A Double Dose of Reform for Innovative Drugs: Insurance Expansion and Central Negotiation

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November 16, 2024

Abstract

Making expensive, innovative drugs affordable and accessible is a pressing global challenge. In this paper, we explore the welfare and equity effects of a recent policy reform in China that coupled centralized drug price negotiation with expanded insurance coverage. Before the reform, innovative drugs were mostly excluded from insurance, leading to high out-of-pocket expenses for consumers. The reform offered insurance coverage for these drugs, contingent on mutually-agreeable price reductions negotiated between the government and drug producers. Our design-based analysis shows that successful negotiations were followed by 48% decreases in retail prices, 80% reductions in out-of-pocket prices, and 350% increases in utilization.

Focusing on cancer drugs, we estimate a flexible demand and supply model that features heterogeneous households, bargaining between the central government and drug producers with potential breakdowns, and a government objective function that depends on consumer surplus and insurance expenditure. Our counterfactual analyses yield three key insights. First, there's a notable synergy between insurance expansion and price negotiation. Insurance coverage combined with central negotiation incentivizes drug producers to reduce drug prices, which increases consumer surplus gains by 77% relative to scenarios where drugs are covered without negotiation. Second, we evaluate the average and distributional welfare effects of decentralized, province-level negotiations. Third, we characterize an equity-efficiency tradeoff in coinsurance design; paradoxically, a regressive schedule with lower co-insurance rates for high-income households increases drug access through increased bargaining leverage.

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1 Introduction

Making innovative drugs affordable and accessible is a pressing global challenge. Take, for example, Verzenio (Abemaciclib), a breakthrough therapy for breast cancer developed by Eli Lilly in October 2015 and approved by the U.S. Food and Drug Administration (FDA) in 2017. While it has been shown to improve 5-year survival rates by 12%, the cost is prohibitively high — $180,000 per year in the U.S. and an initial price of ¥60,000 per year in China.[1] Such exorbitant prices place these life-saving treatments out of reach for the majority of self-paying patients, creating a severe equity issue where the latest pharmaceutical innovations are largely inaccessible to many who need them most (Nyman, 1999). Prescription drug insurance programs increase access to these drugs for a wider population, but they also come with substantial costs. For instance, the Medicare Part D prescription drug insurance program for the elderly in the U.S. allocates 61% of its budget to the top 100 highest-priced drugs (CMS, 2024).

In this paper, we examine the economic and policy implications of an ongoing drug insurance policy reform in China that began in 2016: the National Reimbursement Drug List (NRDL) Reform.[2] The NRDL Reform has several unique features that make it particularly relevant to current healthcare policy debates in the U.S. and other countries. A key aspect of the reform is its combination of expanded insurance coverage with centralized negotiation of innovative drug prices. Prior to the reform, the NRDL — the national drug formulary that determines drug coverage under China's universal health insurance (covering 95% of China's population) — provided no coverage for innovative drugs.[3] Patients were required to pay the full cost of these expensive medications out of pocket, in many cases leading to financial hardship and patients foregoing treatment altogether. These challenges were poignantly illustrated in the 2018 film *Dying to Survive*, which is based on the true story of a leukemia patient who resorted to smuggling cancer medicine from India; the film had China's fourth-biggest theatrical opening weekend ever. The NRDL Reform expands universal insurance coverage to include an increasing number of innovative drugs, provided that their manufacturers success-

[1] The drug was included in China's NRDL in 2021 with a post-negotiation retail price of ¥20k, significantly lower than the pre-negotiation price at ¥60k per year. UK's National Health Service negotiated a price cut with Eli Lilly to recommend it as a routine use for breast cancer treatment in 2021. See https://www.theguardian.com/society/2021/aug/12/breast-cancer-drug-approved-for-nhs-after-maker-agrees-discount.

[2] The program is also referred to as the "National Health Insurance Negotiation," the "Reimbursement-Linked Drug Price Negotiation," and "China's National Negotiation of Drug Prices" (Sun et al., 2021; Zhou et al., 2024; Lu and Zhang, 2023).

[3] For a list of drugs covered by NRDL in 2017, see: https://www.gov.cn/xinwen/2017-02/23/5170392/files/60c89aae96da450e9efb6175ed8dafe4.pdf.

fully negotiated price reductions with China's National Healthcare Security Administration (NHSA). Once a drug is added to the NRDL, patients can access the drug at a fraction of the negotiated price, where the patient's share of the drug cost — the "coinsurance rate" — ranges from 20% to 45% depending upon provincial subsidies.

The NRDL Reform in China offers a valuable context for analyzing potential policy instruments aimed at controlling the rising costs of pharmaceuticals, particularly innovative drugs. In contrast to the U.S., where commercial insurance plays a significant role, China's healthcare system is predominantly public, which significantly simplifies the modeling challenges and allows us to evaluate the effectiveness of central-government insurance expansion without the complication of other competing insurance marketplaces. The reform's staggered implementation across products provides ample panel variation in prices and coverage for the empirical analysis. Furthermore, in contrast to many settings where only successful negotiation outcomes are observed, negotiation failures occur in approximately 25% of cases, providing a unique opportunity to infer government preferences and to estimate the shadow value of government expenditures. Additionally, variation in coinsurance rates across provinces, driven by differing provincial budget constraints, offers a natural experiment that allows us to investigate the optimal design of coinsurance schedules.

Our analysis of the NRDL Reform utilizes a unique dataset that provides comprehensive coverage of drug sales across China from 2017 to 2023. The primary data source is Sinohealth, a publicly listed health consulting firm whose data are widely utilized by major international and domestic pharmaceutical companies, including Pfizer, Roche, Bayer, AstraZeneca, GlaxoSmithKline, Merck, and Eli Lilly, among others. We supplement the Sinohealth data with additional datasets that detail negotiation outcomes for all participating drugs, approved usage of each drug for different indications, clinical evidence concerning improved survival times, and provincial demographic information.

This project aims to make several contributions. First, we present to our knowledge the first comprehensive evidence on the price and quantity effects of China's NRDL Reform between 2017 and 2023. To do so, we aggregate drug sales data to the province-quarter level and analyze the changes in prices and quantities dispensed after a drug's inclusion in the NRDL, relative to other drugs not yet covered by the NRDL. The documented effects were tremendous. The program expanded coverage of 487 innovative drugs (out of the 643 drugs invited to negotiation) to over a billion people during our study period. The associated price negotiations resulted in a 48% reduction in retail price for the average drug and, due to the introduction of coinsurance at the same time, an even larger 80% reduction in the

consumer's out-of-pocket price. These sharp price drops drove large increases in the utilization of innovative drugs: the average successful negotiation was followed by a quantity increase of 350%.[4] These findings contribute to a broad literature examining the effects of prescription drug insurance coverage and generosity on utilization, prices (Abaluck et al., 2018; Duggan and Morton, 2010; Einav et al., 2018), and pharmaceutical manufacturer innovation (Dranove et al., 2022; Blume-Kohout and Sood, 2013; Agha et al., 2022). We also contribute to a relatively nascent literature on China's recent drug market reforms (Cao et al., 2022; Fang et al., 2021).

Second, we build a structural model consisting of a demand model that features random preferences and differences in affordability across income groups, and a supply side where the government and pharmaceutical firms negotiate to split surplus contingent on successful negotiations. The empirical framework for the supply side features centralized bargaining with heterogeneous households, bargaining breakdowns, and a government objective function that depends on measures of patient welfare and government expenditure. The structural model allows us to estimate several key parameters: patients' effective price elasticities of demand across different income levels, firms' marginal costs of producing and distributing innovative drugs, the bargaining parameter that determines the surplus split between firms and central government during negotiation, and the relative weights the central government places on patient surplus vs. government expenditures. Several empirical challenges arise in this analysis. As is common in demand studies, drug prices are endogenous. We address this endogeneity using the NRDL policy shock as an instrumental variable, which, when interacted with local demographics, generates more granular variation. In addition, the marginal costs and bargaining parameters of drug companies are not observed. We recover them by inverting first-order conditions and imposing parametric restrictions on bargaining parameters.

The structural analysis focuses on two classes of innovative anti-cancer drugs: monoclonal antibodies and protein kinase inhibitors. These classes include complex therapies, many of which are biologics, that treat cancers across various body systems. Of the 97 such cancer drugs invited for negotiation, 57 were successful and accounted for two-thirds of revenues for successfully negotiated drugs in NRDL program. As expected in pharmaceutical markets where firms are often short-term monopolies, margins are high (75% on average) in the pre-reform period. Consistent with prior work on global drug markets, price elasticities are

[4]The reform period also saw an acceleration in new drug entries into the Chinese market. For example, the ratio of new cancer drug indication approvals in China relative to the U.S. was 0.24 between 2001-2016 and more than doubled to 0.5 during 2017-2020, providing suggestive evidence that the program was beneficial to firms and stimulated market entry.

somewhat low, around -1.2 for the median patient (Dubois et al., 2022). There is a significant gradient in income, with low-income patients noticeably more price-sensitive. The government assigns equal weight to consumer surplus and program expenditures for the median drug and higher weights to consumer surplus gains for more effective drugs that demonstrate large survival improvements in phase III clinical trials. Firms have a bargaining parameter of 0.63, suggesting that while firms have considerable bargaining power, there is room for the government to bring down prices through central negotiation.

Turning to policy effectiveness, negotiation without insurance expansion has no impact on prices or quantities. This is because the government lacks the leverage to negotiate price discounts, as firms can simply sell at profit-maximizing prices in the retail market. On the other hand, insurance expansion alone reduces price sensitivity, leading to higher retail prices (though out-of-pocket prices are still lower); see Cutler and Reber (1998), Jaffe and Shepard (2020), and Liu and Jin (2015). The combination of negotiation and insurance expansion, as implemented in China's NRDL Reform, increases the market share of innovative drugs among all cancer drugs by 18 ppt, which exceeds the gains achieved by insurance alone (5 ppt) and negotiation alone (0 ppt). This double dose of reform with both central negotiation and insurance expansion reduces out-of-pocket costs by 89% and delivers the greatest consumer surplus gains compared to either insurance expansion alone or negotiation alone. Furthermore, the improved access to innovative drugs enhances average overall survival by four months per cancer patient during our sample period. Altogether, social surplus (consumer surplus plus producer surplus minus government expenditures) increases by ¥8,280 per cancer patient, compared to only ¥5,720 with insurance expansion alone and ¥0 with negotiation alone.

Our model shares similar features with structural work on drug markets (Atal et al., 2022; Branstetter et al., 2016; Cao and Chatterjee, 2022; Chaudhuri et al., 2006; Xia, 2024) and with the recent empirical literature on bargaining in health care markets more broadly (see Grennan and Swanson (2022) for a review). One innovation of our model is its ability to infer the central government's weight on government expenditures relative to patient surplus, which can be interpreted as the shadow cost of the government's budget constraint. As this weight increases, the set of feasible negotiated prices narrows; eventually, the negotiation fails as including any drug in the NRDL formulary at a price acceptable to the drug company would be too costly for the government. We recover the distribution of this shadow cost that varies across drugs using a novel maximum likelihood specification, estimated on both successful and failed negotiations. This aspect of the model is most closely related to Dubois and Lasio (2018), which examines drug firm optimization under government price regulation.

Our third contribution is related to three sets of counterfactual simulations we have conducted that shed light on optimal policy design. First, having noted that negotiation alone has no "teeth," we consider strengthening the government's leverage by modeling a "market access" negotiation, with and without insurance expansion, in which the government's threat point is the exclusion of the drug from the Chinese market entirely. This analysis contributes to recent work on bargaining with exclusion and alternative formulary structures (Ho and Lee, 2019, 2024). We do find stronger effects of negotiation in this case. If firms must negotiate with the government to access the market, even without insurance expansion, retail prices (which are equivalent to out-of-pocket prices absent insurance) would decrease by 59% at zero cost to the government. This expands the innovative drugs' share of the cancer drug market by 3 ppt. Nevertheless, we continue to find that insurance expansion reinforces the effects of negotiation. Market access negotiation *plus* insurance expansion reduces retail prices by 65% and OOP prices by 87%, expanding the negotiated drugs' share of the cancer drug market by 16 ppt.[5] Taken together, these results confirm our original finding that negotiation and insurance expansion reinforce one another.

Next, we examine the role of centralization in the NRDL Reform. As noted previously, there is wide variation in income and price sensitivity across provinces. Centralized negotiation may create winners and losers relative to a decentralized province-by-province negotiation. To investigate this, we contrast the effects of centralized national bargaining with those of a counterfactual program in which each province negotiates its own prices. This analysis sheds light on recent policy debates and academic research regarding the costs and benefits of central procurement; see, e.g., Dubois et al. (2021), Dubois and Sæthre (2020), Dubois et al. (2022), Ho and Pakes (2024), and Maini and Pammolli (2023). We analyze the effects on both the extensive and intensive margins. On the extensive margin, decentralized bargaining leads to a 19% increase in negotiation failures, as the market expansion and gains in consumer surplus in lower-income regions are insufficient to justify the government's expenses. On the intensive margin, decentralized province-level negotiations result in retail prices that are 22% higher (for successfully negotiated drugs) and a 5.6 percentage point decline in these drugs' share of the cancer drug market compared to centralized negotiations. These effects vary significantly across regions: while most low- to moderate-income provinces suffer from fewer successful negotiations and higher prices under provincial-level negotiations, the highest-

[5]Note that 'market access' negotiation plus insurance expansion delivers similar equilibrium outcomes as the current reform where negotiation is not tied to market access. This is because the government cares about losses in consumer surplus if a drug is excluded from the market. Consequently, the government might not have stronger bargaining power in the scenario where negotiation is tied to market access.

income provinces tend to benefit from decentralization.

The last set of counterfactual analyses examines the efficiency and equity implications of more and less regressive coinsurance schedules. Public insurance programs often include income-based subsidies. For example, in the US, the Medicare program for the elderly offers reduced medical and prescription drug insurance premiums for low-income enrollees, the Medicaid program provides largely free health insurance for households with incomes below 138% of the federal poverty level, and the health insurance marketplaces created under the Obama administration tie subsidies to income between 138% and 400% of the federal poverty level. Our analyses on the coinsurance design contribute to the literature that examines income-based subsidies for privately-supplied products, see, e.g., Polyakova and Ryan (2022) and Finkelstein et al. (2019).

We explore two-tier structures with different coinsurance rates for households above and below the median income that vary between 20% and 50%. To assess equity and progressiveness, we follow public finance literature (e.g., Saez (2002)) and reweight households' consumer surplus by $income^{-\nu}$. When $\nu = 0$, the measure reflects utilitarian preferences, while higher ν indicates a stronger emphasis on equity and redistribution.

We document a few notable results. First, our simulations characterize a key tradeoff in which lower coinsurance rates lead to more bargaining failures, which hurt both low- and high-income patients. At the extreme, offering a 20% coinsurance rate to all consumers would reduce the fraction of successful negotiations to 50%. Second, both low-income and high-income households benefit when high-income households receive lower coinsurance rates, as the more generous insurance expands demand and increases firms' willingness to grant price discounts in exchange for inclusion in the national formulary. Third, aggregate social surplus is maximized with a moderately regressive insurance schedule, as demand expansion from high-income households offers the government greater bargaining leverage.

The rest of the paper proceeds as follows. Section 2 provides institutional background and describes the data. Section 3 presents the model and Section 4 discusses estimation results. Section 5 conducts counterfactual analyses to shed light on policy designs. Section 6 concludes. The appendices contain more details and additional analyses.

2 Institutional Background and Data

2.1 Institutional features: CHS and the NRDL Reform

The Chinese healthcare system, known as CHS, provides nearly universal coverage to over 95% of Chinese citizens, making it the largest healthcare insurance program in the world (Yu, 2015). It was created in 1999 and went through several changes over the years. Today, it consists of two major health insurance plans: the urban employee basic medical insurance plan (UEBMI) for individuals working in the formal sectors, and the urban resident medical insurance plan (URRMI) for the elderly and other populations groups that are not affiliated with the formal sectors. The premium for the universal insurance is set at ¥1080, with individuals paying ¥380 in 2023 and the government subsidizing ¥700. The commercial insurance market in China is relatively small, accounting for less than 7% of total expenditure (National Health Commission of the PRC, 2023). Given CHS's widespread insurance coverage, we do not model insurance participation decisions and assume all households are enrolled.[6]

Historically, CHS's National Reimbursement Drug List (NRDL) excluded innovative drugs due to budget considerations. In recent years, CHS has faced criticism for its limited coverage of innovative drugs, resulting in limited access to effective treatment and high out-of-pocket prices for the general public. In response to public pressure, CHS launched the innovative drug reform in 2016 that is ongoing today (Macabeo et al., 2023). Each year, the NHSA comes up with an "eligible list" of drugs and invites drug producers to participate in a negotiation. Firms and the NHSA often exchange information on drugs and government preferences during the pre-negotiation stage, which can last for up to a month. On the day of the negotiation, the government sends representatives and negotiates with delegates from each drug company simultaneously and independently. Table 1 summarizes the seven rounds of annual negotiations from 2016 to 2022, with an average success rate of 76%.

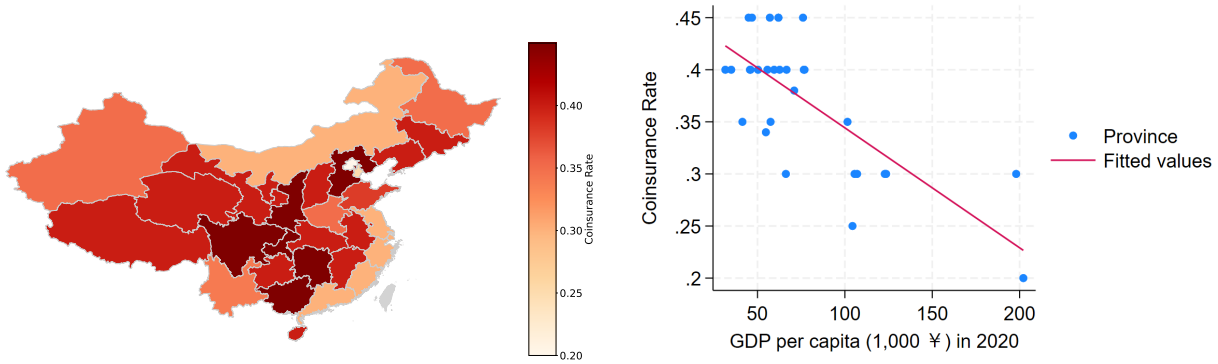
There are three notable features of this negotiation process. First, both parties possess a lot of information about drug prices and demand, as most of the drugs on the eligible list are already sold in the private market. During the pre-negotiation stage, information is exchanged frequently between the parties. As a result of this process, the government is likely to have a good understanding of the firm's production costs and the drug firms are likely to know the government's preferences. Second, the government prioritizes social benefits and government expenditures. It hires two groups of experts for each negotiation: pharmacoeconomic experts

[6]China had various price caps and price regulations on pharmaceutical drugs during the 1980s-2000s. In 2015, China removed these price regulations and only kept anesthetics under price control. See https://www.gov.cn/gongbao/content/2015/content_2901387.htm.

who calculate potential patient benefits, and finance experts who assess the drug's affordability for the health insurance fund. Lastly, negotiations for each drug are conducted independently. Each government team negotiates with a specific drug company's representative in a separate room without communicating with other teams. Thus, each negotiation is treated as an independent event, with no strategic interaction across negotiations.

If the negotiation is successful, the drug will be included in the NRDL, typically within a quarter. Once a drug is included in the NRDL, consumers can access it by paying a reduced fraction (a "coinsurance rate") of the retail price. While the coverage decision is made centrally, coinsurance rates are set provincially, leading to significant variation across provinces. See Figure 1 for a map of coinsurance rates across region, and the relationship between coinsurance and provincial income. Consumers in wealthier provinces like Beijing and Shanghai pay about 20-25% of the retail price, whereas those in regions like Gansu pay up to 45%. Typically, there are two major CHS insurance plans in each province: the "urban employee basic medical insurance plan" (UEBMI) and the "urban and rural resident medical insurance plan" (URRMI). Both cover the same sets of drugs but have different coinsurance rates. UERMI, covering more than 70% of the population, sometimes offers slightly more favorable coinsurance rates (on average, 5 ppt lower).[7] We use URRMI's coinsurance rate for the baseline analysis and incorporate UEBMI's coinsurance rate in a robustness analysis.

Figure 1: Coinsurance Rate Design



(a) Coinsurance Rate across Province (b) Coinsurance Rate and GDP per Capita

Note: Figure (a) plots the provincial coinsurance rate for innovative drugs in the universal healthcare insurance for residents. Figure (b) plots the negative relationship between coinsurance and GDP per capita. Richer provinces tend to offer more generous coinsurance rates.

[7]For a summary of the two alternative types of insurance, see: this report.

2.2 Data and sample description

The primary dataset we use contains comprehensive coverage of drug sales in China from 2017 to 2023, sourced from SinoHealth. Sinohealth is the only health consulting firm that is publicly listed in China and supplies data to all major international pharmaceutical companies, including Pfizer, Roche, Bayer, AZ, GSK, Merck, Eli Lilly, etc. Sinohealth's price and sales data closely match the information posted on NHSA's website and published in China's Statistic Yearbooks. Sinohealth provides better coverage than IQVIA, another commonly used database on pharmaceuticals, particularly in rural China. We focus on hospital sales because nearly all innovative drugs are dispensed through hospitals. This dataset is at the province-quarter level and includes total drug sales, quantities dispensed (standardized to years' supply), and retail prices at the SKU level. The second primary dataset is sourced from the CHS website and details negotiation outcomes: eligible drugs, successfully negotiated drugs, and negotiated prices. We use the drugs that are eligible for negotiation but never included in the NRDL as a natural control group when we analyze the data patterns in Section 2.3 below.

We focus on cancer drugs in our structural analyses and have constructed several ancillary datasets. First, we have gathered brand-year-level indications from the Handbook of Innovative Cancer Drugs, which details the approved usage of each cancer drug for different indications by China's National Medical Products Administration, the equivalent of the U.S. FDA. Second, we collected clinical evidence for all innovative cancer drugs from Phase-III Trials on Clinicaltrials.gov. We use the clinical trial results to measure the quality of each drug. Our preferred measure is the effect of the drug on overall survival, compared to the previous standard of care. When this measure is missing (less than 30% of cases), we use alternative measures such as overall survival rates and progression-free survival (PFS). Third, we collected provincial-level demographics from each province's Statistics Yearbook, along with cancer incidence data from the annual reports published by the National Cancer Center.

We focus on cancer drugs for two main reasons. First, this market is significant from both health and economic perspectives. In 2020, China had 4.6 million cancer cases and 3 million cancer-related deaths, accounting for 23.7% of global cancer incidence and 30% of global cancer mortality. China's pharmaceutical market for anti-cancer drugs is growing rapidly, with total sales reaching ¥140 billion (around 0.1% of China's GDP) in 2022. Second, anti-cancer drugs are the most critical category in NRDL negotiations, with successfully negotiated anti-cancer drugs comprising more than 60% of revenues among all successfully negotiated drugs.

There are four major types of anti-cancer drugs on the market: monoclonal antibodies

(mAb), protein kinase inhibitors (PKI), cytotoxins (traditional chemotherapy), and hormone drugs. mAb and PKI include all the innovative cancer drugs and are the primary focus of the NRDL Reform. Cytotoxins are effective in killing cancer cells but are associated with very strong side effects. Hormone drugs are useful for treating certain types of cancers. In addition to these four major types, there are ancillary drugs used for cancer treatments, including traditional Chinese medicine-based products. By 2022, there had been 97 negotiations involving innovative anti-cancer drugs, with 57 successes.

Figure 2 presents key data patterns regarding the cancer drug market. First, the NRDL Reform led to substantial market expansion effects for innovative cancer drugs (mAb and PKI). Sales skyrocketed from ¥13 billion in 2017 to ¥64 billion in 2022 (Figure 2(a)). At the same time, sales of traditional chemotherapy drugs declined, suggesting that there was some switching from cytotoxin treatment to innovative anti-cancer treatment. Figure 2(b) decomposes the sales of innovative cancer drugs into insured and non-insured products. In 2017, the innovative anti-cancer drug market was entirely uninsured and consumers had to pay full retail price to receive treatment. In 2022, six years after the first negotiation, more than 80% of innovative cancer drug sales were from insured (successfully negotiated) products. Over the same time horizon, Figure 2(c) shows that the average retail price of innovative cancer drugs declined substantially. This effect is even more pronounced for residualized prices after partialing out brand fixed effects (Figure 2(d)) to account for price changes due to product entry and exit.[8]

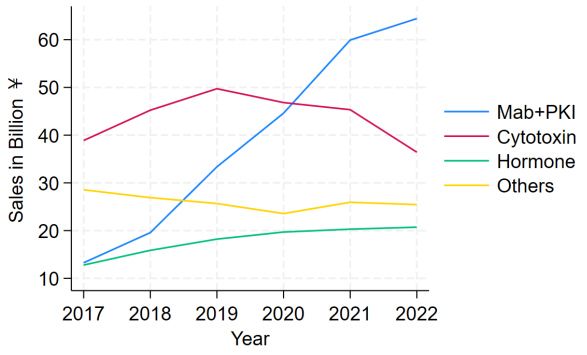
This period also saw significant market entry and a growing variety of innovative cancer drugs. Figure 2(e) shows that the number of innovative drugs available surged for each type of cancer between 2017 and 2022, and Figure 2(f) demonstrates that the number of innovative cancer drugs available in China nearly tripled over that period. Many of these new entrants to the Chinese market were already available in developed countries, suggesting that the insurance expansion may have increased the anticipated profitability of entering the Chinese market and thereby made it more attractive for drug companies.

2.3 Descriptive patterns

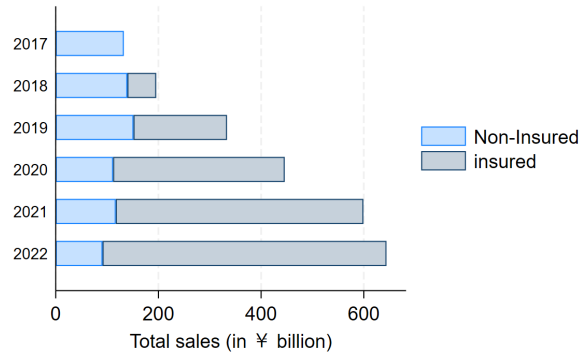
In this Section, we present event study evidence on what happens to prices and quantities after drugs are included in NRDL, across all innovative drugs and for cancer drugs specifically.

[8]There is a small decline in prices for cytotoxin drugs, likely due to the 2019-20 introduction of a procurement auction program targeting generic drugs (Cao et al., 2022).

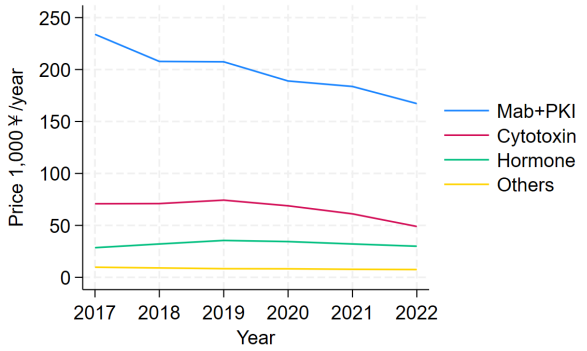
Figure 2: Overview of the Anti-Cancer Drug market



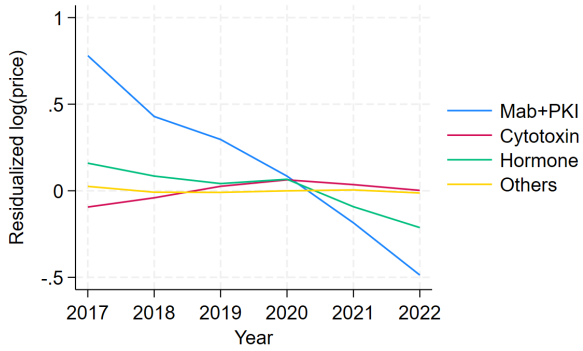
(a) Market sales



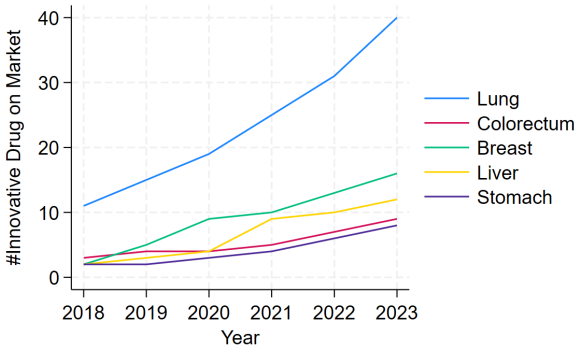
(b) Fraction of insured sales for Innovative Drugs (mAb+ PKI)



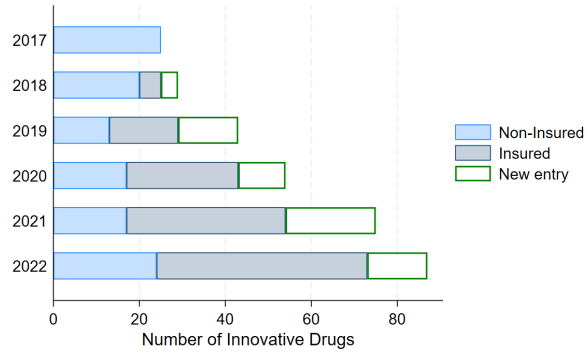
(c) Retail Price (raw)



(d) Price (net of product fixed effects)



(e) Approved Indications for Major Cancer Types



(f) Number of Innovative Drugs on Market

Note: There are several major types of anti-cancer drugs. The two most important categories are monoclonal antibody and PKI, which include most of the innovative drugs in this market, and their joint sales account for 0.1% of China's GDP. Figure (a) plots the sales of each major category of anti-cancer drugs by year. Figure (b) further decomposes the Mab+PKWe category into insured sales and non-insured sales. Figure (c) plots the raw price. Figure (d) plots the residual log price of drugs in each category after controlling for the drug-fixed effects and time-fixed effects. Figure (e) reports the number of drugs that treat certain indications, and Figure (f) reports the number of drugs on the market each year, with incumbent denoted by the blue solid bar and new entries denoted by the green outlined bar.

Prices and quantities Table 1 summarizes the negotiation outcomes for all innovative drugs. Negotiations occur annually, and the number of negotiated drugs has rapidly increased since the initial pilot years.

Table 1: Summary of Each Round of Negotiation 2016-2022

Round	2016	2017	2018	2019	2020	2021	2022	All
# Negotiated Products	5	44	18	150	162	117	147	643
# Successful Negotiations	3	36	17	97	119	94	121	487

Data source: NHSA website. Overall success rate: 75.7%.

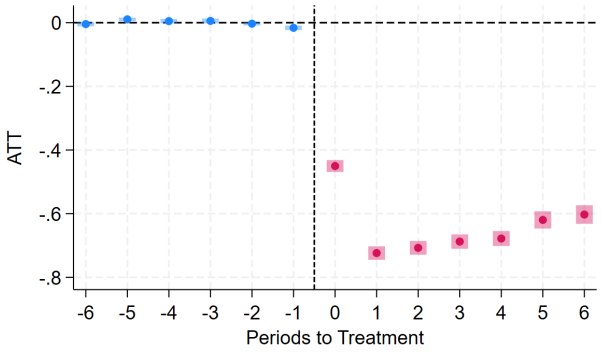
Panels (a) and (b) of Figure 3 compare outcomes for successfully negotiated innovative drugs with those of a never-treated group (defined as drugs that appeared on the "eligible list" but were never successfully negotiated), using the regression method presented in Callaway and Sant'Anna (2021). The program led to a 50% reduction in prices and a 350% increase in quantity.[9] The price response is immediate — retail prices adjust to the negotiated price within one quarter, while the quantity response takes slightly longer to fully materialize. There are no visible pre-trends in prices or evidence that firms strategically manipulate retail prices in anticipation of the negotiation. We also report the treatment effects by cohort (negotiation years) in the Appendix Figure A1. In the second set of robustness checks, we limit the regression sample to all successfully negotiated drugs and identify the treatment effect of successful negotiation using a Two-Way Fixed Effects (TWFE) regression that leverages the staggered timing of negotiation across drugs for identification. The results are similar and can be found in the Appendix Figure A2.

Panels (c) and (d) of Figure 3 present the event study estimates of the treatment effects for successfully negotiated cancer drugs, using non-included innovative anti-cancer drugs as the control group. Given the greater potential for competition (business stealing) across drugs, these estimates are likely to underestimate the price response and overestimate the quantity response. The results align with, but are more pronounced than, the patterns observed for all innovative drugs: we estimate a 57% reduction in retail prices and a dramatic 930% jump in quantity.

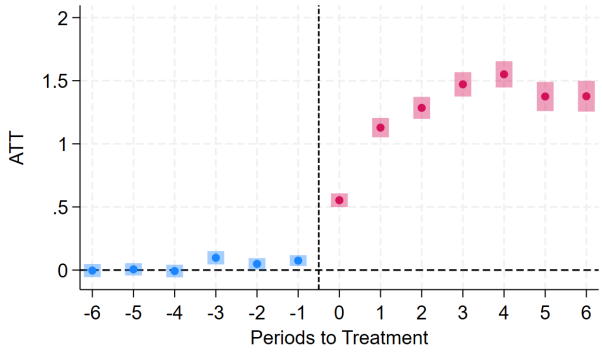
Negotiation successes and failures Next, we present descriptive evidence on the negotiation successes and failures in order to motivate our structural model. Figure 4 reports the number of cancer drugs on the market that were ineligible for NRDL negotiation, the

[9] A few innovative drug companies offer a "Patient Assistance Program" that provides discounts off the retail price to consumers. We have adjusted the retail prices to reflect these discounts.

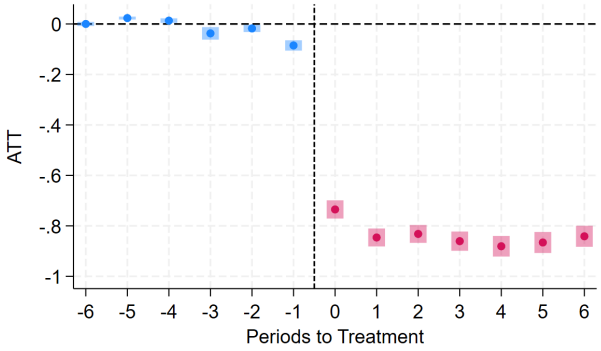
Figure 3: The Effects of the Centralized Negotiation Program on Price and Quantity



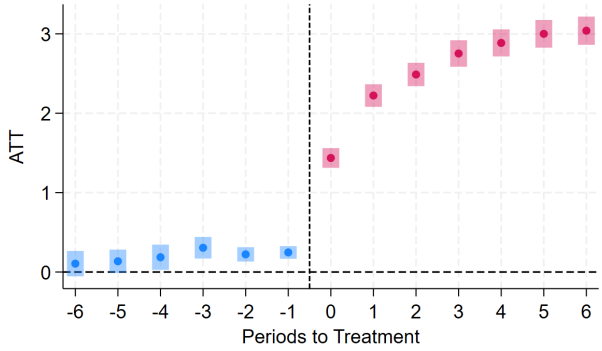
(a) Retail price: all categories



(b) Quantity: all categories



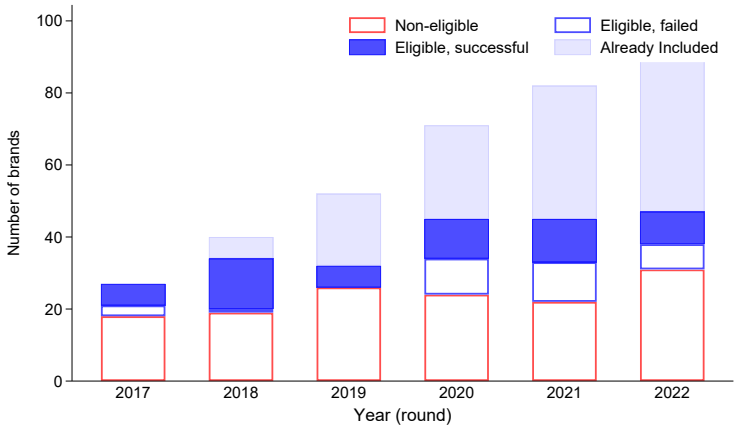
(c) Retail price: anti-cancer drugs



(d) Quantity: anti-cancer drugs

Note: This figure reports the effects of the centralized negotiation on the retail prices of quantities of successfully negotiated drugs. The horizontal axis denotes the relative quarters to the negotiation period. The vertical axis reports Callaway Sant'Anna's CSDID estimated dynamic treatment effects.

Figure 4: Summary of Negotiations with Cancer Drugs



Note: This figure shows the negotiation status of innovative cancer drugs. The light blue solid bar denotes the drugs that have already been included. The dark blue solid bar denotes drugs that get successfully negotiated each year. In combination, the solid bars denote the number of drugs insured by CHS each year. The empty blue bar denotes failed negotiations, and the empty red bar denotes the drugs that are not negotiated. In combination, the empty bars denote the drugs out of CHS each year.

number that resulted in successful negotiations, the number that failed the negotiations, and the number already included in NRDL each year from 2017 to 2022. On average, around half of cancer drugs were eligible for negotiation. By 2022, there had been 97 negotiations involving anti-cancer drugs, with 57 resulting in success. Notably, there were more successful negotiations in the early rounds, while later rounds saw an increase in negotiation failures.[10]

To understand the factors that determine negotiation outcomes, we conduct a simple set of regressions of negotiation success on drug characteristics. Table 2 presents the results. Several patterns emerge. First, expected longevity improvement is important. The NRDL is 1.5-2.1 percentage points more likely to include a drug if it improves survival by one additional month. Second, negotiations are more likely to be successful if the drug is the first negotiation for a given indication (i.e., for a cancer target). This is consistent with the higher success rate in the early years after the NRDL Reform. Third, higher lagged sales also predict a higher success rate, indicating that market demand and perceived quality are important factors in negotiation outcomes. Finally, the origin of the drug company (whether international or domestic) and the number of years since Chinese market entry does not appear to influence negotiation success.

[10] A negotiation fails when the drug is brought to the negotiation table, and the two parties fail to reach an admissible price. The negotiation also fails when the government screens out the drug.

Table 2: Regressions on Bargaining Outcome

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Δ survival (month)	0.021***						0.015**
	(0.007)						(0.006)
$\mathbb{1}$(1st negot. of an indication)		0.225*					0.257**
		(0.117)					(0.115)
#Indications			-0.094**				-0.131***
			(0.047)				(0.048)
International firm				0.008			-0.070
				(0.098)			(0.082)
#Year since entry					-0.057		-0.055
					(0.046)		(0.044)
log(sales$_{-1}$)						0.087***	0.081***
						(0.015)	(0.015)
Constant	0.424***	0.471***	0.626***	0.523***	0.620***	0.527***	0.664***
	(0.059)	(0.054)	(0.068)	(0.076)	(0.088)	(0.042)	(0.099)
R^2	0.072	0.034	0.037	0.000	0.014	0.245	0.381
Independent Variable Mean	5.00	0.21	1.05	0.60	1.62	-0.00	

Note: This table presents how the outcome of 97 observed negotiations depends on different features of the product. 58 of the negotiations result in a success. Years since entry denotes how long the drug has been sold on the Chinese market at the negotiation time. Δ Expected longevity (month) provides estimated improvement in overall survival from Phase III trial registered in China. Indications denotes the number of approved indications of the drug, and $\mathbb{1}$(First neg of an indication) takes the value of 1 if the drug has an indication that has not been covered by any other insured drugs. log(sales$_{-1}$) denotes the sales in the quarter before the negotiation.

3 Model

We now present a model of China's anti-cancer drug market that formulates how market primitives, such as demand, cost, government budget constraint, and bargaining power, jointly determine policy effectiveness. In addition, the model serves two primary counterfactual objectives. First, it helps policy evaluation by attributing the effects of the program to the insurance expansion part and the centralized negotiation part. Second, the model enables the simulation of outcomes under alternative insurance designs and negotiation protocols.

3.1 Model of patient demand

Patient i's utility from taking drug j in market (province-quarter) t is assumed to take the following form:

$$u_{ijt} = \alpha_{it} \times \log(OOP_{jt}) + \mathbf{x}_{ijt}\delta + \epsilon_{ijt}, \tag{1}$$

where OOP_{jt} is the out-of-pocket price for product j in market t, defined as

$$OOP_{jt} = p_{jt} \times (\mathbb{1}(\text{insured})_{jt} \times \text{Coins rate}_t + \mathbb{1}(\text{not insured})_{jt}).$$

Our preferred specification allows patient i's price sensitivity to depend on income: $\alpha_{it} = \alpha_0 + \alpha_1 \times \log(\text{income})_{it}$, where the empirical distribution of $\text{income}_{it} \sim logN(\mu_t, \sigma_t)$ in each province is observed in the Census data. In alternative specifications, we introduce a random coefficient term in price sensitivity: $\alpha_{it} = \alpha_0 + \alpha_1 \times \log(\text{income})_{it} + \alpha_2 \times \nu_r$, where ν_r follows a standard normal distribution. All specifications control for $\mathbf{x}_{ijt}$, which include product and province-by-quarter fixed effects, dummy variables on the cancer body system indications, and the count of cancer indications for each drug j in year t.

The sets of instruments we use are as follows: (1) a negotiation dummy (=1 if the drug is included in the insurance), which exogenously shifts the retail price and out-of-pocket price; (2) a negotiation dummy interacted with province-level median income, which allows differential responses to the price shock created by the NRDL Reform among high-income consumers; (3) a negotiation dummy interacted with the 25th, 50th, and 75th percentiles of province-year income, to provide flexibility relative to (2); and (4) the number of direct rival products within the same drug class-province-year, aiming to capture how local competition intensity might shift prices. The "drug class" is the 5th-level Anatomical Therapeutic Chemical classification (ATC5), which groups pharmacological products according to their chemical substance.

3.2 Bargaining model

We posit that the negotiation process between the government and pharmaceutical companies is best described by a complete information multi-lateral Nash-in-Nash framework. Following the literature, we assume that bargaining outcomes are binding in all contingencies, and the failure of one negotiation does not influence the outcomes of others. These assumptions are supported by the institutional features of the NRDL Reform, wherein each group of experts designated by the government is responsible for negotiating over a specific drug with the pharmaceutical company that holds its patent.[11]

Firm profit Pharmaceutical companies participate in NRDL negotiations to maximize their profits in the Chinese market. While profits associated with a successful negotiation are standard, the threat points – firms' profits when negotiations fail – are different in our setting. Typically, negotiation breakdowns would result in the product being excluded from the market entirely. However, in our context, a failed negotiation means the drug is excluded from the NRDL formulary but remains available in the private market. The key difference is the coinsurance amount: without NRDL inclusion, patients would bear 100% of the retail price,

[11] See discussion in Section 2.1 above.

compared to the 20%-40% coinsurance if the drug were included. As a result, firms' deviation payoff in the event of a negotiation failure is the maximum achievable profit via Bertrand-Nash pricing, given the formulary status and prices of other products in the market.

For simplicity in the following discussion, we assume single-product firms, though our estimation procedure accommodates multi-product firms. Specifically, let $\mathcal{G}$ denote all drugs included in the NRDL formulary, and let m denote a market (which is a province in our setting). Under a successful negotiation, firm j's profit at retail price p_j and given the insurance network $\mathcal{G}$ is:

$$\pi_j(p_j; \mathbf{p}_{-j}, \mathcal{G}) = \sum_m (p_j - c_{jm})\, q_{jm}\left(p_j; \mathbf{p}_{-j}, \mathcal{G}\right).$$

Firm j's payoff with a failed negotiation is the profit achieved from selling the drug in the private market a la Bertrand-Nash competition:

$$\pi_j^{dev}(p_j^{BN}; \mathbf{p}_{-j}, \mathcal{G}) = \max_{\tilde{p}_{jm}} \sum_m (\tilde{p}_{jm} - c_{jm})\, q_{jm}(\tilde{p}_{jm}; \mathbf{p}_{-j}, \mathcal{G}/\{j\})$$

Crucially, firm j can set different prices in different provinces under the Bertrand-Nash pricing. Its gains from trade at price p_j and network $\mathcal{G}$ is defined as: $\Delta\pi_j(p_j; \mathcal{G}) \equiv \pi_j(p_j; \mathbf{p}_{-j}, \mathcal{G}) - \pi_j^{dev}(p_j^{BN}; \mathbf{p}_{-j}, \mathcal{G})$.

Government incentives The central government cares about patient welfare but faces constraints on drug insurance spending. We consider several welfare metrics, including the standard measure of consumer surplus, but also more equitable measures, such as inverse-income weighted consumer surplus following the public finance literature (Saez, 2002; Hendren, 2020). The discussions below focus on consumer surplus, though the analyses are similar with other welfare metrics. Let V denote the government objective function, where β captures the government's relative weight on insurance spending:

$$V(\mathbf{p}; \mathcal{G}) = CS(\mathbf{p}; \mathcal{G}) - \beta TC(\mathbf{p}; \mathcal{G}),$$

The change in CS from NRDL inclusion is

$$\Delta CS_j = \sum_m \mathrm{MS}_m \cdot \int_i \int_{p_j}^{p_j^{BN}} \underbrace{\frac{p}{\alpha_i}}_{\substack{\$ \text{ per} \\ \text{util}}} \cdot \underbrace{\frac{\partial \mathrm{Welfare}_{im}(p; \mathbf{p_{-j}}, \mathcal{G})}{\partial p}}_{\substack{\text{change in utils for} \\ \text{local price change}}} dp \cdot dF(i|m),$$

the aggregate monetized patient utility, where $\mathrm{Welfare}_{im} = \mathbb{E} \max_j u_{ijm}$ denotes the ex-ante

utility of patient i in market m from having different medication choices and patient utility u_{ijm} is defined in Equation (1). Government spending, TC, consists of expenditure on all drugs covered by the NRDL formulary: $TC(\mathbf{p};\mathcal{G}) = \sum_j \sum_m \mathbb{1}(j \in \mathcal{G})\,(1 - \text{Coins}_m)\,p_j q_{jm}$. The government's gains from trade of covering drug j are $\Delta V_j(p_j; \mathbf{p_{-j}}, \mathcal{G}) = \Delta CS_j(p_j; \mathbf{p_{-j}}, \mathcal{G}) - \beta \Delta TC_j(p_j; \mathbf{p_{-j}}, \mathcal{G})$.

Negotiation The model predicts that negotiation will succeed if the government and the firm find an *admissible* price such that gains from trade are positive. In this model, the central government's relative weight β on total expenditure, which we assume is a random variable from a given distribution $\beta \sim F_\beta$, serves several purposes. First, it is a parsimonious way to reflect the government's priorities on patient welfare vs. fiscal constraints. Second, the parameter helps rationalize the negotiation failures observed in our data. As β increases, the government's focus on minimizing expenditure intensifies, exerting downward pressure on the drug prices deemed acceptable. If these prices fall below a threshold where the gains from trade for pharmaceutical companies turn negative, negotiations may collapse, with drug companies withdrawing from the bargaining table. Third, the assumption that β is a random variable helps explain the variability in bargaining outcomes among drugs with similar consumer surplus gains. The fact that drugs with similar patient welfare sometimes make it into the NRDL and other times do not suggests that delegates may apply different weights during negotiations with pharmaceutical firms.

Another way to understand the role of β in rationalizing bargaining failures is that it determines the range of admissible prices that yield positive gains from trade for both negotiation parties. Let $\mathcal{P}$ represent this admissible set: $\mathcal{P} \equiv \{p : \Delta V_j(p) \geq 0 \text{ and } \Delta \pi_j(p) \geq 0\} \neq \varnothing$. If β is sufficiently high, such that no mutually agreeable price exists with positive gains for both sides, i.e., the admissible set is empty, $\mathcal{P} = \varnothing$, then the negotiation fails.

For successful negotiations, the post-negotiation price discount is determined by firm j's bargaining parameter, τ_j. The resulting price maximizes the weighted product of gains from trade in the Nash-in-Nash framework:

$$\max_p \left(\Delta \pi_j(p)\right)^{\tau_j} \left(\Delta V(p)\right)^{1-\tau_j} \quad \Rightarrow \quad \{\tau_j : \frac{\tau_j}{\Delta \pi_j(p)} \frac{\partial \pi_j(p)}{\partial p} + \frac{1-\tau_j}{\Delta V_j(p)} \frac{\partial V_j(p)}{\partial p} = 0\}$$

We then have the following first-order condition for successfully negotiated prices:

$$\sum_m \underbrace{(p_j - mc_{jm})}_{\text{retail margin}} \frac{\partial q_{jm}}{\partial p_j} = -\sum_m \underbrace{\frac{q_{jm}}{\text{Coins}_m}}_{\text{expansion effect}} + \underbrace{\left(\frac{1-\tau_j}{\tau_j} \times \frac{\Delta \pi_j}{\Delta V_j} \frac{dV_j}{dp_j} \right)}_{\text{bargaining effect}}, \ \forall j \in \mathcal{G}. \tag{2}$$

To visualize different negotiation outcomes, Figure 5 plots the changes in the firm's profit as a function of negotiation price (the red line) and the changes in the government's objective function (the blue line). The price range where both curves are above zero is considered admissible, indicating the zone of possible agreement. The bargaining parameter determines the final price within this admissible region. If the pharmaceutical company holds all of the bargaining power, the final price will align with the upper bound of the admissible set. Conversely, if the government wields more bargaining power, the final price will be closer to the lower bound of this set. This figure also illustrates how β and τ are identified: the bargaining outcome – whether it results in success – pins down the upper bound of β, while the location of the negotiated price within the admissible set together with parametric assumptions identifies τ and β.

Estimation Given the recovered demand primitives and the observed data—the successful and failed drugs and the negotiated prices—we can empirically estimate the supply model parameters (**mc**, the distribution of β, and τ). Estimation proceeds through the following steps:

1. Recover **mc** from the pre-negotiation prices and Bertrand-Nash FOC.

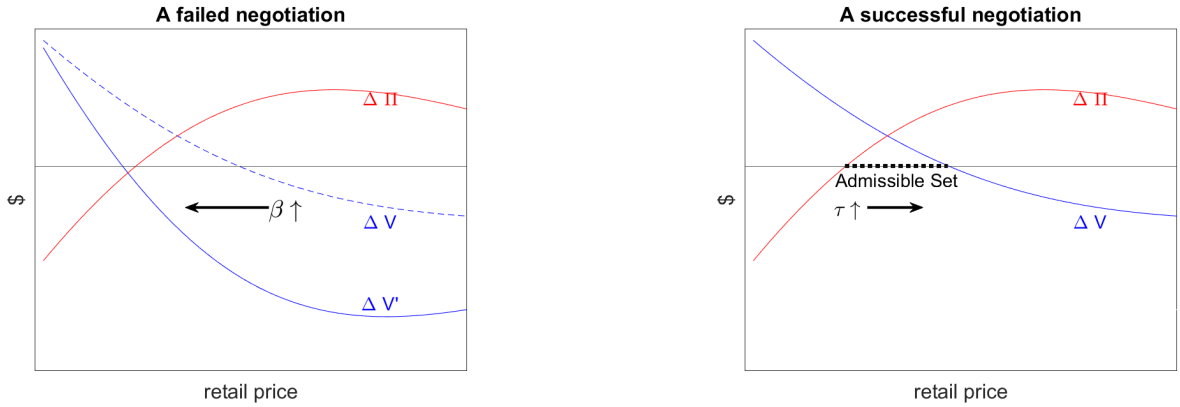
2. Assume the government relative weight on insurance spending β follows a log-exponential distribution: $\beta \sim log(Exp(\mu_\beta; \theta_\beta))$. Firm's bargaining parameter depends on firm attributes (such as firm nationality): $\tau_j = f(X_j; \theta_\tau)$.

3. Construct the sample log-likelihood, given observed negotiation outcomes $\{\mathcal{G}_j, p_j\}$:

   - For failed negotiations ($\mathcal{G}_j = 0$), β satisfies the corner condition: $\beta_j > \underline{\beta_j}$, where $\underline{\beta_j}$ is the lowest possible β such that the admissible set is empty. The value is calculated by setting the government's gains from trade equal to 0 at the price that the firms' gains from trade equal to 0:

$$\underline{\beta_j} = \frac{\Delta CS_j(p_j^l; \mathbf{p_{-j}}, \mathcal{G})}{\Delta TC_j(p_j^l; \mathbf{p_{-j}}, \mathcal{G}),}$$

Figure 5: An Illustration of Model Predicted Bargaining Outcomes



(a) Identification of β

(b) Identification of τ

Note: This figure illustrates the roles of β and τ in determining the bargaining outcomes using a simulated example. Firm's gains from trade is $\Delta\Pi$ in red, and the government's gains from trade is $\Delta V(\beta)$ in blue. Panel (a) plots the government gains from trade with two different β values: the dashed blue line represents a low β (ΔV), and the solid blue line represents a high β ($\Delta V'$). When β is low, there exists a set of retail prices that result in positive gains from trades for both parties: $\{p : \Delta V > 0 \text{ and } \Delta\Pi > 0\}$. However, when β is high enough, the admissible set is empty, leading to negotiation failures. Panel (b) plots changes in the negotiated price when firm's bargaining power τ increases. If the firm holds all the bargaining power, the negotiated price aligns with the upper bound of the admissible set that maximizes the firm's surplus. Conversely, if the government wields all the bargaining power, the negotiated price is at the lower bound of the admissible set that maximizes the government's surplus.

where p_j^l is the lowest price the firm is willing to accept in the negotiation such that $\Delta\pi_j(p_j^l; \mathcal{G}) \equiv \pi_j(p_j^l; \mathbf{p}_{-j}, \mathcal{G}) - \pi_j^{dev}(p_j^{BN}; \mathbf{p}_{-j}, \mathcal{G}) = 0$. We can write the likelihood function for observing with drug j negotiation fails as $Pr_j(\beta > \underline{\beta_j}) = 1 - F_\beta(\underline{\beta_j}; \theta_\beta)$.

- For successful negotiations ($\mathcal{G}_j = 1$), β satisfies the interior condition: β_j and observed negotiated price p_j must satisfy the bargaining first-order-condition (2). The equation is invertible with respect to β_j and we have the closed-form solution:

$$\beta_j(p_j, \tau_j) = \frac{-\vartheta \Delta CS_j + \Delta\pi_j \frac{\partial CS_j}{\partial p_j}}{\vartheta \Delta TC_j - \Delta\pi_j \frac{\partial TC_j}{\partial p_j}},$$

where $\vartheta = -\frac{\tau_j}{1-\tau_j}\frac{\partial \pi_j}{\partial p_j}$. Therefore, we can write the likelihood function for observing negotiation with drug j succeeds at price p_j as $Pr_j(\beta = \beta_j) = \frac{\partial \beta_j}{\partial p_j} f_\beta(\beta_j(p_j; \tau_j); \theta_\beta)$.

4. The joint log-likelihood function is:

$$log\mathcal{L}(\theta) = \sum_j \underbrace{\mathbb{1}(\mathcal{G}_j = 1) log\left(Pr_j(\beta = \beta_j)\right)}_{\text{successful negotiations}} + \underbrace{\mathbb{1}(\mathcal{G}_j = 0) log\left(Pr_j(\beta > \underline{\beta_j})\right)}_{\text{failed negotiations}}.$$

We estimate the supply-side parameters via maximum likelihood.

4 Results

4.1 Demand estimates

The estimated parameters of the demand model are shown in Table 3. Column (1) reports the OLS estimates, and Column (2) reports the IV estimates with the negotiation shock as the instrument. Columns (3)-(4) interact income with prices. Column (3) uses the negotiation dummy, alone and interacted with province-year median income, as instruments. Column (4) uses the negotiation dummy, alone and interacted with the 25th, 50th, and 75th percentiles of province-year income, as instruments. Column (5) adds a random coefficient on price to the specification, and additionally uses the number of direct rival products within the same ATC5-province-year as an instrument.

Comparing Columns (1) and (2), we see that instrumenting for OOP has the expected effect of increasing the estimated price coefficient, as product-quarters with large positive demand shocks likely have both higher prices and higher quantities, biasing the price coefficient downward. In the IV logit specification in Column (2), the median own-price elasticity of demand is -1.2, consistent with other recent work on global drug markets (Dubois et al., 2022).

Columns (3)-(5) interact income with prices. Column (5) additionally adds a random coefficient on OOP. Across these specifications, the interaction between income and price is significant both statistically and economically, reflecting the fact that higher-income individuals have lower price sensitivities. According to our preferred specification in Column (3), the median own-price elasticity is -1.6, with an inter-quartile range of [-1.96, -1.3]. These estimates highlight the importance of distributional considerations, especially in our setting where the highest-income provinces also tend to have the lowest coinsurance rates. The results in Columns (3) and (4) are very similar. The random coefficient specification in Column (5) yields key parameter estimates similar to those in Column (3), but indicates a higher elasticity of about -2.35. The standard deviation of the random component is estimated to be 0.6 and

somewhat imprecise, likely due to limited variation in the number of rival products across markets, which we use as our instrument.

Table 3: Demand Estimates

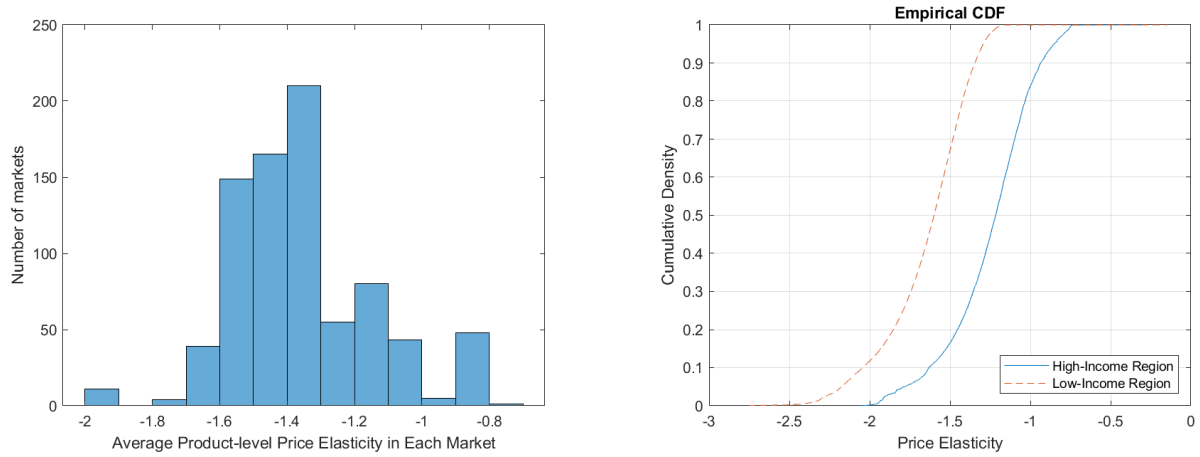
	OLS	IV	IV+RC		
	(1)	(2)	(3)	(4)	(5)
log(OOP)	-0.716	-1.211	-10.542	-9.783	-9.482
	(0.009)	(0.022)	(0.654)	(0.640)	(0.711)
log(OOP) × log(income)			0.865	0.795	0.692
			(0.060)	(0.059)	(0.059)
log(OOP) × ν_r					0.605
					(0.236)
Indication					
Lung cancer	0.531	0.264	0.224	0.227	0.159
	(0.056)	(0.058)	(0.063)	(0.062)	(0.063)
Breast cancer	-0.001	-0.016	-0.034	-0.033	0.012
	(0.112)	(0.114)	(0.107)	(0.106)	(0.109)
Colon cancer	0.626	0.663	0.767	0.759	0.602
	(0.088)	(0.089)	(0.084)	(0.084)	(0.089)
Stomach cancer	0.630	0.557	0.617	0.613	0.453
	(0.090)	(0.091)	(0.077)	(0.076)	(0.089)
#Indication	0.161	0.118	0.073	0.077	0.080
	(0.012)	(0.012)	(0.013)	(0.012)	(0.012)
Observations	112019	112019	112019	112019	112019
P75 elasticity	-0.72	-1.21	-1.30	-1.28	-1.89
Median elasticity	-0.72	-1.21	-1.60	-1.56	-2.35
P25 elasticity	-0.72	-1.21	-1.96	-1.89	-2.85
Product FE	Yes	Yes	Yes	Yes	Yes
Province*Time FE	Yes	Yes	Yes	Yes	Yes

Note: The table shows the demand estimates. Column (2) instrument: negotiation dummy. Column (3) instruments: negotiation dummy, alone and interacted with province-year median income. Column (4) instruments: negotiation dummy, alone and interacted with 25th, 50th, and 75th percentiles of province-year income. Column (5) instruments: negotiation dummy, alone and interacted with province-year median income, plus the count of rival products within the same ATC5-province-year. The median elasticity reported in this table is the median individual-level elasticity ($\frac{ds_{ij}/s_{ij}}{dp_j/p_j}$) across products.

To make the variation in elasticities clearer, we plot a histogram of the implied average product-level own-price elasticities across provinces in Figure 6a, using the demand estimates from Column (3) of Table 3. The distribution is centered around the population median elasticity of -1.6, but there are some provinces with average elasticities of -1 and -2. This finding highlights the importance of distributional considerations, as the highest-income provinces are those with the lowest coinsurance rates and the lowest price elasticities. Of course, there is heterogeneity in income within the province as well. Figure 6b describes the within- and across-

province heterogeneity, plotting the cumulative distribution function of the estimated price elasticity separately for provinces with above-median incomes (blue line) and for provinces with below-median incomes (red line). The high-income province CDF is shifted significantly to the right of the low-income province CDF, underscoring the substantial difference in the income distribution across provinces.

Figure 6: Estimated Income Elasticity across Different Income Levels



(a) Histogram of Price Elasticity

(b) CDF of Price Elasticity

Note: Figure (a) plots the model implied average product-level own-price elasticities across different markets and Figure (b) plots the model-implied own-price elasticities across consumers, both according to the specification in Column (3) of Table 3. The solid line denotes consumers in high-income provinces (Beijing, Shanghai, Guangdong, Tianjin, Zhejiang, Jiangsu, Fujian), and the dashed line denotes consumers in low-income provinces.

4.2 Supply estimates

Turning to our supply model, Table 4 presents the estimates for β, the government's weight on drug insurance spending, and τ, the firm's bargaining power parameter. The columns to the left estimate mean parameters only; the columns to the right additionally interact β with ΔOS, the life-years saved per course of treatment as estimated from published phase III clinical trials, and estimate τ separately for foreign and domestic firms.

Focusing first on β, we estimate that the government's weight on spending is lower for drugs with greater overall survival benefits. The θ parameters for the log-exponential distribution imply that β =0.78 for the average drug and β =1 for the median drug. That is, for the median drug, the government equally weights drug spending and consumer surplus, but the implied government budget constraint is relaxed for higher-quality drugs. This finding implies

that the government prioritizes the inclusion of high-quality drugs in the NRDL formulary.

Table 4: Supply-side Estimation

	Baseline		More Covariates	
Variable	Coef.	S.E.	Coef.	S.E.
Gvt. Budget Constraint				
θ_β^0	3.99	0.46	4.79	1.43
θ_β^1 (Δ survival)			-0.12	0.04
Firm Bargaining Power				
θ_τ	0.63	0.06		
θ_τ^0 (Foreign)			0.63	0.04
θ_τ^1 (Domestic)			0.60	0.06

Note: This table presents the supply side estimates. The estimation sample includes 97 negotiations with anti-cancer drugs in 2016-2022. β is assumed to follow a log-exponential distribution with inverse scale parameter determined by θ_β. τ is assumed to be a deterministic function of θ_τ.

The bottom panel of the table indicates that the average bargaining power of firms, τ, is roughly 0.6, with the difference in bargaining power between foreign multinationals and domestic firms being small and imprecisely measured. This estimate indicates that firms generally have more bargaining power than the government, but that negotiated prices are significantly below Nash Bertrand levels in the private market.

As a robustness check, we allow the government to have preferences over equity, by reweighting the government value function using a Pareto weight for each consumer: $w = \frac{income^{-\nu}}{H}$, where H is the consumer's income, ν is a scalar parameter that represents the government's preference for redistribution, and H is the sum of $income^{-\nu}$ across all consumers. We find that the estimates of θ_τ are robust across different νs, and that $\nu = 0$ delivers the best in-sample fit as measured by the likelihood, so we use $\nu = 0$ as our preferred specification in the remainder of the draft. However, we return to the issue of potential efficiency-equity tradeoffs involved in the NRDL Reform and various policy alternatives below.

4.3 Decomposition of NRDL Reform effects

In this Section, we use simulations to explore the economic mechanisms driving the price, quantity, and welfare impacts of the NRDL Reforms, on average and across different geographies and income groups.

Each of our counterfactual scenarios considers the 2023Q2 anti-cancer drug market. The 57 drugs that were included in the NRDL formulary during our study period of 2017-2023 were negotiated on a staggered basis over time. There were 13 drugs that were negotiated but failed the negotiations and thus were not included in the NRDL formulary. We simulate outcomes in this Section allowing for counterfactual insurance and negotiation treatments for all eligible drugs in 2023. The resulting impacts of counterfactual scenarios on prices, quantities, and welfare are larger than they would have been in 2017, when a small subset of these drugs was eligible for negotiation. In our simulations, we also adjust the equilibrium prices of unsuccessful and ineligible innovative drugs, which were sold in the private market a la Nash-Bertrand, and quantities of all anti-cancer drugs.

Baseline counterfactual All scenarios are compared to a baseline scenario where the NRDL Reform program did not exist—all successfully negotiated drugs are excluded from the formulary and sold in the private market at Nash-Bertrand prices. This is akin to the pre-reform world (before 2017), but includes new drugs that entered the Chinese market between 2017 and 2023.

Expansion-only counterfactual In this counterfactual scenario, we assume the NHSA implements a policy in which the government covers the 57 successfully negotiated anti-cancer drugs on the NRDL formulary of the universal insurance program, implying that patients can access them at province-specific coinsurance rates. However, firms continue to set prices unilaterally a la Nash-Bertrand.

Negotiation-only counterfactual In this counterfactual scenario, we assume the NHSA implements a policy to centrally negotiate prices of anti-cancer drugs. However, the government does not offer NRDL coverage for successfully negotiated drugs, and the firm can still sell on the private market when the negotiation fails. This counterfactual delivers the same results as the baseline counterfactual, since firms have no incentive to participate in negotiation.

We begin by decomposing the price and quantity impacts of the NRDL Reforms into those driven by the two key levers: insurance expansion and bargaining. Starting with the baseline world in which the focal 57 drugs are not on the formulary and are priced a la Bertrand-Nash, we first allow the Chinese government's NHSA to negotiate prices centrally with drug firms ("Negotiation only"), then we return to the Bertrand-Nash pricing world but add the focal 57 drugs to the NRDL formulary with universal insurance coverage ("Expansion only"), and finally we combine the two reforms as in the actual 2023 world ("Expansion+negotiation").

The baseline price and quantity results can be seen in the top row of Figure 7(a).[12] Absent the NRDL Reforms, both OOP and retail price would average about ¥251,000 per year (equivalent to about $35,000), and the focal innovative drug would have only a 2% quantity share of the cancer drug market.

The "Negotiation only" counterfactuals in the second row of Figure 7(a) are identical to the Baseline. This is because, without insurance expansion, the government has nothing to offer firms to induce them to participate in the negotiation. Without a promise of market expansion, firms will opt instead to sell their drugs in the private market at profit maximizing prices. In order to offer a more informative analysis of negotiation without expansion, we consider an alternative negotiation regime in Section 5.1 below in which firms must negotiate in order to have access to the Chinese drug market.

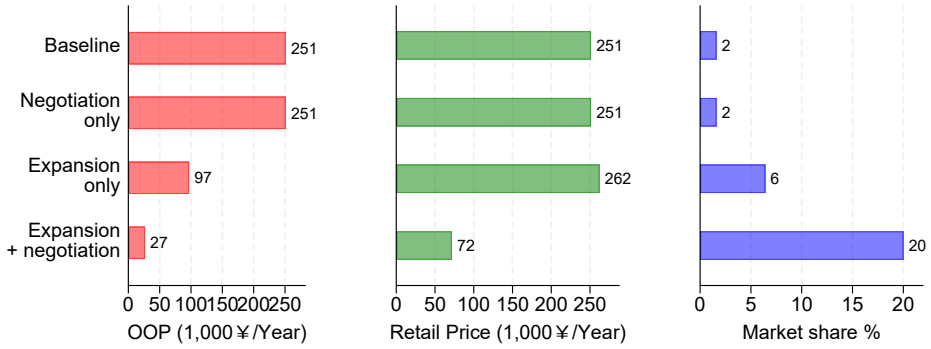
The "Expansion only" counterfactuals, presented in the third row of Figure 7(a), are more instructive. First, consider the price effects of providing insurance for the focal drugs, without negotiation. Adding insurance implies that, for a 100¥increase in retail price, patients pay only 20-50¥. This decreases patients' sensitivity to retail price, and firms' optimal prices increase to 262,000¥per year (4%). At the same time, patients' out-of-pocket prices decrease to 97,000¥per year (-61%) due to their insurance coverage. This substantial out-of-pocket price decrease leads to a large market expansion; the focal innovative drugs' share of the cancer drugs market increases to 6% (+200% relative to baseline).

The fourth row of Figure 7(a) shows the combined effect of the NRDL Reforms: "Expansion+negotiation." In contrast to "Expansion only," the combined reform decreases both OOP *and* retail prices, by 225,000¥per year (89%) and 182,000¥per year (72%), respectively. These larger price increases imply greater market expansions; the focal innovative drugs' total share of the cancer drug market increases by 18 ppt (+1,133% relative to baseline). This is similar to the 930% quantity expansion documented in the descriptive regression analyses in Section 2.3 above. However, the simulation results reveal that the combined effects of insurance expansion and negotiation are far more dramatic than those for insurance expansion alone, suggesting that negotiation complements insurance in this environment.

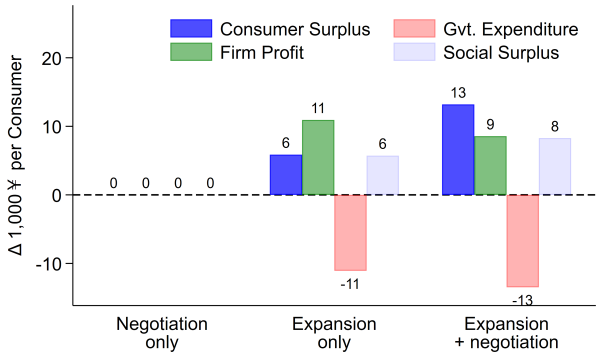
Welfare Figure 7(b) shows the impact of each simulation scenario on welfare relative to the Baseline of no NRDL Reforms. In order from left to right, each group of bars shows the change in Consumer Surplus, Firm Profit, Government Expenditures, and Total Surplus associated with moving from the Baseline to the scenario specified. To make clear that lower Government

[12] See Appendix Table A2 for numbers.

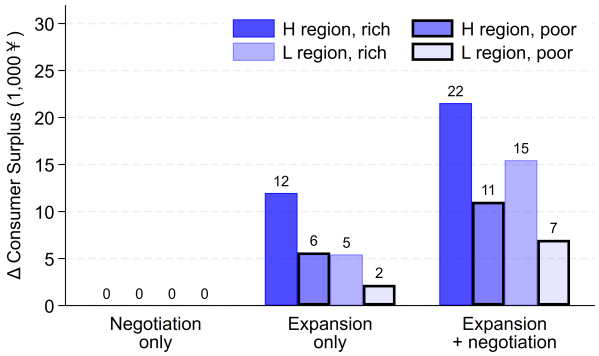
Figure 7: NRDL Reform—Decomposition Results



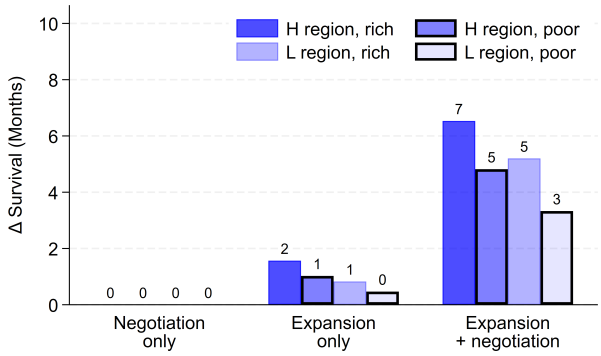
(a) Price and market share



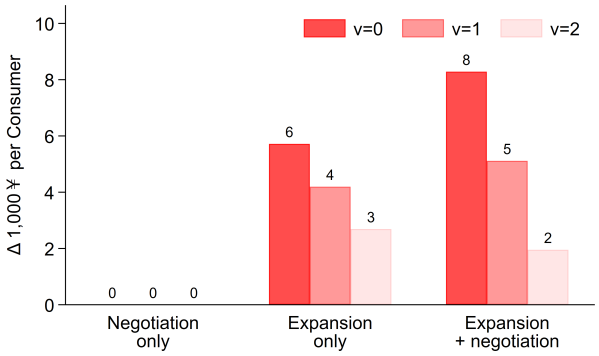
(b) Welfare breakdown



(c) Δ Consumer surplus (WTP) across income groups



(d) Δ Survival across income groups



(e) Alternative social surplus measures

Note: This figure summarizes the counterfactual outcome on average retail prices, out-of-pocket prices, and market shares for 57 cancer drugs that were successfully negotiated as of 2023. In the decomposition part, we compare four scenarios. "Baseline" denotes the scenario of Bertrand-Nash pricing of these 57 drugs without insurance coverage. "Negotiation only" assumes that the government negotiates with firms to cut prices but does not offer insurance coverage. This firm would never participate in the negotiation because of negative gains from trade, so the outcome will be the same as the baseline. "Expansion only" assumes that the government offers insurance coverage to the 57 drugs but does not negotiate prices with companies. Companies set optimal prices to maximize profits instead. "Expansion+negotiation" refers to the current program, where the government offers insurance coverage and actively negotiates prices.

Expenditure is preferred, all else equal, the Figure multiplies Government Expenditure by -1. Consistent with this approach, Total Surplus = Consumer Surplus + Firm Profit − Government Expenditure.

Trivially, "Negotiation only" has no effect on welfare relative to Baseline. "Expansion only" increases Consumer Surplus by 6,000¥per patient and Firm Profit by 11,000¥per patient, but also increases Government Expenditure by 11,000¥per patient. The combined "Expansion+negotiation" reform increases Consumer Surplus by 13,000¥per patient, more than double the effect of "Expansion only" due to the far larger effect of the combined reform on OOP prices. The Consumer Surplus increase is equivalent to the increase in Government Expenditure, suggesting that the combined reform is far more successful at meeting the government's balanced objective. Firm Profit increases by 9,000¥per patient in the combined reform, lower than "Expansion only" but far higher than Baseline.

These results indicate that negotiation alone has no impact on welfare, whereas insurance expansion alone induces an OOP price reduction and market expansion that benefit consumers, as well as a large transfer from the government to firms. However, the two reform instruments are complementary: the insurance expansion ensures broader access and makes the pie bigger, while negotiation shifts the split of the pie in favor of the government and consumers. On balance, Total Surplus is highest under the combined reform, representing an increase of 8,000¥per patient relative to Baseline, compared to only ¥6,000 (5,000) for either expansion alone or negotiation alone.

An alternative method of valuing the welfare benefits of the market expansion under each reform scenario is to consider health outcomes. Based on the clinical evidence of drug effectiveness from the medical literature, the increased access to innovative drugs under the combined NRDL Reform would be expected to extend overall survival by 4.85 months per patient purchasing cancer drugs (1,372% relative to Baseline), a more than five-fold increase over the already-substantial survival benefits of insurance expansion alone (0.92 months, or 259% of Baseline).

Equity The aggregate welfare effects presented above mask substantial heterogeneity in impacts across consumers in different parts of the income distribution. These distributional effects are shown in Figure 7(c). NRDL coinsurance is more generous for wealthy provinces, so a given reduction in retail prices leads to a larger reduction in out-of-pocket prices for consumers in high-income provinces. Moreover, high-income households are less price sensitive and therefore more likely to purchase innovative drugs absent the NRDL Reform. These two factors imply that rich people living in high-income (low-coinsurance) regions have the highest

dollarized welfare increases from the "Expansion only" and "Expansion+negotiation" policies (¥12,000 and 22,000, respectively). These surplus increases are far higher than those obtained by poor consumers in low-income provinces (¥2,000 and ¥7,000, respectively).

A similar, though less extreme, pattern is observed when we measure consumer benefits using survival increases, as shown in Figure 7(d). Rich households in high-income provinces still benefit most from the combined reform, followed by rich households in low-income provinces, then poor consumers in high-income provinces, and lastly poor households in low-income provinces. But the gap is much smaller. Intuitively, survival is a quantity-based measure and therefore less sensitive to the differing levels of price-sensitivity between high-income and low-income consumers.

Turning to social surplus, Figure 7(e) shows that both the "Expansion only" and "Expansion+negotiation" policies lead to increases in social surplus. However, both policies are regressive as implemented, and the ranking of the policies hinges on the social planner's preference for equity. When the social planner has a higher weight on equity ($\nu = 1$ or 2), the social surplus gain associated with each policy declines. The reason for this is that each policy entails a higher government subsidy to high-income consumers than to low-income consumers, and a higher equity weight penalizes such transfers. If the social planner is utilitarian ($\nu = 0$) or has a moderate preference for equity ($\nu = 1$), then the efficiency benefits of "Expansion+negotiation" dominate and the combined reform is preferred. If the social planner has a stronger preference for equity ($\nu = 2$), then the flatter gradient in Consumer Surplus under "Expansion only" seen in Figure 7(c) is more desirable than the steep gradient under "Expansion+negotiation." Therefore, with sufficiently strong preferences for equity, "Expansion only" is preferred over "Expansion+negotiation."

5 Counterfactual Policy Simulations

In this Section, we compare performance of the observed NRDL Reform design to several feasible alternative designs.

5.1 Market access negotiation

In Section 4.3, we demonstrated that negotiation for NRDL formulary inclusion alone has no effect; negotiation must be paired with insurance expansion in order to have an effect on welfare. In this Section, we consider strengthening the government's leverage by modeling a "market access" negotiation, in which the government negotiates with firms over drug entry.

That is, in this negotiation regime, a failed negotiation blocks the drug from being sold in the Chinese market entirely. This is termed the "Canadian regime" in Dubois et al. (2022).

For these simulations, we consider two scenarios: with or without insurance expansion. The government can negotiate with the threat of market access *without* insurance expansion, so the formulary of covered innovative drugs is an empty set ($\mathcal{G}^{ma,ni} = \varnothing$), and suppose that the vector of negotiated prices is $\mathbf{p}^{ma,ni}$. Given that negotiation failure implies that product j is excluded from the market, the firm's gains from trade at price $p_j^{ma,ni}$ and network $\mathcal{G}^{ma,ni} = \varnothing$ will equal: $\Delta\pi_j(p_j^{ma,ni}; \varnothing) \equiv \pi_j(p_j^{ma,ni}; \mathbf{p}_{-j}^{ma,ni}, \varnothing) - 0$.

Given this change in firm gain from trade, the equilibrium prices and formularies will depend on whether the government expands insurance at the same time as it negotiates prices. First, consider the market access negotiation without insurance expansion. The government's objective is then to maximize consumer surplus. Government expenditure is not of concern because the government does not offer coinsurance for drugs. Therefore we can write down the government's gains from trade as:

$$\Delta V_j^{ma,ni}\left(p_j^{ma,ni}; \mathbf{p}_{-jt}^{ma,ni}, \varnothing\right) \equiv CS_j\left(p_j^{ma,ni}; \mathbf{p}_{-j}^{ma,ni}, \varnothing\right) - CS_j\left(\infty; \mathbf{p}_{-j}^{ma,ni}, \varnothing\right).$$

The Nash-in-Nash first-order condition implies,

$$\sum_m \frac{\partial q_{jm}}{\partial p_j^{ma,ni}}\left(p_j^{ma,ni} - mc_j\right) = -\left(1 - \frac{1-\tau}{\tau}\frac{\Delta\pi_j^{ma,ni}}{\Delta V_j^{ma,ni}}\right)\left(\sum_m q_{jm}\right).$$

Second, consider the market access negotiation *with* insurance expansion. The government can include the drug in NRDL if the negotiation is successful but deny market access if the negotiation fails. The government's objective is then to maximize consumer surplus minus expenditure. Therefore, we can write down the government's gains from trade as:

$$\begin{aligned}\Delta V_j^{ma,wi}\left(p_j^{ma,wi}; \mathbf{p}_{-jt}^{ma,wi}, \mathcal{G}^{ma,wi}\right) \equiv\ & CS_j\left(p_j^{ma,wi}; \mathbf{p}_{-j}^{ma,wi}, \mathcal{G}^{ma,wi}\right) - CS_j\left(\infty; \mathbf{p}_{-j}^{ma,wi}, \mathcal{G}^{ma,wi}/\{j\}\right) \\ -\ & \beta\left(TC_j(p_j^{ma,wi}; \mathbf{p_{-j}}^{ma,wi}, \mathcal{G}^{ma,wi}) - TC_j(\infty; \mathbf{p_{-j}}^{ma,wi}, \mathcal{G}^{ma,wi}/\{j\})\right).\end{aligned}$$

The Nash-in-Nash first-order condition implies,

$$\sum_m \left(p_j^{ma,wi} - mc_{jm}\right)\frac{\partial q_{jm}}{\partial p_j} = -\sum_m \frac{q_{jm}}{\text{Coins}_m} + \left(\frac{1-\tau_j}{\tau_j} \times \frac{\Delta\pi_j^{ma,wi}}{\Delta V_j^{ma,wi}}\frac{d\Delta V_j^{ma,wi}}{dp_j^{ma,wi}}\right),\ \forall j \in \mathcal{G}^{ma,wi}.$$

The results are shown in Figure 8, with detailed calculations in Appendix Table A3. The

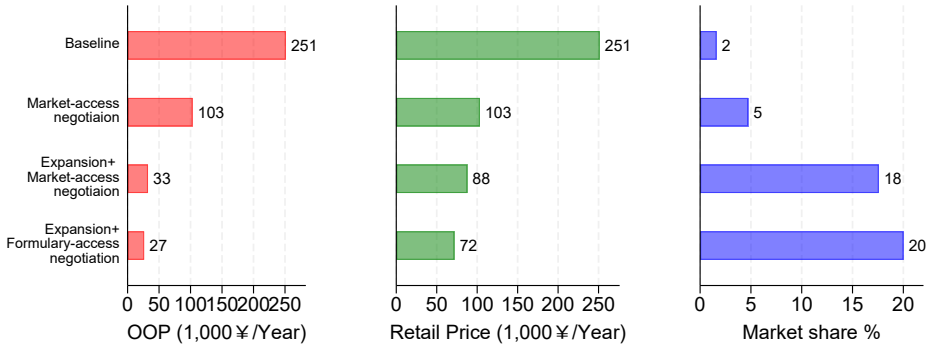
Baseline results are identical to those shown previously in Figure 7. Figure 8(a) presents simulated prices and quantities for the alternative "Market access negotiation" regime without insurance expansion, then for the "Expansion+market access negotiation" regime, and finally, for comparison with our original results, the "Expansion+formulary access negotiation" regime (i.e., the combined NRDL Reform studied in Figure 7).

First, consider the "Market access negotiation" regime. Due to the low marginal costs of innovative drugs relative to Consumer Surplus, the model will always predict a successful negotiation. Moreover, under the threat of market exclusion, the government can obtain a large price decrease. We estimate that the average drop in the (unweighted) retail price for the 57 drugs included in the NRDL formulary is ¥148,000 (59%) per year. Because there is no accompanying insurance expansion in this regime, the benefits of negotiation pass through to consumers and the OOP price decrease is also ¥148,000 per year. This results in a market expansion of 3 ppt, or 191% of baseline.

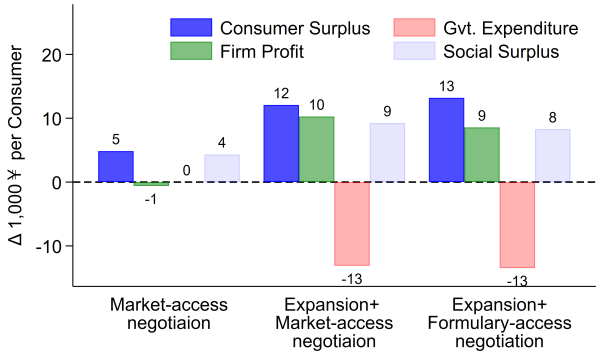
Next, consider the "Expansion+market access negotiation" regime. There are several key differences between this bargaining regime and the NRDL Reform's "Expansion+formulary access negotiation" regime. Negotiation for market access shifts the price under a failed negotiation from p^{BN} to ∞. This implies higher gains from trade for both the government and firms. From the government's perspective, keeping the product in the market generates more Consumer Surplus, though at the cost of greater insurance subsidies. On the firm side, having the product in the market generates positive profit and is therefore strictly better than exclusion. Keeping the bargaining power fixed, whether the resulting negotiated price is higher with negotiation for market access or with negotiation for formulary access is ambiguous, and therefore an empirical question.

In Figure 8(a), we see that "Expansion+market access negotiation" reduces retail prices by ¥163,000 (65%), and OOP prices by ¥219,000 (87%). The resulting market expansion is 16 ppt (983%). These results, and the accompanying welfare and survival results in the remainder of Figure 8, are nearly identical to the results achieved by the "Expansion+formulary access negotiation" regime. These results imply that, while market access negotiation is (infinitely) more effective than formulary access negotiation when there is no benefit to being on-formulary (i.e., absent insurance expansion), negotiation for formulary access performs similarly to negotiation for market access when negotiation is accompanied by insurance expansion. These results are intuitive in light of the fact that the documented market expansion effects of insurance expansion are so high in this setting.

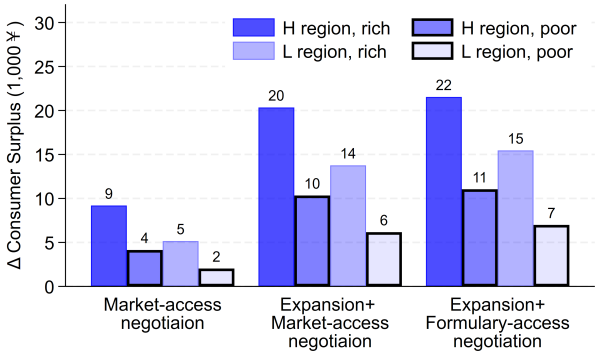
Figure 8: Counterfactual Results: Alternative Bargaining Formats



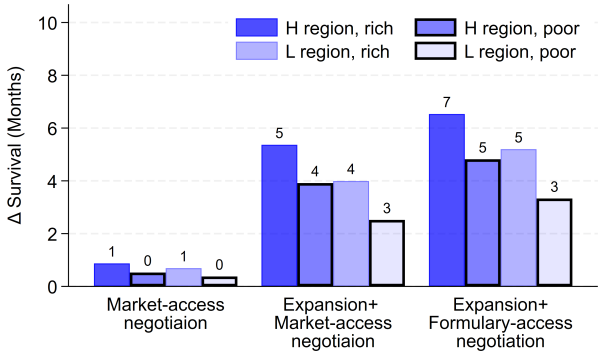
(a) Price and market share



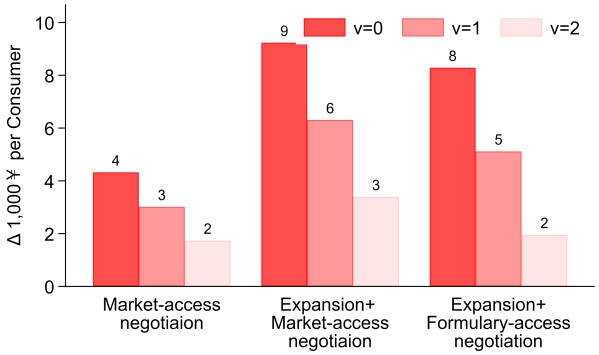
(b) Welfare breakdown



(c) Δ Consumer surplus (WTP) across income groups



(d) Δ Survival across income groups



(e) Alternative social surplus measures

Note: This figure summarizes the counterfactual outcome on average retail prices, out-of-pocket prices, and market shares for 57 cancer drugs that were successfully negotiated as of 2023. In the Alternative negotiation format part, we consider three cases. "Market access negotiation" is a special form of negotiation where the government excludes the drug from the market as the threat point while fixing the bargaining power at the estimated level. "Market access negotiation+ expansion" further provides insurance coverage at current coinsurance rates if the negotiation is successful. "Formulary access negotiation+ expansion" is the current program.

5.2 Centralized vs. decentralized negotiation

The findings in Section 4.3 on the distributional effects of the NRDL Reform motivate two sets of counterfactuals that explicitly investigate the geographic variation and regressivity of the program. Focusing first on geography, we contrast the effects of centralized national bargaining (the status quo) with those of a counterfactual program that allows each province to negotiate its own prices. This analysis sheds light on recent policy debates and academic research regarding the costs and benefits of central procurement; see, e.g., Dubois et al. (2021), Dubois and Sæthre (2020), Dubois et al. (2022), and Maini and Pammolli (2023).

In the decentralized negotiation setting, we assume each provincial government manages their own formulary. Each provincial government negotiates with the innovative drug firms for formulary access, and the threat point is the exclusion from the provincial formulary. We keep β and τ the same as we estimated (from observed centralized negotiation). We set the local coinsurance rate equal to the national average level (0.37) across all provinces. Fixing the coinsurance rates across province allows us to isolate the distributional effects of centralized negotiation without having to microfound the provincial coinsurance rates, which might change under decentralization.

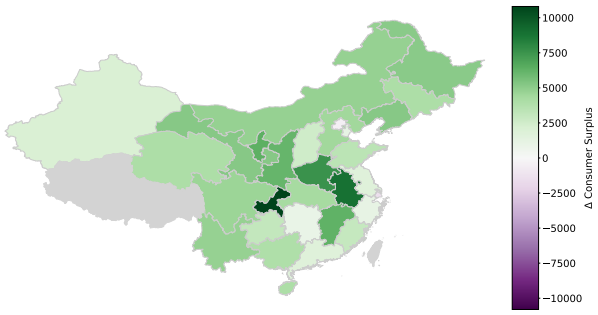
There are 13 drugs in the 2023Q4 market that failed the (centralized) negotiations in the data. In the decentralized counterfactual, we allow the provincial government to negotiate with these drugs' firms. Because these drugs failed the negotiations, we cannot recover their $\boldsymbol{\beta}$s from the negotiated prices. Rather, we observe the lower bound $\underline{\boldsymbol{\beta}}$s, the thresholds at which each negotiation would have failed. In the main text, we assume these 13 failed negotiations always fail in the decentralized negotiations (effectively setting $\boldsymbol{\beta} = \infty$). Alternatively, as a robustness check, we set $\boldsymbol{\beta} = \underline{\boldsymbol{\beta}}$ for these drugs, implying that even a minor increase in the gains from trade on either side would make these failed negotiation succeed.[13]

In all the results below, we compare the counterfactual negotiated outcome and prices under centralized and decentralized negotiations.[14] Figure 9 shows the distributional impacts of centralization across provinces.

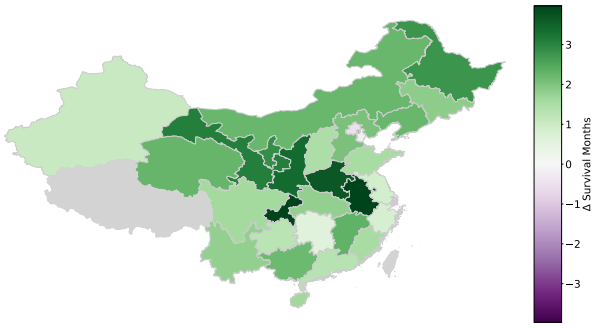
[13] Because one drug's negotiation success or failure may affect gains from trade of other negotiations, and change another negotiation's success, there may be multiplicity concerns in the counterfactual equilibrium. We impose the equilibrium selection rule that the more popular drugs (measured by quantity sold) move first.

[14] We also recalibrate the centralized negotiations because the coinsurance rate across provinces is set at the uniform level now. As a robustness check, we compare the centralized at uniform level and the centralized at the observed coinsurance level. We confirm that the aggregate welfare does not change, but not surprisingly, the provinces with lower coinsurance rates would benefit more compared to uniform rates.

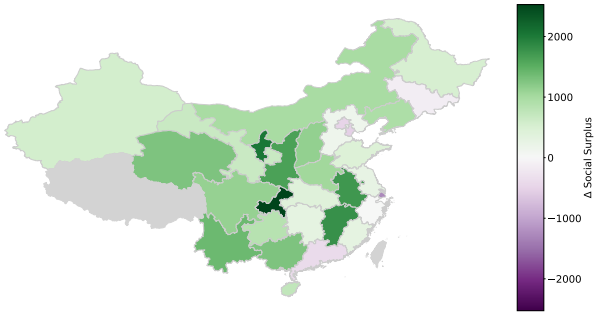
Figure 9: Effects of Centralized vs. Decentralized Negotiations



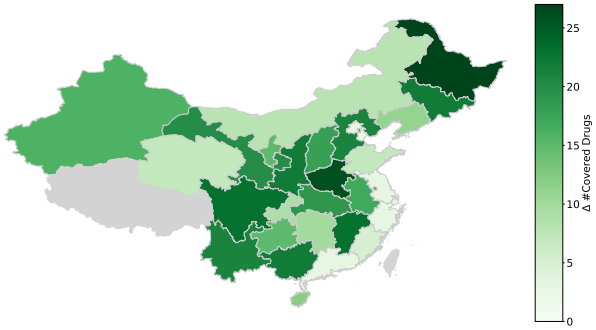
(a) Δ CS (in ¥/consumer)



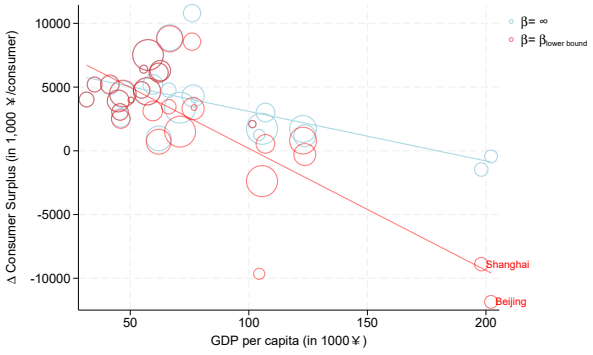
(b) Δ Survival months (per consumer)



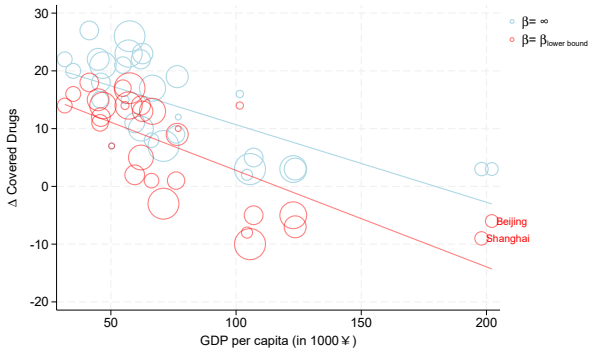
(c) Δ Social Surplus (in ¥/consumer)



(d) Δ Number of covered drugs



(e) Δ CS- Income Gradient



(f) Δ Number of covered drugs- Income Gradient

Note: Figure (a)-(d) shows the distributional outcome under insurance expansion and centralized negotiation (compared to insurance expansion and decentralized negotiations). A darker, greener color indicates a bigger positive change from decentralized negotiations to centralized negotiations, and purple denotes negative changes. Figures (e) and (f) further link changes in consumer surplus and the number of covered drugs when moving from decentralized to centralized negotiations. Each scatter indicates one province. The size of the scatter denotes the population. The blue dots and line are based on the simulated outcome when we set $\boldsymbol{\beta} = \infty$ for failed negotiations, and the red dots and line are based on the simulated outcome when $\boldsymbol{\beta} = \underline{\boldsymbol{\beta}}$ for failed negotiations.

Aggregate effects of decentralization We first document the aggregate effects on both the extensive and intensive margins as shown in Table A3. On the extensive margin, decentralized bargaining would result in a 19% increase in negotiation failures relative to centralized bargaining, as the market expansion effects in lower-income regions are insufficient to justify the government's expenses. On the intensive margin, our model predicts that average retail (OOP) prices would be 60% (64%) higher and the innovative drug market share would be 5.6 pt lower under decentralized province-level negotiation relative to centralized negotiation.

What makes decentralized negotiation different? Theoretically, if all provinces are homogeneous, then centralized negotiation would lead to the same price and quantity outcomes. However, because of regional heterogeneity in WTP, decentralized negotiation leads to many negotiation failures in lower-income provinces, where the Consumer Surplus gains associated with negotiation success are insufficient to justify the increased government costs. This can be seen in Figure 9 panels (d) and (f). As a result, pooling provincial budgets softens the government's budget constraints, so that negotiations are less likely to fail under centralization. In addition, bundling provinces together changes the relative bargaining leverage for the government and firms. Including lower-income, more price-sensitive provinces increases the central government leverage and tends to drive down average prices.

Welfare effects of decentralization by province Next, we break down the welfare effects of centralization across provinces. Given the above discussion, the distributional impacts of decentralized bargaining are intuitive. Centralization increases the leverage of poor provinces at the expense of rich provinces. Figure 9 panels (a) and (b) plot the differences in Consumer Surplus as measured by WTP and survival, between the centralized and decentralized negotiation regimes. Centralized negotiation benefits most regions, especially regions in the center and west of China. Moving to centralized negotiations achieves ¥3,210 (1.8 months) gains for low-income consumers in low-income regions and ¥1,410 (0.7 months) gains for high-income consumers in high-income regions. See Figure 9 panel (e) for the income gradient in Consumer Surplus. Figure 9 panel (c) plots the change in Social Surplus in each region under centralization, calculated as $CS + Profit - Expenditure$ in that region. Four provinces (Beijing, Shanghai, Tianjin, and Guangdong) experience drops in Social Surplus under centralization because they could have negotiated a better price on their own. And Figure 9 panel (d) shows the changes in number of covered drugs—all regions cover more drugs under centralization, but the impact of centralization on formulary coverage is much smaller in rich provinces than poor provinces. For example, Beijing and Shanghai would cover only two more drugs, and both are fringe products. Figure 9 panel (f) shows the income gradient in drug coverage.

5.3 Efficiency vs. equity in coinsurance design

As a last exercise, we examine the efficiency and equity implications of the NRDL Reform's current regressive coinsurance schedule, and explore the welfare effects of alternative coinsurance schedules. In our context, there are many possible income-based coinsurance schedules. For simplicity, we focus on a two-tier structure with different coinsurance rates for households with above- and below-median income. We simulate equilibrium prices, quantities, and surplus as we vary the coinsurance rate for high-income consumers and low-income consumers between 20% and 50%, roughly the range observed in the data.[15] In order to allow for preferences over equity in the social planner's objective, we present multiple measures of surplus in which we weight a given household's Consumer Surplus by $income^{-\nu}$. The scenario with $\nu = 0$ reflects the preference weights of a utilitarian social planner, and higher values of ν reflect stronger preferences for equity and redistribution.

Thorectically, the effects of lowering coinsurance on the market outcomes are ambiguous. Holding fixed negotiation outcomes, low coinsurance rates increase government expenditure, but increase Consumer Surplus and expected survival.

Coinsurance rates are also expected to affect negotiation outcomes. Conditional on negotiation success, lower coinsurance rates increase firms' gains from trade, thereby increasing the government's bargaining leverage. On the other hand, lower coinsurance rates increase the likelihood of negotiation failure.

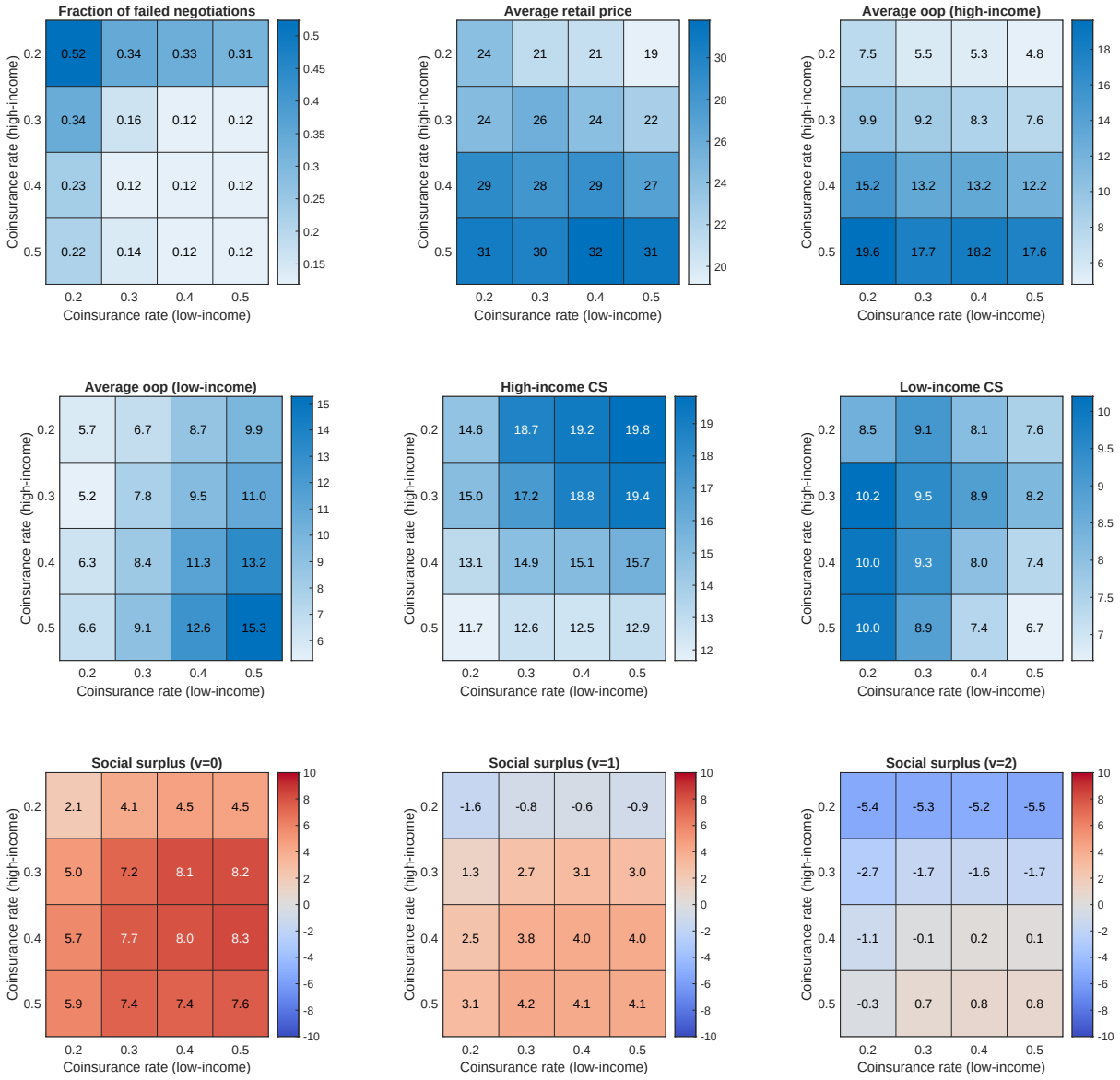
The effects of alternative coinsurance schedules are presented in Figure 10.[16] First, Figure 10(a) confirms that low coinsurance rates increase the rate of negotiation failure. For example, when coinsurance equals 20% across all consumers, the model predicts that half of negotiations will fail.

Figure 10(b) shows the average retail price of innovative cancer drugs, weighted by market shares of each drug. The diagonal terms show that lowering coinsurance rates tends to decrease the average retail price despite more negotiation failures. This is because the government gains more leverage conditional on successful negotiations and can negotiate a better deal. However, this leverage effect dominates only when we lower high-income consumers' coinsurance rates (across rows). When we only lower low-income coinsurance rates (across columns), the gains in the government's leverage are more than offset by the increase in negotiation failures, which tends to increase negotiated retail prices. Intuitively, the market expansion effect from

[15] High-income is defined as income above the national median income.

[16] Figure 10 fixes the negotiation outcomes of all negotiations that failed under the NRDL Reform as implemented. As a robustness check, we relax this restriction and present results assuming $\boldsymbol{\beta} = \underline{\boldsymbol{\beta}}$ in Appendix Figure A3. The patterns described below hold under both (extremal) assumptions.

Figure 10: Coinsurance Design



Note: This set of heatmaps shows the market outcome under different coinsurance designs. A darker color indicates bigger values. The horizontal axis shows the coinsurance rate for low-income (below median) consumers, while the vertical axis shows the coinsurance rate for high-income (above median) consumers. "Fraction of failed negotiations" reports the model predicted failed negotiations under each coinsurance rate design. "Average retail price" is the unweighted average retail price across the 57 negotiated products. "Average OOP" is the unweighted average out-of-pocket price for consumers. "High-income CS" denotes the consumer surplus for high-income consumers, "High-income CS" denotes the consumer surplus for high-income consumers. "Social surplus" is reported based on different equity criteria ($\nu = 0, 1, 2$).

lowering coinsurance rates is much more substantial for high-income consumers, leading to higher gains from trade for firms and stronger leverage for the government.

Figure 10(c) shows that the high-income consumers' out-of-pocket price decreases as we decrease their own coinsurance rate (because of both the direct coinsurance effect and the leverage effect), but increases as we decrease the low-income coinsurance rate (through the negotiation failure channel). Hence, Figure 10(c) implies that the optimal coinsurance schedule from the high-income consumers' perspective would be (H 0.2, L 0.5).

In contrast, Figure 10(d) shows that low-income consumers' out-of-pocket price decreases as we decrease their own coinsurance rate and as we decrease the high-income coinsurance rate. Figure 10(d) implies that the optimal coinsurance schedule from the low-income consumers' perspective would be (H 0.3, L 0.2). Low-income consumers would prefer a low coinsurance rate for high-income consumers, in order to bring down negotiated retail prices through the leverage channel. In other words, offering high-income consumers generous coinsurance rates can benefit all consumers because it increases firms' willingness to reduce retail prices. These contrasting patterns can be seen in panels (e) and (f) as well.

Lastly, Figure 10(g) shows that if the social planner's goal is to maximize Social Surplus, the optimal coinsurance rate is (H 0.4, L 0.5). This is quite close to the schedule observed in practice. However, a more Rawlsian social surplus goal ($\nu = 1, 2$) would prefer a higher coinsurance rate, as shown in Figure 10 panels (h) and (i), particularly higher for high-income consumers. This is because lowering coinsurance rates allows marginal consumers to adopt the innovative drug and, at the same time, transfers subsidies to inframarginal consumers who would have purchased the drug anyway. A higher portion of the government spending on high-income consumers is pure transfers to high-income households who would have bought the innovative drug anyway. Rawlsian social surplus penalizes this type of expenditure. Hence, it is much harder to rationalize low coinsurance rates from the when equity concerns are high. Ultimately, an optimal coinsurance schedule must strike a balance between these competing factors—equitable benefit distribution and effective negotiation leverage.

6 Conclusion

Innovative drugs have the potential to significantly increase human life expectancy; for example, 35% of the increase in life expectancy in the U.S. between 1990 and 2015 was attributable to pharmaceuticals (Buxbaum et al., 2020). However, many of the most promising new drugs have extremely high prices, to the point where they're mostly inaccessible to self-payers and

place a large burden on public and private insurance systems (CMS, 2024). The reforms studied in this project occurred amid substantial political momentum in favor of centralized drug procurement both within and across countries. Most recently, the U.S. Inflation Reduction Act of 2022 announced that the Medicare program would negotiate prices for 10 prescription drugs directly with participating manufacturers (The White House, 2023). Similarly, the European Parliament's Pharmaceutical Proposal of 2024 aims to create a single market for medicines with centralized pricing for all member states (Ho and Pakes, 2024).

This project provides unique new evidence on the cost, access, health, and welfare effects of national drug policy reforms, on optimal design of coinsurance schedules and the tradeoffs of centralization, and more broadly on competition in drug markets. The proposed frameworks and results can be used to evaluate drug pricing proposals in a variety of settings, and thereby have practical relevance for government agencies and other payers. To put the potential impact of this research in context, our work indicates that the degree of reform achieved by 2023 led to consumer surplus gains of nearly ¥40 billion per year ($5.6 billion) and a total survival increase of 900,000 life-years among Chinese cancer patients.

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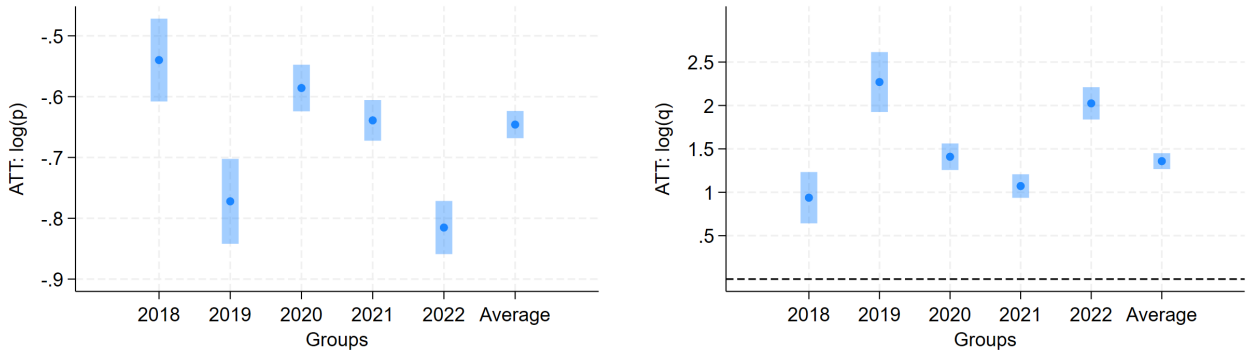
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Online Appendix

A Appendix Figures

Figure A1: Cohort-Specific Effects of the Centralized Negotiation Program on Price and Quantity

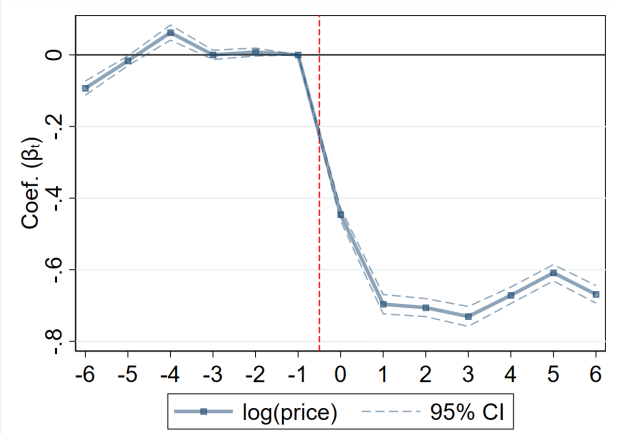


(a) Retail price: all categories

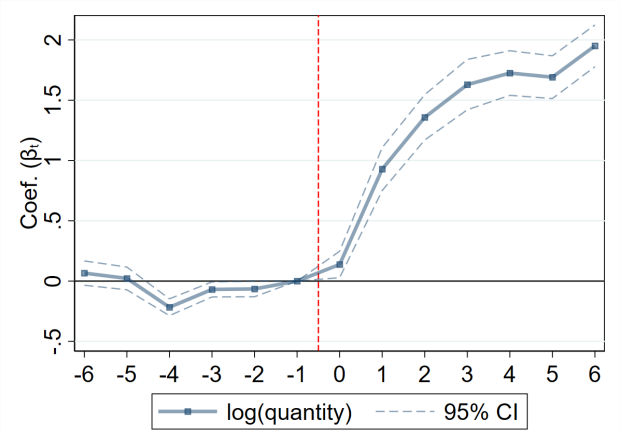
(b) Quantity: all categories

Note: This figure reports the effects by negotiation years of the centralized negotiation on the retail prices of quantities of successfully negotiated drugs. The horizontal axis denotes the relative quarters to the negotiation period. The vertical axis reports Callaway Sant'Anna's CSDID estimated dynamic treatment effects.

Figure A2: TWFE: Centralized Negotiation Program on Price and Quantity



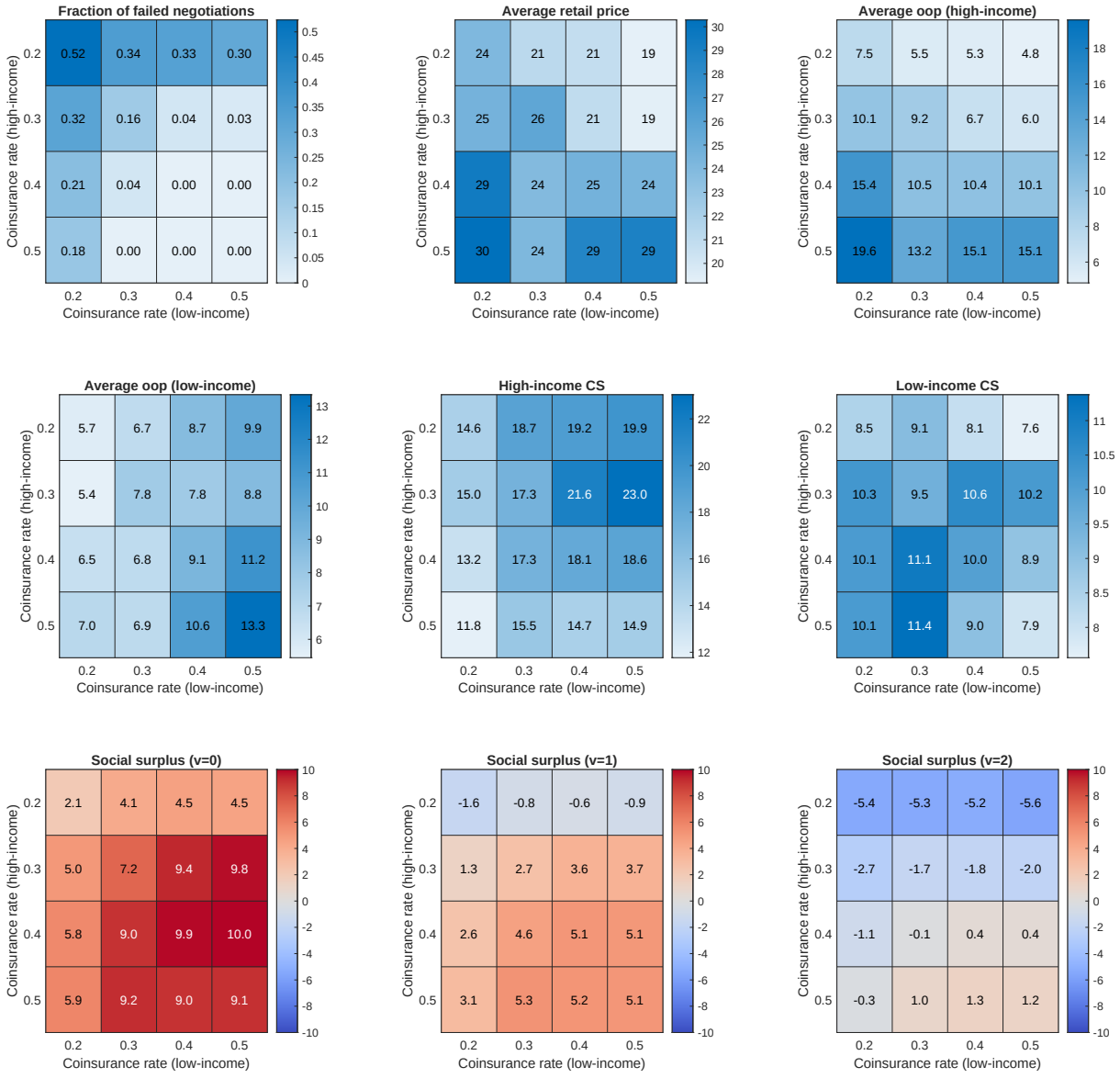
(a) Retail price: all categories



(b) Quantity: all categories

Note: This figure reports the event study (Two-way-fixed-effects) estimates of retail prices of quantities of successfully negotiated drugs. The specification is $y_{jt} = \sum_{\tau \neq -1} \beta_\tau \mathbb{1}(\chi_{te} = \tau) + \eta_j + \lambda_t + \epsilon_{jt}$, where χ_t is the period t relative to the formulary inclusion, and therefore, the omitted group $\tau = -1$ is one period before the formulary inclusion. The horizontal axis denotes the relative quarters to the negotiation period. The vertical axis reports the estimated β_τ.

Figure A3: Optimal Coinsurance Design: $\boldsymbol{\beta}_{failed} = \underline{\boldsymbol{\beta}}$, considering failed negotiations in 2023Q2



Note: This set of heatmaps shows the market outcome under different coinsurance designs. A darker color indicates bigger values. The horizontal axis shows the coinsurance rate for low-income (below median) consumers, while the vertical axis shows the coinsurance rate for high-income (above median) consumers. "Fraction of failed negotiations" reports the model predicted failed negotiations under each coinsurance rate design. "Average retail price" is the weighted average retail price across the 70 negotiated products (57 successful and 13 failed): $\sum_{j\in\mathcal{N}} \frac{p_j * s_j}{s_j}$. "Average OOP" is the weighted average out-of-pocket price for consumers: $oop^h = \sum_{j\in\mathcal{N}} \frac{p_j \times Coins^h \times s_{j,h}}{s_{j,h}}$. "High-income CS" denotes the consumer surplus for high-income consumers, "High-income CS" denotes the consumer surplus for high-income consumers. "Social surplus" is reported based on different equity criteria (with weight= income$^{-\nu}$ and $\nu = 0, 1, 2$).

B Appendix Tables

Table A1: Overview of Top 20 Innovative Cancer Drugs in China

Drug	Success in	Eligible since	Global Entry Time	Local Entry Time	Company	Sales (bn ¥)	Type
Bevacizumab	2019	2017		2010	Roche	8.31	mAb
Trastuzumab	2017	2017	1998	2009	Roche	6.00	mAb
Osimertinib	2018	2018	2015	2017.3	AZ	5.56	PKI
Rituximab		2017	1997	2006	Roche	3.82	mAb
Pertuzumab	2019	2019	2011	2018	Roche	3.29	mAb
Anlotinib	2018	2018	2021	2018	Chia Tai*	2.74	PKI
Alectinib	2019	2021	2017	2018.8	Roche	2.38	PKI
Tislelizumab	2020	2020	2019.12	2019.12	Baiji*	2.15	mAb
Cetuximab	2018	2017	2004	2007	Merck	1.85	mAb
Lenvatinib	2020	2020	2019	2018	Eisai	1.85	PKI
Almonertinib	2020	2020	2021	2020.3	Hansoh*	1.78	PKI
Camrelizumab	2020	2020	2019.5	2019	Hengrui*	1.62	mAb
Pembrolizumab		2020	2014	2018.7	Merck	1.53	mAb
Sintilimab	2020	2020	2018.12	2018	Xinda*	1.47	mAb
Imatinib Mesylate			2001	2002.4	Novartis	1.43	PKI
Icotinib	2021	2021	2011	2011	Betta*	1.34	PKI
Pyrotinib	2019	2021	2022	2018	Hengrui*	1.18	PKI
Regorafenib	2018	2018	2012	2017.3	Bayer	1.15	PKI
Nimotuzumab	2017	2017	2002	2008	Baitai*	1.07	mAb
Crizotinib	2018	2018	2011	2013	Pfizer	1.01	PKI

Note: This table lists the top 20 cancer drugs by annual sales in China for the year 2022. Eligible denotes the first year the drug appeared on the eligible list for the centralized negotiation program. Success indicates the year of a successful negotiation. Target denotes the mechanism of action aimed at particular targets within the body of each drug, and company with asterisks denotes domestic firms.

Table A2: Decomposition of the Effects of Expansion & Negotiation

		(1) Baseline	(2)	(3)	(4)	(5)
			+ Expansion Only		+ Expansion &Negotiation	
		y	Δy	$\Delta y\%$	Δy	$\Delta y\%$
Market Outcomes						
Avg. Retail Price	Inno, Success	251.42	32.51	12.93	-181.56	-72.22
(¥1,000 per year)	Inno, Others	19.21	1.91	9.96	1.91	9.96
	Traditional	13.54	-0.02	-0.16	-0.02	-0.16
Avg. Out-of-pocket Price	Inno, Success	251.42	-154.30	-61.37	-224.83	-89.43
(¥1,000 per year)	Inno, Others	19.21	-0.00	-0.03	-0.00	-0.03
	Traditional	13.54	-0.02	-0.16	-0.02	-0.16
Market Share	Inno, Success	1.62	4.79	295.04	18.40	1133.25
(%|inside)	Inno, Others	25.05	-1.22	-4.89	-4.70	-18.76
	Traditional	73.32	-3.57	-4.86	-13.70	-18.68
Welfare Effects in 1,000 ¥per consumer per year						
Consumer Surplus	H region, Rich	4.78	11.98	250.56	21.53	450.48
	H region, Poor	1.90	5.65	297.20	11.04	580.86
	L region, Rich	3.76	5.43	144.49	15.46	411.17
	L region, Poor	1.30	2.21	170.38	6.99	539.44
	Average	2.87	5.91	206.23	13.34	465.20
Share-weight OS	H region, Rich	0.48	1.57	329.10	6.53	1372.64
(months per consumer)	H region, Poor	0.23	1.02	438.02	4.82	2061.52
	L region, Rich	0.49	0.83	167.25	5.20	1054.21
	L region, Poor	0.21	0.47	219.25	3.33	1564.08
	Average	0.35	0.92	259.03	4.85	1371.64
Gvt. Expenditure		1.43	11.08	774.37	13.48	942.27
Variable Profits	Inno, Success	4.31	10.93	253.85	8.56	198.95
	Inno, Others	4.77	-0.01	-0.29	-0.05	-1.09
	Traditional	8.53	-0.02	-0.28	-0.09	-1.02
Welfare	$\nu = 0$	16.20	5.72	35.29	8.28	51.14
	$\nu = 1$	16.19	4.20	25.91	5.11	31.58
	$\nu = 2$	16.18	2.69	16.62	1.95	12.07

Note: This table decomposes the effect of all rounds of policy reform (as of the year 2023) into its two main channels. The baseline scenario excluded all 57 anti-cancer drugs that were included due to the program. We report consumer surplus in four groups: "H region, Rich" denotes high-income consumers (above median) in high-income (above median) provinces. Total welfare is reported according to different weights on households, as a function of income: $income^{-\nu}$ where $\nu = 0$ is utilitarian and $\nu \to \infty$ is Rawlsian. To compute baseline consumer welfare, we calculate the change in consumer surplus between the baseline equilibrium and an alternative equilibrium in which only outside option treatments (i.e., no anti-cancer drugs) are available. Share-weight OS is based on clinical evidence of increased months of survival collected from Phase III trial data. Results for market outcomes report the national averages. Δy is the average level change in an outcome relative to baseline across markets, and $\Delta y\%$ is the average percentage change in an outcome relative to baseline across markets. Welfare is reported on a per capita basis, where the denominator includes all consumers who seek pharmaceutical cancer treatment.

Table A3: Counterfactual: Alternative Negotiation Regimes

		(1) Baseline	(2)	(3)	(4)	(5)	(6)	(7)
			+ Market Access &Negotiation		+ Market Access Expansion&Negotiation		+ Decentralized &Negotiation	
		y	Δy	Δy%	Δy	Δy%	Δy	Δy%
Market Outcomes								
Avg. Retail Price	Inno, Success	251.42	-148.11	-58.91	-162.97	-64.82	-139.78	-55.60
(¥1,000 per year)	Inno, Others	19.21	-0.00	-0.03	1.91	9.96	32.13	167.30
	Traditional	13.54	-0.02	-0.16	-0.02	-0.16	22.61	166.93
Avg. Out-of-pocket Price	Inno, Success	251.42	-148.11	-58.91	-218.92	-87.07	-209.66	-83.39
(¥1,000 per year)	Inno, Others	19.21	-0.00	-0.03	-0.00	-0.03	-0.00	-0.03
	Traditional	13.54	-0.02	-0.16	-0.02	-0.16	-0.02	-0.16
Market Share	Inno, Success	1.62	3.10	191.16	15.96	983.38	12.82	789.85
(%|inside)	Inno, Others	25.05	-0.79	-3.17	-4.08	-16.27	-3.27	-13.06
	Traditional	73.32	-2.31	-3.15	-11.89	-16.21	-9.55	-13.02
Welfare Effects in 1,000 ¥per consumer per year								
Consumer Surplus	H region, Rich	4.78	9.20	192.37	20.34	425.49	18.09	378.47
	H region, Poor	1.90	4.14	217.68	10.33	543.51	9.17	482.49
	L region, Rich	3.76	5.15	137.00	13.76	365.95	8.67	230.54
	L region, Poor	1.30	2.03	156.84	6.17	475.72	4.04	311.64
	Average	2.87	4.87	170.01	12.20	425.66	9.39	327.48
Share-weight OS	H region, Rich	0.48	0.87	183.04	5.37	1127.67	4.12	864.81
(months per consumer)	H region, Poor	0.23	0.52	224.47	3.92	1675.39	3.00	1282.44
	L region, Rich	0.49	0.69	140.31	3.99	809.44	2.67	540.46
	L region, Poor	0.21	0.38	176.57	2.52	1183.33	1.76	826.50
	Average	0.35	0.60	170.24	3.83	1083.49	2.77	783.74
Gvt. Expenditure		1.43	-0.00	-0.13	13.12	917.20	8.68	607.14
Variable Profits	Inno, Success	4.31	-0.53	-12.38	10.27	238.55	7.28	169.20
	Inno, Others	4.77	-0.01	-0.17	-0.05	-0.95	-0.20	-4.27
	Traditional	8.53	-0.01	-0.16	-0.08	-0.89	-0.07	-0.77
Welfare	$\nu = 0$	16.20	4.32	26.67	9.23	56.99	10.56	65.17
	$\nu = 1$	16.19	3.01	18.62	6.31	38.94	7.51	46.37
	$\nu = 2$	16.18	1.74	10.73	3.39	20.93	4.49	27.73

Note: This table decomposes the effect of all rounds of policy reform (as of the year 2023) into its two main channels. The baseline scenario excluded all 57 anti-cancer drugs that were included due to the program. Column 1 shows outcomes in the baseline (Betrand-Nash competition) without the reform. Columns 2-5 change negotiation formats. Columns 2 and 3 show a counterfactual scenario where the government negotiates with drug manufacturers for market entry but provides no insurance coverage, i.e., failed negotiation leads to market exclusion, while successful negotiation does not offer insurance coverage. Columns 4 and 5 show a counterfactual scenario where the government negotiates with drug manufacturers for both market entry and insurance coverage, i.e., failed negotiation leads to market exclusion, while successful negotiation offers insurance coverage. Columns 6 and 7 show a counterfactual provincial negotiation; the negotiation format is the same as the current program, where each provincial government negotiates with a drug company for insurance access, i.e., failed negotiation leads to insurance exclusion, while successful negotiation offers insurance coverage. In all the simulations, τ is set at 0.6 from Table 4). In each column, "H region, Rich" denotes rich (above median income) people in high-income (low-coinsurance) provinces. Total welfare is reported according to different weights on income: $income^{-\nu}$ where $\nu = 0$ is utilitarian and $\nu \to \infty$ is Rawlsian. To compute baseline consumer welfare, we calculate the consumer surplus between the baseline equilibrium and an alternative environment in which only the outside option is available. Share-weight OS is based on clinical evidence of improved survival months collected from Phase III trial data. Results for market outcomes report the national averages. In particular, Δy is the average level change in an outcome relative to baseline across markets, and Δy% is the average percentage change in an outcome relative to baseline across markets. Results for welfare report aggregate outcomes across all markets.