

Risk Corridors in Medicare Part D: Financial Risk Sharing or Profit Limiting Mechanism?*

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Abstract

Publicly-funded and privately-provided health insurance programs in the U.S. are regulated to ensure a competitive marketplace. However, private firms can strategically respond to government rules and regulations that may lead to market outcomes away from the government's intended goals. I study insurers' strategic responses to the interaction of two regulations in Medicare Part D: profit margin regulation and risk corridors (a risk sharing policy). The government utilizes insurers' self-reported cost estimates to implement both regulations. This creates a trade-off for firms; they can lower their cost report to reduce risk exposure or increase their cost report to charge higher prices. To quantify the effects of insurers' strategic responses, I estimate a structural model in which insurers are risk averse and can strategically misreport their costs. I find that insurers over-report their cost estimates by 7.5%, leading to 10% higher prices for consumers; however, by over-reporting their cost estimates, insurers are expected to pay back the government 2% of premium revenue in risk corridor payments. Thus, risk corridors limit ex-post profits more than serving as a risk sharing mechanism. I propose an alternative linear risk sharing rule to replace the existing risk corridors, which increases total surplus by 11% while maintaining insurers' risk exposure.

JEL Codes: G22, H51, I13, I18, L1, L2

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1 Introduction

Increasingly, public health insurance programs in the US are being delivered through private insurance companies (e.g. Medicare Advantage, Medicaid, ACA Exchanges, etc.). Government spending on these programs is enormous; the US government contributes \$0.6 trillion in annual health insurance subsidies towards health coverage that is delivered by private insurance companies (CBO, 2020). The success of such privately-provided health insurance programs is predicated on successful competition among private firms leading to efficient provision of goods at low prices. In practice, to ensure a competitive marketplace, the government heavily regulates private firms in these settings. Examples of regulations include pricing regulations, product design regulations, and risk sharing arrangements. However, if not carefully designed these regulations also introduce strategic incentives for firms that could distort their intended goal. Understanding and evaluating how the design of these regulations affect the behavior of strategic firms is crucial to a successful publicly-funded, privately-provided market, especially when the program is administered by firms with market power.

In this paper, I study insurers' strategic responses to the interaction of regulations in Medicare Part D, a US federal program administered through private insurance companies, which provides prescription drug coverage to older adults. I focus on two regulations. The first is ex-ante profit margin regulation, which puts an upper bound on price that insurers can charge relative to self-reported expected cost. The second is risk corridors (RC), a risk sharing policy that ex-post reimburses (charges) insurers for any cost overruns (underruns) relative to insurers' self-reported expected cost. While the two regulations were designed with distinct purposes, both regulations rely on insurers' self-reported cost estimates. This gives insurers a strategic incentive to misreport their costs to increase their revenue. A few recent papers study insurers' strategic responses to a single policy or regulation in isolation (Decarolis, 2015; Geruso & Layton, 2020; Sacks *et al.*, 2021). However, the health insurance markets are often laden with numerous regulations that may affect one another. I study how the interaction of two different regulations balances insurers' strategic incentives to distort the regulatory outcomes, albeit imperfectly.

The two regulations apply to widely-used policies that the government utilizes beyond Medicare Part D. The margin regulation limits market power by constraining insurers from earning ex-

cessive profits. This is commonly used in other health insurance markets like Medicare Advantage and Medicaid. More broadly, it is comparable to the rate-of-return regulations used to regulate monopolies in the utility industry. Risk corridors protect insurers from ex-post uncertainty in cost by sharing in expenses (savings) from any cost overruns (underruns). The government utilizes risk corridors to stabilize the market (e.g. ACA exchanges and Medicaid), especially in new markets where insurers may face increased uncertainty around costs of enrollees. At the outset of the COVID-19 pandemic, the federal government contemplated extending risk corridors beyond the government programs to include the entire US health insurance market.¹ Despite the widespread use by the policymakers, there is very little research on risk corridors in the economics literature.

To illustrate how the regulations affect the market with strategic insurers, I build a stylized model with asymmetric information in which risk averse insurers can strategically report their expected cost. I show that the two sets of regulations have opposing incentives. With just the ex-ante profit margin regulation, insurers will tend to overestimate their costs so that the price they charge will appear not too high relative to their reported cost estimates. This is closely related to the theoretical literature on regulation ([Baron & Myerson, 1982](#); [Baron & Besanko, 1984](#)), which shows that firms have incentives to report higher costs when their revenue or price is linked to cost reports. With just risk corridors, insurers want to underestimate their costs in order to increase their chance of cost “overruns”, thereby increasing their likelihood of receiving reimbursements from the government. The latter result is line with [Sacks *et al.* \(2021\)](#) who show that risk corridors in the ACA marketplace create similar incentives for insurers, acting as an implicit subsidy.

However, when both policies are present the two may balance, and dampen the insurers’ incentives to over/underestimate their costs. If insurers overestimate their costs, they can increase the upper bound on the price that they can charge, allowing them to set higher prices; overestimating their costs, however, will also increase their chance of cost “underruns”, increasing their likelihood of making ex-post risk corridor payments to the government. So when insurers overestimate their costs, the risk corridor acts as an ex-post penalty function for the insurers. On the other hand, if insurers underestimate their costs, they can increase the likelihood of receiving ex-post risk corridor

¹The HEROES Act, a COVID-19 relief bill passed by the House of Representatives in May 15 2020, included measures to enact risk corridors to the broader US health insurance market. The bill proposed providing a one-sided risk corridor to the Medicare Advantage, individual and small/large group health insurance market. For more details see [House of Representatives \(2020\)](#).

reimbursements from the government; underestimating their costs, however, will also constrain the maximum price that they can charge. Which incentive dominates is an empirical question, as is quantifying the magnitude of the distortion induced by this set of policies. This paper aims to fill this gap in our understanding of the impact of the policy.

Using data from insurers' financial statements, I present descriptive evidence in line with my model implications. I compare the ex-post profit margins of insurers' Part D businesses to the margins of insurers' commercial businesses that are used as a benchmark for the Part D margin regulation. I find that insurers are much more profitable in the Part D market compared to their commercial businesses. If insurers had estimated their costs correctly, their Part D margins should be similar or lower than the commercial business margins, due to the margin regulation. Instead, most insurers overestimated their costs, allowing them to charge higher prices. Insurer level risk corridor payments show similar outcomes. The distribution is heavily skewed towards positive payments to the government, meaning most insurers have overestimated their costs. I find that these overestimates are persistent across insurers, suggesting that the overestimates are due to strategic cost reporting rather than random uncertainty in cost is playing a role. These descriptive results suggest that the current design of risk corridors acts more as a profit-limiting mechanism than it is as a risk sharing mechanism.

To quantify the degree of insurers' strategic behavior and the impact on market outcomes, I build and estimate a structural model of demand and supply. On the demand side, I build on the discrete choice model of demand estimated in [Decarolis *et al.* \(2020\)](#), allowing for substantial heterogeneity across consumer types. My model of supply departs sharply from existing models in two ways: i) endogenizing the strategic self-reporting of cost estimates by the insurers and ii) allowing insurers to behave as "risk averse". That is, insurers face a disutility from taking on greater risk. Modeling insurers as "risk averse" is crucial for understanding the role of risk corridors in reducing the risk that insurers face. In the standard model of risk neutral insurers, risk sharing has no meaningful effect on outcomes. However, in reality insurers seem to exhibit risk averse behavior. Insurers face financial/regulatory frictions ([Kojen & Yogo, 2015](#)), and often purchase reinsurance policies to lower their exposure to risk. So the amount of risk assumed by insurers impacts their marginal cost, which in turn affects their pricing decisions.

The estimates highlight a few facts. First, I estimate that most insurers have overestimated their

costs by around 8% on average. In line with the descriptive evidence, insurers would like to charge a relatively high markup in their Part D business compared to their commercial market. Insurers overestimate their costs to relax the margin regulation, and charge higher prices. At the same time, by overestimating their costs, insurers face an increasing risk of having to pay money to the government in ex-post risk corridor payments. Insurers are expected to pay back the government 2% of premium revenues in risk corridor payments. Second, I find that insurers are not that risk averse. The estimated risk aversion coefficients imply that insurers face an average risk charge of \$17.5 for enrolling an additional enrollee, which is around 2% of insurers' marginal cost or 15% of the average margin. Third, while the magnitude of risk aversion coefficients is small, I find that the coefficients are negatively correlated with insurers' RBC ratios. That is, I find that insurers are less risk averse when they are better capitalized or more financially solvent. This suggests that insurers' risk averse behavior is driven by financial/regulatory frictions that they face (Kim & Li, 2022).

With the estimates in hand, I look at equilibrium outcomes under different market designs to quantify the effect of insurers' strategic reporting under current regulations. If insurers had correctly reported their expected costs (truthful reporting) the average price would be 10% lower, while increasing the average risk level by a factor of four. The lower price translates to a 15% higher consumer surplus. In the absence of both risk corridors and ex-ante profit margin regulation, prices would be 5.2% higher, and the risk level would be five times higher. The higher price translates to a 10% lower consumer surplus. Of the 5.2% increase in prices, I find that only 0.3% is due to increased risk level and the remaining 4.9% is from the removal of profit margin regulation. Although the risk corridor significantly reduces the amount of risk that insurers face, insurers are almost risk neutral, so the amount of risk that insurers face doesn't seem to play a large role in the market outcomes. So the intended role of the risk corridor in sharing the risks that insurers face is not significant in the current market. On the other hand, the profit margin regulation is playing a large role in keeping insurers' prices low. The risk corridor plays an important role as an ex-post transfer mechanism that penalizes insurers for over-reporting their cost estimates. As a result, risk corridor payments help enforce the profit margin regulation.

While the current market outcome yields a higher consumer surplus than would be the case without any regulations, it is much lower than the case in which insurers truthfully report their

cost estimates. Given that risk corridors are in practice being used to limit ex-post profits in the market, a natural question is whether there are alternative risk corridor designs that could raise the consumer surplus. To explore this, I alter the design of risk corridors to a simple linear risk sharing rule. I vary the degree of risk sharing from 0%, indicating a fixed-price contract or no regulation to 100%, indicating a cost-plus contract that fully reimburses (charges) the insurer for any cost overruns (underruns). I find that with linear risk sharing of 58%, the government can increase its total surplus and achieve even higher surplus levels than the truthful reporting, case while maintaining the same level of risk that insurers currently face.

Related Literature

This paper is related to several distinct groups of literature on the design of social health insurance programs, supply-side frictions of insurance firms, and the regulation of private firms.

First, this work adds on to the growing body of literature on strategic responses of private firms in the health insurance markets. A closely related paper, [Sacks *et al.* \(2021\)](#) studies the temporary risk corridor program in the ACA markets. The authors find that the insurers had an incentive to lower their cost benchmarks in order to increase the chance of reimbursements from the government. This is in line with the findings in this paper: when there are only risk corridors, insurers have an incentive to lower their cost benchmark. Other papers like those of [Geruso & Layton \(2020\)](#); [Brown *et al.* \(2014\)](#) study insurers' strategic behavior in response to the design of the risk adjustment program. They find evidence of insurers/providers upcoding patient diagnoses to increase the risk adjustment payments and/or screening selectively healthy patients conditional on their risk scores. [Decarolis \(2015\)](#) looks at how insurers can strategically game the low income subsidy design and documents evidence of such strategic behavior leading to increased premiums. While existing papers study an insurer's strategic response to a single regulation, this paper focuses on how the interaction of two different regulations can balance insurers' strategic incentives. In heavily regulated markets like the health insurance markets, different regulations may interact with one another, and as such it is important to study the interaction of policies and not just a single policy in isolation.

Second, this paper studies risk corridors, an ex-post risk sharing policy in the health insurance markets. While there are several papers on ex-ante risk sharing or risk adjustment policies ([Brown](#)

et al., 2014; Einav *et al.*, 2016; Geruso *et al.*, 2019; Carey, 2017) that make ex-ante transfers based on enrollee's predicted health risk, there is little work studying ex-post risk sharing policies. Layton *et al.* (2016) conducts a simulated study on how risk corridors and reinsurance policies affect the distribution of insurers' costs. Sacks *et al.* (2021) studies how the removal of the risk corridor program in the ACA exchanges led to sharp premium increases. In this paper I study how risk corridors affect the market by directly modeling and estimating "risk averse" insurers and studying how risk corridors affect insurers' pricing decisions by changing insurers' risk exposure.

Third, by modeling insurers' behavior as "risk averse", this paper adds to the literature on the supply-side frictions of insurance firms. Recent work by Koijen & Yogo (2015, 2016, 2022) documents financial/regulatory frictions that life insurance companies face and how such supply-side frictions may play a significant role in the pricing of insurance contracts. Health insurance companies are also subject to similar financial regulations, and so may face similar frictions for taking on risk; in reality, health insurers will behave as if they are risk averse. To the author's knowledge, this is one of the first papers to document and incorporate such supply-side frictions in modeling the health insurance companies.

A large body of theoretical literature has studied the regulation of private firms in the context of government procurement or monopoly regulation (Baron & Myerson, 1982; Baron & Besanko, 1984; Laffont & Tirole, 1986). There is also an empirical literature on this topic.² This paper adds to the empirical literature by studying an empirical analogue of Baron & Besanko (1987), in which the government seeks to regulate risk averse firms in the presence of asymmetric information.³ The paper also contributes to the literature on price regulation in healthcare markets. Cicala *et al.* (2019) studies the MLR regulation introduced by the ACA and find that it decreased incentives for insurers to control costs, thereby raising the overall costs of care. Dubois & Lasio (2018) study the price regulation of pharmaceuticals in France and finds that the government's price-regulation resulted in a modicum of decreases in price.

Lastly, this paper contributes to the large body of literature on the Part D program. Most of the earlier literature on Part D focuses on the demand side, looking at individuals' plan choice be-

²Brocas *et al.* (2006) study the cost of asymmetric information in the rate of return regulation of water utilities, studying the empirical analog of Brocas *et al.* (2006). Abito (2020) study emissions and rate of return regulation in electric utilities, in the context of Laffont & Tirole (1986).

³Unlike Baron & Besanko (1987), this paper does not model the moral hazard of cost side.

haviors with respect to the rationality of plan choice, consumer myopia, and inertia.⁴ Overall, this paper contributes to this literature by showing that an often overlooked regulation, risk corridors, matter when modeling the supply side. The paper finds yet another flawed market design because there is a misalignment between the objective of the government and private incentives. This leads to a worse market outcome than the government has intended.

The rest of the paper is structured as follows. In section 2, I provide a brief description of the Medicare Part D market, paying particular attention to the supply side policies. I then present a stylized theoretical model in section 3, showing the effect of both the risk corridor and the margin regulation on the market, especially in the presence of asymmetric information. In section 4, I detail the data used for the structural model. In section 5, I present the structural model of demand and supply and in section 6, the estimates. Lastly in section 7, I present the market equilibrium under various counterfactuals. Section 8 concludes.

2 Institutional Details

Medicare is a federal health insurance program primarily designed for Americans aged 65 and older. It provided coverage for 62 million people in 2020. Medicare Parts A&B, also known as traditional Medicare or the fee-for-service (FFS) program, directly offer hospital/medical coverage. Under Parts A&B, the government pays health care providers directly for beneficiaries' utilization or healthcare services. Alternatively, beneficiaries can get their Medicare benefits from a private health insurance plan known as Medicare Part C or Medicare Advantage (MA). Under Part C, a private health insurer provides similar coverage benefits as those offered under Medicare Parts A&B. Enrollees may pay an additional premium to the insurer.⁵ The private health plan may include additional benefits such as vision, dental and prescription drug coverage.

⁴Examples of this literature include: [Abaluck & Gruber \(2011\)](#); [Kling et al. \(2012\)](#); [Ketcham et al. \(2012, 2015\)](#); [Abaluck et al. \(2018\)](#); [Einav et al. \(2015\)](#); [Dalton et al. \(2020\)](#); [Ho et al. \(2017\)](#); [Lucarelli et al. \(2012\)](#); [Polyakova \(2016\)](#). A majority of this literature focuses on the demand side choice frictions, but some papers like [Ho et al. \(2017\)](#); [Lucarelli et al. \(2012\)](#); [Polyakova \(2016\)](#) look at insurers' strategic responses to such demand side frictions. They find that there is strong evidence for such frictions and that policies that remove such frictions will lead to welfare increases by lowering prices and decreasing drug expenditure of enrollees. On the supply-side, a few papers look at insurers' strategic benefit designs. [Einav et al. \(2018\)](#) documents within plan heterogeneity in cost sharing across different types of drugs. [Lavetti & Simon \(2018\)](#); [Starc & Town \(2020\)](#) study benefit design differences between medically-integrated (MA-PD) vs. stand-alone prescription drug (PDP) plans, finding that MA-PDs have more generous formulary designs because PDPs do not internalize spillovers between drug and medical costs.

⁵The actual premium is heavily subsidized, and insurers receive a capitated payment for each enrollee.

Medicare Part D was introduced as part of the Medicare Modernization Act (MMA) in 2003. It provides prescription drug benefits to Medicare beneficiaries. Unlike Parts A&B, in which the government provides the coverage directly, Part D benefits are provided solely by private prescription drug plans, much like part C. In 2020, 47 million Medicare beneficiaries received prescription drug benefits through Part D, costing the government \$90 billion.⁶

When it comes to the prescription drug benefits, Medicare enrollees usually choose to either: i) enroll in traditional Medicare (Part A&B) for medical coverage and enroll in a private stand-alone prescription drug coverage (PDP) or ii) enroll in a private health plan via Medicare Advantage (Part C) that provides both medical and prescription drug coverage (MA-PD).⁷ This paper focuses on the stand-alone prescription drug coverage (PDP) market.⁸

The PDP market is comprised of 34 PDP regions, or groups of neighbouring states.⁹ Each PDP region defines a unique market and acts as a centralized marketplace in which insurers can enter and compete by offering different prescription drug plans. Every June of the year prior to the plan benefit year, insurers will submit their “bids” to the Center for Medicare & Medicaid Services (CMS) for each plan that they’re planning to offer for the following year.¹⁰ Included in the bids are plan financial characteristics (premium, deductible, co-insurance/co-payment, actuarial value, etc.) and the formulary design (the type of drugs covered), which need to meet regulatory requirements.¹¹ More importantly, the bids also include insurers’ estimated average costs for the plan.¹² CMS reviews the insurers’ bids for compliance. CMS then uses the information in insurers’ bids to compute the beneficiary subsidy level, and determine the post-subsidy enrollee premiums.¹³ From mid-October to December of the preceding year, enrollees choose a plan from

⁶<https://www.cbo.gov/data/baseline-projections-selected-programs#10>.

⁷Medicare enrollees could also choose to not have any prescription drug coverage via Part D whether that’s enrolling in traditional Medicare and not purchasing a PDP or enrolling in a MA plan that does not provide any prescription drug coverage. This accounted for around 25% of enrollees in 2020.

⁸While most of the paper’s empirical study focuses on PDPs, MA-PDs are faced with very similar if not identical policies to those addressed in this paper. In fact, some of the policies like the margin regulation exist in the MA market as well.

⁹See figure A.1 for how the regions are broken up.

¹⁰Note that here “bid” does not refer to a bid in an auction setting in which only one firm wins the contract. Bids refer to the premiums that insurers would like to charge. So the bids here can be thought of as prices that firms set in a standard product market setting

¹¹For details on the exact requirements, refer to <https://crsreports.congress.gov/product/pdf/R/R40611/19>.

¹²To be more precise, insurers need to submit their expected plan-liable cost including any administrative costs as well as plan profits.

¹³The enrollee subsidy is determined by multiplying a factor by the weighted average of all plan bids, called the National Average Bid Amount. The factor was around 0.53 in 2015 i.e. the subsidy covered just over 50% of the average

a menu of plan options available in their region.

2.1 Bid Gain/Loss Margin Requirement

Aside from the requirements on plan benefit structures, insurers also face a margin regulation that limits the price that they can charge relative to the reported average cost estimate.

At the individual plan bid level, CMS scrutinizes any bids that have very high or low margins and wants to ensure that “*bids must provide benefit value in relation to the margin*”. In practice, CMS will scrutinize any plans that have negative expected margins or plans that have extraordinarily high expected margins. At the firm level, CMS requires that “*the aggregate (projected enrollment-weighted average) Part D margin as a percentage of revenue must be within 1.5 percent of the Part D sponsor’s margin for all non-Medicare business, as measured by percentage of revenue*”.¹⁴ Here, *non-Medicare business* refers to insurers’ commercial health insurance businesses.^{15,16}

CMS is intended to impose a rate-of-return type regulation by benchmarking insurers’ Part D margin to their commercial business counterpart. The stated purpose of the margin requirement is

*Gain/loss margin refers to the additional revenue requirement beyond allowed prescription drug costs and non-benefit expenses. The gain/loss requirements ensure that gain/loss margins are reasonable and that a Part D organization’s Part D business is not used to subsidize its other insurance lines of business.*¹⁷

CMS does not want insurers to make “excessive” profit by exercising market power in the Part D business. It enforces this through the margin requirement. This regulation, however, is an ex-ante margin regulation; CMS applies this when the insurers submit their bids. The margin used is insurers’ reported *expected* margin using insurers’ reported cost estimate before costs have been

price, meaning enrollees only had to pay 50% of the premium to purchase an average-priced plan.

¹⁴To be more precise, insurers can choose the level at which aggregate margin can be applied. It could be at the contract level, or at the firm level. However, most firms choose requirements to be at the firm level.

¹⁵To be more precise, the term “non-Medicare” business refers to “all health insurance business that is not Medicare Advantage or Part D. Non-Medicare business includes, but is not limited to, the following line of business: Medicare-Medicaid, Medicare-supplemental, Medicaid and commercial.”

¹⁶For insurers that do not have any business outside of Medicare, the margin requirement is based on a “risk-capital-surplus” approach.

¹⁷<https://www.cms.gov/Medicare/Health-Plans/MedicareAdvtgSpecRateStats/Bid-Pricing-Tools-and-Instructions-Items/BPT2015>

Figure 1: Risk Corridor payment reconciliation as a function of actual vs. target or expected cost

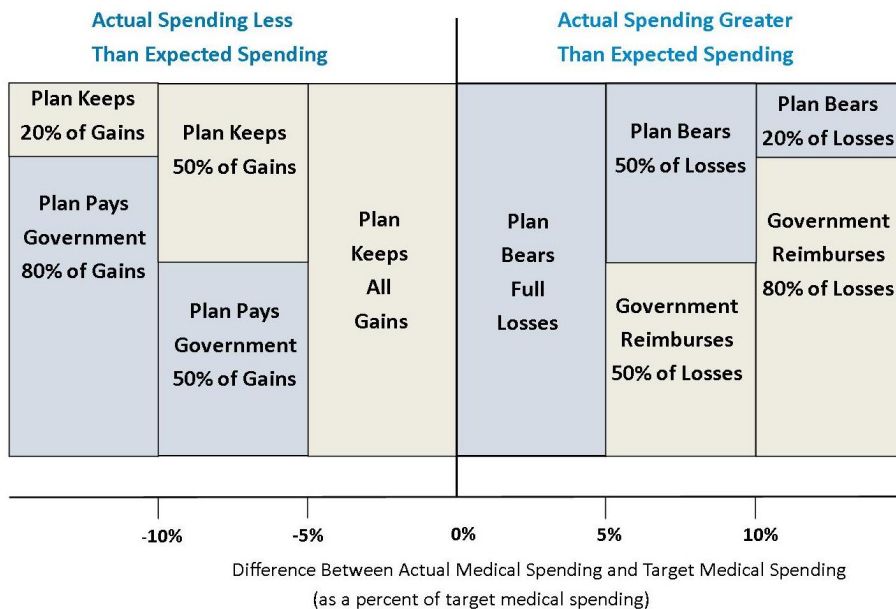


Figure shows risk corridor policy parameters in Medicare Part D.

realized. As a result, insurers’ ex-post realized margin may not be in line with the margin requirement.

2.2 Risk Corridors: Risk Sharing in Medicare Part D

When the Part D market was first introduced, policy makers were concerned about insurer participation and drug benefit affordability. To address these concerns, CMS put forth several risk sharing policies that limit insurers’ financial risk. Risk corridors are one such policy.

Risk corridors are an ex-post transfer scheme between the insurer and the government. They are a function of insurers’ expected cost, or *target spending* and insurers’ realized cost, or *actual spending*. The government sets insurers’ reported average cost estimate as *target spending* for the risk corridor program. After the contract year, insurers will report their realized cost for each plan. The government takes this as *actual spending*. The government then applies the transfers for the risk corridor program, as shown in Figure 1.

If the plan’s actual cost is within 5% of the expected cost, there will be no transfers and the insurer will bear the full risk for that plan. If the actual cost is larger (smaller) than the expected cost by 5 – 10%, then the government will reimburse (charge) the insurer 50% of the difference

over the 5% threshold. If the actual cost is larger (smaller) than the expected cost by more than 10%, then the government will reimburse (charge) the insurer 80% of the difference over the 10% threshold on top of the 50% cost sharing in the 5 – 10% threshold. In short, the risk corridor is a risk sharing policy that reimburses (charges) insurers if the actual cost is higher (lower) than the expected cost.

There are two additional risk sharing policies in the premium stabilization program: risk adjustment and reinsurance. Risk adjustment is primarily there to address adverse selection. It evaluates ex-ante the riskiness of individual enrollees based on each individual's health and expected spending.¹⁸ The plans' capitated monthly premiums (i.e. the plan "bid") are then adjusted by enrollee's risk score such that they are paid relatively more for sicker enrollees and relatively less for healthier ones. By construction, this measure is expected to be budget neutral for the government: it delivers ex-ante transfers from plans that enrolled sicker enrollees to plans that enrolled healthier enrollees.

Reinsurance acts as an ex-post subsidy for the insurers for incurring high-cost enrollees. When an enrollee has sufficient spending to reach the out of pocket threshold, CMS will reimburse a significant portion of the cost beyond the threshold.¹⁹ It acts as insurance for the primary insurer. In fact, this type of contract is quite common in the broader health insurance market, in which primary insurers will purchase private reinsurance from a third party, often at a high markup. Here, the government acts as a reinsurance company without collecting any premiums from the insurer, effectively providing free reinsurance.²⁰

All three of the above risk sharing policies are widely used in other government-funded social insurance programs like Medicaid and the ACA Exchanges. Furthermore, ex-post risk sharing policies like risk corridors and reinsurance are commonly used in the private market.

2.3 "Risk Aversion" of Insurers

Here, I briefly discuss how risk affects insurance companies. While the traditional theory of the firm assumes firms to be risk neutral, in reality there are several reasons why insurance compa-

¹⁸In practice, CMS takes the enrollee's historical drug expenditure as well as pre-existing medical conditions to predict drug expenditure and constructs numeric risk scores.

¹⁹The out of pocket threshold, also known as catastrophic cap, is a pre-defined threshold set by the government each year. In 2015, it was at about \$7,000.

²⁰So the government's provision of reinsurance is a supply-side subsidy.

nies may be “risk averse” (Fama & Jensen, 1983).²¹ First, firms are managed by individuals who may be risk averse, especially if their pay is tied to the firms’ performance. Empirically, there is strong evidence (Hall & Liebman, 1998) of a growing correlation between manager pay and firm performance.

Second, insurance companies are subject to financial regulations. Insurance regulators (as well as rating agencies) regularly assess the financial strength of insurers, much like the capital requirements (or the solvency regulations) in the banking industry (Walter, 2019). In the U.S., while individual states have their own set of insurance regulators, most of them follow the risk-based capital (RBC) regulation set out by the National Association of Insurance Commissioners (NAIC). Risk-based capital ratios (also known as RBC ratios) determine the minimum amount of capital required for a given amount of risk assumed by the insurer and compares it to the insurer’s total capital and surplus levels. For health insurers, the required capital is often some factor applied to the total claims that they are liable for.^{22,23} Each year, insurance regulators review the RBC ratios of the insurers and may take action if it falls below certain standards.²⁴ In fact, Koijen & Yogo (2015) document that life insurance companies face a high degree of financial/regulatory frictions due to RBC regulation and Kim & Li (2022) find that insurers’ financial solvency level affects their premium setting decisions.

Third, there is an active private reinsurance market in which primary insurance companies purchase insurance products (Bovbjerg *et al.*, 2008). These private reinsurance policies are often sold by unaffiliated reinsurance companies and are purchased despite their high markups.²⁵ If insurers were risk neutral, there would be no market for such policies.

Finally, there is ample evidence that insurance companies take into account the amount of risk they face in setting their premiums. The actuarial literature frequently factors in “risk premium” or “risk charges”, often measured by the variance or the standard deviation of the claims liability (Kahane, 1979). Furthermore, according to the American Academy of Actuaries, policies like risk

²¹The rationale for risk neutral firms is that investors can diversify their investment portfolio through diversification and minimize any firm specific risk.

²²The exact factor varies but is usually between 5 – 15% i.e. the required capital is often set as 5 – 15% of the total claims.

²³Note that for health insurers, the RBC ratio is often an ex-post measure of financial solvency. This is because the minimum required capital is a function of already realized claims vs. some expected liability, as is the case for other insurance sectors.

²⁴In the extreme case, the regulator will assume direct control of the insurance company (NAIC, 2011).

²⁵The loading factor i.e. the portion of premiums above and beyond the expected claims can be as high as 50%.

corridors can reduce premiums by reducing risk charges:

“Risk corridors can allow insurers to reduce their risk charges, although risk charges are usually a fairly small percentage of the premium (e.g., 2% – 4%). Another way risk corridors can result in lower premiums is that having a backstop can allow insurers to price using less conservative assumptions.” (American Academy of Actuaries, 2020)

As described above, there are many reasons why insurers may act as if they are risk averse. It is especially important in studying a risk sharing policy like risk corridors, as such a policy will have no real effect on risk neutral insurers. As a result, I depart from the standard model of risk neutral firms and allow insurers to behave as “risk averse”.

3 Stylized Model

Here I present a stylized model where a monopoly insurer faces some frictions for taking on risk. I introduce the two sets of regulations in the Part D market: risk corridor and margin constraint, first studying each policy by itself and later combining both together. I compare the effect of these policies in the presence of symmetric information vs. asymmetric information about costs, in which the insurer has private information about its expected cost.

3.1 Stylized Model

Consider a monopoly insurer facing an elastic demand for its product, $q(p)$.²⁶ For each individual it enrolls it faces a random marginal cost of $\tilde{c}_i = c + \epsilon_i$, where c is the expected cost, and ϵ_i is a *iid* zero-mean shock with $Var(\epsilon_i) = \sigma^2$.²⁷ With demand $q(p)$, the insurer faces a random total cost of $\tilde{C} = \sum_{i=1}^{q(p)} \tilde{c}_i$. Given the uncertainty in cost, the insurer incurs a risk charge as a function of the variance of the total cost, $V(\tilde{C})$. This can be seen as an approximation to an insurer that faces some cost of financial frictions for incurring ex-post losses.^{28,29} Alternatively, the insurer can be taken to

²⁶Note that we are implicitly assuming that there is no uncertainty in demand.

²⁷Here we assume the individual level cost shocks are independent, which seems plausible in the context of health insurance. However, we can generalize the results to a case in which individual costs are correlated.

²⁸The approximation is to a model in which insurer faces some convex cost function for incurring ex-post losses. See Appendix A for more details.

²⁹In reality, insurance companies do seem to face some financial/regulatory frictions regarding their solvency measures. There are state regulations on insurers’ risk-based capital ratios as well as evidence of insurers purchasing private reinsurance policies to reduce risk that they face.

be risk averse, which will be isomorphic to a model in which the insurer faces financial frictions.³⁰

The insurer maximizes the following expected profit function:

$$\max_p pq(p) - \underbrace{cq(p)}_{E[\tilde{C}]} - \underbrace{\rho V(\tilde{C})}_{\text{risk charge}} \quad (1)$$

where $\rho \geq 0$ is the coefficient of risk charge. The insurer's FOC yields:

$$p_0^* \left(1 + \frac{1}{\epsilon^D}\right) = c + \underbrace{\rho \frac{\frac{\sigma^2}{\partial V(\tilde{C})}}{\partial q}}_{\text{marginal risk charge}} \quad (2)$$

where ϵ^D is the price elasticity of demand. We get a similar FOC to a standard monopoly model where marginal revenue equals marginal cost. However, here the effective marginal cost includes a marginal risk charge term that makes the marginal cost strictly higher. Note that (2) makes it clear that as the coefficient of risk charge and/or the uncertainty in cost increases, the marginal risk charge will increase, leading the insurer to charge higher prices.³¹

Let p_0^* denote the optimal price in (2) i.e. the insurer's profit-maximizing price in the absence of any regulations. In the latter sections, I compare the optimal prices under different regulations vs. p_0^* .

3.2 Ex-ante Margin Constraint

Now suppose the monopoly insurer faces a margin regulation such that the insurer's margin relative to its expected cost is constrained by an upper bound of \bar{m} . The insurer now faces the following constrained profit function:

$$\max_p pq(p) - cq(p) - \rho V(\tilde{C}) \quad s.t. \quad p \leq \bar{m}c \quad (3)$$

³⁰In fact, under exponential utility and normally distributed cost the model of risk averse insurer is equivalent to the mean variance objective in (1). See section C.1 for more details.

³¹This is in line with what many insurers seem to be doing when there is increased uncertainty in the cost.

The insurer's new FOC will now be:

$$p \left(1 + \frac{1}{\epsilon D} \right) = c + \rho \frac{\partial V(\tilde{C})}{\partial q} + \frac{\lambda}{\frac{\partial q}{\partial p}} \quad (4)$$

where $\lambda \geq 0$ is the Lagrange multiplier to the margin constraint. It is easy to see that the solution to the above FOC will be $p^* = p_0^*$ if the constraint does not bind (i.e. price stays the same as in (1)) or $p^* = \bar{m}c$ if the constraint binds.

3.2.1 Asymmetric Information

We explore the asymmetric information case, in which the insurer can strategically report its cost.

$$\max_{p, \delta \in [\underline{\delta}, \bar{\delta}]} pq(p) - cq(p) - \rho V(\tilde{C}) \quad s.t. \quad p \leq \underbrace{\bar{m} \delta c}_{\hat{c}} \quad (5)$$

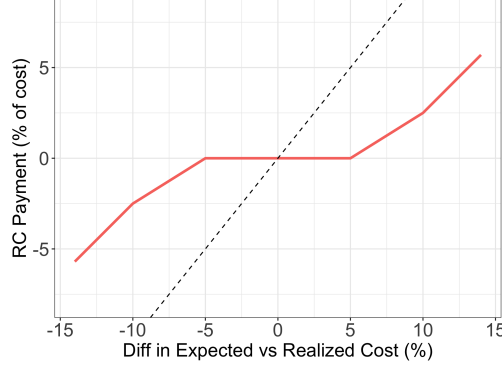
The insurer can now over or underestimate its ex-ante expected cost by parameter $\delta \in [\underline{\delta}, \bar{\delta}]$, $\bar{\delta} > 1 > \underline{\delta} \geq 0$, reporting a cost estimate of $\hat{c} = \delta c$. If $\delta < 1$ (or $\delta > 1$), then the insurer under-reports (over-reports) its expected cost, where $\delta = 1$ denotes the insurer reporting the true expected cost.³²

Assumption 1 $p_0^* \leq \bar{m}\bar{\delta}c$.

Proposition 1 $\delta^* = \bar{\delta}$ will always be optimal for the insurer's problem in (5). Furthermore if assumption 1 holds, $p_m^*(\delta^*) = p_0^*$ where $p_m^*(\delta)$ denotes the insurer's profit-maximizing price in (5) for a given δ .

Proposition 1 states that when we allow the insurer to strategically report its expected cost, the margin constraint plays no role in the insurer's pricing decision. This is because whatever price the insurer wants to set (i.e. p_0^*), it can set the price by reporting δ s.t. its reported cost estimate is high enough for the margin constraint to be satisfied without being penalized for misreporting its cost. In short, it will be always optimal for the insurer to report $\delta^* = \bar{\delta}$ when there is only an ex-ante margin constraint.

Figure 2: $T(\tilde{C}, C)$



Plot of $T(\tilde{C}, C)$ shown in percentage of the expected cost C . The horizontal axis shows the difference in expected cost C and the ex-post cost \tilde{C} as a percentage of C . The vertical axis shows the RC payment as a percent of expected cost C .

3.3 Risk Corridor

Here, I illustrate the effect of risk corridor payments (RCP) in reducing the risk that an insurer may face. RCP act as an ex-post transfer function between the insurer and the government as a function of ex-post cost, \tilde{C} and ex-ante expected cost $C = E[\tilde{C}] = cq$ (see figure 2). With RCP, the insurer's new ex-post cost will be:³³

$$\tilde{C}^{rc} = \tilde{C} + \underbrace{T(\tilde{C}, C)}_{\text{rc payment}} \quad (6)$$

$$\text{where } T(\tilde{C}, C) = \begin{cases} -0.8\tilde{C} + 0.855C & \text{if } \tilde{C} > C \text{ by more than } 10\% \\ -0.5\tilde{C} + 0.525C & \text{if } \tilde{C} > C \text{ by } 5 - 10\% \\ 0 & \text{if } \tilde{C} \text{ within } 5\% \text{ of } C \\ -0.5\tilde{C} + 0.475C & \text{if } \tilde{C} < C \text{ by } 5 - 10\% \\ -0.8\tilde{C} + 0.745C & \text{if } \tilde{C} < C \text{ by more than } 10\% \end{cases} \quad (7)$$

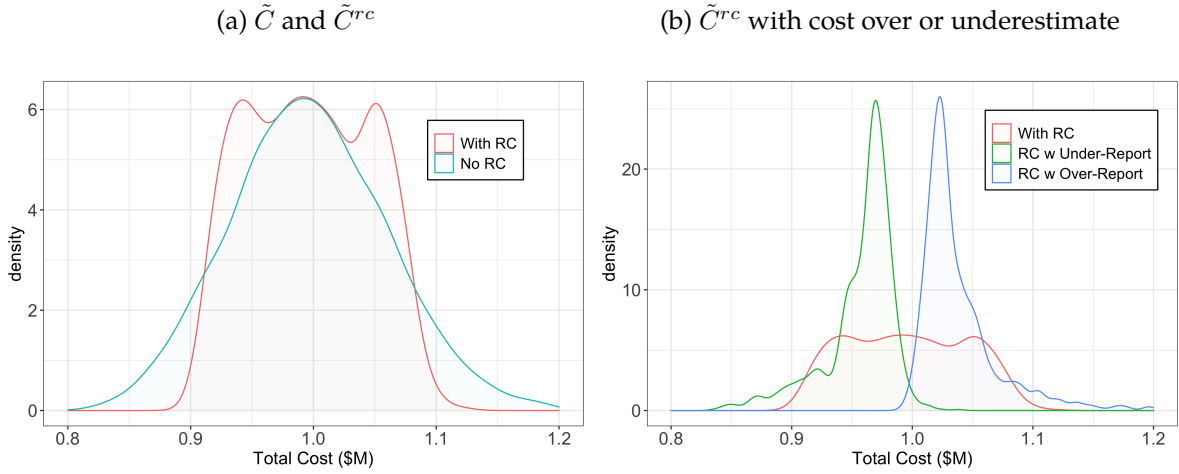
In short, the RCP is such that if the actual cost is lower (higher) than the expected cost by more than 5%, the insurer will pay (receive) a portion of the difference where the payment is determined via a kinked-linear function. If I assume that the distribution of the insurer's total cost \tilde{C} is symmetrical about its mean, then the expected risk corridor payments will be zero i.e. $E[T(\tilde{C}, C)] = 0$

³²In other words, $\delta = 1$ can be seen as the symmetric information case in which the government knows the expected cost of the insurer.

³³Note that the function $T(x, y)$ is homogeneous of degree one. Hence, $T(\tilde{C}, C) = T(\tilde{C}/q, e)q(p)$.

and hence $E[\tilde{C}^{rc}] = E[\tilde{C}] = cq$.³⁴ The variance of the \tilde{C}^{rc} on the other hand will be directly affected by the risk corridor payments and be weakly smaller i.e. $V(\tilde{C}^{rc}) \leq V(\tilde{C})$. This is illustrated in Figure 3a where the distribution of the cost with RC is more condensed, and hence will have lower variance.

Figure 3: Distribution of Cost



Panel (a) plots a simulated distribution of cost with and without risk corridors. Panel (b) plots a simulated distribution of cost with risk corridors when insurers over or underestimate their costs.

In the model (1), this implies that insurer will face lower risk charge (hence lower effective marginal cost), and charge a lower price.

3.3.1 Asymmetric Information

We now explore the asymmetric information case in which the insurer can strategically report its cost.³⁵ The insurer can now over or underestimate its ex-ante expected cost by parameter δ , hence reporting a cost estimate of $\hat{C} = \delta C$. If $\delta < 1$ (or $\delta > 1$), then the insurer under-reports (over-reports) its expected cost, where $\delta = 1$ denotes the insurer reporting the true expected cost.³⁶ The insurer maximizes a similar profit function as in (1) except that now the insurer's payoff is affected by the risk corridor payments through both the expected cost and the variance. Furthermore, the

³⁴If we maintain the assumption that individual level costs are independent, then the central limit theorem will imply that the distribution of total cost will be approximately normal, which is symmetric.

³⁵This could be seen as the government having a uniform prior on the cost. Though in reality, the government does have some historical cost data.

³⁶In other words, $\delta = 1$ can be seen as the symmetric information case in which the government knows the insurer's expected cost.

insurer can alter its payoff by over or under-reporting its expected cost denoted by parameter δ .

$$\max_{p, \delta \in [\underline{\delta}, \bar{\delta}]} pq(p) - cq(p) - \underbrace{E[T(\tilde{C}, \delta C)]}_{\text{expected RC-payment}} - \underbrace{\rho V(\tilde{C}; \delta)}_{\text{risk-charge}} \quad (8)$$

Note that the insurer's choice of δ impacts both the expected value and the variance of total cost as illustrated in Figure 3b. When the insurer underestimates its cost ($\delta < 1$), the distribution of cost is shifted to the left and more condensed, lowering both the expected cost and the variance. When the insurer overestimates its cost ($\delta > 1$), the distribution of cost is shifted to the right and more condensed, increasing the expected cost while lowering the variance. This is further illustrated in Figure 4 where I plot the expected RC payment and the variance as a function of δ for a given price. It shows that the expected RC payment is an increasing function of δ with it being 0 when $\delta = 1$. So when the insurer over (under) estimates its cost, it is expected to pay the government and vice versa. On the other hand, the variance of the cost is highest at $\delta = 1$ and hence decreases when the insurer either over or underestimates its cost. Figure 4 implies that the insurer will choose to underestimate its cost as much as possible. I formalize this argument below.

Figure 4: Expected risk corridor payment and variance of cost as a function of δ

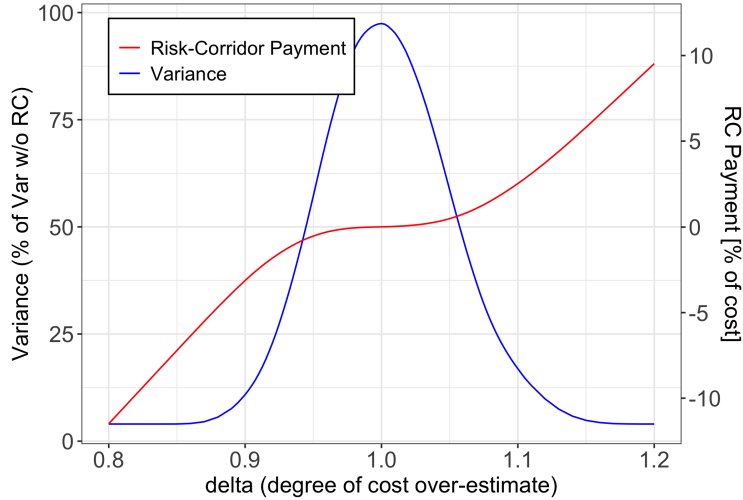


Figure plots expected risk corridor payment and variance of total cost as a function of the insurer's strategic cost reporting, δ

Assumption 2 $1 - \underline{\delta} \geq \bar{\delta} - 1$.

Assumption 2 puts restrictions on $\{\underline{\delta}, \bar{\delta}\}$. The lower bound on the degree to which the insurer

can underestimate its cost is equal to or smaller in magnitude than to the upper bound of how much the insurer can overestimate its cost.

Proposition 2 *Under Assumption 2, the optimal δ^* to the insurer's problem in (8) will be $\underline{\delta}$ i.e. the insurer will always report the lowest possible expected cost. And furthermore $p_{rc}^*(\underline{\delta}) < p_{rc}^*(1) \leq p_0^*$ where $p_{rc}^*(\delta)$ denotes the insurer's profit-maximizing price in (8) for a given δ .*

The intuition for this proposition is simple. For a given price, the insurer will always want to choose δ as low as possible in order to achieve the lowest expected RCP, thereby decreasing its expected cost. The lowest δ will also minimize the variance of the cost and hence the risk that the insurer faces. Given the choice of $\delta = \underline{\delta}$, the insurer will face strictly lower expected and variance of the cost and hence will lower its price below the price at $\delta = 1$.

3.4 Both Regulations

Now suppose there are both sets of regulations in place i.e. both the ex-post risk corridor payments and the ex-ante margin constraint.

The insurer's profit function will now be:

$$\max_{p, \delta} \quad pq(p) - cq(p) - \underbrace{E[T(\tilde{C}, \delta C)]}_{\text{expected RCP}} - \underbrace{\rho V(\tilde{C}; \delta)}_{\text{risk charge}} \quad s.t. \quad p \leq \underbrace{\bar{m}\delta}_{\bar{m}'} c \quad (9)$$

The endogenous cost reporting δ affects the insurer's profit in three different ways. First, δ affects the insurer's expected cost through $E[T(\tilde{C}, \delta C)]$. Second, δ affects the insurer's risk level through $V(\tilde{C}; \delta)$. Lastly, δ affects the insurer's margin constraint $p \leq \bar{m}\delta c$. From previous sections, the insurer will want to underestimate its cost ($\delta < 1$) in order to lower its expected RC payment. On the other hand, the insurer will want to overestimate its cost ($\delta > 1$) in order to increase its upper bound on the margin. When combined together, it's unclear whether the insurer will over or underestimate its cost depends on a few things. We formalize the direction of the optimal δ below.

Proposition 3 *The optimal δ^* in the insurer's problem in (9) will be $\underline{\delta} \leq \delta^* < 1$ or $1 < \delta^* \leq \bar{\delta}$ if the margin constraint does not bind or if the margin constraint strictly binds at $p_{rc}^*(1)$, respectively. Furthermore the insurer's profit-maximizing price, p_{both}^* will be s.t. $p_{rc}^* \leq p_{both}^* \leq p_0^*$.*

Proposition 3 states that the insurer will either over or underestimate its cost. The direction will depend on various primitives like the demand and marginal cost, as well as the upper bound on the margin. In general, if at $\delta = 1$ the optimal price $p_{rc}^*(1) < \bar{m}c$ then the insurer will want to underestimate its cost in order to lower its expected RC payment, decreasing its expected cost up until the margin constraint binds. Hence, the insurer will underestimate its cost but likely not all the way to $\delta = \underline{\delta}$. On the other hand, if $p_{rc}^*(1) > \bar{m}c$ (i.e. the margin constraint binds) the insurer will want to overestimate its cost in order to increase its upper bound on the margin, thereby allowing it to charge higher prices. However, the insurer will not overestimate its cost all the way to $\delta = \bar{\delta}$ as doing so would increase the expected RC payment.

In summary, the above model illustrates that when the government and the firm have symmetric information on costs, the risk corridor can reduce any frictions by reducing the risk that insurers face, and that margin constraint limits market power by constraining the price the insurer can charge. However, when there is asymmetric information (i.e. knowledge about expected cost is the insurer's private information and that the government only observes the ex-post realized cost), the risk corridor gives the insurer an incentive to underestimate its cost. On the other hand, margin regulation gives the insurer an incentive to overestimate its cost. When these incentives are both in play, the net effect is indeterminate and will depend on the context.

4 Data and Descriptives

4.1 Data

The paper uses three different types of data.

CMS Plan Data:³⁷ CMS's market-plan-year level data includes details on all Part D plans that were offered from 2010-2015.³⁸ It includes plan prices, detailed plan characteristics like deductibles, the drug formulary design and associated co-insurance/co-pay rates, as well as the plan-specific average price for each drug in the formulary.³⁹ It also includes total monthly enrollment,

³⁷All CMS data are publicly available and can be found here: <https://www.cms.gov/Research-Statistics-Data-and-Systems/Research-Statistics-Data-and-Systems>

³⁸Specifically, I use the following data from CMS: i) Medicare Advantage/Part D Contract and Enrollment Data ii) Prescription Drug Plan Formulary, Pharmacy Network, and Pricing Information Files.

³⁹However, the premium information is only available for PDP as the premium for MA-PD also include rebates from MA that insurer can apply to buy down the part D premium.

and the average risk score of the enrollees enrolled in the plan. CMS also publishes the total number of Medicare-eligible beneficiaries. I exclude plans that are employer-sponsored plans and restrict the sample to the 50 US continental states.

Although not at the plan level, I also observe year-contract level risk corridor payments to insurers from CMS's payment files. A contract is defined as a group of similar products that an insurer offers and can be thought of as firm level risk corridor payments.

Medicare Current Beneficiary Survey Data: I use the 2012-2015 Medicare Current Beneficiary Survey (MCBS) Limited Data that includes a nationally representative sample of Medicare beneficiaries.⁴⁰ For each individual, it includes detailed demographic information including income, age, and overall health level as well as the Part D plan enrollment, which details the specific Part D plan that the individual was enrolled in, if any. The MCBS data also includes administrative claims data with information on the individual's drug purchase history for the given year; the information about the specific drug purchased and the total cost of the drug for each consumer. I restrict the sample to include individuals in the 50 U.S. states, individuals for whom I observe Part D information, and individuals for whom I observe their claims data. This results in 27,262 individual-years.⁴¹

Insurer Financial Statements Data: I use insurer financial statements data to get firm level Part D costs as well as the insurer's non-Medicare margins. I use two filings from the National Association of Insurance Commissioners (NAIC): 2012-2015 Medicare Part D Coverage Supplement filing and 2008-2019 5-Year Historical filing. The first filing has detailed yearly financial statements for insurers' Part D businesses (PDP-only), including the total cost incurred for each insurer in the Part D market. The second filing has firm-year level aggregate financial information like the insurer's RBC ratio, a financial solvency measure used by the insurance regulators. Lastly, I use 2010-2015 CMS's Medical Loss Ratio data that has firm-year level financial statements data across different lines of the health insurance business. I use this to get the insurer's non-Medicare or commercial business margin used as a benchmark for the Part D margin regulation.

⁴⁰2014 is excluded due to MCBS missing the data for that year.

⁴¹I also exclude individuals enrolled in employer-sponsored Part D plans.

4.2 Descriptives

Table 1 shows summary statistics on the Part D PDP market from 2012-2015.⁴² The average price for a PDP plan was \$1,191, of which enrollees only had to pay \$643 on average. The difference between the two, \$548, reflects the average consumer subsidy paid by the government. Plans on average had 9,600 enrollees but there is a large variation ranging from 10 to 300,000.

Table 1: Summary Statistics

	Mean (1)	Std.Dev. (2)	Min (3)	Max (4)
A. Plan Level				
Bid (\$)	1,191	367	596	2,618
Enrollee Premium (\$)	643	360	150	2,096
Enrollment (000)	9.6	23.9	0.01	293.4
B. Market Level				
No of Plans	31.19	3.00	23	39
No of Insurers	13.65	1.34	10	17
Enrollment (000)	298	206	7	847
HHI Index*	2,452	489	1,801	3,822
Market Share of Top 3 Firms (%)*	74.4	5.1	64.9	84.7
Market Share of Top 5 Firms (%)*	90.0	2.5	84.4	95.5

Notes: the table shows summary statistics of the Part D stand-alone prescription drug (PDP) market from 2012-2015 in the 34 PDP regions for regular enrollees. Plan level data shows summary statistics taken across individual year-market-plan. Market level data shows summary statistics taken across year-market level. Enrollee premium refers to premium faced by regular enrollees. An insurer is defined as a unique parent organization in the CMS data. * HHI index and market share of top firms are computed using regular enrollees only.

Consumers on average had 31 Part D PDP plans to choose from, offered by 13-14 different insurers. While consumers had a good number of options to choose from, the number is smaller than earlier years of the Part D market (Decarolis *et al.*, 2020). This is in part due to CMS implementing a number of regulations that limit the total number of plans each insurer can offer.⁴³ But it also reflects the more concentrated market (Chorniy *et al.*, 2020). The mean Herfindahl-Hirschman index across markets from 2012-2015 was close to 2,500, which the Department of Justice regards as a highly concentrated market.⁴⁴ On average, the top three firms account for 75% of market share

⁴²The summary statistics only include regular enrollees. The summary statistics for the low-income subsidy (LIS) eligible enrollees can be found in Table A1.

⁴³In 2010, CMS issued “meaningful difference” requirements in which an insurer couldn’t offer two plans that were too similar to one another.

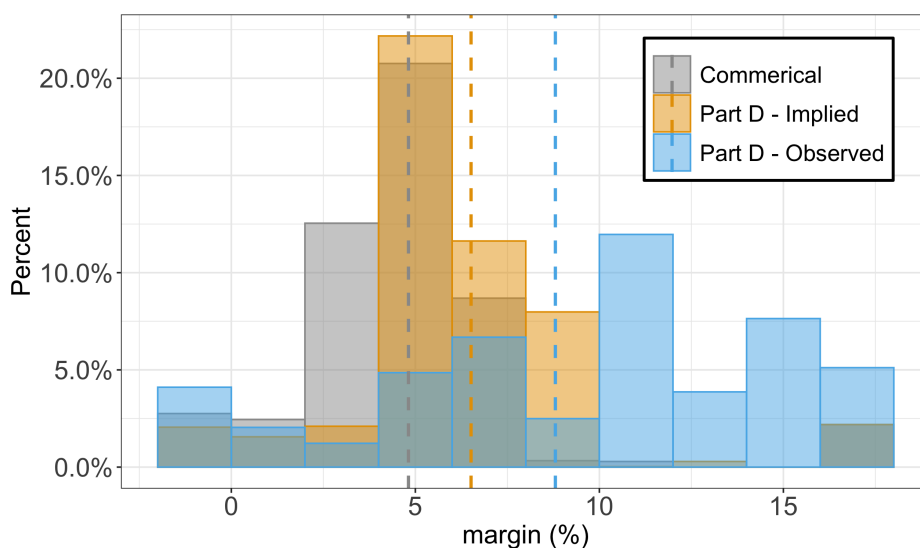
⁴⁴The horizontal merger guidelines from the Department of Justice and the Federal Trade Commission classifies

and the top five firms account for 90% of the market share.

Consistent with the relatively high level of concentration in the Part D market, figure 5 shows that insurers are much more profitable in their Part D business compared to their non-Medicare or commercial business. In fact, insurers' ex-post profit margins in their Part D business is higher than what the profit margin regulation would dictate. Figure 5 shows that insurers' observed ex-post Part D business profit margins are much higher than what's implied by the regulation i.e. within 1.5% of insurers commercial business margins. So for most insurers, the profit margin regulation likely binds and constrains the margin that they can charge in the Part D market, meaning insurers over-report their cost estimates to relax the constraint.

Figure 5: Distribution of Risk Corridor Payments and Insurer Margin

Figure 6: Part D vs. Non-Medicare Margin



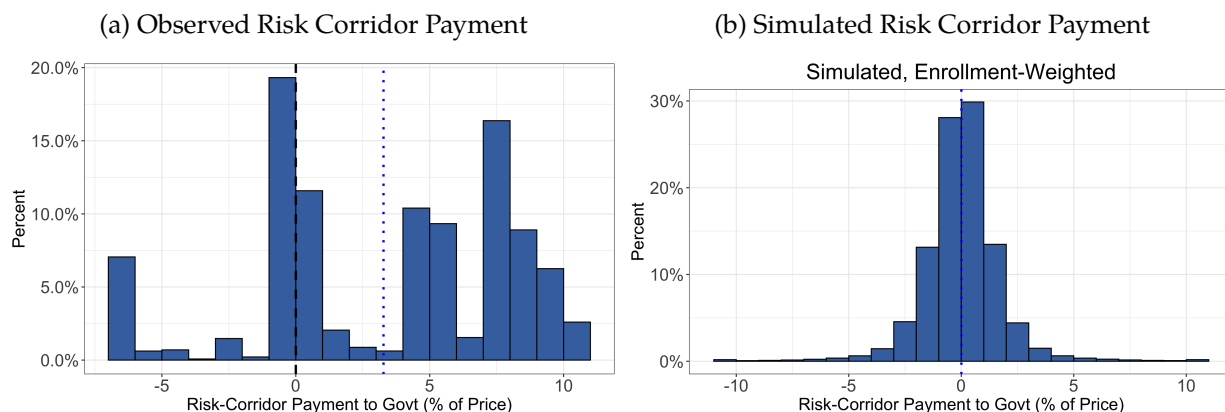
The figure shows the distribution of 2012-2015 Part D insurers' i) non-Medicare or commercial business ex-post profit margins ii) allowable or implied profit margins under the ex-ante profit margin regulation (i.e. i) shifted by 1.5% margin) iii) observed ex-post profit margins of the PDP business. The distributions are weighted by observed enrollment.

The observed risk corridor payments in figure 7a further show patterns consistent with insurers over-reporting their cost estimates. The distribution is heavily skewed towards the right, implying many insurers' actual costs were much higher than their reported expected cost, and thus insurers are making large ex-post payments to the government. This is in stark contrast with figure 7b that shows the simulated risk corridor payments had insurers truthfully reported their cost estimates.

markets with HHI above 2500 as highly concentrated markets.

Furthermore, the risk corridor payment patterns are persistent across years. Insurers are much more likely to have positive risk corridor payments if they had positive risk corridor payments in the prior year, and vice versa.⁴⁵

Figure 7: Distribution of Observed vs. Simulated Risk Corridor Payments



Panel (a) plots the distribution of observed risk corridor payments from 2012-2015 for each PDP contract. Panel (b) plots the distribution of simulated risk corridor payments assuming insurers truthfully report their expected cost. The distributions are weighted by observed enrollment.

5 Empirical Model

5.1 Model of Demand

I model the demand for PDP coverage for Medicare beneficiaries in the 34 Part D markets over the years 2012-2013 and 2015.⁴⁶ I do so using a standard discrete choice model (Berry *et al.*, 1995) similar to Decarolis *et al.* (2020) in which a consumer derives indirect utility from choosing a particular product and chooses the product that maximizes his or her utility. I estimate the demand separately for the two populations in the market: regular enrollees and low-income subsidy (LIS) eligible enrollees.⁴⁷ Below, I detail the demand specification for the regular enrollees as the specification for the LIS enrollees follows a similar structure.⁴⁸

⁴⁵See figure A.2 for more details. For more evidence of risk corridor payments being random, see A.3.

⁴⁶I leave out demand estimation for year 2014 due to missing MCBS data in year 2014.

⁴⁷LIS eligible beneficiaries receive extra assistance from the government in premiums as well as extra cost sharing in drug spending.

⁴⁸The demand specification for the LIS enrollees is similar to that of the regular enrollees, except that I limit some preference heterogeneity within the LIS enrollees. For example, I do not partition the LIS enrollees into different income groups. I also adjust many of the plan attributes to reflect the extra cost sharing that LIS enrollees receive. For example, the deductible is zero for LIS enrollees, and many of the plan premiums are also zero if they are below the LIS benchmark.

Individual i 's utility from choosing plan j in market m is given by:

$$u_{ijm} = \alpha_i p_{jm}^e + \beta_i X_{jm} + \xi_{jm} + \varepsilon_{ijm} \quad (10)$$

p_{jm}^e is the enrollee plan premium after government subsidy has been applied.⁴⁹ X_{jm} are other observable plan characteristics that include the plan deductible, whether the plan provides additional coverage beyond the minimum requirement (i.e. an enhanced plan), whether the plan has extra coverage in the donut hole, and the number of drugs covered in the plan's formulary. Following [Decarolis et al. \(2020\)](#) and [Starc & Town \(2020\)](#), I also include plan vintage or the number of years the plan has been in the market as a reduced-form way of capturing consumer inertia.⁵⁰

Lastly, the observable plan characteristics include a constant, denoting the value of inside-good relative to the outside option whose utility is normalized to zero. The outside option here indicates Medicare beneficiaries enrolling in a Medicare Advantage medical plan with drug benefits (MA-PD) or opting to not purchase any prescription drug coverage through Medicare part D.^{51,52}

I allow heterogeneity in preferences by allowing α_i , the price sensitivity, to vary across an individual's observable characteristics:

$$\alpha_i = \alpha_0 + \sum_{g=2}^5 \alpha_g^{health} \mathbb{1}\{health(i) = g\} + \sum_{g=2}^3 \alpha_g^{age} \mathbb{1}\{age(i) = g\} + \sum_{g=2}^3 \alpha_g^{income} \mathbb{1}\{income(i) = g\} \quad (11)$$

Here, α_0 indicates the base level of price-sensitivity common for all individuals. I then allow price-sensitivity to vary by individuals' self-reported health level. The MCBS data includes survey results in which individuals are asked to select between five health levels ranging from "poor" to "excellent".⁵³ This is denoted by $\mathbb{1}\{health(i) = g\}$, a dummy variable equal to one if individual i 's health level $health(i)$ is g and zero otherwise. Next, I allow the preferences to vary by demographic

⁴⁹The consumer subsidy in Medicare Part D acts like a flat voucher in which government provides a pre-set $\$S$ amount regardless of which plan the enrollee chooses. The subsidy level S for a given year is usually some factor multiplied by the lagged-enrollment weighted average prices across all plans.

⁵⁰[Decarolis et al. \(2020\)](#) show that this approach corresponds to "structural two-stage model of inattention and choice" ([Hortaçsu et al. , 2017](#)).

⁵¹In 2015, 43% of Medicare beneficiaries chose a PDP plan or the inside-good in the model, 28% chose an MA-PD plan, and the remaining 29% chose not to purchase a drug coverage through Part D. It is estimated that of the beneficiaries who do not purchase any coverage, 64% of them receive drug coverage through a third party and the remaining 36% has no drug coverage.

⁵²For LIS enrollees, the outside option strictly refers to purchasing a MA-PD plan.

⁵³These self-reported health levels are a good predictor of the overall medical and drug spending.

groups: I group individuals into three age bins and three income bins. This is denoted by similar dummy variables for age and income groups. Thus, the price coefficient for the least healthy, youngest and lowest income group is the baseline coefficient α_0 whereas the price coefficient for the most healthy, oldest and highest income group is given by $\alpha_0 + \alpha_5^{health} + \alpha_3^{age} + \alpha_3^{income}$. Similarly, I allow β_i , the taste for other plan characteristics, to vary across individuals' observable characteristics in the same way. While not used in the baseline demand specification, as a robustness check I also allow for unobserved heterogeneity through random coefficients.⁵⁴

The final component of the utility is the term: $\xi_{jm} + \varepsilon_{ijm}$. Following the literature, I assume ε_{ijm} is a *i.i.d.* type I extreme-value distributed random taste shock. The ξ_{jm} is the unobserved plan quality specific to each market that may be correlated with the product characteristics. I first include product and market fixed effects to control for any product specific or market specific unobserved quality.⁵⁵ As is commonly the case, I assume that all non-price attributes are exogenous but allow prices to be endogenous.⁵⁶ I instrument for price using the number of contracts that the insurer has in nearby markets (Decarolis *et al.*, 2020) as well as the insurer's RBC ratio in the prior year.^{57,58} The number of contracts in nearby markets reflects potential cost-shifters in insurers' cost (e.g. negotiating prices with local pharmacies).⁵⁹ The insurer's RBC ratio in the prior year can be treated as "excluded shifter of firm markups" in Berry & Haile (2022). This is similar to Koijen & Yogo (2022) that uses life insurers' reserve valuation as an instrument for variable annuities demand. While the existing literature uses prices in nearby markets (Hausman-style instruments) as valid instruments, it hinges on ξ_{jm} not being correlated across markets. Instead, I use supply-side

⁵⁴See demand estimates section for more details on this specification.

⁵⁵Here, the product is defined as contract plan-type pair. Within my time period, the insurer usually offers two or at most three products in each market. These products are usually vertically differentiated products in which one is a "basic" plan that offers the standard coverage and the other is an "enhanced" plan that offers additional coverage beyond the minimum level.

⁵⁶This is motivated by the fact that plans are limited to offering two or three plans that meet certain actuarial values. Beginning in 2011, insurers are subject to meaningful difference requirements across plans that they offer i.e. the insurers are not allowed to offer two plans that are similar attributes and must pass the "meaningful difference" requirements set out by CMS. Furthermore, insurers tend to offer a stable portfolio of plans across the years I study.

⁵⁷RBC ratio is a commonly used measure of financial solvency level of health insurers. In the model, this could be affecting the coefficient of risk charge or the degree of how "risk averse" insurers behave. Kim & Li (2022) show evidence of such financial solvency measures affecting premiums of health insurers.

⁵⁸One concern here could be that the RBC ratio is in part correlated to ongoing demand shocks of that insurer. While that may be true, RBC ratio concerns the insurer's financial situation across all its business lines. However, given that the Part D business usually makes up a small portion of the insurer's business it's unlikely that the demand shocks in Part D will have a large impact on the overall RBC ratio of the insurer.

⁵⁹It might be easier for the insurers to negotiate costs with pharmacies and/or drug manufacturers by operating in larger markets.

instruments that do not rely on such an assumption.

I estimate the demand following [Goolsbee & Petrin \(2004\)](#). In the first step, I estimate the individual demographic-related coefficients and the mean utility via maximum likelihood. In the second step, I estimate the mean coefficients using two-stage least squares regression using the aforementioned instruments.

5.2 Model of Supply

Accurately modeling the supply side of the Part D market is very complicated due to the numerous regulatory provisions in the market.⁶⁰ For simplicity, I present the main objective function of insurers and defer any other details to appendix D. The below model closely follows the stylized model presented in section 3 except that now insurers are multiproduct firms in an oligopoly setting, as opposed to being a single-product monopoly. The objective function of each insurer (suppressing the firm subscript) that offers a set of PDP products J_m in each market m is given by:

$$\Pi_{\{b\},\delta} = \sum_m \sum_{j \in J_m} (b_{jm} - c_{jm}) \underbrace{Q_{jm}(b)}_{\text{risk-adj demand}} - \underbrace{\gamma_{jm}(\delta, Q_{jm}) c_{jm} Q_{jm}(b)}_{\text{expected rc payment}} - \underbrace{\rho V_{jm}(\delta, Q_{jm})}_{\text{risk charge}} \quad (12)$$

$$s.t. \quad \sum_m \sum_{j \in J_m} b_{jm} Q_{jm}(b) \leq \bar{m} \sum_m \sum_{j \in J_m} \underbrace{\delta c_{jm}}_{\text{cost estimate}} Q_{jm}(b) \quad (13)$$

The insurer maximizes the above objective by choosing the bid-vector $\{b\}$ (comprised of b_{jm} 's, one for each PDP plan), and δ , the degree of strategic cost reporting. If $\delta > 1$ (or $\delta < 1$), then the insurer chooses to overestimate (or underestimate) its cost, and $\delta = 1$ corresponds to the insurer correctly reporting its expected cost to the government.

The insurer's objective function comprises three parts that are summed over all the plans. The first part is the standard expected profit i.e. price (or "bid" in this setting) minus the expected average cost times the demand. The second part is the expected risk corridor **transfer payments to the government**. It is the product of the plan's expected risk corridor function as a share of

⁶⁰[Decarolis et al. \(2020\)](#) documents a large portion of these and tries to incorporate them as well as possible in their model. However, they do not take account of everything: in particular, the risk corridors and ex-ante margin regulations that insurers face, which is the focus of my paper. I focus on modeling these two regulations as well as possible, while incorporating the other regulatory provisions that [Decarolis et al. \(2020\)](#) include: ex-ante risk adjustment, consumer subsidy rules, especially for the LIS enrollees, etc. However, I make some simplifying assumptions where necessary in order to make the model more tractable and focus primarily on the two regulations.

total expected cost, $\gamma_{jm}(\delta, Q)$, and the total expected cost, $c_{jm}Q_{jm}$. The final part of the objective function is the risk charge. It is the product of the coefficient of risk charge, ρ and the plan's variance of total cost, $V_{jm}(\delta, Q)$. Here, I am implicitly assuming that the costs across plans are independent and hence the variances can be summed across the plans.⁶¹ Lastly, I make the assumption that $\rho \geq 0$, that is I assume insurers are not risk seeking.

$$Q_{jm}(b) = \sum_t \theta_t M_t s_{jm}^t(b) \quad (14)$$

Equation (14) shows how the risk-adjusted demand is constructed. The risk-adjusted demand is the sum of demand across individuals of different risk types, where the demand gets adjusted for different risk-types via the scaling factor θ_t . M_t and s_{jm}^t are the market size and share function of consumer of risk type t , respectively. I allow six different risk types across individuals: five different health levels (the same health levels used in demand) across regular enrollees, and a single type for the LIS enrollees.

The risk-adjusted demand reflects two things: selection on the cost side and CMS's risk adjustment on the revenue side. On the cost side, health insurance markets typically exhibit selection in which consumers' costs may vary across different types of individuals. To model this, I allow consumers' expected marginal cost to vary by their risk types: a consumer of risk type t has a marginal cost of $\theta_t c_{jm}$ if he/she enrolls in plan j in market m . So c_{jm} is the baseline marginal cost that corresponds to the insurer's expected marginal cost of an average risk enrollee. On the revenue side CMS risk-adjusts the plan's revenue by scaling the plan's bid by the average risk score of the plan.⁶² So the plan receives $\theta_t b_{jm}$ in premiums for enrolling a consumer of risk type t where b_{jm} reflects the plan's bid for an average risk enrollee. The risk adjustment inflates (deflates) the premiums of plans that enroll observably sicker (healthier) enrollees.

While I allow for selection in the model, I assume that there is perfect risk adjustment similar to [Curto et al. \(2021\)](#).⁶³ This is reflected by using the same risk adjustment factor for both the

⁶¹In the model, the uncertainty in cost is coming from random draws of enrollees whose costs are independent of one another. While in theory, I could allow for a more flexible correlation in costs across enrollees and/or plans, this makes the inversion of FOC much more difficult. Furthermore it makes it computationally intractable due to i) non-linearity of the risk corridor function and ii) the cost shocks need to be integrated across individual plans that could be in the order of 100+ integrals for some large insurers. I'm currently working on an approximation method that could allow a more flexible correlation structure across plan costs.

⁶²For details refer to section 2

⁶³In the appendix, I detail the full model where I allow for imperfect risk adjustment.

marginal cost and the bid. While I could allow for imperfect risk adjustment, I assume perfect risk adjustment for the following reasons. First, the focus of the paper is on ex-post risk sharing i.e. risk sharing due to unpredictable uncertainty not ex-ante predictable risk, as is the case for risk adjustment. Second, assuming perfect risk adjustment simplifies the model a great deal and allows me to more reliably estimate the supply-side model without running into numerical issues.⁶⁴

Lastly, the final component of the objective function is the ex-ante margin constraint in (13). The margin constraint dictates that the total revenue of the insurer compared to its reported expected total cost can't exceed the firm specific maximum margin, \bar{m} . It's clear that as the insurer overestimates its cost (i.e. $\delta > 1$), its reported expected total cost will increase, relaxing the margin constraint.

I make the usual conduct assumption that insurers compete via Bertrand-Nash in prices.⁶⁵ Note that here the insurer's decision to misreport its expected cost, δ , does not affect other insurers' payoffs; only their pricing decisions (through the demand) affect other insurers' payoffs.

5.2.1 Identification/Estimation

Estimating the supply-side model is challenging for a variety of reasons. First, as pointed out by [Decarolis et al. \(2020\)](#) LIS-benchmark plans or the "LIS-distorted" plans have a non-linear share function that makes the standard approach of inverting first order conditions difficult.⁶⁶ Second, there are more "unknowns" than the number of first order conditions I can derive from the conduct assumption. I resolve these issues by making some reasonable assumptions on the marginal costs, and using a combination of first order conditions and observed data.

Table 2 shows the list of variables used in the supply-side model and categorizes them as either coming from data, demand estimation, or parameters that are to be estimated. The share functions s_{jm} are separately estimated from the demand estimation, so we can treat them as known objects. The plan bids as well as the associated enrollee premiums are observed in the CMS's plan level data. The maximum allowed margin which is at the insurer-year level is taken as the insurers' non-

⁶⁴As I mention in the estimation section, I sometimes run into numerical issues when I try to solve for the FOC's due to the non-linearities in the FOC's. I find that this is especially worse when I allow for imperfect risk adjustment.

⁶⁵While this is true for the most part, in section D.1, I detail how for some plans this is difficult to do due to how the subsidy is set for LIS enrollees.

⁶⁶For more details, see section D.1

Table 2: Supply-Side Parameters and Identification

Object	Description	Inference
s_{jm}^t	market share of consumer type t	demand estimates
$\frac{\partial s_{jm}^t}{\partial \theta_{km}}$	derivative of market share	demand estimates
b_{jm}	plan bids	data
\bar{m}_f	maximum allowed margin	data
θ_t	risk adjustment multiplier for consumer type t	data*
$\gamma_{jm}(\delta, Q)$	expected risk corridor payment share function	data/simulated**
$V_{jm}(\delta, Q)$	variance of plan total cost function	data/simulated**
c_{jm}	marginal cost	estimation via FOC
δ_f	degree of strategic cost reporting	estimation via FOC
ρ_f	coefficient of risk charge	estimation via cost moment

Notes: the table shows the list of variables/functions needed to evaluate the supply-side model, and specifies how each object is constructed. *This is inferred from using claims data of individuals across different risk types. **These functions are estimated by simulating the cost distribution of plans using the claims data.

Medicare business margin from the insurers' financial statements.⁶⁷ The risk adjustment factor (or the cost multiplier) across different consumer types is inferred from the claims data.⁶⁸

The functions $\gamma_{jm}(\delta, Q)$, the expected risk corridor payment share and $V_{jm}(\delta, Q)$, the variance of total cost are obtained using the claims data and the plan level attributes data. Using the sample distribution of the enrollee's claims cost (adjusted for plan specific cost sharing), I simulate the distribution of the plan's (claims) cost for different values of strategic cost reporting, δ and the plan's demand, Q . I then approximate the functions using a 2-dimensional spline method to get a smooth function of both variables. The full details of this process can be found in Appendix E.

Then, I am left with the main parameters of interest: the marginal cost vector, c_{jm} , insurers' strategic cost reporting parameter, δ_f and the coefficient of risk charge ρ_f . For the marginal cost and the strategic cost reporting parameter, I can construct associated first order conditions to the objective in (12) derived in section D.2. As mentioned above, one challenge to this is that I can't use the FOC's of the plans that are "LIS-distorted". And unlike Decarolis *et al.* (2020), my model's FOC's are highly non-linear with respect to the marginal costs and have cross-market ties (due to

⁶⁷I use a combination of financial statements data from NAIC as well as the CMS's Medical-Loss Ratio data to get the prior year margins of insurers' non-Medicare business as defined by CMS.

⁶⁸I take the ratio of average costs of individuals of type t to the overage cost of the overall population. For more detail, see the Appendix E.2

the margin constraint) that makes it hard to separately estimate the marginal costs of regular plans vs. the LIS-distorted plans.⁶⁹

Instead, I make the following restrictions on the marginal cost of the LIS-distorted plans vs. regular plans in the same market.

$$c_{j'm}^{LIS} = \frac{1 - AV_{j'm}}{1 - AV_{jm}} c_{jm}^{regular} \quad (15)$$

For each LIS-distorted plan j' , I find a non-distorted plan j by the same insurer in the same market.⁷⁰ I then restrict the ratio between the costs to be the same as the insurer liable average share of enrollee's costs or one minus the actuarial value of the plan. Insurer will often offer two plans in the market that are vertically differentiated by the plans' cost sharing generosity or the actuarial value. As such, the above restriction seems to be a reasonable assumption.

For the coefficient of risk charge, I construct a set of cost moments at the firm-group year level:

$$\sum_m \sum_{J_m} w_{jm} c_{jm}(\rho) = \underbrace{\frac{\text{Total Cost}}{\text{Total \# Enrollees}}}_{\hat{c}} \quad (16)$$

where w_{jm} is the enrollment weight and $c_{jm}(\rho)$ is the model-implied marginal cost given a fixed value of ρ . The right hand side of the equation is the average cost of firm or firm-group observed in the data. The above identifies ρ by trying to match model-implied cost with the observed cost data or in other words by matching the implied margins with the observed ones. Suppose $\rho = 0$ i.e. insurers are risk neutral. If I find that the observed cost (relative to premiums) is much lower than the model-implied cost, then insurer likely incurs risk charges and prices accordingly. So ρ will have to be some value $\rho > 0$, and by matching the above moment ρ will be estimated in such a way.

I construct the above moments at the firm-year level for the larger insurers, but group some of

⁶⁹Decarolis *et al.* (2020) invert the FOC's of regular plans to back out the marginal costs of those plans first. They then project these marginal costs onto observable characteristics and predict the marginal cost of LIS-distorted using this projection on observable characteristics.

⁷⁰For some plans that don't have other non-distorted plans in the same market, I find a plan in the nearby market.

the smaller insurers together.⁷¹ I estimate all the parameters jointly using a constrained GMM.⁷²

$$\begin{aligned} & \min_{\rho} g'Wg & (17) \\ \text{s.t. } & FOC(\rho) = 0 \\ \text{where } & g = \sum_m \sum_{J_m} w_{jm} c_{jm}(\rho) - \hat{c} \end{aligned}$$

6 Model Estimates

6.1 Demand Estimates

Table 3 shows the demand estimates for regular enrollees. Most of the coefficients follow intuitive patterns. Healthier enrollees are more price sensitive, and higher income and older individuals are less price sensitive. The implied mean premium elasticity of the demand model is -4.13, and varies from -3.7 to -4.3 depending on the health level of enrollees. These seem economically reasonable estimates and are similar in magnitude compared to the elasticities estimated in other papers (-5 to -13 in Decarolis et al 2020, -2 to -6 in Lucarelli et al 2012, and -5 to -6.3 in Starc and Town 2015).⁷³

Non-price coefficients also follow intuitive patterns. Healthier consumers are less likely to purchase drug coverage through the PDP market. This may be from healthier enrollees opting to enrol in MA-PD plans or that they choose not to have any drug coverage through Part D.⁷⁴ Consumers dislike higher deductibles and derive positive utility from plan generosity: they prefer enhanced plans that have higher actuarial value, likes having extra coverage in the gap and like having more drugs being covered in their plans. Lastly, the coefficient on plan age is positive and significant, meaning that existing plans are more likely to capture a larger pool of beneficiaries. The coefficient is smaller for higher income consumers, meaning they are less likely to stick with existing plans.

The demand estimates for LIS enrollees (Panel B) also show similar patterns in demand. I

⁷¹This is because some of the smaller firms don't have enough enrollees and/or plans to reliably construct the above moment. However, this means that I can't estimate ρ at the firm level but at the firm-group level.

⁷²While I could solve the minimization problem by a solver, I've often ran into different numerical issues where the solver had convergence issues. In practice, I create a grid of ρ values and find associated marginal cost vectors and δ values that make the FOC hold. I then select ρ among the grid of values that minimizes the GMM objective.

⁷³These papers estimate demand in the first few years of the PDP market whereas I estimate demand using more recent years.

⁷⁴This is in line with the findings that healthier enrollees are more likely to enroll in Medicare-Advantage plan. In our model given the outside option includes MA-PDs, it may be that healthier enrollees are more likely to enroll in MA-PDs.

exclude many of the plan characteristics as LIS enrollees face little variation in those attributes due to increased cost sharing. The price coefficient for LIS enrollees is also negative and significant and follow similar patterns across age bins: younger consumers are more price sensitive. I also find positive and significant coefficient on plan age, meaning similar to the regular enrollees, LIS enrollees are more likely to stick with existing plans.

Table 3: Demand Estimates

	A. Regular Enrollees									B. LIS Enrollees		
	Mean Utility	Demographic Interactions								Mean Utility	Demographic Interactions	
	β_0	Health				Income		Age			Age	
		Fair	Good	VeryGood	Excellent	Medium	High	< 65	> 80		< 65	> 80
Premium (\$000s)	-5.95	-0.40	-0.95	-1.24	-0.97	0.39	0.85	-0.44	0.28	-4.81	-0.39	0.14
s.e.	(0.36)	(0.41)	(0.39)	(0.39)	(0.43)	(0.20)	(0.26)	(0.42)	(0.22)	(0.15)	(0.28)	(0.35)
Constant		-0.10	0.44	0.63	0.76	0.05	0.14	-0.82	-0.63		0.75	-0.10
s.e.		(0.33)	(0.30)	(0.30)	(0.31)	(0.14)	(0.18)	(0.28)	(0.16)		(0.11)	(0.16)
Deductible (\$000s)	-2.42	0.39	-0.40	-0.24	0.18	-0.18	-0.54	0.35	-0.70			
s.e.	(0.59)	(0.66)	(0.62)	(0.62)	(0.65)	(0.29)	(0.37)	(0.51)	(0.33)			
Enhanced	1.82	-0.10	-0.13	-0.23	-0.26	0.13	-0.09	-0.14	0.01			
s.e.	(0.17)	(0.19)	(0.18)	(0.18)	(0.19)	(0.08)	(0.10)	(0.16)	(0.09)			
Extra Coverage-Gap	0.88	0.24	0.25	0.18	0.20	-0.02	-0.04	-0.18	0.04			
s.e.	(0.25)	(0.29)	(0.27)	(0.27)	(0.30)	(0.14)	(0.17)	(0.31)	(0.14)			
No. of Drugs Covered	0.12	-0.06	-0.04	-0.09	-0.21	-0.08	-0.08	0.22	0.10	0.12	-0.03	-0.11
s.e.	(0.05)	(0.06)	(0.06)	(0.06)	(0.06)	(0.03)	(0.04)	(0.05)	(0.03)	(0.02)	(0.03)	(0.04)
Plan Age	0.32	0.02	-0.01	-0.00	-0.05	-0.06	-0.08	0.04	0.09	0.30	0.01	0.12
s.e.	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.01)	(0.02)	(0.03)	(0.02)	(0.01)	(0.02)	(0.02)

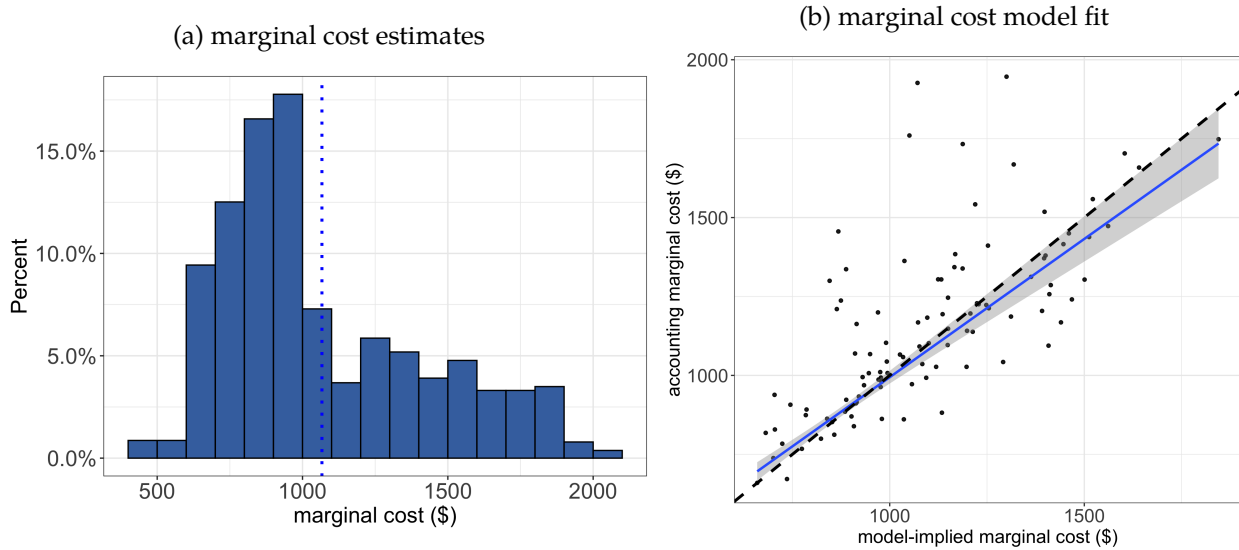
Notes: the table shows demand estimates for regular and low-income subsidy (LIS) enrollees. Many of the product characteristics for LIS enrollees are excluded as they face identical cost-sharing characteristics like deductible across plans.

6.2 Supply-Side Estimates

Expected Marginal Cost, c_{jm}

Figure 8a shows the distribution of the expected marginal cost estimates c_{jm} 's. The marginal cost is centered around \$1,066, but with a large variance (standard deviation of \$354). Much of this variation comes from the variation in plans' cost sharing characteristics. For example, plans with the standard benefit design have a mean marginal cost of \$851 where as plans with enhanced benefit design have a mean marginal cost of \$1,271. I also project the estimated plan level marginal costs onto observable plan characteristics.⁷⁵ I find intuitive patterns: higher deductible is associated with lower marginal costs, higher cost sharing (e.g. extra coverage gap, enhanced plan benefit design) is associated with higher marginal costs.

Figure 8: Marginal Cost Estimates



Panel (a) plots the distribution of the marginal cost estimates, c_{jm} . Each observation is plan-year. Panel (b) plots the estimated marginal costs vs. observed accounting cost data at the firm-year level. For the model, the firm level marginal costs are computed by taking the enrollment-weighted average across all the firm's plans. The dashed line indicates the 45-degree line, and the blue line shows the best-fit line where the observations are weighted by enrollment.

To assess whether these are reasonable marginal cost estimates, I compare the marginal cost estimates with the observed accounting cost data from the insurers' financial statements, which is shown in figure 8b. It shows that the estimated expected marginal cost closely follows the observed data. While there are some observations that are further from the 45-degree line, these are driven

⁷⁵See Table A2 for the results of this regression.

by small insurers whose costs will vary more from year to year. The enrollment-weighted average marginal cost is estimated to be \$883 vs. observed cost of \$885, suggesting that the marginal cost estimates are reasonable.⁷⁶

The given marginal cost estimates imply that firms' implied margin is around 12.3% on average (vs. 13% observed in the data), which is much higher than the 7 percent estimated in [Decarolis et al. \(2020\)](#). This may be because i) I use data from much later years of the program, and/or ii) because in my supply model, I endogenize the effect of strategic cost reporting on the insurers' risk corridor payments.⁷⁷ When I follow [Decarolis et al. \(2020\)](#)'s approach to estimating the marginal cost, I get an enrollment-weighted average marginal cost estimate of \$917, much higher than what I estimate and what is observed in the data.⁷⁸ This higher marginal cost estimate implies 8.8% margin, suggesting a model that does not endogenize the strategic cost reporting and the insurers' risk charges may lead to biased marginal cost estimates.

Strategic Cost Reporting Parameter, δ

Figure 9a shows the distribution of firm's strategic cost reporting parameter, δ . Consistent with observed risk corridor payment patterns, I find that the insurers overwhelmingly overestimate their costs. On average, the insurers overestimated their costs by 7.5 percent. But this varies from an insurer underestimating costs by 10% to an insurer overestimating costs by 12%.

To see whether these strategic cost reporting parameters are reasonable, I look at the expected risk corridor payments implied by the insurers' strategic cost reporting behaviors. 9b shows this model-implied expected risk corridor payments vs. the observed risk corridor payments by the insurers. While the two don't align perfectly, the two distributions are centered very closely to one another suggesting the model can explain the skewed distribution of the observed risk corridor payments.⁷⁹

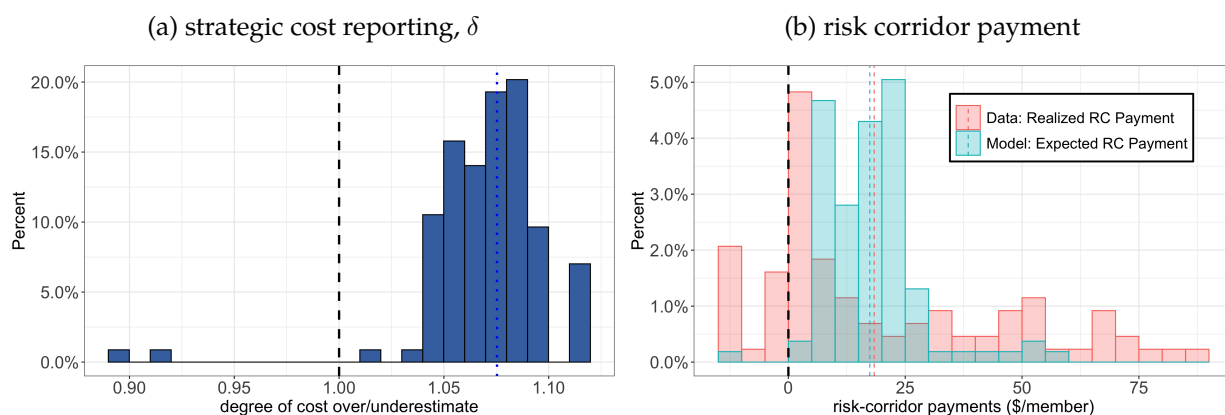
⁷⁶Part of this will be "mechanical", since our estimation relies on matching the model-implied cost with the observed data. However, it doesn't guarantee that the costs will be exactly the same since for most firms, moments are aggregated across the firms.

⁷⁷Over the years, Medicare Part D market has become more concentrated. So the higher margin that I estimate may in part be reflecting higher market power that the insurers have. It could also be because I endogenize the strategic cost reporting and its effect on the two sets of regulations in the market. It's unclear in which direction the estimates will be

⁷⁸In figure A.5, I assess the fit of these marginal cost estimates similar to figure 8b, which shows that the [Decarolis et al. \(2020\)](#)'s approach of marginal cost estimates may lead to biased estimates.

⁷⁹The model implied risk corridor payment is in expectation i.e. without any shocks to the costs. As a result, we would expect the realized risk corridor payments to be noisier and have larger variance than the model-implied expected

Figure 9: Estimated degree of strategic cost reporting, δ and implied risk corridor payments



Panel (a) plots the distribution of the strategic cost reporting parameter, $\delta_{f,t}$. Each observation is firm-year. The dashed line indicates the mean of the distribution. Panel (b) plots the distribution of estimated expected per-enrollee risk corridor payments and observed per-enrollee risk corridor payments. Each observation is firm-year. The dashed lines indicate the mean of the distribution, respectively.

Coefficient of Risk Charge, ρ

Figure 10a shows the distribution of the coefficient of risk charge, normalized to the variance of an average enrollee. On average, the insurers face \$17.5 of risk charge for enrolling an additional average enrollee, however there is quite a bit of variation here as well. A large number of insurers are estimated to be risk neutral where ρ is close to zero where as some insurers have ρ implying \$80 of risk charge. To put the magnitude of these risk charge coefficients in perspective, on average the insurers' risk charges are around 2 percent of their expected marginal costs.⁸⁰ This magnitude is in-line with actuarial documents that suggest that insurers' risk charges are usually 2 – 4% of their premiums (American Academy of Actuaries, 2020).

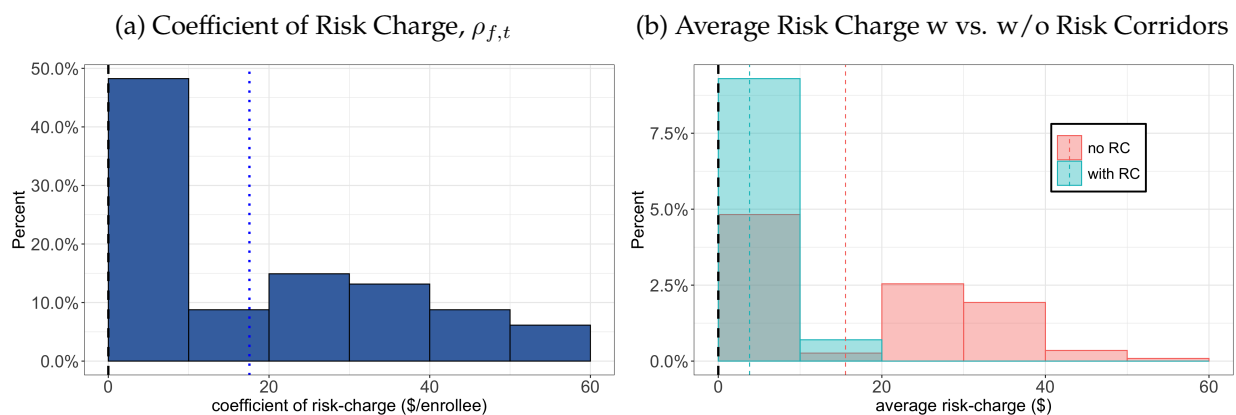
While looking at the risk charge coefficient shows the risk averseness of insurers, it doesn't show the actual risk charges that the insurers face in the current market. The insurers have risk sharing arrangements with the government through the risk corridors and so will face lower risk levels. Figure 10b shows the realized risk charges that the insurers face with the risk corridors and compare it with the risk charges without the risk corridors. The insurers face significantly smaller risk charges with the risk corridors. With risk corridors, the insurers face average risk charge of \$4.1 vs. risk charge of \$17.5 or 76% reduction in risk charges. The large reduction in risk charges is

risk corridor payments.

⁸⁰I find that this ranges from 0-5 percent, depending on the insurer.

likely amplified due to the strategic cost reporting of the insurers as shown above. Recall in section 3, the risk level (variance of cost) that the insurers face decreases regardless of which direction the insurers misreport their costs. And here because the insurers have overestimated their costs, their risk level is significantly reduced, lowering their risk charges.

Figure 10: Estimates of Coefficient of Risk Charge, $\rho_{f,t}$ and Average Risk Charge



Panel (a) plots the distribution of the coefficient of risk charge estimates, ρ . Each observation is firm-year. ρ is normalized to the variance of average enrollee’s cost i.e. the normalized ρ represents the insurer’s risk charge of enrolling an additional average enrollee. Panel (b) plots the distribution of average risk charge with risk corridors (i.e. the current risk charge level) vs. average risk charge w/o any risk corridors. Observation is at the plan-year level.

To look at heterogeneity of the coefficient of risk charge parameter across the insurers, I investigate if ρ is correlated with the insurer characteristics, especially insurer size. Columns 1 & 2 of table 4 show that smaller (larger) insurers tend to have lower (higher) ρ and therefore are less (more) “risk averse”. However, the results are not statistically significant in part due to the lack of observations I have.⁸¹

Column 3 shows that ρ is negatively correlated with the RBC ratio of the insurers, meaning more financially solvent insurers have lower risk charge coefficient and therefore less “risk averse” albeit not statistically significant. However if I control for insurer fixed effects, ρ is negatively correlated with the insurer’s prior year RBC ratio with statistical significance, which is shown in column 4. So if the insurer has higher RBC ratio (i.e. more financially solvent) in a given year, the lower the ρ or less “risk averse” the insurer will be in that year. To interpret the magnitude, insurers’ average standard deviation of RBC ratio is 1.3, meaning that one standard deviation increase in RBC ratio

⁸¹This is because, for smaller firms I have to group them together and estimate a single “average” ρ for the group. As a result, while there may be more heterogeneity even among the smaller firms I am only able to estimate the average ρ for the group and so it’s unclear if the above relationship will hold if I am able to observe ρ at the firm level for the smaller insurers.

is correlated with \$5.7 decrease in the coefficient of risk charge. This suggests that “risk averse” behavior of the insurers may be coming from financial/regulatory frictions that the insurers face (Kojen & Yogo, 2022).

Table 4: Coefficient of Risk Charge vs. Insurer Characteristics

	<i>Dependent variable:</i>			
	$\rho_{f,t}$			
	(1)	(2)	(3)	(4)
$\mathbb{1}\{\text{small firm}\}$	-2.84 (9.26)			
$\log(\text{enrollment}_{f,t})$		2.91 (2.37)		
RBC-Ratio $_{f,t-1}$			-0.81 (1.30)	-4.30* (2.26)
Year FE	Y	Y	Y	Y
Firm FE	N	N	N	Y
Observations	38	38	38	38
R ²	0.229	0.261	0.237	0.678

Note:

*p<0.1; **p<0.05; ***p<0.01

The table shows results from regressing the coefficient of risk-charge estimates of firm (group) f in year t on firm characteristics. ρ_{ft} is normalized to the variance of an average enrollee i.e. ρ indicates the risk-charge of insurer for enrolling an additional average enrollee. Small-firm is an indicator for firms that have < 50,000 enrollees. RBC-Ratio $_{f,t-1}$ is the firm f 's prior year RBC-ratio. For firm-groups, the RBC-ratio represents enrollment weighted average of RBC-ratios across the firms within the group.

7 Alternative Market Designs

Given the structural model estimates, I run several counterfactuals to understand the effects of the two regulations: risk corridors and margin regulation. However there are several challenges to this, so I make a few abstractions.

First, as pointed out before the subsidy design of the low-income subsidy eligible consumers make it difficult to model the insurers’ pricing behavior for these consumers. I instead restrict my attention to the regular enrollees and model the insurers pricing optimally targeting these consumers only.⁸² Second, the outside option in my model involves a bundle of options for the con-

⁸²The regular enrollees account for a little over 60 percent of the total consumers.

sumers; opting to not purchase any drug plan or opting for an MA-PD plan. While some of the changes I make to the PDP market may also impact the MA-PD plans, I assume that these markets are separate.⁸³ This also implies that I assume the outside option will remain fixed throughout my counterfactual results. So the counterfactuals can be seen as a partial equilibrium setting in which I hold everything else constant and only look at changes in the PDP market.

Another challenge is in evaluating the welfare, in particular the large government spending in consumer subsidies. Throughout the counterfactuals, I keep the overall government expenditure on enrollee subsidy fixed i.e. I adjust the PDP subsidy level so that the total government subsidy expenditure is held constant through out my counterfactuals. This allows me to isolate the welfare effects on the consumer surplus and the insurer profits, as well as any changes in government spending due to the risk corridor payments but not the subsidy expenditure. Lastly, I restrict my counterfactuals to 2015.⁸⁴

To see how the current set of regulations affect the market, I compare two alternative market designs relative to the baseline (i.e. the status quo).⁸⁵ First, I remove both sets of regulations and allow the insurers to optimally set prices in the absence of these regulations. I refer to this counterfactual as “no regulation”. Second, I include both sets of regulations but ban the insurers from strategically reporting their cost. In practice, this could reflect the government having full set of information that the insurers has in which there is no asymmetric information regarding costs. I refer to this counterfactual as “truthful reporting”. Lastly, I look at changing the design of risk corridors to a linear risk sharing rule to study the effects of different risk sharing levels. I vary linear risk sharing from no risk sharing (fixed price contract) to full risk sharing (cost plus).

7.1 Removal of Regulations

Table 5 shows market summary statistics across different counterfactuals. Column 1 shows the results for the baseline (or current) market. Column 2 shows the counterfactual results of removing both risk corridors and margin regulation in the market. Allowing the insurers to freely choose

⁸³Most notably, the overall consumer subsidy level in Part D is computed using the bids of MA-PDs and the PDP plans. Treating these markets separately could be seen as the government severing the ties between these two markets by computing separate subsidy levels or benchmarks for each market.

⁸⁴This is for simplicity. But in theory, I could run it for all other years in which I have the demand/supply-side model estimates.

⁸⁵Because I restrict my attention to regular consumers I recompute the optimal bids under the baseline market design. The resulting bids remain similar to the observed bids in the data.

prices without any constraints lead to higher prices of \$1,014 vs. \$963 (or 5.2%). This leads to 8 percent decrease in enrollment, and 10 percent decrease in consumer surplus. The increase in prices is in part from the increased risk level that the insurers face from no longer having risk sharing through the risk corridors. This is reflected in the average variance of cost in the baseline, which is only 17.7 percent of the level faced without any regulation, translating to 86 percent decrease in the average marginal risk charge.

Table 5: Counterfactual Comparisons with Baseline

	(1) Baseline	(2) No Regulation	(3) No Regulation w baseline risk	(4) Truthful Reporting $\delta = 1$
Average Bid (\$)	963	1,013.8	1,010.2	864.4
Avg Marginal Risk Charge (\$)	1.3	9.9	1.4	8.6
Avg Variance of Cost (%)	17.6	100	17.8	80.9
Enrollment (M)	11.1	10.2	10.4	12.5
Consumer Surplus (\$M)	2,145.3	1,927.9	1,964	2,470.8
Insurer Profit (\$M)	955.1	1,508.5	1,444.7	375.6
Risk Corridor Payment (\$M)	136.2	0	0	0
Total Risk Charge (\$M)	17.7	100.7	17.7	109.4
Total Welfare (\$M)	3,236.6	3,436.4	3,408.7	2,846.4
Total Welfare w Risk Charge (\$M)	3,218.9	3,335.7	3,391	2,737

Notes: the table shows various market level statistics for different counterfactuals. Column (1) shows the baseline or status-quo market. Column (2) shows counterfactual in which both risk corridors and margin regulations are removed. Column (3) shows column (2) but with the insurers' risk level reduced to the baseline level. Column (4) shows the "truthful reporting" where both regulations exist but the insurers are banned from strategically report their costs. All averages are computed using enrollment-weighted average. Avg variance of cost refers to percent of variance relative to risk level w/o any risk sharing. Risk corridor payment are payment from the insurers to the government (i.e. positive number indicates government is receiving payment from the insurers). Insurer profit equals to total revenue minus total expected cost minus the expected risk corridor payment to the government, but excludes the risk charges. Total welfare is the sum of consumer surplus, insurer profit and the risk corridor payments. Total welfare with risk charge is the total welfare numbers subtracting the total risk charge numbers.

The higher prices significantly increase the insurer profit, increasing it by 57 percent. Note that the insurer profit is smaller in the baseline, not just because of the lower prices but also from the expected risk corridor payments the insurers make to the government due to overestimating their costs. Without the risk corridor payments the insurers' profits would be 14 percent higher in the baseline, which would bring the baseline insurer profit to be within 38% of the insurer profit with no regulation. So here the risk corridor payments act as an ex-post transfer mechanism that brings down the insurers' profits.

The total welfare, which is the sum of consumer surplus, insurer profit and government earn-

ings (via risk corridor payments) increase by 3 percent in the absence of any regulation. This reflects the large increase in the insurer profit relative to the modicum decrease in consumer surplus. The results are similar when we include the total risk charges in the welfare measure.

While comparing the baseline with no regulation counterfactual is informative, it shows combined effect of two things. First, it shows the removal of the margin constraint that allows the insurer to freely charge higher prices. Second, it also shows the removal of risk sharing arrangements via risk corridors, increasing the overall risk level that the insurers face. To decompose these two effects, I run a modified “no regulation” counterfactual in which I lower the insurers’ risk levels to the same level that the insurers face in the baseline. The results are shown in column 3.⁸⁶

The modified no regulation counterfactual shows that the prices still increase significantly, increasing by 4.9 percent vs. the 5.2 percent in the initial no regulation counterfactual. Other numbers remain at similar levels, meaning the removal of margin regulation dominates any changes brought by the removal of the risk sharing. This is because the magnitude of risk charge is relatively small even without any risk sharing arrangements.

7.2 Truthful Reporting: No Strategic Cost Reporting

To better understand the effect of the insurers’ strategic cost reporting on the market, I run a counterfactual where I ban the insurers from strategically reporting their costs. I impose the insurers’ strategic cost reporting parameter, δ to be one for all the insurers while facing both sets of regulations. Column 4 of table 5 presents the results. The average price decreases from \$963 to \$864 (or 10.3%). The lower prices lead to 15.1 percent increase in consumer surplus, but 60 percent decrease in the insurer profit, resulting in 12 percent lower total welfare relative to the baseline.

Under no strategic cost reporting, the insurers’ risk level is higher than the baseline. While in the baseline, the insurers’ average variance of cost is 17% (relative to the level without any risk sharing), under the truthful reporting case, the insurers’ risk level is 80%. This is due to the insurer on average having overestimated their costs in the baseline. Recall from section 3 that when the insurers under or overestimate their costs, not only do their expected risk corridor payments change, but their variance of cost change as well. And this is due to the non-linearity in the risk

⁸⁶I take the estimated degree of cost reporting, δ and assume the insurers face risk level of $V(\delta, Q)$ with risk corridors vs. facing the full risk level w/o any risk corridors.

corridors function.⁸⁷

To look at the heterogeneity in risk sharing across the insurers, I look at how the reduction in variance varies by insurer size. Figure 11a plots these for baseline and the counterfactual in which I disallow strategic cost reporting. It shows that overall level of variance is lower for most insurers in the baseline vs. the truthful reporting case, in line with the summary results in table 5. However, it shows that in the baseline, the variance of cost is reduced more for larger insurers compared to smaller insurers. On the other hand, when there is no strategic cost reporting the opposite is true. The variance of cost is reduced more for smaller insurers compared to larger insurers. This flipped relationship between insurer size and variance of cost is driven from larger insurers overestimating their costs more as shown in figure 11b. So risk corridors in the absence of strategic cost reporting is intended to reduce the risk that smaller insurers face more than the larger insurers. But due to the insurers' strategic cost reporting, in the current market larger insurers' risk is reduced more than the smaller ones. And the overall risk level that the insurers face is smaller.

Figure 11: Enrollment vs. Variance of Cost, and δ across Insurers

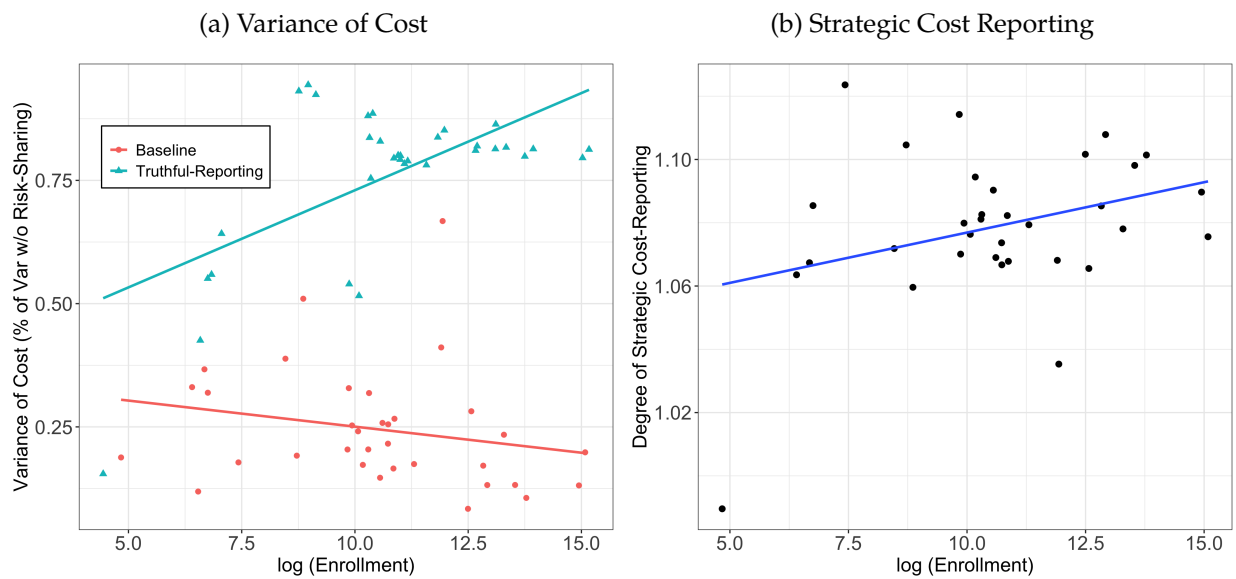


Figure plots the log enrollment numbers against variance of cost under baseline vs. truthful reporting regulations. The variance of cost is shown as a percentage of the variance of cost w/o any risk sharing regulations. Each observation is an insurer.

If I take the truthful reporting as indicative of the government's policy goals, there are two main takeaways. One is that the government wants to combat market power by severely constraining

⁸⁷When the insurers over or underestimate their costs, they also increase the probability that they trigger risk sharing payments (or reimbursements). So this decreases the variance of their overall cost.

the margin that the insurers can charge, decreasing the equilibrium prices and therefore increasing consumer surplus. Second is that the government wants to limit some but not all risk that the insurers face. Furthermore, the government wants to protect the smaller insurers against variation in cost more so than the larger insurers. And these seem to be consistent with what's stated in the initial policy goals of the regulations.

7.3 Linear Risk Sharing Rule

Here, I modify the design of risk corridors to a linear risk sharing rule. I change the ex-post risk corridor function to be:

$$T(\tilde{C}, \delta C) = \alpha(\delta C - \tilde{C}) \quad (18)$$

The risk sharing parameter, α governs the degree of risk sharing where $\alpha = 0$ implies no risk sharing (i.e. fixed-price contract) and $\alpha = 1$ implies full risk sharing (i.e. cost reimbursement contract). I still allow the insurers to strategically report their cost via the parameter, δ that shifts their reported expected cost. I also assume the government keeps the existing margin regulation, in which it constrains the price the insurers can charge relative to their reported expected cost.

Figure 12: Risk Corridor Function: Baseline vs. Linear Risk Sharing

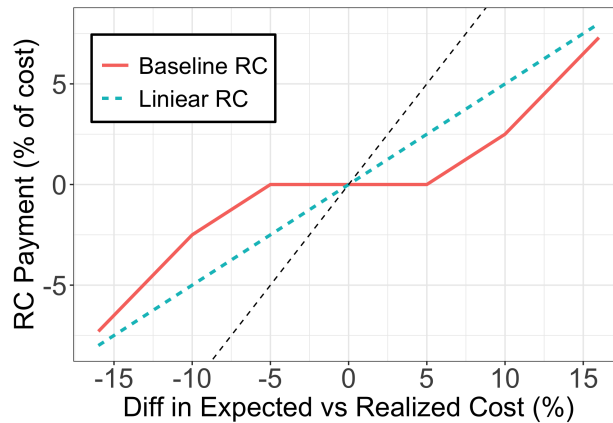


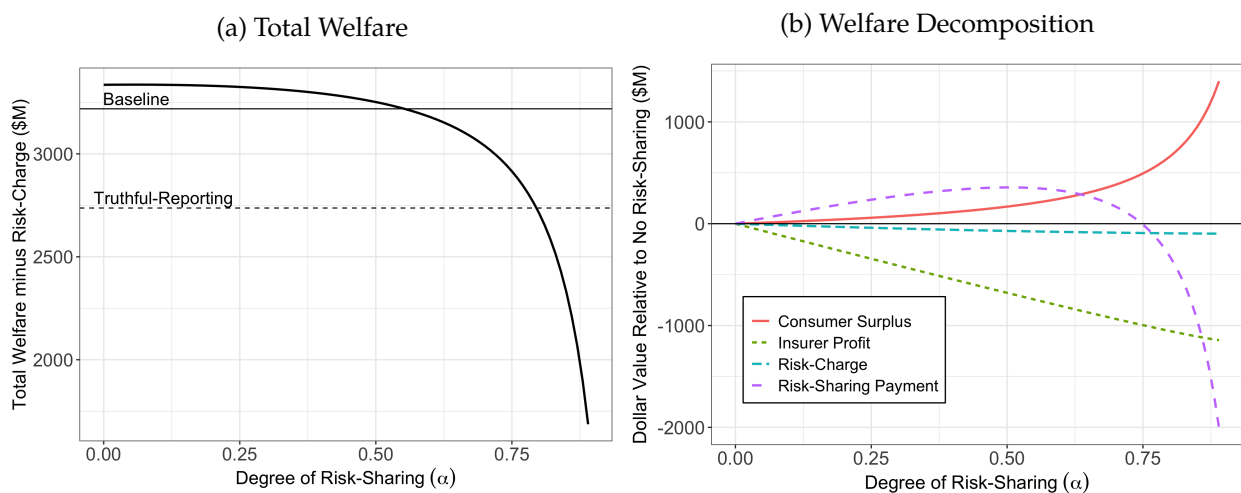
Figure plots the baseline risk corridor function vs. linear risk sharing function explored in the counterfactual.

The main difference between the linear risk sharing vs. the baseline risk corridor function is both the continuity and linearity of the transfer function with respect to the expected and realized cost. Figure 12 illustrates this. This means that with linear risk sharing, the insurers' strategic cost

reporting will have no effect on the variance of the insurers' cost. It will be governed by the risk sharing parameter α . The specific results are derived in appendix F. So while the insurers' strategic cost reporting will still change the expected risk corridor payments, their variance of cost will not be affected by δ but only by the risk sharing parameter α .

Figure 13 shows that similar to the results found in Table 5, total welfare decreases as we increase risk sharing. However, the effect varies widely across different components of the welfare. Figure 13b shows that as risk sharing increases consumer surplus increases, but insurer profit decreases by even more. And as expected more risk sharing leads to decreased risk charges as the insurers' variance of cost is decreased. However this decrease in magnitude is very small relative to other measures, meaning the direct effect of increased risk sharing on the insurers' risk level is dominated by the indirect effect of limiting the ex-post profit of the insurers. This can be seen by the positive and initially increasing expected risk corridor payments, transferring part of the insurers' profits to the government. But as risk sharing increases further, the expected risk corridor payments decrease and turns negative, meaning the insurers are receiving payments from the government. So at higher levels of risk sharing, the risk sharing payment is acting as an indirect supply-side subsidy.

Figure 13: Welfare vs. Degree of Risk Sharing, α

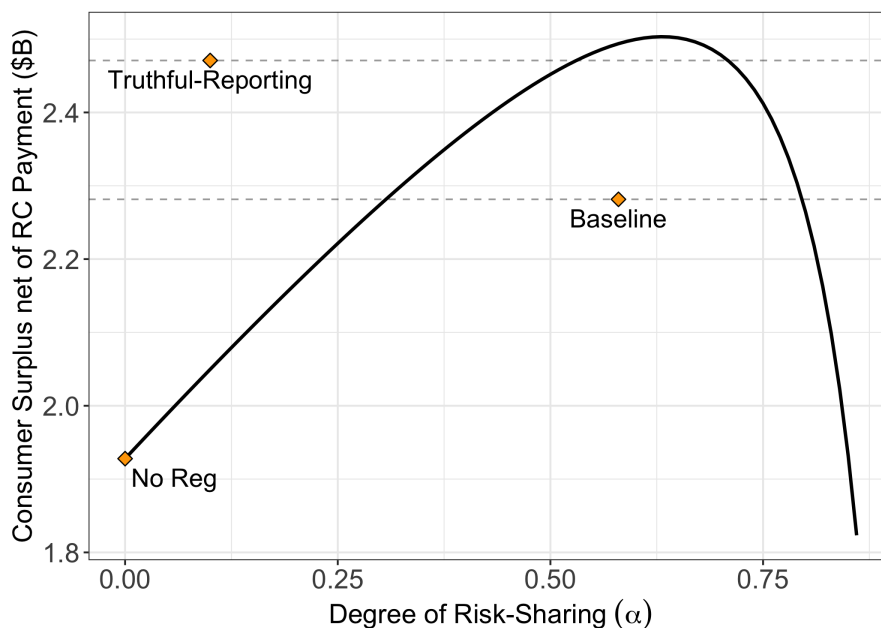


Panel (a) plots the total welfare which is the sum of consumer surplus, expected insurer profit minus total risk charge, and risk corridor payment vs. degree of risk sharing, α . Panel (b) decomposes the total welfare into individual components. Insurer profit is the sum of total revenue minus the total expected cost net of any expected risk corridor payments, minus the total risk charges. All numbers are shown relative to when $\alpha = 0$.

Given that Medicare is a social insurance program, and the government's usage of regulations

like profit margin regulation the government may be more interested in maximizing consumer surplus. Figure 14 shows what happens to the consumer surplus net of government expenditure on risk sharing payments and compare the values relative to other counterfactual benchmarks in table 5. It shows that with $\alpha = 0.64$, the total surplus measured by the sum of consumer surplus and government earnings can be maximized. In fact, this “optimal” level is just above the level of the truthful reporting case.

Figure 14: Consumer Surplus net of RC Payment vs. Degree of Risk Sharing, α



The figure plots the sum of consumer surplus and risk corridor payments to the government for varying degrees of linear risk sharing, α . The orange points denotes where different counterfactual scenarios. For example, the status quo shows

While choosing a risk sharing level that yields high total surplus may be ideal, it may also over protect the insurers. Figure 14 shows that the truthful reporting case is comparable to relatively low level of risk sharing. Although not modeled in this paper, over protecting the insurers may decrease the insurers’ incentive to contain their costs (Cicala *et al.*, 2019). So here, there’s a trade-off between over-insuring the insurers vs. achieving high levels of surplus. While the linear risk sharing rule won’t be able to achieve comparable surplus levels at the truthful reporting risk level, it can still improve on the baseline policy. The insurers’ risk level in the baseline policy is comparable to $\alpha = 0.58$. At this risk sharing level, similar total surplus levels as the truthful reporting case can be achieved. So changing the baseline risk corridor to a linear risk sharing rule with $\alpha \in [0.3, 0.58]$

can yield higher total surplus while not lowering the insurers' risk levels any further.

8 Conclusion

I study how insurers' strategic responses to regulations can distort the intended purpose of both the risk corridors and margin regulation in Medicare Part D. Both regulations use the insurers' self-reported cost estimate where insurers have a strategic incentive to over or underestimate their costs to increase their revenue. However insurers have conflicting incentives to misreport under each regulation. Under risk corridors, insurers want to underestimate to receive payments. Under margin regulation, insurers want to overestimate to charge higher prices. Having both will have a balancing effect.

Using a structural model, I estimate that insurers have overestimated their costs by 8% on average. I find that insurers are not that risk averse and so the impact that risk corridors can have as a risk sharing policy may be limited in the current market. Instead, risk corridors act more as an ex-post penalty function for insurers that overestimate their costs. Risk corridors therefore help enforce the margin regulation, keeping the prices lower than without the regulation. Given the findings, I propose a linear risk sharing function to replace the current risk corridors, which increases total surplus while maintaining the same level of risk for insurers.

Neither regulation is unique to Medicare Part D and they are widely used in other publicly-funded health insurance markets, such as Medicaid and ACA exchanges. This is especially true for risk corridors. During the heightened uncertainty brought on by COVID, Congress discussed implementing risk corridors at a national level, affecting all health insurance markets.⁸⁸ As such, ensuring careful design of these policies without causing other distortions is crucial, especially when they are being implemented in a much broader scope.

More generally, these findings highlight two challenges that the government should consider in designing regulations for private firms. One is carefully examining private firms' incentives and determining whether those are aligned with the government's objectives. But more importantly, government and researchers alike should also examine the interaction of different policies in the

⁸⁸The Heroes Act, passed by the House of Representatives on May 15, 2020 included provision that would establish risk corridor program to stabilize premiums for the individual and commercial markets as well as the Medicare Advantage markets, essentially covering most if not all health insurance markets.

market. While studying a single policy in isolation may be valid in certain settings, markets are often laden with several different regulations. Failing to account for the interaction between regulations may have unintended consequences in the market, and in some cases bring more harm than good.

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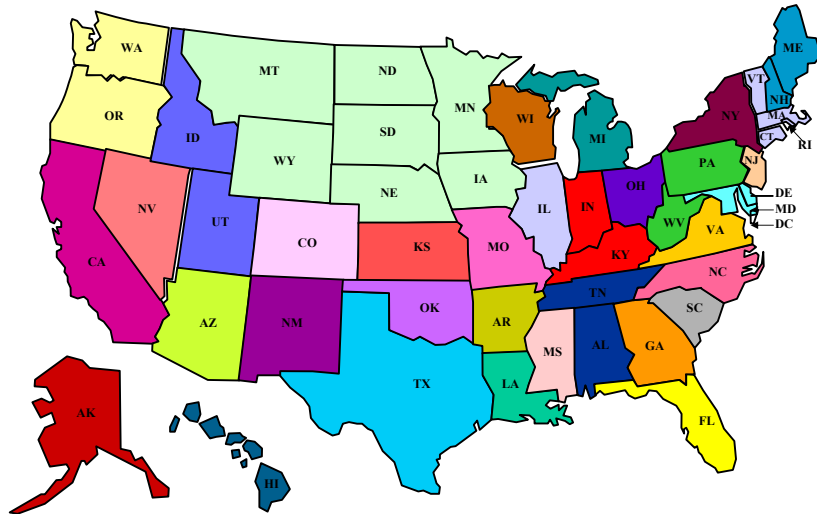
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Appendices

A Additional Figures

Figure A.1

PDP Regions



Note: Each territory is its own PDP region.

Figure shows the 34 PDP regions in the U.S.

Figure A.2: Persistence of Risk-Corridor Payment

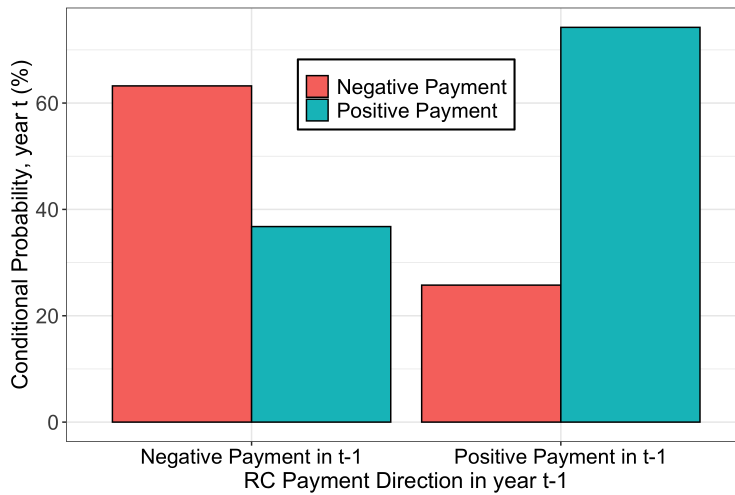
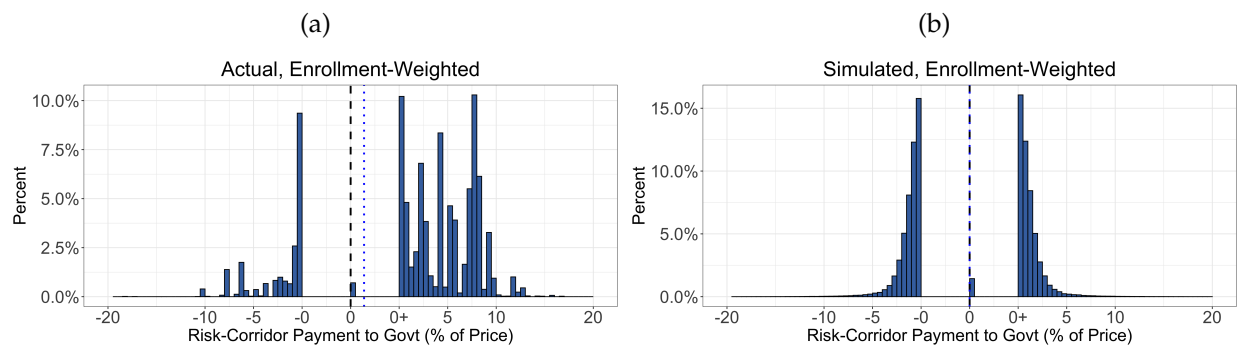


Figure plots the conditional probability of risk-corridor payment being positive vs. negative as a function of insurer's risk-corridor payment direction in the prior year.

Figure A.3: Distribution of Risk-Corridor Payments



Panel (a) plots the distribution of observed contract-level risk-corridor payments from 2009-2015. Panel (b) plots the distribution of simulated risk-corridor payments from 2009-2015 using the claims data. The distributions are weighted by observed enrollment.

Figure A.4: Marginal Cost Estimates: Standard vs. Enhanced Plans

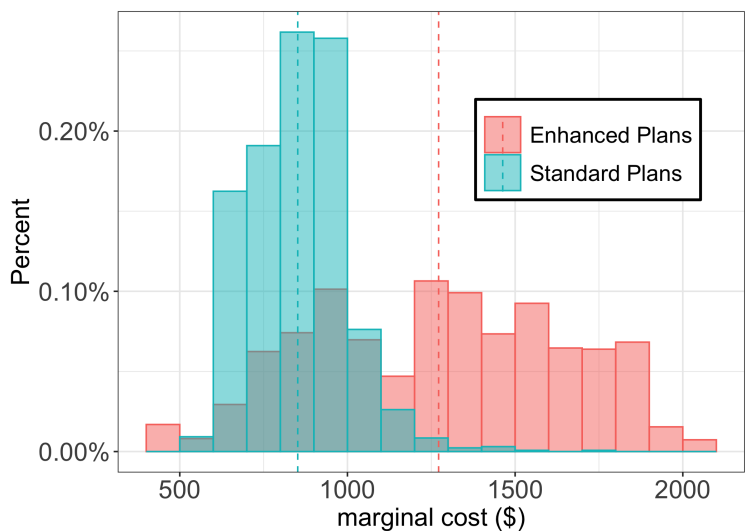


Figure plots the distribution of marginal cost estimates separately for standard plans vs. actuarially enhanced plans. Standard plans refer to plans that meet the basic/minimum benefit design and enhanced plans refer to plans that have increased cost-sharing benefits above the standard benefit design. Each observation is plan-year.

Figure A.5: Model fit of MC using Decarolis et al

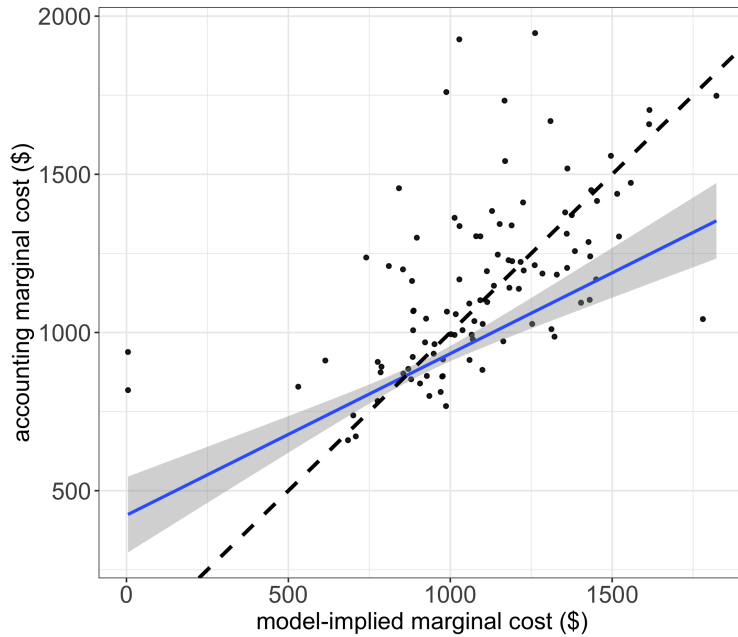


Figure plots the marginal cost estimates obtaining using [Decarolis et al. \(2020\)](#) approach vs. the observed per-enrollee risk-corridor payments at the firm-year level. The dashed line indicates the 45-degree line, and the blue line shows the best-fit line.

Figure A.6: Model fit of risk-corridor payments

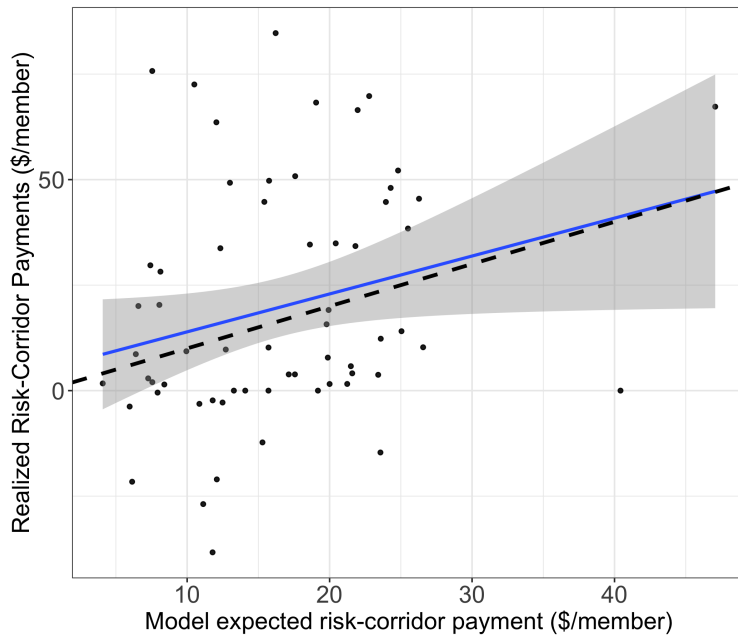
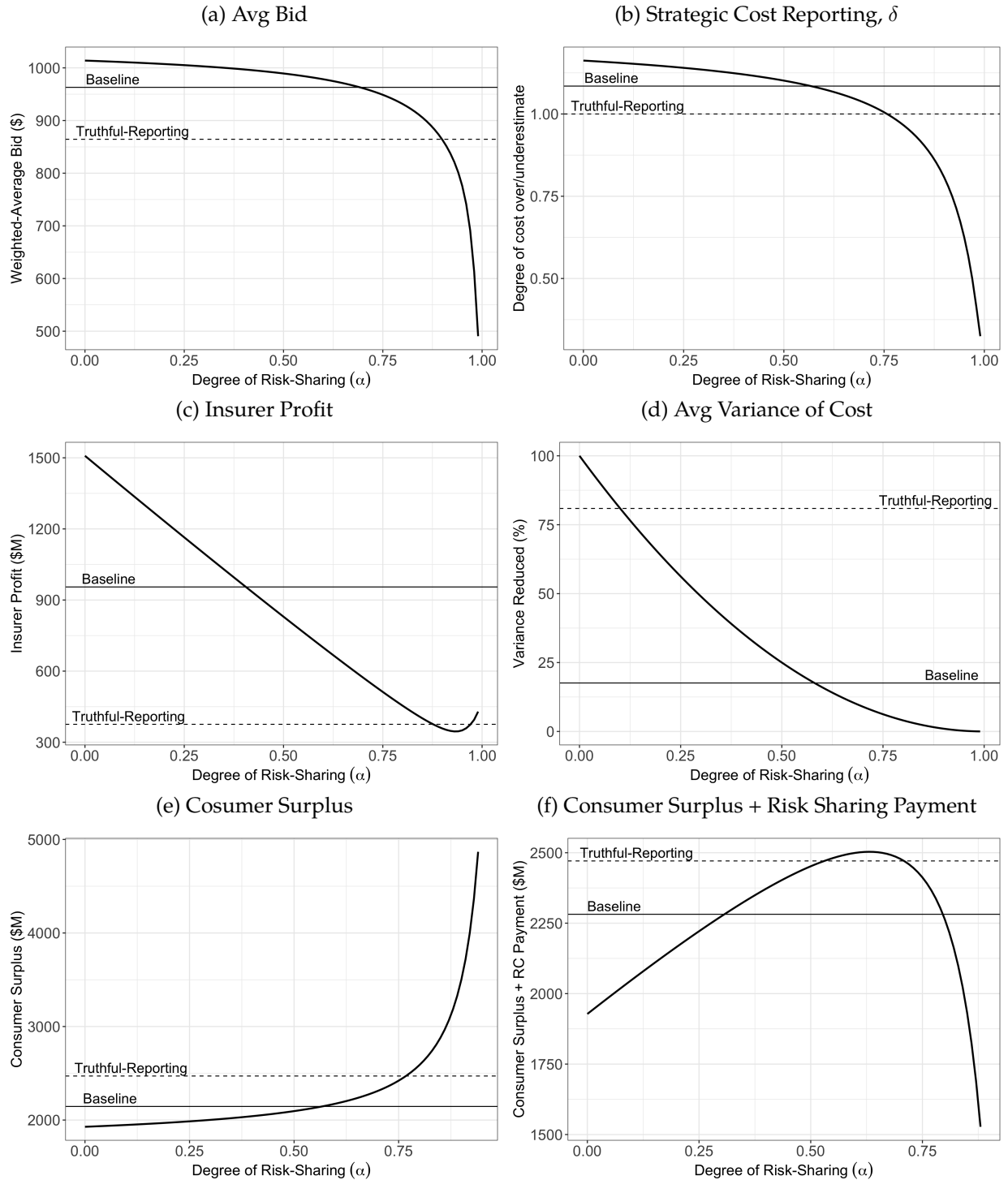


Figure plots the model implied expected per-enrollee risk-corridor payments vs. the observed per-enrollee risk-corridor payments at the firm-year level. The dashed line indicates the 45-degree line, and the blue line shows the best-fit line.

Figure A.7: Market level Variables vs. Degree of Risk Sharing, α



Panel (a) plots the average bid. Panel (b) plots average δ , degree of strategic cost reporting parameter across firms. Panel (c) plots the total insurer profit. Panel (d) plots the average variance of cost relative to the case w/o any risk sharing (i.e. $\alpha = 0$). All averages are computed by taking the enrollment-weighted average across all plans in the market. Panel (e) plots the total consumer surplus, and panel (f) plots the sum of total consumer surplus and risk corridor payments from insurers to the government. The solid horizontal line indicates the baseline numbers and the dashed horizontal line indicates the truthful reporting counterfactual.

B Additional Tables

Table A1: Summary Statistics for Low-Income Subsidy Eligible Enrollees

	Mean (1)	Std.Dev. (2)	Min (3)	Max (4)
A. Plan-Level				
Bid (\$)	1,191	367	596	2,618
Enrollee Premium (\$)	298	342	0.0	1,831
Enrollment (000)	7.7	21.4	0.01	409.0
B. Market-Level				
No of Plans	31.19	3.00	23	39
No of Insurers	13.65	1.34	10	17
Enrollment (000)	240	195	14	1,021
HHI Index*	1,965	593	1,106	4,252
Market Share of Top 3 Firms (%)*	64	11	44	91
Market Share of Top 5 Firms (%)*	82	8	60	97

Notes: the table shows summary statistics of the Part D stand-alone prescription drug (PDP) market from 2012-2015 in the 34 PDP regions for low-income subsidy (LIS) eligible enrollees. Plan-level data shows summary statistics taken across individual year-market-plan. Market-level data shows summary statistics taken across year-market level. Enrollee premium refers to premium faced by LIS enrollees. An insurer is defined as a unique parent organization in the CMS data. * HHI index and market share of top firms are computed using LIS enrollees only.

Table A2: Marginal Cost vs. Plan Characteristics

	<i>Dependent variable:</i>			
	<i>mc_{jm}</i>			
	(1)	(2)	(3)	(4)
deductible	−0.55*** (0.05)	−0.47*** (0.05)	−0.46*** (0.05)	−0.48*** (0.05)
isExtraCovgGap	493.41*** (11.85)	481.14*** (11.35)	481.00*** (11.24)	468.55*** (11.12)
isEnhanced	3.83 (16.30)	35.27** (15.60)	36.22** (15.44)	45.83*** (15.17)
n_drugs_tier1	0.03*** (0.004)	0.01 (0.004)	0.01 (0.004)	0.001 (0.01)
Observations	2,661	2,661	2,661	2,661
R ²	0.64	0.67	0.68	0.75
Year FE	N	Y	Y	Y
Market FE	N	N	Y	Y
Firm FE	N	N	N	Y
Observations	2,661	2,661	2,661	2,661
R ²	0.64	0.67	0.68	0.75

Note:

*p<0.1; **p<0.05; ***p<0.01

The table shows a hedonic regression of marginal cost estimates on observable plan characteristics.

C Details on the Stylized Model

C.1 Generalization of Stylized Model

Here we show that the stylized model in 3.1 is an approximation to a model in which insurer faces a financial frictional loss function. Consider the same setting, but now the insurer faces some convex financial frictional loss function:

$$\max_p \quad pq(p) - \underbrace{cq(p)}_{E[\tilde{C}]} - \underbrace{E_{\tilde{C}} \left[L(\overbrace{pq(p) - \tilde{C}}^{\pi(p)}) \right]}_{\text{expected financial frictions cost}} \quad (19)$$

where $L()$ is a continuous, non-decreasing, and convex function. Taking the FOC yields:

$$p^* \left(1 + \frac{1}{\epsilon^D} \right) = c + \underbrace{\frac{E \left[L(\pi) \frac{\partial f(\tilde{C})}{\partial \tilde{C}} \right]}{1 - E[L'(\pi)]}}_{\text{marginal financial frictional cost}} \quad (20)$$

The FOC in (20) yields similar form as (2), except that the marginal financial frictional cost takes the place of the marginal risk charge term in the original model. The marginal financial frictional cost term above is a function of the loss function $L()$ and the distribution of the total cost \tilde{C} . Hence, if we parametrize $L()$ function upto some parameter ρ and take the second moment of the cost distribution \tilde{C} i.e. $V(\tilde{C})$ to describe the cost distribution then we can take the original stylized model to be an first order approximation of the above model in (19).

Similarly, if we assume a model in which the insurer is risk-averse where the insurer's objective function is now:

$$\max_p \quad E_{\tilde{C}} \left[\overbrace{U(pq(p) - \tilde{C})}^{\pi} \right] \quad (21)$$

where $U()$ is some continuous, non-decreasing and concave utility function. The FOC yields:

$$p^* \left(1 + \frac{1}{\epsilon^D}\right) = c + \underbrace{\frac{E \left[U(\pi) \frac{\frac{\partial f(\tilde{C})}{\partial \tilde{C}}}{f(\tilde{C})} \right]}{-E[U'(\pi)]}}_{\text{marginal risk disutility}} \quad (22)$$

In fact if we make additional functional form assumptions on the utility function $U(\cdot)$, and the distribution of cost, \tilde{C} we can show that insurer's objective in (21) is equivalent to (1). Let $U(\cdot)$ be an exponential function i.e. without loss of generality let $U(x) = -e^{-\rho x}$. Let $\tilde{C} \sim N(\mu, \sigma^2)$. Then,

$$\begin{aligned} E[U(pq(p) - \tilde{C})] &= - \int e^{\rho(pq(p) - \tilde{C})} f(\tilde{C}) d\tilde{C} \\ &= - \int e^{\rho(pq(p) - \tilde{C})} \frac{1}{\sqrt{2\pi\sigma}} e^{-\frac{1}{2}\left(\frac{\tilde{C}-\mu}{\sigma}\right)^2} d\tilde{C} \\ &= -e^{\rho pq(p)} \int \frac{1}{\sqrt{2\pi\sigma}} e^{\rho\tilde{C} - \frac{1}{2}\left(\frac{\tilde{C}-\mu}{\sigma}\right)^2} d\tilde{C} \\ &= -e^{\rho pq(p) + \rho\mu + \frac{1}{2}\rho^2\sigma^2} \underbrace{\int \frac{1}{\sqrt{2\pi\sigma}} e^{-\frac{1}{2}\left(\frac{\tilde{C} - (\mu + \rho\sigma^2)}{\sigma}\right)^2} d\tilde{C}}_{=1} \\ &= -e^{-\rho(pq(p) - \mu - \frac{1}{2}\rho\sigma^2)} \\ &= U\left(pq(p) - \mu - \frac{1}{2}\rho\sigma^2\right) \\ &= U\left(pq(p) - E[\tilde{C}|p] - \frac{1}{2}\rho\text{Var}(\tilde{C}|p)\right) \end{aligned}$$

which is equivalent to maximizing the mean-variance objective in (1).

C.2 Stylized Model Proof

Proposition 1: $\delta^* = \bar{\delta}$ will always be optimal for the insurer's problem in (5). And furthermore if assumption 1 holds, $p_m^*(\delta^*) = p_0^*$ where $p_m^*(\delta)$ denotes the insurer's profit-maximizing price in (5) for a given δ .

Proof: I begin by proving that it is always optimal for the insurer to choose $\delta = \bar{\delta}$. First note that insurer's choice of δ does not directly affect its objective function. δ only affects insurer's margin constraint which is relaxed the most when $\delta = \bar{\delta}$, allowing the insurer to choose any price $p \leq \bar{m}\bar{\delta}c$.

Hence, it is always optimal for the insurer to choose $\delta^* = \bar{\delta}$.

Next, if assumption 1 holds then insurer can choose the maximum $\delta = \bar{\delta}$ in which case $p_0^* \leq \bar{m}\bar{\delta}c$ by the assumption and as a result continue to charge its optimal price without the margin constraint of p_0^* . ■

Proposition 2: Under Assumption 2, optimal δ^* to the insurer's problem in (8) will be $\underline{\delta}$ i.e. insurer will always report lowest possible expected cost. And furthermore $p_{rc}^*(\underline{\delta}) < p_{rc}^*(1) \leq p_0^*$ where $p_{rc}^*(\delta)$ denotes insurer's profit-maximizing price in (8) for a given δ .

Proof: Without loss of generality, I restrict my attention to a simplified risk-corridor function. A simple risk-corridor function can be written as:

$$T(\tilde{C}, C) = \begin{cases} \alpha(0.95C - \tilde{C}) & \text{if } \tilde{C} < 0.95C \\ 0 & \text{if } 0.95C \leq \tilde{C} \leq 1.05C \\ \alpha(1.05C - \tilde{C}) & \text{if } \tilde{C} > 1.05C \end{cases} \quad (23)$$

where $\alpha \in [0, 1]$ is the degree of risk-sharing parameter. I can re write the ex-post total cost with strategic cost-reporting parameter δ as

$$\tilde{C}^{rc}(\delta) = \tilde{C} + T(\tilde{C}, \delta C) = C(x + T(x, \delta))$$

where $x = \tilde{C}/C$. I begin by showing that $\frac{\partial E[T(x, \delta)]}{\partial \delta} > 0 \forall \delta$.

$$\begin{aligned} E[T(x, \delta)] &= \int_0^{0.95\delta} \alpha(0.95\delta - x)dF(x) + \int_{1.05\delta}^{\infty} \alpha(1.05\delta - x)dF(x) \\ &= E[\alpha(0.95\delta - x)|x < 0.95\delta]Pr[x < 0.95\delta] + E[\alpha(1.05\delta - x)|x > 1.05\delta]Pr[x > 1.05\delta] \\ \frac{\partial E[T(x, \delta)]}{\partial \delta} &= \alpha \int_0^{0.95\delta} 0.95dF(x) + \alpha \int_{1.05\delta}^{\infty} 1.05dF(x) \\ &= \alpha (0.95Pr[x < 0.95\delta] + 1.05Pr[x > 1.05\delta]) > 0 \end{aligned}$$

Next, I show how the variance of cost changes as a function of δ . The variance of total cost with

RC can be decomposed into three components:

$$Var(x + T(x, \delta)) = Var(x) + \underbrace{Var(T(x, \delta)) + 2Cov(x, T(x, \delta))}_{V(\delta)}$$

The first term is variance of x , where as the last two terms are the variance of the RC payment and the covariance between x and the RC payment.

$$\begin{aligned} V(\delta) &= E[\alpha(0.95\delta - x)(\alpha(0.95\delta - x) + 2(x - 1))|x < 0.95\delta]Pr[x < 0.95\delta] \\ &\quad + E[\alpha(1.05\delta - x)(\alpha(1.05\delta - x) + 2(x - 1))|x > 1.05\delta]Pr[x > 1.05\delta] - E[T(x, \delta)]^2 \\ \frac{\partial V(\delta)}{\delta} &= 1.9\alpha \int_0^{0.95\delta} \alpha(0.95\delta - x) + (x - 1)dF(x) + 2.1\alpha \int_{1.05\delta}^{\infty} \alpha(1.05\delta - x) + (x - 1)dF(x) \\ &\quad - 2E[T(x, \delta)] \frac{\partial E[T(x, \delta)]}{\partial \delta} \\ &= 1.9\alpha E[\alpha(0.95\delta - x) + (x - 1) - E[T]|x < 0.95\delta]Pr[x < 0.95\delta] \\ &\quad + 2.1\alpha E[\alpha(1.05\delta - x) + (x - 1) - E[T]|x > 1.95\delta]Pr[x > 1.95\delta] \end{aligned}$$

Given the above derivations, I present the following lemma.

Lemma 1 *There exists a unique $\delta_0 \in (\underline{\delta}, \bar{\delta})$ such that*

$$\begin{cases} E[T(x, \delta)] < 0, \frac{\partial V(\delta)}{\delta} > 0 & \text{if } \delta < \delta_0 \\ E[T(x, \delta)] = 0, \frac{\partial V(\delta)}{\delta} = 0 & \text{if } \delta = \delta_0 \\ E[T(x, \delta)] > 0, \frac{\partial V(\delta)}{\delta} < 0 & \text{if } \delta > \delta_0 \end{cases}$$

I begin by showing that such δ_0 exists for the expected RC payment. From above, I showed that $\frac{\partial E[T(x, \delta)]}{\partial \delta} > 0 \forall \delta$. When $\delta = 0$, $E[T(x, 0)] = -\alpha E[x] < 0$. When $\delta \rightarrow \infty$, $E[T(x, \delta)] = \infty > 0$. As a result there must be unique $\delta = \delta_0$ such that $E[T(x, \delta_0)] = 0$.

Furthermore, if the distribution of cost \tilde{C} is symmetric around its mean, $\delta_0 = 1$. If the distribution is positively skewed, then $\delta_0 > 1$. Conversely, if the distribution is negatively skewed, then $\delta_0 < 1$. So if I assume that the distribution of \tilde{C} is either symmetric or positively skewed around its mean, then the following lemma will hold true.

Lemma 2 *If the distribution of \tilde{C} is symmetric or positively skewed around its mean, then under assumption 2, $V(x, \underline{\delta}) \leq V(x, \bar{\delta})$.*

Given the above set of statements, I now prove the main preposition. δ affects insurer's objective function in two ways: expected risk-corridor payments and the variance of total cost. For the expected risk-corridor payment, I showed that it is always increasing in δ , meaning the firm will want to choose $\delta = \underline{\delta}$ to minimize its expected risk-corridor payment. For the variance, I showed that it is decreasing in the absolute value of $\delta - \delta_0$ where $\delta_0 \approx 1$. That is as the firm over or underestimates its cost, its variance decreases. The minimum of such variance is achieved at either extremes. And with the assumption that the firm's lower bound and upper bound on cost over or underestimation is equal, the firm's variance of cost will also be minimized at $\delta = \underline{\delta}$. As a result, it is optimal for insurer to choose $\delta = \underline{\delta}$.

This will have an intuitive effect on insurer's optimal prices. At $\delta = 1$, insurer's expected cost remains unchanged while its variance of cost will be smaller. As a result, insurer will incur lower marginal risk-charge and hence its optimal price will be lower. At $\delta = \underline{\delta}$, insurer will incur negative expected risk-corridor payment, and its variance of cost will be even lower than at $\delta = 1$. As a result, insurer's effective marginal cost and marginal risk-charge will decrease, lowering its optimal price even further.

■

Proposition 3: Optimal δ^* to the insurer's problem in (9) will be $\underline{\delta} \leq \delta^* < 1$ or $1 < \delta^* \leq \bar{\delta}$ if the margin constraint does not bind or if the margin constraint strictly binds at $p_{rc}^*(1)$, respectively. And furthermore insurer's profit-maximizing price, p_{both}^* will be s.t. $p_{rc}^* \leq p_{both}^* \leq p_0^*$.

Proof: Suppose the insurer's margin constraint isn't binding at $\delta = 1$. Then insurer can underestimate its cost by setting $\delta' = 1 - \varepsilon$ for some small $\varepsilon > 0$ without violating the margin constraint. Then from the proof in earlier preposition, the expected risk-corridor payment will decrease and the variance of cost will also decrease. This will increase the insurer's objective function and hence insurer will not report truthfully. Furthermore, because of the decrease in insurer's marginal cost and marginal risk-charge, insurer will now charge a lower price.

Now suppose the insurer's margin constraint is binding at $\delta = 1$. Then it means the insurer will want to charge higher price in the absence of the constraint. Therefore the insurer can overestimate its cost and set $\delta' = 1 + \varepsilon$ for some small $\varepsilon > 0$. Insurer can then increase its price by $\varepsilon \bar{m}c$ which

will be closer to the optimal price it would like to charge, increasing its expected profit. ■

D Details on the Supply-Side Model

Here, I provide additional details on the supply-side model presented in (12). I first expand on how different parts of the insurer's objective function is constructed.

Insurer's cost is a function of individuals that it enrolls and is altered by the risk-corridor transfers ex-post. Let $\tilde{c}_{ij} = c_{ij} + \varepsilon_{ij}$ denote individual i 's ex-post cost for plan j (suppressing the market index) where c_{ij} is the expected cost, and ε_{ij} is the zero-mean ex-post shock. Then the plan's total ex-post cost prior to risk-corridor transfers will be $\tilde{C}_j = \sum_i^{q_j} \tilde{c}_{ij}$ where q_j is the demand for plan j . With the risk-corridor transfers, plan's ex-post cost will be:

$$\tilde{C}_j^{rc} = \tilde{C}_j + T(\tilde{C}_j, \delta E[\tilde{C}_j]) \quad (24)$$

Given my model of "risk-averse" insurer, the insurer cares about both the expected value as well as the variance of the cost. The expected cost can be written as:

$$E[\tilde{C}_j^{rc}] = C_j + E[T(\tilde{C}_j, \delta C_j)] = C_j + \underbrace{E\left[T\left(\frac{\tilde{C}_j}{C_j}, \delta\right)\right]}_{\approx \gamma_j(\delta, q_j)} C_j \quad (25)$$

expected risk-corridor
payment share

where $C_j = E[\tilde{C}_j]$. The expected cost that insurer faces can be broken down into the expected cost, C_j component prior to any risk-corridor payments and the expected risk-corridor payments. Furthermore, the expected risk-corridor payments can be written as an expected share of expected costs.⁸⁹ This expected risk-corridor payment share will be a function of δ and q_j and so can be written as $\gamma_j(\delta, q_j)$, which is part of the insurer's main objective function in (12). γ_j is a function of q_j because the risk-corridor transfer, $T()$ is a non-linear function and hence the expected value will depend on higher moments of the random variable, \tilde{C}/C_j which will depend on the demand.⁹⁰

⁸⁹This hold true because the risk-corridor transfer function is homogeneous of degree one.

⁹⁰To see this, assume that $c_{ij} = c_j$ and $Var(\varepsilon_{ij}) = \sigma_j^2$. Then $Var(\tilde{C}/C_j) = \frac{\sigma_j^2 q_j}{c_j^2 q_j^2} = \frac{\sigma_j^2}{c_j^2 q_j}$, which is a function of demand q_j .

The variance of insurer's cost for the plan will be:

$$Var \left(\tilde{C}_j + T(\tilde{C}_j, \delta C_j) \right) \approx V_j(\delta, q_j) \quad (26)$$

which is also a function of δ and the demand, q_j and can be written as $V_j(\delta, q_j)$, which is part of the main objective function in (12).

I allow individuals' expected costs to vary by risk-type of the individuals. For an individual i whose risk type is t , his/her expected cost will be $c_{ij} = \kappa_t c_j$ where κ_t is risk-type t 's multiplier and c_j is the baseline expected cost of plan j for an average enrollee. The multiplier κ_t is assumed to be same across different plans, meaning the ratio of cost of risk-type t to t' under the given plan is held constant regardless of which plan the risk-types are enrolled in.

On the revenue side, each plan will submit bids b_j 's to CMS which reflects the plan's premium for an average enrollee. CMS then takes the bid and risk-adjusts the bids according to the risk profile of the individual. So the premium that the plan receives from enrolling risk-type t would be $\theta_t b_j$.⁹¹

Insurer's expected profit for plan j (without the risk-corridor transfers and the risk-charges), is then

$$\sum_t (\theta_t b_j - \kappa_t c_j) M_t s_j^t(b) \quad (27)$$

where M_t and $s_j^t(b)$ is the market-size and demand share function of consumers of risk-type t , respectively. I further make the assumption that there is perfect risk-adjustment i.e. $\theta_t = \kappa_t$.⁹² The expected profit can then be re-written as

$$(b_j - c_j) \underbrace{\sum_t \theta_t M_t s_j^t(b)}_{\substack{Q_j(b), \\ \text{risk-adj demand}}} \quad (28)$$

I allow 6 different risk-types across individuals; five health-levels for regular enrollees (the same

⁹¹Here, CMS is paying the difference between $\theta_t b_j$ and b_j as enrollees are faced with the same premiums regardless of their risk profiles.

⁹²As mentioned in section 5.2, this is mainly to help with numerical issues in the supply-side estimation

health-level used in demand estimation) and a single type for the LIS enrollees.

Putting the expected profit with the expected risk-corridor transfers and risk-charges, we have the following objective:

$$\sum_m \sum_{j \in J_m} (b_{jm} - c_{jm}) \underbrace{Q_{jm}(b)}_{\text{risk-adj demand}} - \underbrace{\gamma_{jm}(\delta, Q_{jm}) c_{jm} Q_{jm}(b)}_{\text{expected rc payment}} - \underbrace{\rho V_{jm}(\delta, Q_{jm})}_{\text{risk-charge}} \quad (29)$$

D.1 Enrollee Subsidy

Given plans' bids, CMS sets the enrollee subsidy, S such that the enrollee's premium for purchasing plan j is:

$$p_j^e = \max \left\{ 0, b_j - \underbrace{(0.745\bar{b} - 0.255\bar{r})}_S \right\} \quad (30)$$

where \bar{b} is the lagged enrollment-weighted average of all the bids across all the markets in the US and \bar{r} is the average expected reinsurance subsidy per enrollee.⁹³ The subsidy S is set so that on average government pays for 74.5% of the benefit expenses and enrollee pays for 25.5%. To see this, enrollee's premium for purchasing an average plan would be $\bar{p}_j^e = \bar{b} - S = 0.255(\bar{b} + \bar{r})$.⁹⁴

For the low-income subsidy (LIS) eligible population, they face an even greater subsidy rate. For a LIS enrollee, his/her premium for purchasing plan j in market m is:

$$p_{jm}^{LIS} = \max \{ 0, b_{jm} - \bar{b}_m \} \quad (31)$$

where \bar{b}_m is the lagged enrollment-weighted average of bids within the same market, also known as the LIS benchmark premium. LIS enrollees will pay zero premium for plans below the benchmark, which by design there will always be at least one such plan.⁹⁵ For plans that are above the benchmark, LIS enrollees will pay the difference between the plan bid and the benchmark.

The above subsidy design poses several challenges in accurately modeling the supply-side due

⁹³In practice, insurers submit each plan's expected per-enrollee reinsurance cost to the government along with their bids. Similar to \bar{b} , \bar{r} is the lagged-enrollment weighted average of all the plans' expected reinsurance cost across the markets.

⁹⁴In theory, if b_j is sufficiently low enough enrollee premium for the plan could be 0. However, for the sample period of 2012-2015 regular enrollees faced no zero-premium plans.

⁹⁵In practice, a large portion of LIS enrollees are randomly assigned to plans that are below the benchmark. However, after they are auto-enrolled in the randomly assigned plan, they are free to choose a different one.

to how the demand share function looks like. For the regular enrollees, the subsidy-level S is a weighted-average of the bids and hence is a function of insurer's own bids. While I could model insurers as internalizing this effect, I assume that insurers take the subsidy-level S as given (i.e. treat it as exogenous). This seems reasonable as there are close to 1000 different plans per year that are used to construct the weighted-average bid and includes both the PDP and the MA-PD bids.

For the LIS consumers, it gets even more difficult. First, the benchmark is constructed at the market level and hence it could be more susceptible to insurers' strategic behaviors (Decarolis, 2015). While this may be problematic when insurers can offer many plans which was the case in the earlier years of Part D market, for the years of my analysis, insurers are restricted in the number of plans they offer in a single market. More specifically, starting from 2010 CMS imposed a "meaningful difference" requirement across plans that made it harder for insurer to offer more than two plans. In the data, an insurer usually offers one or two plans and at most three plans in a single market. Second, the plans' share function will not be continuously differentiable with respect to their bids at or below the benchmark. This is because LIS premium will be zero and will not change as long as it's at or below the benchmark. As a result, I can't use a standard first-order condition for these plans.

Similar to Decarolis (2015), I make the following assumptions. I assume that plans whose bids are sufficiently above the benchmark premium face an elastic demand and price optimally according to the demand. I refer these as regular plans. For the bids that are at or below the benchmark premium, I do not model how insurers set those bids but take them as given. So while I can still construct FOC's with respect to bids of plans whose bids are above the benchmark, I can not do the same for the plans whose bids are below the benchmark. I refer these as LIS-distorted plans.

D.2 First-Order Conditions

Given the insurer's objective in (12) and the above assumptions, we can derive the following first-order-conditions with respect to all the regular plans' bid b_{km} :

$$\begin{aligned}
& b_{km} + \sum_{j \in J_m} (b_{jm} - c_{jm}) \frac{\partial Q_{jm}(b)}{\partial b_{km}} \\
& - \sum_{j \in J_m} \left(\gamma_{jm} c_{jm} \frac{\partial Q_{jm}(b)}{\partial b_{km}} + \frac{\gamma_{jm}(\delta, Q_{jm})}{\partial Q} \frac{\partial - Q_{jm}(b)}{\partial b_{km}} c_{jm} Q_{jm}(b) \right) \\
& - \sum_{j \in J_m} \rho \frac{V_{jm}(\delta, Q_{jm})}{\partial Q} \frac{\partial Q_{jm}(b)}{\partial b_{km}} \\
& - \lambda \left(b_{km} + \sum_{j \in J_m} (b_{jm} - \bar{m} \delta c_{jm}) \frac{\partial Q_{jm}(b)}{\partial b_{km}} \right) = 0
\end{aligned}$$

and FOC's with respect to the strategic cost-reporting term δ :

$$- \sum_m \sum_{j \in J_m} \left(\frac{\partial \gamma_{jm}(\delta, Q_{jm})}{\partial \delta} c_{jm} Q_{jm} + \rho \frac{\partial V_{jm}(\delta, Q_{jm})}{\partial \delta} \right) + \lambda \bar{m} \sum_m \sum_{j \in J_m} c_{jm} Q_{jm} = 0$$

Furthermore, with the binding margin constraint we have that⁹⁶

$$\sum_m \sum_{j \in J_m} b_{jm} Q_{jm} - \bar{m} \sum_m \sum_{j \in J_m} \delta c_{jm} Q_{jm} = 0$$

We can rewrite the above in a vectorized form:

$$\frac{\partial \mathbf{Q}}{\partial \mathbf{b}}^{-1} \underbrace{\left(\mathbf{Q} + \frac{\partial \mathbf{Q}}{\partial \mathbf{b}} \mathbf{b} \right)}_{\text{MR}} = \underbrace{\frac{(1 - \lambda \bar{m} \delta)}{(1 - \lambda)} \mathbf{c} + \frac{1}{(1 - \lambda)} \overbrace{\rho \frac{\partial \mathbf{V}}{\partial \mathbf{Q}}}}_{\text{Effective MC}} + \frac{1}{(1 - \lambda)} \overbrace{\left(\gamma + \frac{\partial \gamma}{\partial \mathbf{Q}} \mathbf{Q} \right)}_{\text{marginal RC payment}} \quad (32)$$

$$\text{where } \lambda = \frac{\rho \frac{\partial V}{\partial \delta} - \frac{\partial \gamma'}{\partial \delta} \mathbf{Q}}{\bar{m} \mathbf{c}' \mathbf{Q}}, \quad \delta = \frac{\mathbf{b}' \mathbf{Q}}{\bar{m} \mathbf{c}' \mathbf{Q}} \quad (33)$$

The above FOC while similar to the standard FOC's where marginal revenue equals to the marginal costs is much more complicated. In a standard model, inverting the FOC should yield

⁹⁶I assume that the margin constraint is always binding for firms. This can be proven as long as the risk-charge term is not too big. For example, I make a reasonable economic assumption that marginal risk-charge can't be larger than the marginal costs in which case I can show that the margin constraint will be always binding.

the marginal cost on the right hand side of the equation. However, here the right hand side is an “effective marginal cost” that is composed of marginal cost, marginal risk-charge as well as the marginal risk-corridor payments, some of which are non-linear due to the margin constraint.

E Details on Simulating Cost Distribution

E.1 Computing plan-specific distribution of cost

In this section, I detail how I use the sample claims data to construct a plan-specific sample distribution of cost. The goal is to create a sample distribution of enrollees and their associated claims cost that each plan could be facing.

From the MCBS data, I observe a nationally representative sample of Medicare beneficiaries and their detailed prescription drug consumption information through the whole year. The information includes the date of the prescription drug fill, the quantity, and the specific drug or the NDC code of the drug purchased.

From the CMS Part D Prescription Drug Plan Formulary, Pharmacy Network, and Pricing Information Files, I observe detailed plan benefit design and formulary data. The information includes financial cost-sharing information like the deductible, co-insurance/co-pay rates across different tiers of drugs, drug formulary design (i.e. which set of drugs are in tier 1, tier 2 and so on) as well as plan level average monthly costs for each drug.

With the above two data sets, I can create $N \times J$ total individual-plan level cost. I follow the procedure for each market m . For a given individual i and plan j , I compute the hypothetical cost to the enrollee and the insurer if individual i were to be enrolled in plan j . This is done by feeding in individual i 's prescription drug purchase information through plan j 's plan formulary/benefit design information.⁹⁷ This results in an estimated object: c_{ij}^{plan} , plan j 's cost of enrolling in individual i , and c_{ij}^{enrol} , individual i 's out of pocket cost of enrolling in plan j with the given prescription drug consumption. After the procedure, I'm left with two matrixes that is N (number of individuals) by J (number of plans); one for plan liable cost, and the other for enrollee liable out of pocket cost. More importantly, for each plan j I'll have a sample distribution of costs of N individuals:

$$\{c_{ij}^{plan}\}_{i=1}^N.$$

⁹⁷Here, I'm implicitly assuming there is no moral-hazard i.e. individuals' consumption of drugs do not depend on the plan's benefit generosity.

E.2 Computing Enrollee’s Risk-Score

Here, I detail how I estimate the risk-adjustment factor across different enrollee types. Given the plan-individual level imputed cost data from E.1, I first compute the expected cost across all individual-plans i.e.

$$\bar{c} = \frac{1}{NJ} \sum_i \sum_j c_{ij}^{plan} \quad (34)$$

Then I compute the expected cost of each risk-type across all plans:

$$\bar{c}_t = \frac{1}{N_t J} \sum_{i, r(i)=t} \sum_j c_{ij}^{plan} \quad (35)$$

The risk-type specific adjustment factor is then computed by

$$\theta_t = \frac{\bar{c}_t}{\bar{c}} \quad (36)$$

The resulting factors across different risk-types are shown in table A3. The risk-adjustment factors follow intuitive patterns where healthier enrollees receive lower risk-adjustment factor.

Table A3: Enrollee Risk-Type Risk-Adjustment/Cost Factor

Enrollee Health Risk-Type	θ_t
Excellent	0.45
Good	0.68
Fair	0.92
Poor	1.26
Very Poor	1.52
LIS	1.39

Notes: the table shows estimated risk-adjustment/cost factor across different risk-types of individuals.

E.3 Simulating $V(\delta, Q)$ and $\gamma(\delta, Q)$

Here, I detail how the variance of total cost subject to risk-corridor, $V(\delta, Q)$ and the expected risk-corridor payment share function, $\gamma(\delta, Q)$ is simulated and then estimated via a 2-dimensional spline method.

From section E.1, for each plan j , I have a sample distribution of individual-level cost: $\{c_{ij}^{plan}\}_{i=1}^N$. I then take the following steps to get a distribution of total cost that insurers may be facing and compute the associated variance and the expected risk-corridor payment share:

1. fix a value of Q , the total demand or the number of enrollees in plan j and δ the degree of strategic cost-reporting parameter.
2. draw Q enrollees from the distribution of cost: $\{c_{ij}^{plan}\}$ to get a vector of cost: $\{e_{ij}\}$
3. then compute the total cost incurred to the plan: $C_j = \sum_i^Q e_{ij}$
4. Repeat steps 2 to 3 from $k = 1$ to K times to get a distribution of total cost that the plan could be facing: $\{C_{j,k}\}_{k=1}^K$
5. Compute the expected total cost as $\bar{C}_j = \frac{1}{K} \sum_k^K C_{j,k}$
6. Apply the risk-corridor function to each k^{th} draw of the total cost i.e.

$$C_{j,k}^{rc} = C_{j,k} + T(C_{j,k}, \delta \bar{C}_j) \quad (37)$$

where $T()$ is the ex-post risk-corridor function in (7).

7. compute the variance of total cost and the expected risk-corridor share function as:

$$V(\delta, Q) = \frac{1}{K-1} \sum_{k=1}^K (C_{j,k}^{rc} - \bar{C}_j^{rc})^2 \quad (38)$$

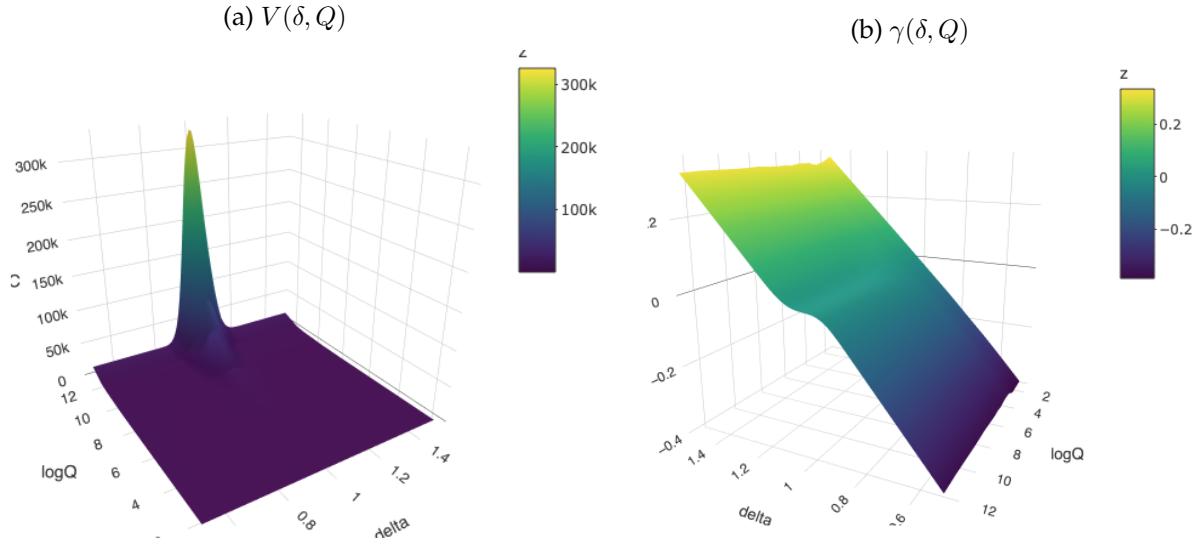
$$\gamma(\delta, Q) = \frac{1}{K} \sum_{k=1}^K \frac{T(C_{j,k}, \delta \bar{C}_j)}{\bar{C}_j} \quad (39)$$

where \bar{C}_j^{rc} is the average total cost after the risk-corridor function has been applied.

8. Repeat the above steps for various values of δ and Q .

The above procedure will allow me to generate various values of the variance and the risk-corridor payment share for different values of δ and Q . Figure E.1 shows the results for a sample plan.

Figure E.1: Simulated $V(\delta, Q)$ and $\gamma(\delta, Q)$



Panel (a) plots the simulated values of the variance of total cost as a function of δ and Q . Panel (b) plots the simulated expected risk-corridor payment share as a function of δ and Q .

While the above procedure is straightforward to implement, it can get quite computationally intensive and as such I approximate and estimate the function: $V(\delta, Q)$ and $\gamma(\delta, Q)$ using a 2-dimensional spline methods i.e. I estimate the above using a series of polynomial coefficients across different basis functions of δ, Q . The estimated function results look very similar to the simulated ones where the R^2 is close to 0.99. I do so for each plan to estimate the functions: $V_{jm}(\delta, Q)$ and $\gamma(\delta, Q)$.

F Details on the Linear Risk-Sharing Rule

Here, I provide additional details on the linear risk-sharing rule of the form:

$$T(\tilde{C}, \delta C) = \alpha(\delta C - \tilde{C}) \quad (40)$$

where \tilde{C} is the ex-post realized total cost, C is the ex-ante expected total cost and δ is the strategic cost-reporting parameter. With the linear risk-sharing rule, insurer's ex-post total cost will be

$$\begin{aligned} \tilde{C}_\alpha &= \tilde{C} + T(\tilde{C}, \delta C) \\ &= (1 - \alpha)\tilde{C} + \alpha\delta C \end{aligned} \quad (41)$$

So the insurers' expected cost and variance of cost will be:

$$\begin{aligned} E[\tilde{C}_\alpha] &= C + E[T(\tilde{C}, \delta C)] \\ &= C + \underbrace{\alpha(\delta - 1)C}_{\text{expected rc payment}} \end{aligned} \quad (42)$$

$$Var(\tilde{C}_\alpha) = (1 - \alpha)^2 Var(\tilde{C}) \quad (43)$$

This shows that the expected cost will still be a function of insurer's strategic cost-reporting parameter, δ . If insurer overestimates its cost ($\delta > 1$), then it will be expected to pay the government and vice versa. However, insurer's variance of cost is no longer dependent on δ as shown above. This is contrary to the existing risk-corridor function that makes both insurers' expected cost and the variance of cost be function of δ .