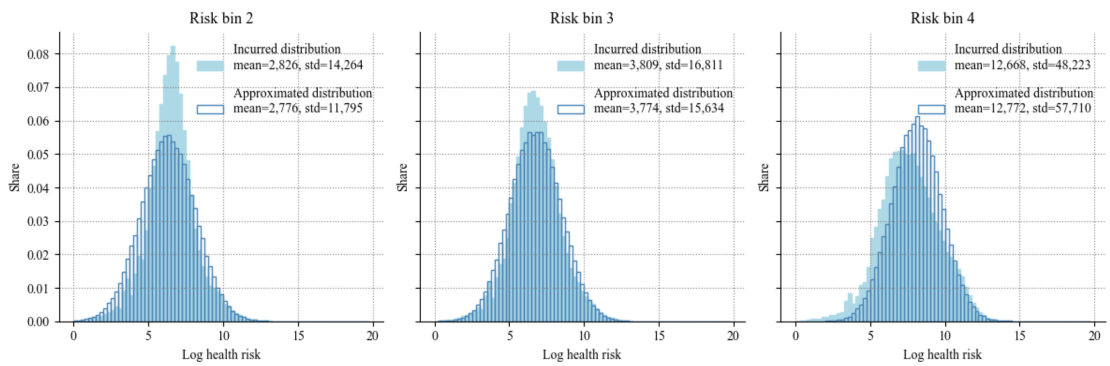
Notes: This figure reports point estimates and 95% confidence interval of the effect of state reinsurance on medical expenses from the estimation of equation (9). The outcome variable is monthly medical expenses per enrollee in panels (a) and (c), and whether the enrollees' annual expenses exceed the reimbursement threshold of the public reinsurance program in panels (b) and (d). We restrict to individual-year units that only report one payer for medical coverage. Panels (a)-(b) include individuals that were part of the exchange and remained in the exchange for all years in 2016-2023. The treatment indicator is whether the individual's county is in the highest two tiers of public reinsurance cost-shares. Panels (c)-(d) include individuals that were part of the exchange or commercial (i.e., fully-insured small and large group) market, and remained in the same market segment for all years in 2016-2023. The treatment indicator is whether the individual's market segment in a specific year has public reinsurance in place. All regressions control for individual, year, county, market segment-insurer fixed effects. Standard errors are clustered at the county level.

Figure A4. Simulated versus realized health risk distribution

(a). By Age bins

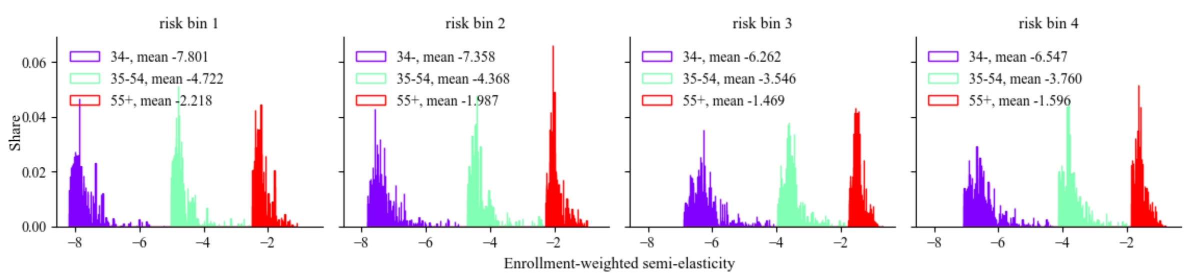


(b). By risk bins



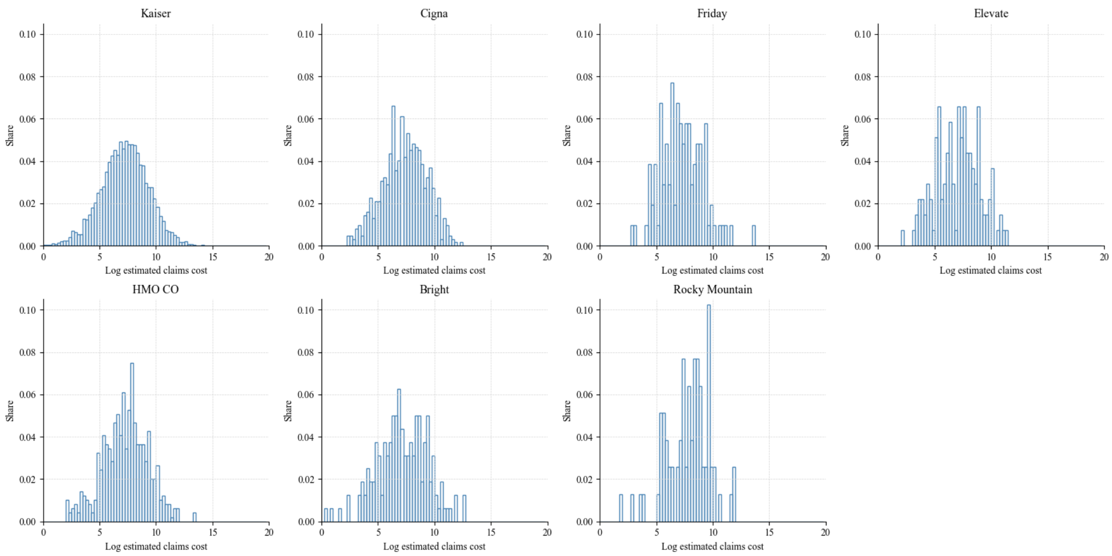
Notes: This figure plots the realized risk score distributions versus the our log-normal approximation, by age and risk bins. Risk scores are predicted using the previous year's claims records, and then divided into four quartiles. The risk bin 1 does not incur any claims records. The parameters of the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

Figure A5. Estimated distribution of own-premium semi-elasticity



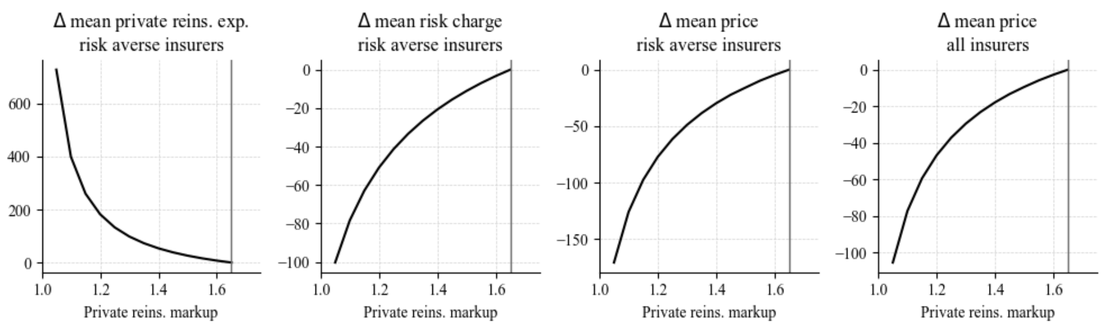
Notes: The table summarizes the enrollment-weighted averages of sensitivity to premiums conditioning on different age-risk bins. Risk bins are four quartiles based on the predicted risk scores using claims from previous years. The statistics reported are functions of the demand parameters reported in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

Figure A6. Estimated claims cost distribution by insurers



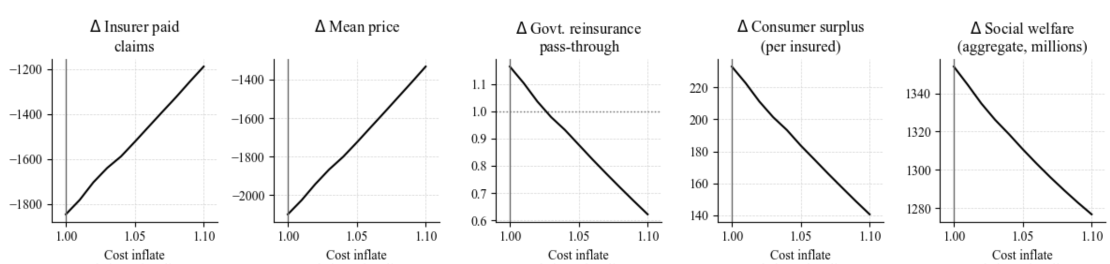
Notes: This figure plots each insurer's estimated claims cost distribution (before applying insurers' cost shares) in 2019. The sample size plotted corresponds to the realized enrollment numbers for that insurer.

Figure A7. Effect of private reinsurance markup on equilibrium pricing strategies



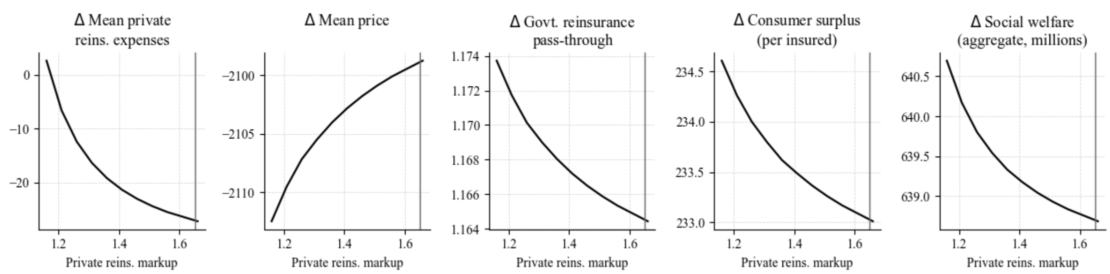
Notes: This figure plots simulated equilibrium prices under different reinsurance markup, using market primitives estimated in 2019. The simulation sample and specifications other than markup are the same as Figure 6. The averages are enrollment-weighted. The vertical dashed line denotes the status quo markup.

Figure A8. Effect of public reinsurance subsidies, sensitivity to moral hazard



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

Figure A9. Effect of public reinsurance subsidies, sensitivity to private reinsurance markup



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

B. Theoretical Model Derivations and Extensions

B1. Proof to Propositions

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

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

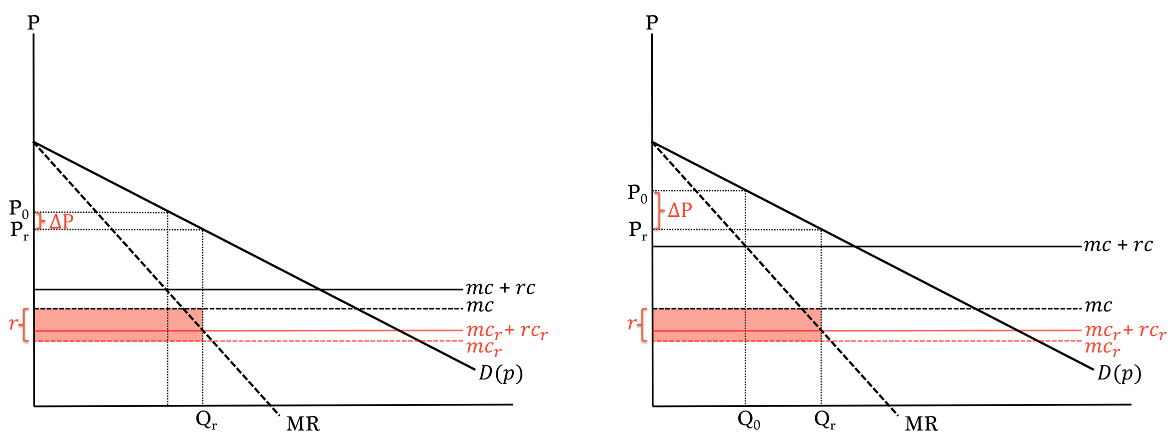
Without reinsurance, $p_0^* = c + \rho\sigma^2 + a/b$. When the government provides reinsurance of level θ, then it will decrease the insurer's expected cost by $r(\theta) = c - c(\theta)$. So the corresponding pass-through rate will be

$$\frac{p^*(\theta) - p_0^*}{r(\theta)} = \frac{1}{2} + \frac{1}{2}\frac{\rho\overbrace{\left(\sigma^2(\theta) - \sigma^2\right)}^{\Delta\sigma^2(\theta)>0}}{r(\theta)}$$

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 as shown in Figure A10.

Figure A10. Pass-through of Reinsurance

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



Notes: This figure illustrates the change in equilibrium price in response to reinsurance subsidy in a linear demand setting. Panel (a) shows a case where the relative magnitude of change in risk charge is small, leading to pass-through of smaller than 1. Panel (b) shows a case where the relative magnitude of change in risk charge is large, leading to pass-through of larger than 1.

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

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

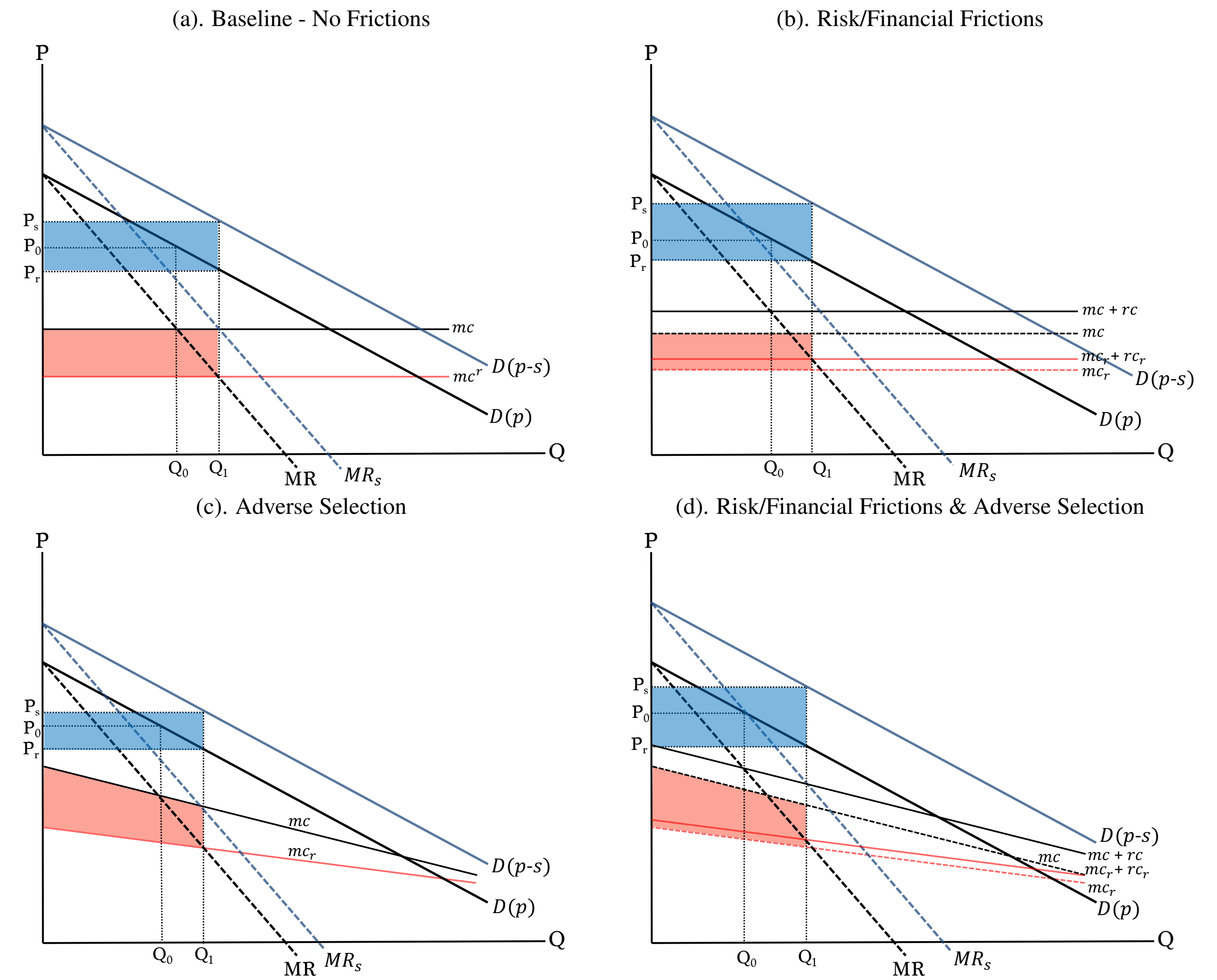
Under adverse selection, $F_h(t) < F_\ell(t)\ \forall\, t$. This directly implies that $r_\ell(\theta) < r_h(\theta)$. We now show that the marginal reinsurance cost is smaller than the average reinsurance cost. Given that $r_\ell(\theta) < r_h(\theta)$, if $\alpha(p) < \lambda(p)$ then $r(\theta) > s(\theta)$ 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. The results for a linear demand setting are illustrated in Figure A11.

Figure A11. Reinsurance vs. Demand Subsidy



Notes: This figure illustrates the relative magnitude of total government spending on demand subsidy (in blue) vs. reinsurance subsidy (in red) with linear demand in variety of scenarios. Panel (a) shows a baseline case without any form of frictions. Panel (b) shows a case where insurers are faced with financial frictions in the form of risk charge. Panel (c) shows a case where there is adverse selection. Panel (d) shows a case with both adverse selection and risk/financial frictions.

B2. Model with Aggregate Cost Shock

Here, we explore a model in which insurers are subject to both the individual-level tail risk, and aggregate cost shocks.

Consider a similar setting to the theoretical model in Section 4. Suppose now that there is a perfectly correlated aggregate cost shock common to all individuals, $x \sim N(1, \sigma_x^2)$. So, each individual's ex-post cost is now given by $y_i^t = x\tilde{c}_i^t$.[1] Then, the insurer's mean-variance utility will be given by

$$\max_p \quad p\underbrace{\left(q_\ell(p) + q_h(p)\right)}_{Q(p)} - \underbrace{\left(c_\ell q_\ell(p) + c_h q_h(p)\right)}_{\mu_c(p)} - \rho \overbrace{\left[(1+\sigma_x^2)\underbrace{\left(\sigma_\ell^2 q_\ell(p) + \sigma_h^2 q_h(p)\right)}_{\sigma_c^2(p)} + \sigma_x^2 \mu_c^2(p)\right]}^{\text{total variance}}. \quad (19)$$

Then, the corresponding FOC will be:

$$\underbrace{p + \frac{Q(p)}{\frac{\partial Q(p)}{\partial p}}}_{MR} = \underbrace{\left(\lambda(p)c_\ell + (1-\lambda(p))c_h\right)}_{MC(p)} + \underbrace{\rho\overbrace{\left[(1+\sigma_x^2)\left(\lambda(p)\sigma_\ell^2 + (1-\lambda(p))\sigma_h^2\right) + 2\sigma_x^2\mu_c(p)MC(p)\right]}^{\text{marginal variance, } MV(p)}}_{\text{marginal risk charge, } MRC(p)} \quad (20)$$

Note that the FOC in (20) is similar to the main theoretical model, except that the marginal risk charge is composed of other variance and co-variance terms related to the aggregate cost shocks. So, the larger the variance of the individual-level cost shock, or the aggregate cost shock, the larger the risk charge will be.

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

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

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

$$\underbrace{p + \frac{Q(p)}{\frac{\partial Q(p)}{\partial p}}}_{MR} = \underbrace{\left(\lambda(p)c_\ell(\theta) + (1-\lambda(p))c_h(\theta)\right)}_{MC(p;\theta)} + \rho\, MV(p;\theta) \quad (21)$$

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

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

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

$$
\begin{aligned}
s(\theta) &= p_s^* - p_r^*(\theta) \\
&= \underbrace{\lambda(p) r_\ell(\theta) + \big(1 - \lambda(p)\big)\, r_h(\theta)}_{\text{marginal reinsurance cost}} + \underbrace{\rho\,\overbrace{\big(MV(p;0) - MV(p;\theta)\big)}^{>0}}_{\text{marginal change in risk charge}}. \qquad (22)
\end{aligned}
$$

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

C. Additional Derivations of the Empirical Model

This subsection describes detailed expressions for key objects in Section 6.

C1. Insurers' Costs Without Reinsurance.

Insurers' costs are 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},

$$
\mathbb{E}[c_{ijmt}] = \psi_{fmt}\lambda_j \exp(\mu_i + \frac{1}{2}\sigma_i^2), \quad \text{Var}[c_{ijmt}] = \sigma_i^2. \qquad (23)
$$

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},

$$
C_{ft}(\vec{p}_t) \xrightarrow{d} N\Big(\mathbb{E}[C_{ft}(\vec{p}_t)], \text{Var}[C_{ft}(\vec{p}_t)]\Big), \qquad (24)
$$

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

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

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

$$L_{ft}(\vec{p}_t) = \rho_f \text{Var}[C_{ft}(\vec{p}_t)], \tag{25}$$

where ρ_f is an insurer-specific risk-aversion parameter that is constant over time. The loss function terms capture insurers' induced risk aversion. Similar to the theoretical model in Section 4, this reduced-form model with a mean-variance utility allows us to flexibly account for potential frictions without specifying a particular financial or regulatory mechanism. The mean-variance utility is also equivalent to maximizing expected utility under an exponential utility function and normally distributed aggregate costs (Kim, 2022). Although higher-order moments of the distribution could be considered, we focus on the second-order moment for computational tractability.

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.

C2. 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.

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.

C3. 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

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

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

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

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.

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.

$$C_{ft}(\vec{p}_t, \kappa_{ft}, \kappa_g, \theta_g) = \sum_{m,i,j} N_m w_{im} s_{ijmt}(\vec{p}_{mt}) c^r_{ijmt}(\kappa_{ft}, \kappa_g, \theta_g),$$

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

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

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

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

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