The Human Cost of Collusion: Health Effects of a Mexican Insulin Cartel

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Abstract

Despite recent attention on the role of competition in determining health outcomes in developed nations, little is known about how market power impedes access to quality care in lower-income countries. This paper studies the effects of policy changes that stopped collusion among firms supplying insulin to one of Mexico's largest health care providers. I document increased insulin utilization and decreased diabetes complications and mortality following the sudden drop in insulin prices caused by the cartel's collapse. These adverse health outcomes expand the assessment of damages caused by the cartel. The findings highlight the importance of market design policies in health markets, particularly for low- and middle-income countries.

JEL: H51, I18, L41, L65, O15

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1 Introduction

Provision of health care is one of the most important issues facing low- and middle-income countries. Despite significant progress in recent decades, access to high quality health care advice and treatment lag far behind developed nations (Das and Hammer (2014), Kremer (2002)). The rise in chronic diseases, such as cardiovascular disease, cancer, and diabetes, has placed additional burdens on these health care systems. More than 80 percent of all deaths due to chronic diseases occur in low- and middle-income countries, and half of these deaths occur in individuals younger than 70 years (Abegunde et al. (2007)). Effective long-term management of chronic diseases is essential to improving quality of life and life expectancy.

The challenges to improving the treatment of chronic diseases in lower-income countries are numerous and complex.[1] Currently, there is little known about how the functioning of markets contributes to these challenges. While many countries use centralized, non-market means to provide health care, access to inputs of health care provision, such as labor, medical equipment, and pharmaceuticals, are still largely determined by market forces. Well-regulated health care markets are crucial to supplying treatment at the regular intervals required for adequate care of chronic diseases. However, weak institutions can undermine the regulation necessary for the delivery of these inputs, and designing regulation in the presence of weak institutions remains a difficult task (Estache and Wren-Lewis (2009)).

This paper shows how effective market design can overcome weak regulation and improve health outcomes in lower-income countries. Specifically, I demonstrate how simple policy changes were able to stop collusion in Mexico's pharmaceutical sector and led to improved health outcomes for those directly affected by the cartel. Identification comes from the collapse of a cartel for generic insulin in Mexico due to policy

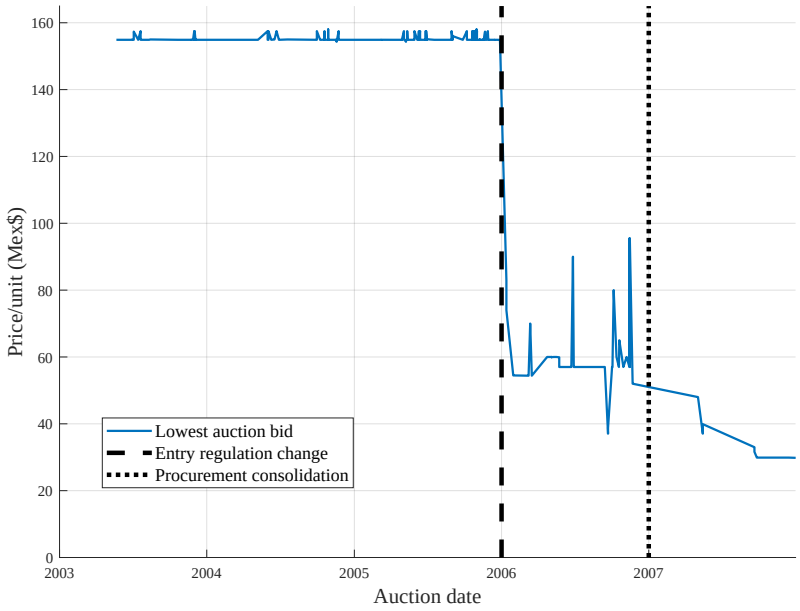
[1] Previous studies of health care in lower-income countries have explored incentives for health care professionals (Banerjee et al. (2008)), R&D for drugs and therapies (Kyle and McGahan (2012), and quality of medical advice (Das et al. (2008)).

changes made by the Mexican government. Insulin is used by diabetes patients to control blood sugar levels and is often required to manage diabetes effectively. From 2003 through 2005, a four-firm bidding ring controlled the market for generic insulin sold to Instituto Mexicano del Seguro Social (IMSS), one of Mexico's largest health care providers. Government interventions, detailed in Section 2, that relaxed entry restrictions and increased incentives to price competitively by consolidating purchases were instituted in 2006 and 2007, respectively.

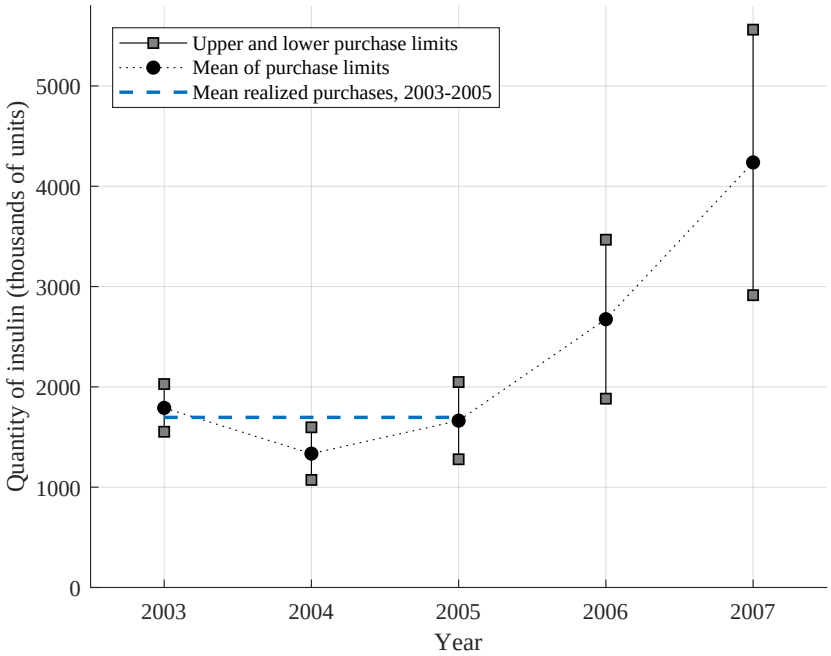
These interventions successfully restored competitive pricing. Figure 1 displays prices and quantities of insulin purchased by IMSS from 2003 through 2007. Figure 1a shows that by the end of 2007, the price of insulin sold to IMSS had fallen 78 percent from the average price during the cartel period. IMSS responded to the price decline by substantially increasing insulin purchases: Figure 1b shows annual insulin purchases (minimum and maximum purchase quantities) for 10ml vials of insulin from 2003 to 2007.[2] Taking the midpoints of these purchase ranges as the estimated annual quantity suggests that insulin purchases increased by 149 percent from 2005 to 2007, greatly expanding the availability of insulin for IMSS diabetic patients.

[2]IMSS procurement contracts stipulate a minimum purchase quantity and may include the option to purchase additional units over the contract's duration. An analysis of the legal proceedings conducted by the Mexican competition authority contains data on average realized purchases of insulin per year over the cartel period of 2003 to 2005 (Comisión Federal de Competencia Económica (2015b)).

Figure 1: Prices and quantities of IMSS insulin, 2003 - 2007



(a) Lowest recorded bid for insulin



(b) IMSS insulin purchases

To measure the health impacts of the cartel on diabetic patients covered by IMSS, I use three large-scale data sets on health care and diabetes outcomes in Mexico. The Encuesta National de Salud y Nutrición (ENSANUT) survey gathers detailed health care and diabetes diagnosis and treatment information from a large sample of the Mexican population using a repeated cross-sectional design. The survey wave timing enables comparing changes in insulin utilization and diabetes complications during and after the cartel. To examine the effect on mortality, I use Instituto Nacional de Estadística y Geografía (INEGI) vital records data, which contains age, insurance information, and cause of death for more than 7 million deaths between 2000 and 2014. Finally, I use the Mexican Family Life Survey (MXFLS), a longitudinal household survey of socioeconomic and health information that tracks diabetes diagnoses and insurance coverage over time.

Using a difference-in-differences (DiD) regression framework, I study the effects of the cartel's collapse by comparing insulin utilization, diabetes complications, and mortality among diabetic patients covered by IMSS to those insured by other public health care providers in Mexico. The results indicate that the cartel's collapse increased insulin usage by 42 percent, decreased complications by 25 percent, and lowered the yearly risk of diabetes-specific mortality by over 3 percent. The lower mortality risk implies a reduction of 971 diabetes-related deaths per year had the cartel never operated. These findings are robust to a wide variety of placebo tests and robustness checks which assess pre-trends in insulin usage, flexible functional form and time interaction specifications, and numerous specifications for medical controls. Several of these tests draw on the longitudinal survey data of MXLFS, allowing for direct tests of selection into IMSS insurance coverage and changes to diabetes diagnoses within IMSS following the cartel's collapse.

The success of procurement policy changes in eliminating collusion demonstrates the importance of market design in the face of weak institutions. At the time of the insulin cartel's operation, Mexican antitrust law limited the ability of regulators to

prosecute and punish collusive pricing.[3] The ability of IMSS to stop the cartel by changing the design of the procurement market shows that market design can be an alternative and complementary approach to antitrust policy when weak institutions inhibit traditional enforcement. Market design may be a particularly attractive policy tool as these policies often do not require new legislation or costly enforcement procedures. The magnitude of the improvement in health outcomes, which are generally far greater than similar effects in developed countries, and the efficacy of market policies to eliminate collusion suggests that health market design in developing countries is an important element in improving health care quality.

This paper combines industrial organization, health economics, and development economics and contributes to each of these areas. Within industrial organization, this paper contributes to the study of cartel damages by demonstrating the direct human development consequences of collusion. Empirical studies of cartels predominantly focus on intermediate goods (Levenstein and Suslow (2015)) and measure consumer welfare in a price-theoretic setting by measuring the loss of consumer surplus due to higher prices (Jacquemin and Slade (1989)) or through productive misallocation (Asker et al. (2019)). These approaches require strong assumptions on the nature of demand and supply, and they are generally restricted to partial equilibrium welfare assessments. Antitrust economists increasingly recognize the importance of the welfare effects of cartels that are not detectable through price changes alone (Asker and Nocke (2021)). By demonstrating consumer harm due to adverse health effects in a final goods market, this paper expands how damages from cartels are measured and assessed.

Previous theoretical work on market design when collusion is a concern has stressed limiting the frequency of market interactions as a way to deter collusion (Marshall and Marx (2012)), and regulators have emphasized this as a potential source of mar-

[3]For example, antitrust violations drew paltry fines even for substantial infractions, and antitrust regulators were limited in the information they could obtain during an investigation without the investigated firm's knowledge or consent. Section 2 elaborates.

ket power to consider in merger review (US Department of Justice and Federal Trade Commission (2010)). However, no empirical evidence exists to document the effectiveness of such restrictions in practice. The reduction in insulin prices effected by the procurement consolidation enacted by IMSS provides this evidence, giving empirical justification for the proposals motivated by theory and helping to inform future public procurement design.[4]

This paper adds to the literature on the market design of health care markets in developing countries by studying the health effects of market power.[5] Previous empirical work on pharmaceutical markets in lower-income countries includes studies of patent protections (Chaudhuri et al. (2006), Goldberg (2010), Chatterjee et al. (2015), and Duggan et al. (2016)), the impact of retail pharmacy market structure on drug prices and quality (Bennett and Yin (2019)), and collusion initiation in Chile's retail pharmacy industry (Chilet (2018)).[6] These papers estimate drug price, quantity, and quality effects of market changes; I add to this literature by directly measuring the health effects of pharmaceutical market design changes.

Finally, this paper is also related to the literature on market power and health care quality. While the effects of provider consolidation on health care prices have been extensively studied,[7] the literature on the relationship between market power and quality of care is relatively more recent. Several studies have found evidence that increasing market concentration reduces the quality of care, including Ho and Hamilton (2000) and Beaulieu et al. (2020), which examine hospital mergers and acquisitions, and Eliason et al. (2020), which follows dialysis facilities before and after acquisition.

[4]Dubois et al. (2021) study the effects of centralized procurement on drug prices in low- and middle-income countries and find that centralization leads to lower prices but that higher industry concentration attenuates the price reduction. I document substantial price declines after consolidation, suggesting that market concentration and firm conduct may interact separately with centralization policies.

[5]Data limitations often impede the study of collusion in non-developed countries. Existing empirical studies of bid-rigging and public procurement collusion primarily focus on developed countries, as in Porter and Zona (1993), Pesendorfer (2000), Asker (2010), and Kawai and Nakabayashi (2014).

[6]Rau et al. (2021) document increased birthrates in Chile following price increases of contraceptives due to the collusion initiation documented in Chilet (2018).

[7]See Dafny et al. (2012) for an example and Gaynor and Town (2011) for a survey of this literature.

Studies of the effects of government-level market reforms include Cooper et al. (2011), Gaynor et al. (2013), and Bloom et al. (2015), who investigate competition-promoting market reforms and the impact on health outcomes in the context of the United Kingdom's National Health Service. By studying the impact of collusion within the pharmaceutical sector, this paper expands the understanding of how market power influences health outcomes beyond provider concentration.

2 The collapse of an insulin cartel

2.1 Health care provision in Mexico

Health care in Mexico consists of the public system and the private system. Private health care operates as in many other countries in that individuals may elect to purchase health care services or insurance plans directly from the market. The public health system has two components: Social Security and the Social Protection System in Health. Social security offers health care, pensions, and other social protections for employed workers and their families. There are several social security schemes in Mexico, but the largest is IMSS, which covers workers in the private sector.[8] As of 2013, IMSS insured 42 million people.

Other social security programs in Mexico cover workers in other sectors. After IMSS, the largest of these programs is Instituto de Seguridad y Servicios Sociales de los Trabajadores del Estado (ISSSTE), which covers employees of the federal government and their families. The remaining programs cover workers in the oil and energy sector, military personnel, and programs at the state level. All social security programs, including IMSS, are funded by a payroll tax paid by employers and employees and federal government contributions. Each social security scheme has a separate

[8]Formally, there are two component programs under the umbrella of IMSS: the main program, IMSS, which covers the vast majority of individuals, and IMSS Oportunidades, which focuses on the indigenous and marginalized populations of Mexico and has a much lower enrollment.

provider network, and beneficiaries of one scheme cannot visit providers belonging to another scheme.

Health care for individuals with coverage through a social security program, including pharmaceutical treatment, is nominally free in that there is no out-of-pocket cost (Moïse and Docteur (2007)). However, there are limited financial resources to meet the demand for health care in practice. Public health care expenditures were just 2.8 percent of GDP in 2002, among the lowest of OECD countries. These financial constraints are associated with significant implicit rationing (OECD (2005)). Individuals often wait long periods before medications and other treatments become available and, in some cases, may be forced to purchase medicines from the private market (Gidi (2010)).

The other area of the public health care system is the Social Protection System in Health (Sistema de Protección Social en Salud or SPSS). The purpose of SPSS is to cover all individuals in Mexico without access to other healthcare. The main pillar of SPSS is *Seguro Popular*, which grew from its inception in 2003 to cover 52 million people as of 2013 (Bonilla-Chacín and Aguilera (2013)). *Seguro Popular* was a relatively recent program that saw significant enrollment increases over the sample period; I discuss how this is incorporated into the empirical analysis in Section 4.1.

2.2 Diabetes treatment in Mexico

Diabetes treatment in Mexico is emblematic of the challenges facing health care provision in lower-income countries. Access to care is low, and the health outcomes associated with diabetes are more severe than in high-income countries. In 2005, the final year of the insulin cartel's operation, there were an estimated 53.1 million individuals without health insurance, accounting for 51.6 percent of the population (Urquieta-Salomón and Villarreal (2016)). In the same year, an estimated 7.2 million adults had diabetes.

The prognoses for those with diagnosed diabetes in Mexico are grim. Diabetes is a public health crisis in Mexico due not only to its increasing prevalence but also to the high mortality risk associated with diabetes (Beaubien (2017)). Diabetes was the leading cause of death from 2005 to 2009, accounting for 13.8% of deaths. The mortality rate for adults aged 35 to 74 with diabetes in Mexico is more than double that of high-income countries (Alegre-Díaz et al. (2016)).

Limited access to treatment is one of the critical factors behind poor health outcomes associated with diabetes. Several effective treatments for managing diabetes exist, including diet and exercise, oral treatments such as metformin, and injectable medications such as insulin.[9] Insulin therapy is recommended when blood glucose, commonly measured as glycated hemoglobin or HbA1c, has not been brought under control by other treatments. Insulin treatment is highly effective in lowering HbA1c into recommended ranges (Davies et al. (2018)), with HbA1c levels exceeding 8.0 percent reflecting poor diabetes management.

Insulin usage in Mexico is low relative to high-income countries. According to the CDC, in the United States, 29 percent of diabetes patients use insulin, and 11 percent start using insulin within one year of their diagnosis. In 2005, only 7 percent of diabetics in Mexico reported using insulin. Insulin prescription follows national guidelines authored by physicians from the Mexican Secretary of Health, IMSS, ISSSTE, and other medical professionals from government policy centers and medical research hospitals.[10] Broadly speaking, these guidelines recommend starting patients on nutrition plans and oral medications and then adding insulin therapy if certain biomarkers indicate poor control of the disease, such as HbA1c exceeding 8.0 percent. However, studies of diabetes patients in Mexico suggest insulin shortages that prevent the clin-

[9]Individuals with type 1 diabetes, in which the pancreas produces little or no insulin at all, will require insulin therapy from the time of diagnosis. Type 2 diabetes, in which the body becomes resistant to insulin, often does not require immediate insulin therapy and can be managed with various treatments.

[10]The Secretary of Health published the first set of national clinical guidelines for diabetes treatment in 1994, with updates in 2001 and 2007. All guidelines include recommendations for insulin prescription based on biomarker targets.

ical guidelines from being followed. For example, Herrington et al. (2018) found that 47 percent of diabetes patients had HbA1c levels exceeding 9.0 percent, but only 6 percent reported using insulin.[11] These patterns are consistent with implicit rationing noted in OECD (2005) and suggest lack of insulin availability as a key driver behind poor diabetes health outcomes. As stated in Herrington et al. (2018) regarding high diabetes mortality risk in Mexico, "the resources to treat diabetes have not been able to keep pace with the growing obesity and diabetes pandemic."

2.3 IMSS Procurement, Collusion, and Regulation Changes

To obtain the materials necessary to deliver health services to its beneficiaries, IMSS holds procurement auctions to acquire medicine and other supplies from private sector firms. IMSS is among the largest purchasers of medicine and medical supplies in Latin America; in 2011, purchases of medicines and medical supplies exceeded US$3 billion. Procurement auctions are first-price sealed bid, with the lowest bidder being awarded the sale subject to being below the reserve price per unit set by IMSS. In the case of insulin, bidders submit bids in prices per unit, where each unit is a 10ml vial containing 100 IU of NPH insulin (also known as isophane insulin).

Until 2007 procurement was carried out by 52 separate procurement divisions that collectively were responsible for the state delegations and 25 High Specialty Medical Units (HSMU) that obtained medicines and medical supplies through these procurement auctions. While the auction format, bidding rules, and reserve price were constant across all procurement units, each unit acted autonomously and there was no central authority that coordinated auctions or monitored winning bids across them.

Concerns over potential bid manipulation led the Comisión Federal de Competencia (CFC) to issue recommendations for changes to the procurement methods used by

[11] Other studies that report similarly sparse insulin utilization despite high prevalence of biomarkers outside of recommended levels include Mimenza-Alvarado et al. (2020) and Flores-Hernández et al. (2015).

IMSS in 2002.[12] IMSS subsequently made two changes to the procurement market.

The first change was a reduction in entry barriers beginning in 2006. Before this change, only firms that operated a licensed laboratory for the production of insulin within Mexico were permitted to participate in IMSS procurement auctions. Starting on the first day of 2006, pharmaceutical companies that otherwise met the regulations to participate in IMSS insulin auctions but did not operate an insulin production laboratory in Mexico were permitted to bid. This change allowed firms that were importers or distributors of insulin, but not necessarily manufacturers themselves, to participate in IMSS procurement auctions. On Jan 30, just after the regulatory change aimed at encouraging entry was enacted, a new participant, Dimesa, entered the market.

The second policy, enacted in 2007, was a consolidation of procurement conducted by a central IMSS authority. Under this policy, all public tenders for generic pharmaceuticals were conducted by this central authority in fewer than ten auctions per year, with the purchased goods then allocated to the various state delegations and HSMUs. Before 2007, each of the 52 IMSS procurement divisions conducted separate auctions for insulin, which resulted in up to 132 insulin auctions each year. In 2007 there were nine insulin auctions held.

2.4 Conceptual Framework

The two policies enacted by IMSS were motivated by market design principles. This section provides a theoretical framework for these changes, with additional details and a discussion of other potential mechanisms in Appendix A. Reducing barriers to entry is a well-known tool to destabilize cartels (Levenstein and Suslow (2006)). Consolidation affects collusion incentives by encouraging cheating on the cartel agreement by either causing a failure of incentive compatibility or by facilitating renegoti-

[12]The CFC was the primary competition regulatory authority in Mexico until 2013 when it was replaced by the Comisión Federal de Competencia Económica (Cofece).

ation that degrades collusion.

Consider an infinitely repeated Bertrand game in which $I \geq 2$ firms produce a homogeneous good at a constant marginal cost c. Firms sell to a single consumer with multiunit demand where all units up to a quantity q are valued at $v > c$ and additional units have a value of zero.[13] Firms discount future profits at a rate $\delta \in (0, 1)$. In every period $t = 0, 1, 2, ...$, each firm i chooses a price $p_{it} \in [0, \infty)$ and all q units are sold at the lowest price provided $\min_i p_{it} \leq v$. If two or more firms tie for the lowest price, those firms split the quantity evenly.

The unique Nash equilibrium of the static game has all firms submit prices $p_{it} = c$ and earn zero profits. To establish a cartel, firms specify an agreement before the start of the game that maximizes collective profits. The simplest agreement uses grim trigger strategies, in which any deviation from the agreement results in static Bertrand pricing forever. I assume for now that the agreement cannot be renegotiated, a point which will be revisited below. In the optimal collusive agreement in grim trigger strategies, each firm sets prices $p_i = v$ in every period and splits the sale with the other firms to obtain per-period profits of $\pi^C = q(v - c)/I$. For collusion to be sustainable, each firm must be willing to continue colluding and not cheat on the agreement. The incentive compatibility constraint that must be satisfied for each firm is $\sum_{t=0}^{\infty} \delta^t \pi^C \geq I\pi^C$, which simplifies to

$$\delta \geq 1 - \frac{1}{I}.$$

Encouraging entry has a clear goal: increase I so that the incentive compatibility constraint fails and collusion is no longer sustainable. If the number of firms increases so that incentive compatibility fails, there are no collusive equilibrium strategies as firms will always find it beneficial to cheat on such arrangements.

Consolidation makes two changes to the game. The per-period quantity increases due to combining multiple separate offerings into a single sale, and the discount factor

[13] This corresponds to a first-price sealed-bid procurement auction where all firms have constant costs c and the auctioneer buys q units with a reserve price of v.

decreases because the time between sales has increased. Accordingly, I define N-*period consolidation* in the repeated Bertrand game above as a per-period quantity and discount factor $\tilde{q}_N, \tilde{\delta}_N$ such that $\tilde{q}_N = Nq$ and $\tilde{\delta}_N = \delta^N$.

Failure of incentive compatibility

Similar to increased entry, one potential effect of consolidation is to cause a failure in the incentive compatibility constraint. If $\tilde{\delta}_N$ is sufficiently small, then we will have $\tilde{\delta}_N < 1 - \frac{1}{I}$ and collusion will not be an equilibrium outcome. If this constraint fails, then no collusion is possible.

Encouraging cheating by facilitating renegotiation

The preceding analysis supposes that firms can never renegotiate an agreement following cheating. Suppose, however, that firms can meet and renegotiate the agreement following cheating by one of the cartel's members. If this renegotiation is costless, then the ability of the firms to collude will be severely undermined: after detecting cheating by one of its members, the cartel will reconvene and, realizing that it can increase future profits by forgoing punishment, ignore the transgression of the cheating firm and continue as normal. Since all firms know that cheating will not incur punishment, all firms will cheat, and the cartel will collapse. The only equilibrium in pure strategies not subject to this effect, i.e., a weakly renegotiation-proof equilibrium (Farrell and Maskin (1989)), is the repeated static Nash equilibrium of the Bertrand game.

If renegotiation is costly, however, then collusion can be restored. McCutcheon (1997) shows how a meeting cost that exceeds the minimum punishment cost to discourage cheating but is lower than the overall profits of collusion will prevent firms from cheating and encourage collusion. Specifically, suppose that the cartel punishes cheating by committing to static Bertrand Nash equilibrium pricing for T periods. The

length of punishment T is the smallest length of time for which the cost of punishment exceeds the benefit from cheating or the minimum T for which $1 - \frac{1}{I} \leq \delta(1 - \frac{\delta^T}{I})$ holds. For a given punishment length T,[14] the total cost of punishment γ is the total profits forgone by earning zero profits for T periods, or

$$\gamma(\pi^C, \delta) = \pi^C \left(\frac{1 - \delta^T}{1 - \delta} \right).$$

Suppose the cost to meet and renegotiate the collusion agreement is lower than the punishment cost γ. In that case, firms will find it beneficial to cheat, pay the renegotiation cost, and avoid punishment. Hence, the cost of punishment represents the *prohibitive renegotiation cost* of McCutcheon (1997). If renegotiation costs more than this threshold level, then firms will never renegotiate in equilibrium, and collusion is sustainable. Any increases to γ increase the likelihood that renegotiation is used by raising the threshold.

Consolidation encourages cheating because it increases the prohibitive renegotiation cost: $\gamma(\tilde{\pi}_N^C, \tilde{\delta}_N) > \gamma(\pi^C, \delta)$ for any $N \geq 2$. This result, proved in Appendix A, reflects that the punishment required to deter cheating increases under consolidation for two reasons: punishment length T increases as the discount factor decreases, and the per-period cost of punishment increases by a factor of the degree of consolidation N. This more severe punishment means that firms are willing to incur a higher cost to avoid it, thus expanding the set of meeting costs for which renegotiation occurs. Hence, consolidation broadens the scope of renegotiation as a viable option for firms and undermines the cartel agreement.

The primary argument of McCutcheon (1997) was that antitrust fines may *encourage* collusion by preventing renegotiation. Fines represent the expected cost of getting caught discussing collusion explicitly. If antitrust law sets fines for collusion that are smaller than the total profits from the cartel, then the fines will not prevent an ini-

[14] For simplicity of notation, the dependence of T on δ and I is suppressed. This dependence and its implications are made more explicit in Appendix A.

tial meeting to establish a cartel. Moreover, fines that are small relative to total cartel profits but large relative to a single period's profits create an expected meeting cost greater than the prohibitive renegotiation cost—these fines aid collusion by preventing any renegotiation of the agreement. The IMSS insulin case fits these conditions well. The CFC fined each cartel firm Mex$21.5 million, the maximum allowable at the time. This amount is only a small fraction of the total revenue obtained by the cartel, with per-firm revenue averaging Mex$216 million. However, with more than 70 auctions per year, this fine is nearly ten times the revenue obtainable in a single auction, meaning that the renegotiation costs are relatively high. The per-auction profits increased substantially after consolidation in 2007. When per-period profits are high, firms may be willing to suffer a penalty of "only" Mex$21.5 million if they can renegotiate the cartel. If all firms are willing to cheat and renegotiate, collusion fails.

2.5 Cartel Punishment and the Weak Institutions Problem

The sharp drop in insulin prices following the adoption of these two policies provided evidence of collusive bidding that prompted a formal investigation by the CFC.[15] Ultimately, evidence of collusive bidding was uncovered for 20 drug classifications: two types of insulin and 18 varieties of saline solutions.[16] Six companies and eight individuals were implicated and eventually fined by the CFC for bid manipulation.

Four firms were implicated in the insulin market: Eli Lilly, Laboratorios Pisa, Laboratorios Cryopharma, and Probiomed. Table 1 provides summary statistics of the IMSS auction market for insulin over the period 2003 - 2007. Panel A demonstrates that the four cartel members and 2006 entrant Dimesa won 93% of auctions.[17] The four cartel members used the low level of competition to engage in a bid-rotation

[15]Table A.1 in Appendix A gives a timeline of events for the insulin market for the investigation.

[16]Estrada and Vazquez (2013) documents the price effects across pharmaceutical markets that triggered an investigation by the CFC.

[17]Dimesa first participated in January 2006 and frequently under-bid the cartel members. Dimesa submitted a bid lower or equal to the lowest cartel member bid in all but eight auctions in 2006. However, during this period, Dimesa frequently tied exactly with one or more cartel members.

scheme to keep prices high; Appendix A provides additional information on the cartel's operation.

The legal case against the cartel is notable in that the evidence used to convict the cartel was almost entirely indirect. While the CFC had evidence of large price drops following the enactment of the policy changes, there was no direct evidence of a conspiracy to fix prices. The CFC supplemented the price data with information on the timing, but not the contents, of communications between employees of the colluding firms. This information consisted of the timing of phone calls between firms in the days leading up to an auction or when employees from two or more firms attended the same conference or trade organization. The use of indirect evidence was highly unusual in antitrust cases in Mexico up to the 2010 ruling by the CFC, and the lack of direct evidence of conspiracy was one of the primary aspects upon which the insulin cartel members based their judicial appeal (Comisión Federal de Competencia Económica (2015a)). The appeal was unsuccessful, and the original ruling and fines imposed by the CFC were upheld.[18]

The problem of weak institutions is evident in both the conditions that led to the cartel's formation and the legal strategy used by the CFC to punish the colluding firms. As discussed above, the CFC did not have sufficient punitive authority to deter cartel formation. The fines issued to each of the firms in the insulin cartel were the maximum allowable at the time: Mex$21.5 million per firm, or approximately $1.7 million in 2010 US dollars, a small fraction of the bidding ring's revenue. It is also small relative to the direct monetary damages from the cartel, which were approximately Mex$610 million (US$49 million).[19]

The CFC was also limited in its ability to investigate the colluding firms. Dawn

[18]One firm fined for bid-rigging in the market for saline solutions, Baxter, was successful in overturning their fine upon judicial review, perhaps revealing the risky nature of the legal strategy pursued by the CFC.

[19]Monetary damages are calculated as the difference in price before and after the cartel at the total quantity purchased during the cartel period. A back-of-the-envelope calculation for indirect monetary damages arising from increased diabetes complications treatment costs is contained in Appendix A.

Table 1: Auction Statistics, 2003 - 2007

Panel A: Auction participation by firm

Firm	Auctions Won	Auctions Participated
Cryopharma*	102	259
Pisa*	111	215
Eli Lilly*	75	189
Probiomed*	91	122
Dimesa^{+}	43	57
Savi	10	18
SMS	10	16
Maypo	7	15
Audipharma	3	6
Codifarma	1	9

Panel B: Bid levels, total quantity, and auction frequency

Year	Average Lowest Bid	Est. total quantity	Number of Auctions
2003	155.15	1,790,311	53
2004	155.16	1,334,543	71
2005	155.26	1,663,158	132
2006	60.22	2,674,641	76
2007	34.35	4,237,606	9

Notes: * indicates cartel member, $^{+}$ indicates 2006 entrant. This table reports summary statistics on insulin auctions occurring from May 2003 through 2007. Panel A shows auction participation by firm. Panel B shows average minimum bids, estimated quantities (where each unit is a 10ml vial), and auction frequency by year.

raids, which allow agents to carry out unannounced searches of company property for evidence of violations of antitrust law, and other investigative procedures were unusable by regulators until Mexican competition law was strengthened in 2014 (Comisión Federal de Competencia Económica (2015c)). The inability to gather direct evidence of conspiracy necessitated using the indirect evidence discussed above.

2.6 Price and Quantity Effects

Price data for IMSS purchases during the investigation period (2003 through 2007) are obtained from legal documents of the case against the cartel participants (Comisión Federal de Competencia (2010)), and quantity data are obtained from IMSS purchase records. Data for after the cartel period are obtained from the IMSS purchase portal, which records IMSS purchase contracts starting in 2009. Appendix B.2 provides additional details on price and quantity data.

Both policies had a substantial effect on insulin prices paid by IMSS. Panel B of Table 1 summarizes the price and quantity data contained in Figure 1. Substantial price

declines coincided with the implementation of the two procurement policy changes. The average price paid per unit of insulin during the period 2003-2005 was Mex$155.21. In 2006, after the change to entry regulations, the average price declined to Mex$60.22. In 2007, following the procurement consolidation, which saw the number of auctions reduced to nine, the average price fell further to Mex$34.35 per unit. Purchase data obtained from the IMSS procurement portal over the years 2009 to 2016, displayed in Appendix F, shows that the lower price level was persistent, indicating that the enacted policies successfully triggered competitive pricing strategies.

The additional drop in price accompanying the second policy change of consolidation is notable in that it signifies that the entry of Dimesa alone was insufficient to eliminate supracompetitive pricing. The effect of the entrant was to disrupt the pricing of the cartel. The bids submitted by the cartel members fell suddenly just before the entry of Dimesa, likely in anticipation of the entrant disrupting the cartel. Following entry, Dimesa signaled a willingness to coordinate on the previous collusive price of Mex$155 by submitting bids at this level in several auctions sequentially. While these price signaling efforts could not restore the previous collusive price, they stopped further price declines and stabilized the winning bid around Mex$60. Procurement consolidation in 2007 prompted further undercutting and another price decline. Appendix A provides additional discussion, as well as a comparison to the price dynamics of the other 18 drug categories involved in the CFC's ruling that underscores the disruptive effects of entry in the insulin market.

IMSS responded to this price decline by substantially increasing purchases of insulin, as shown in Panel B of Table 1 which displays the midpoint of the purchase range in Figure 1. The estimated quantity for 2006 is 57 percent higher than realized annual insulin purchases during the cartel period, while the 2007 estimated quantity is 149 percent higher than during the cartel period.[20] This increase is corroborated by

[20]Even the most conservative estimate for quantity increases, comparing the upper quantity range in 2005 with the lower quantity range in 2007, indicates a 42 percent increase in insulin purchases. While the data are not suitable for precise estimates of demand elasticities, as done in Einav et al. (2018), this

more recent data for which realized purchase quantities are available; in 2009, IMSS made a sequence of purchases amounting to approximately 3.8 million units of insulin per year, the same magnitude as the estimated purchase range for 2007.

There are several reasons why the changes in price and quantity may have impacted the quality of care for IMSS diabetic patients. Increasing insulin purchases may have expanded insulin use by increasing the frequency of use for those already using insulin and expanding the set of diabetic patients with access to insulin treatment. Both of these factors could influence long-term patient health outcomes.[21] As discussed in Section 2.1, low public health expenditures resulted in rationing and wait times for treatment. The collapse of the cartel lessened financial constraints for the treatment of diabetes within IMSS, making insulin therapy available to more diabetes patients.

There is also an indirect mechanism through which the cartel's collapse may have benefited IMSS diabetes patients: despite the total quantity of insulin increasing from 2005 to 2007, total insulin expenditures fell from Mex$292 million to Mex$143 million (based on means of the quantity ranges). This expenditure reduction may have allowed for the reallocation of resources within IMSS for other diabetes care, such as increased blood testing or treatment of diabetes complications.[22]

2.7 Insulin procurement in other sectors

Public procurement procedures for all public health care organizations are collectively governed by the Procurement Act[23] which sets forth the allowable procedures for all procurement offerings. Like IMSS, other public health care procurement for

represents evidence that purchase quantities are sensitive to prices at an institutional level.

[21] The medical literature provides evidence that incomplete adherence to recommended insulin treatment increases complication risk (Khunti et al. (2017)).

[22] These indirect effects are difficult to measure, as detailed patient treatment data, such as treatment of diabetes complications, is not available. The following sections focus on the direct effects of the cartel on insulin utilization and observable diabetes health outcomes and leave the study of the effects of resource reallocation in the aftermath of the cartel to future work.

[23] Ley de Adquisiciones, Arrendamientos y Servicios del Sector Público, original version available at `http://www.dof.gob.mx/nota_detalle.php?codigo=2049070&fecha=04/01/2000`.

programs such as ISSSTE and *Seguro Popular* is conducted by procurement auctions for many products, including generic pharmaceuticals. These practices also mirror other public procurement practices in the region. In addition to public health care pharmaceutical markets, there are also private health care markets.

The collapse of the insulin cartel generated a considerable disruption to prices and quantities within IMSS. When evaluating the impacts of the cartel's collapse on health outcomes for IMSS patients, one potential concern is that these disruptions had spillover effects on other markets that affected the availability of insulin in other public health care programs. Such spillovers would complicate the interpretation of empirical analyses that use non-IMSS public health care beneficiaries as a reference group in assessing health outcomes after the cartel's collapse.

A detailed discussion of potential sources of spillovers and why they are unlikely to be a significant concern in this setting is contained in Appendix C. These spillovers might arise from production capacity constraints, increasing marginal costs of insulin production, or changes in firm conduct across sectors that change the availability of insulin for other public health care providers or the private market. As discussed in Appendix C.1, I find little evidence of capacity constraints or increasing marginal costs, as prices remained level despite surging quantities across multiple public sector health care providers. Insulin price and diabetes expenditure data from the private market also suggest that the collapse of the insulin cartel did not substantially disrupt private insulin expenditures and consumption outside of IMSS; Appendix C.2 elaborates.

3 Data

Data on diabetes treatment, health outcomes, insurance coverage, and mortality are taken from three sources. The primary data for assessing health outcomes and mortality are the Encuesta National de Salud y Nutrición (ENSANUT) survey and Insti-

tuto Nacional de Estadística y Geografía (INEGI) vital records data. The ENSANUT survey (Instituto Nacional de Salud Pública (2000 - 2016)) is a large, national household health and nutrition survey conducted every six years throughout Mexico. The INEGI vital statistics records (Instituto Nacional de Estadística y Geografía (2000 - 2014)) contain information on individual deaths throughout Mexico, including insurance coverage and cause of death. These data allow for analysis of changes to health and treatment outcomes following the cartel's collapse. I supplement these two datasets with the Mexican Family Life Survey (MXFLS, Centro de Investigación y Docencia Económicas and Universidad Iberoamericana (2002 - 2012)), a longitudinal survey that gathers information on economic, health, and social variables from Mexican households. MXFLS data tracks individual insurance and health status over time and is used to measure selection into IMSS coverage and other effects.

3.1 ENSANUT Health Data

Data on insulin utilization and complications from diabetes are obtained from the Encuesta National de Salud y Nutrición (ENSANUT) survey, a household health and nutrition survey conducted every six years throughout Mexico. The ENSANUT survey selects a representative sample of households in Mexico and conducts interviews with all household members to record demographic, social, economic, and health information. I use data from the 2006, 2012, and 2016 editions of the ENSANUT survey on adult respondents that indicated that they have been diagnosed with diabetes.[24] The 2006 and 2012 editions represent complete surveys, consisting of large, representative samples of the Mexican population, while the 2016 edition is a smaller sample with a primary focus on individuals diagnosed with chronic diseases such as diabetes. Summary statistics for the ENSAUT survey are given in Table 2, and additional information on variable definitions is contained in Appendix B.

[24]The survey does not distinguish between Type I and Type II diabetes; the sample consists of all individuals diagnosed with any form of diabetes. Appendix B provides additional survey details.

While the surveys were published in 2006, 2012, and 2016, the survey interviews were conducted the year before publication, or 2005, 2011, and 2015, respectively. Data from the first survey was gathered during the last year of the insulin cartel's operation, while interviews in later surveys were conducted several years after the collapse of the cartel. The timing of the survey waves provides the opportunity to study the health effects of the cartel's collapse.

Prevalence of diabetes increased from 2006 to 2012, with 3,066 total adults diagnosed with diabetes in 2006 (out of 45,241 total individuals) and 4,490 in 2012 (out of 46,277 total individuals). Several notable changes occurred over this time. First, insulin use became more prevalent. Increased focus on diabetes within the Mexican health care system during this period, such as the national standardization of treatment guidelines, likely contributed to these changes. In Section 4.5 I further discuss these policies. Second, the population of individuals in later surveys is slightly older and has had diabetes for a longer period. These factors likely contribute to the overall increase in complications over this period. They may also provide a partial explanation for the increase in insulin use, as insulin use is commonly associated with the long-term treatment of diabetes.

The data also contains information on the treatment institution of diabetes patients. In the pre-cartel period, 33 percent of diabetes patients reported IMSS as their primary treatment institution, which declined slightly to 30 percent in the post-cartel period. The stable percentage of individuals treated through IMSS over time, combined with the fact that eligibility for other health insurance requires a change of employment sector, suggests that IMSS enrollment is stable and there were no significant changes to the composition of IMSS diabetics. IMSS enrollment over time is investigated further in Section 4.5.

Table 2: Summary statistics, ENASNUT survey

	2006	2012	2016
Total survey size	45,241	46,277	8,824
Number of individuals with diagnosed diabetes	3,066	4,490	972
Health:			
Insulin	0.07	0.12	0.19
	(0.26)	(0.32)	(0.39)
Complications	0.98	1.18	1.24
	(1.15)	(1.23)	(1.23)
Loss of sensation	0.12	0.39	0.38
	(0.33)	(0.49)	(0.49)
Ulcers	0.08	0.06	0.06
	(0.27)	(0.24)	(0.24)
Diminished visual acuity	0.49	0.47	0.52
	(0.50)	(0.50)	(0.50)
Blindness	0.06	0.06	0.08
	(0.24)	(0.24)	(0.27)
Retinal damage	0.14	0.12	0.12
	(0.35)	(0.33)	(0.33)
Amputation	0.02	0.02	0.02
	(0.15)	(0.13)	(0.15)
Heart attack	0.02	0.02	0.03
	(0.15)	(0.15)	(0.16)
Dialysis	0.02	0.01	0.01
	(0.14)	(0.11)	(0.11)
Diabetes duration (years)	8.37	8.88	10.79
	(7.74)	(9.07)	(8.62)
Smoking	0.27	0.33	0.27
	(0.44)	(0.47)	(0.44)
Hypertension	0.41	0.47	0.48
	(0.49)	(0.50)	(0.50)
High cholesterol	0.21	0.23	0.24
	(0.41)	(0.42)	(0.43)
Alcohol	0.40	0.21	0.11
	(0.49)	(0.40)	(0.31)
Demographics:			
IMSS	0.33	0.30	0.29
	(0.47)	(0.46)	(0.45)
Age	56.77	57.59	58.87
	(13.61)	(13.24)	(12.54)
Height (m)	1.56	1.56	1.54
	(0.09)	(0.10)	(0.09)
Weight (kg)	71.10	72.28	71.06
	(15.11)	(15.71)	(15.32)
Waist measurement (m)	1.00	0.99	1.00
	(0.13)	(0.13)	(0.13)
Sex (male)	0.39	0.38	0.32
	(0.49)	(0.49)	(0.47)
Less than primary school	0.17	0.16	0.18
	(0.38)	(0.36)	(0.39)
Primary school	0.57	0.51	0.44
	(0.49)	(0.50)	(0.50)
Secondary school	0.11	0.15	0.16
	(0.31)	(0.36)	(0.37)
Some college or more	0.14	0.17	0.11
	(0.35)	(0.38)	(0.32)
Working	0.33	0.36	0.31
	(0.47)	(0.48)	(0.46)
Not working	0.58	0.54	0.51
	(0.49)	(0.50)	(0.50)
Retired	0.09	0.09	0.08
	(0.28)	(0.29)	(0.27)
Urban	0.81	0.72	0.57
	(0.39)	(0.45)	(0.50)

Notes: This table presents summary statistics for diabetics in each wave of the ENSANUT survey. Means are listed for the estimation sample of 5,773 diabetes patients for whom all health and demographic information is available, with standard deviations in parentheses below. Appendix B provides additional details on sample construction.

The ENSANUT survey gathers information on a set of complications that may arise from poor management of diabetes. These are ulcers, reported loss of sensation, vision deterioration, amputation, retinal damage or blindness, kidney failure resulting from diabetic nephropathy, heart attack, or coma. These conditions indicate poor long-term management of diabetes. The Agency for Healthcare Research and Quality's guidelines on prevention quality indicators classifies all renal, ocular, neurological, macrovascular, and circulatory disorders as signs of long-term poor disease management. As complications from diabetes result from poor long-term management, an extended period after the cartel's collapse is necessary to measure any changes in these outcomes. The multi-year time horizon of the sample after the cartel's collapse allows for the ability to detect any such changes.

3.2 INEGI Mortality Data

INEGI mortality data contains information on all recorded deaths from 2000 to 2014 throughout Mexico. Each record includes age, sex, cause of death, residence location, and insurance information, and they may also include information on socioeconomic factors such as education and occupation. The complete data covers over 7 million observations for deaths over this period.[25] Appendix B contains summary statistics for the data and a description of how causes of death are classified.

Over the years covered in the sample, diabetes became more prominent as a recorded cause of death, rising from 12 percent of deaths in 2000 to 16 percent in 2014. This trend is consistent with the increasing prevalence of diabetes in Mexico. Life expectancy also increases, showing the improvements in the Mexican health care system and the overall health of the Mexican population over time. Finally, the fraction of deaths accounted for by IMSS beneficiaries is stable over time, which is consistent with the stable proportion of diabetic patients covered by IMSS shown in the EN-

[25]For consistency with the ENSANUT survey, I define adult deaths as occurring at age 20 or later and drop all deaths occurring before age 20 from the estimation sample.

SANUT survey.

3.3 MXFLS Data

The final data set used in the empirical analysis is the MXFLS, which is used for selection tests and other robustness analyses. MXFLS is a longitudinal survey of Mexican households that gathers information on various socioeconomic and health factors. Currently, there are three rounds of the MXLFS. The first round of interviews occurred in 2002, the second in 2005 and 2006, and the third round from 2009 through 2012. Each follow-up survey re-interviews original participants and any new members of each participant's household. The total size of the MXFLS is comparable to ENSANUT, with 8,440 households and over 35,000 individuals interviewed in the first wave. After restricting to adults aged 20 or older and eliminating individuals missing complete responses to important health and insurance information, the total sample consists of 16,931 individuals in the first round, growing to 24,894 by the third round through new household additions.

Because the MXLFS does not gather detailed information about diabetes treatment and health outcomes, particularly in the first two rounds of the survey, it is not suitable for analyzing the health effects of the cartel's collapse. However, the longitudinal survey design of the MXFLS lends it to the analysis of changes in program enrollment, diabetes diagnosis, and other factors over time. As each household member is surveyed on their program participation in each round, changes in insurance coverage can be tracked before and after the cartel's collapse. This feature also holds for diabetes diagnoses, allowing any changes in diagnosing behavior at the insurance provider level to be tracked over time.

Appendix B gives summary statistics for diabetic patients contained within the MXLFS survey. The patterns for diabetic patients surveyed by MXFLS are broadly similar to those of the ENSANUT survey: the population of individuals with diag-

nosed diabetes is majority female, grows slightly older over time, and has a stable proportion of individuals insured by IMSS. While the MXLFS does not gather information on specific diabetes medication usage, it does survey participants on out-of-pocket expenditures on diabetes medication.

4 Health Effects of Collusion

4.1 Identifying Health Effects of the Cartel's Collapse

The empirical analysis tests the hypotheses that the collapse of the cartel increased the availability of insulin, decreased the number of diabetes-related complications, and decreased the likelihood of diabetes-related mortality. The analysis involves comparing the outcomes for the treatment group of IMSS diabetes patients with a control group of other diabetes patients in Mexico. Recall that the Mexican health system has three components: Social Security, Social Protection System in Health, and the private health care system. To reduce the possibility of contamination from other policy changes, such as the expansion of the *Seguro Popular* program over the sample period, I do not include individuals affiliated with SPSS or the private health care system in the control group. I compare individuals within IMSS to those receiving health care in the public system from other state and federal social security programs before and after the collapse of the cartel.[26] The base specifications correspond to the canonical DiD framework that features a single treatment group and two time periods, one during the cartel period and one after; Section 4.5 presents specifications examining year-specific effects for all outcome variables.

Specifically, the econometric analysis is a DiD specification that uses the set of

[26]Specifically, the control group consists of members of non-IMSS social security programs. In the ENSANUT data, this excludes (i) individuals who primarily use private health care and (ii) individuals enrolled in SPSS/*Seguro Popular*. The treatment group consists of individuals enrolled in IMSS or IMSS Oportunidades. As IMSS Oportunidades has a separate provider network, I treat these as separate insurance programs that were both subject to the treatment.

diabetes patients within IMSS after the cartel's collapse as the treatment group, and diabetes patients enrolled in non-SPSS public health care as the control group.[27] The equations used in estimation are represented by equation (1) for individual i in survey wave t. The exact controls X_i for individual i vary by specification but include individual demographic and medical information, fixed effects for insurance coverage, and municipality and time fixed effects.[28] Time effects are captured by survey wave fixed effects, represented in equation (1) by Post-Cartel$_t$.

$$Y_{it} = X_i\beta + \delta_0 \text{IMSS}_i + \delta_1 \text{Post-Cartel}_t + \delta_2 \text{IMSS}_i \times \text{Post-Cartel}_t + \epsilon \tag{1}$$

The DiD parameter is captured by the coefficient δ_2 on the interaction term IMSS$_i \times$Post-Cartel$_t$; this parameter measures the change in the outcome variable among IMSS diabetics from the pre-intervention period to the post-intervention period relative to other diabetics enrolled in social security health coverage. This parameter identifies the change in diabetes treatment and health outcomes due to the cartel's collapse under the assumption that the trend in the outcome would have been the same for all patients enrolled in social security. I return to a discussion of this assumption, and the associated empirical analysis, including tests for pre-trends, in Section 4.5.

Because assignment to treatment is determined at the insurance provider level, all standard errors are clustered by insurance provider (Abadie et al. (2017)). The number of clusters ranges from nine to nineteen depending on the number of insurance coverage categories recorded in each data set. Due to the small number of clusters, all hypothesis tests of the DiD parameter are conducted using wild cluster bootstrap methods, which have demonstrated rejection rates similar to theoretical values for as few as six clusters (Cameron et al. (2008)).[29] Implementation follows Roodman et al.

[27] Appendix D shows the results of alternative econometric specifications, including variation to the control group and various matching-based estimators.

[28] In the empirical analysis, I include all insured individuals and include time interactions with private health care and SPSS coverage to isolate the treatment and control groups; Appendix E shows results when other insurance groups are excluded entirely.

[29] The difficulty of accurate inference with small numbers of clusters has been noted by Bertrand et al.

(2019), with linear models using the wild cluster bootstrap of Cameron et al. (2008) and non-linear models using the score bootstrap of Kline and Santos (2012).[30]

Identification of the DiD parameter also requires the exogeneity of the treatment. Exogeneity is based on the premise that the intervention was a random shock to insulin prices affecting only IMSS beneficiaries, that this shock was unanticipated, and that there was no movement between treatment and control groups due to the intervention. The random nature of the price shock is supported by the evidence of the sharp, sudden decline in price following the cartel's collapse. As noted in Section 3, the proportion of individuals receiving diabetes treatment through IMSS is relatively stable across survey iterations, suggesting that there was no substantial shift of individuals into IMSS treatment facilities following the cartel's collapse. In Section 4.5 I further analyze this assumption by testing for selection into IMSS coverage following the cartel's collapse to examine whether there was significant movement between treatment and control groups.

Table 3 shows summary statistics for the treatment and control groups in the ENSANUT data before and after the collapse of the cartel. Insulin use during the cartel period was similar across groups, while in the post-cartel period, insulin increased dramatically for those covered by IMSS. Those covered by IMSS are generally slightly older and have had diabetes for a longer period; these differences are larger for the post-cartel period. Section 4.5 conducts tests for selection into IMSS coverage following the collapse of the cartel, and Appendix D estimates alternative empirical specifications, including matching estimators, that examines how the results might be affected by the differences in demographic composition.

(2004) and Conley and Taber (2011). MacKinnon and Webb (2017) demonstrate that when the number of treated clusters is small in DiD designs, there is a severe tendency to *under*-reject the null hypothesis when the restricted wild cluster bootstrap is used (that is, when the null hypothesis is imposed on the bootstrap DGP). I use only the restricted version of the wild cluster bootstrap, which suggests that the associated p-values for these specifications can be interpreted as conservative estimates of statistical significance tests. The results are robust to various clustering methods, with the wild cluster bootstrap yielding the most conservative p-values.

[30]Because of the computational burden associated with generating confidence intervals using the score bootstrap, only p-values are reported for these results.

Table 3: Balance across groups, ENSANUT data

	(1) Pre×Control	(2) Pre×IMSS	(1) - (2)	(3) Post×Control	(4) Post×IMSS	(3) - (4)
Health:						
Complications	0.84	1.03	-0.19	1.09	1.19	-0.10
	(1.08)	(1.13)	(-2.23)	(1.18)	(1.20)	(-2.04)
Insulin	0.10	0.10	0.00	0.08	0.18	-0.10
	(0.30)	(0.29)	(0.02)	(0.28)	(0.39)	(-6.92)
Diabetes duration (years)	8.88	9.32	-0.44	8.19	10.10	-1.91
	(8.18)	(8.12)	(-0.72)	(8.46)	(9.35)	(-5.11)
Smoking	0.30	0.27	0.03	0.36	0.33	0.03
	(0.46)	(0.44)	(1.02)	(0.48)	(0.47)	(1.50)
Hypertension	0.42	0.47	-0.04	0.43	0.53	-0.09
	(0.50)	(0.50)	(-1.13)	(0.50)	(0.50)	(-4.56)
High cholesterol	0.22	0.26	-0.04	0.21	0.27	-0.06
	(0.42)	(0.44)	(-1.22)	(0.41)	(0.44)	(-3.33)
Alcohol	0.43	0.37	0.05	0.26	0.16	0.09
	(0.50)	(0.48)	(1.48)	(0.44)	(0.37)	(5.63)
Demographics:						
Age	57.41	58.39	-0.98	56.30	59.82	-3.53
	(12.81)	(12.69)	(-1.02)	(13.13)	(12.26)	(-6.70)
Sex (male)	0.39	0.36	0.02	0.43	0.32	0.11
	(0.49)	(0.48)	(0.68)	(0.49)	(0.47)	(5.35)
Height (m)	1.57	1.56	0.01	1.57	1.56	0.01
	(0.10)	(0.09)	(1.92)	(0.10)	(0.09)	(3.29)
Weight (kg)	73.63	72.18	1.45	73.62	72.67	0.95
	(15.93)	(14.74)	(1.28)	(16.26)	(15.12)	(1.47)
Waist measurement (m)	1.01	1.01	0.00	1.00	1.00	-0.01
	(0.12)	(0.13)	(0.01)	(0.13)	(0.13)	(-1.07)
Less than primary school	0.12	0.15	-0.04	0.13	0.13	-0.01
	(0.32)	(0.36)	(-1.34)	(0.33)	(0.34)	(-0.41)
Primary school	0.52	0.60	-0.09	0.45	0.57	-0.12
	(0.50)	(0.49)	(-2.38)	(0.50)	(0.49)	(-5.86)
Secondary school	0.10	0.10	0.00	0.16	0.17	-0.01
	(0.31)	(0.31)	(0.04)	(0.37)	(0.37)	(-0.37)
Some college or more	0.26	0.14	0.12	0.26	0.13	0.13
	(0.44)	(0.35)	(4.40)	(0.44)	(0.33)	(8.30)
Working	0.34	0.27	0.07	0.41	0.29	0.13
	(0.48)	(0.44)	(2.17)	(0.49)	(0.45)	(6.55)
Not working	0.55	0.57	-0.02	0.47	0.57	-0.09
	(0.50)	(0.50)	(-0.49)	(0.50)	(0.50)	(-4.58)
Retired	0.10	0.16	-0.06	0.11	0.14	-0.03
	(0.31)	(0.37)	(-2.08)	(0.31)	(0.35)	(-2.39)
Urban	0.92	0.88	0.04	0.78	0.75	0.03
	(0.28)	(0.33)	(1.61)	(0.42)	(0.43)	(1.61)

Notes: This table presents summary statistics for health and demographic variables before and after the collapse of the insulin cartel. Columns (1) through (4) give means with standard deviations below. Columns (1)-(2) and (3)-(4) give the differences in means with the associated t-statistic in parentheses below.

4.2 Effect on insulin usage and diabetes complications

The results on insulin utilization and diabetes complications are presented in Table 4.[31] Demographic controls are included in all specifications, as well as year fixed effects. Municipality fixed effects are present in all specifications and control for any variation in public health expenditures by state, differing access to health care facilities in rural vs. urban communities, and other geographic determinants of access to care. Specifications (2) and (4) add health controls to account for other conditions that might affect diabetes-related health outcomes. Appendix B contains variable definitions. The table reports the DiD coefficient with wild cluster bootstrap p-values and 95 percent confidence intervals reported below each estimate.

Table 4: Effect on insulin utilization and diabetes complications

	Insulin		Complications	
	(1)	(2)	(3)	(4)
DiD coeff.	0.050	0.050	-0.302	-0.299
p-value	(0.035)	(0.035)	(0.034)	(0.027)
95% CI	$[0.02, 0.22]$	$[0.02, 0.21]$	$[-0.57, -0.10]$	$[-0.53, -0.15]$
Base controls	X	X	X	X
Health controls		X		X
Observations	5,773	5,773	5,773	5,773

Notes: Difference-in-differences coefficients for the effect of the cartel's collapse on insulin usage and health complications from diabetes. Base controls are age, sex, height, weight, waist circumference, diabetes duration, survey year, insurance, education, employment, and municipality. Health controls are smoking, hypertension, high cholesterol, and alcohol use. Wild cluster bootstrap p-values and confidence intervals are reported below each coefficient.

The results indicate a substantial impact of the cartel's collapse on insulin utilization and the number of complications for IMSS beneficiaries. Columns (1) and (2) report the DiD coefficient and standard errors when insulin usage is the dependent variable. The estimates in columns (1) and (2) find that the cartel's collapse increased

[31] For ease of interpretation, results are reported for LPM/OLS specifications, but as shown in Section 4.5 all the results of Table 4 are robust to other functional form assumptions.

insulin usage among diabetes patients in the IMSS system by 5.0 percentage points. This estimate corresponds to a 42 percent increase in the number of IMSS individuals using insulin relative to the 12 percent using insulin before 2006. The midpoint of the purchase ranges for IMSS insulin in Figure 1 implies that overall insulin purchases increased by 149 percent. The greater increase in overall insulin supply relative to the number of individuals using insulin suggests that the increase in insulin supply may have contributed to the frequency of usage and accessibility.

The estimates in columns (3) and (4) report the DiD coefficient for the effect on complications from diabetes. The estimated coefficients are again both statistically significant and large in magnitude. The point estimate of column (4) implies that IMSS beneficiaries reported 0.299 fewer complications on average in the post-cartel period. This estimate implies a 25 percent reduction in reported complications from diabetes.

Effects by socioeconomic status

Previous research (e.g., Lleras-Muney (2005)) suggests that high socioeconomic status can mitigate adverse health effects, perhaps through increased ability to pay for treatment or improved access to care through networks or other means. The concern that low SES individuals may experience the worst consequences of the cartel is especially relevant in Mexico, which ranked among the lowest OECD countries for income inequality during the 2000s. To determine how SES interacts with diabetes outcomes following the collapse of the cartel, I estimate the main specification separately on low- and high-education individuals, where low education represents less than secondary school education. This specification compares low-education IMSS diabetes patients with low-education non-IMSS social security diabetes patients, and similarly for high-education individuals.

The results are presented in Table 5, and show that the primary effect of the cartel is on low SES individuals. Individuals with less than a secondary school education

Table 5: Effects by education status

	Insulin		Complications	
	Low Educ. (1)	High Educ. (2)	Low Educ. (3)	High Educ. (4)
DiD coeff.	0.068	0.002	-0.344	-0.325
p-value	(0.019)	(0.949)	(0.009)	(0.284)
95% CI	$[0.03, 0.16]$	$[-0.28, 0.47]$	$[-0.80, -0.17]$	$[-1.14, 1.33]$
Base controls	X	X	X	X
Health controls	X	X	X	X
Observations	4,212	1,561	4,212	1,561

Notes: Difference-in-differences coefficients for the effect of the cartel's collapse on insulin usage and health complications from diabetes, separated by education status. Low education (columns (1) and (3)) refers to individuals with less than a secondary education, while high education (columns (2) and (4)) refers to individuals who have completed at least a secondary education. For control definitions see Table 4. Wild cluster bootstrap p-values and confidence intervals are reported below each coefficient.

are nearly 7 percentage points more likely to use insulin after the collapse of the cartel and experience 0.344 fewer complications on average. In contrast, neither effect for high-education individuals is statistically significant. The results suggest that the damaging health effects of pharmaceutical cartels are most likely to be borne by low SES individuals.

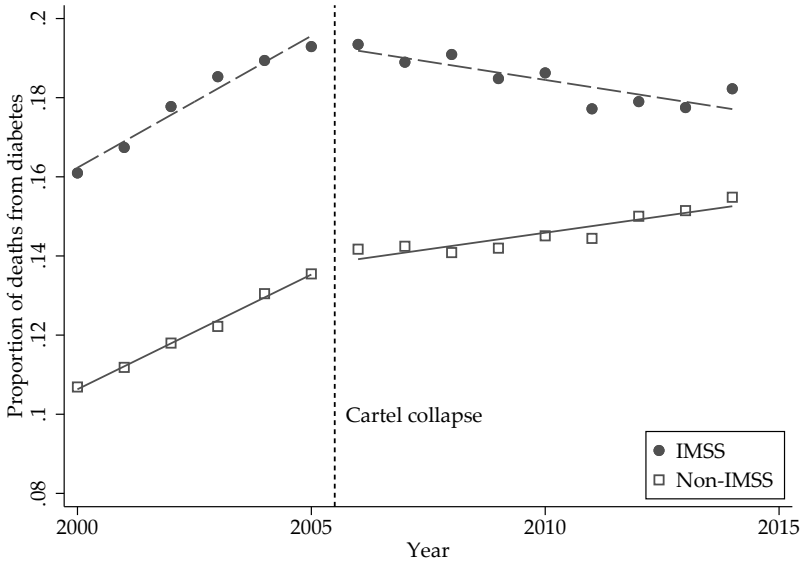
4.3 Effect on mortality

Because the INEGI mortality data records both the cause of death and insurance coverage, it is possible to use this data to investigate the effects of the cartel's collapse on diabetes mortality.[32] The proportion of deaths caused by diabetes for each year between 2000 and 2014 is plotted in Figure 2. Before the cartel's collapse, the rate of increase in the proportion of deaths caused by diabetes was similar across groups. After the cartel's collapse, the proportion of diabetes deaths continues to increase for non-IMSS-affiliated individuals. However, the rate of diabetes deaths declines for

[32] Appendix B describes the classification of deaths by cause.

those within IMSS. This trend is consistent with the health effects estimated in Table 4 and suggests that the collapse of the cartel decreased the risk of diabetes mortality for those receiving treatment through IMSS.

Figure 2: Proportion of deaths due to diabetes, 2000 – 2014



While the observed trends are suggestive, the relative risk of diabetes-related death may not fully capture the effects of increased insulin availability. For instance, increased access to insulin therapy may allow an individual to delay serious complications or death even if that individual dies from diabetes sometime later. To capture these effects and the inclusion of other control variables, I estimate a proportional hazards model of diabetes-specific mortality (Andersen et al. (1985)) using a similar DiD design to the previous section (Clotfelter et al. (2008)). Proportional hazards models assume that individuals share a common hazard rate component $\lambda_0(t)$ at any given age t, and this instantaneous risk is multiplied by an additional factor determined by the predictor variables X_i and coefficients β.[33] The hazard function $\lambda(t|X_i)$ represents the probability of diabetes-related mortality before age $t+1$ conditional on having lived to age t. The equation representing the hazard function used in estimation is

[33]The diabetes-specific mortality proportional hazards model treats other causes of death as independent censoring. In Appendix E I relax this assumption by treating cardiovascular disease as a competing cause of death and find similar results.

$$\lambda(t|X_i) = \lambda_0(t)\exp(X_i\beta),$$

$$X_i\beta = \beta_0 + \beta_1 \text{State}_i + \beta_2 \text{Insurance}_i + \beta_3 \text{Year}_i + \beta_4 \text{IMSS}_i \times \text{Post-Cartel}_i$$

Table 6 shows the estimated DiD hazard ratio $\exp(\beta_4)$ from the proportional hazards diabetes-specific mortality model. Column (1) includes controls for state, year, and insurance coverage, while column (2) adds controls for education and occupation.[34] Following the analysis of Section 4.2, uninsured individuals are omitted and an interaction term for post-cartel SSPS coverage is included to isolate the control group of other social security health insurance. The estimated hazard rate associated with the cartel's collapse is statistically significant and less than one, indicating a reduction in the rate of death due to diabetes following the cartel's collapse. The estimate corresponds to a per-year reduction in the probability of diabetes-related mortality of 3.4 percent.

Table 6: Effect of cartel collapse on diabetes-specific mortality hazard rates

	(1)	(2)
DiD hazard ratio	0.966	0.954
p-value	(0.000)	(0.000)
Education		X
Occupation		X
Observations	4,051,016	3,059,789

Notes: Difference-in-differences hazard ratio for diabetes-specific mortality risk. Controls included in both specifications are sex, insurance, state, and year fixed effects. Score bootstrap p-values are reported below each estimated hazard ratio.

To gauge the overall mortality effects of the cartel, I use the estimated effect to calculate the total number of premature deaths due to diabetes that occurred over the cartel period. I define premature death as an individual who would have lived

[34] Because INEGI changed occupation classifications in 2013, the specification in column (2) uses the sample through 2012.

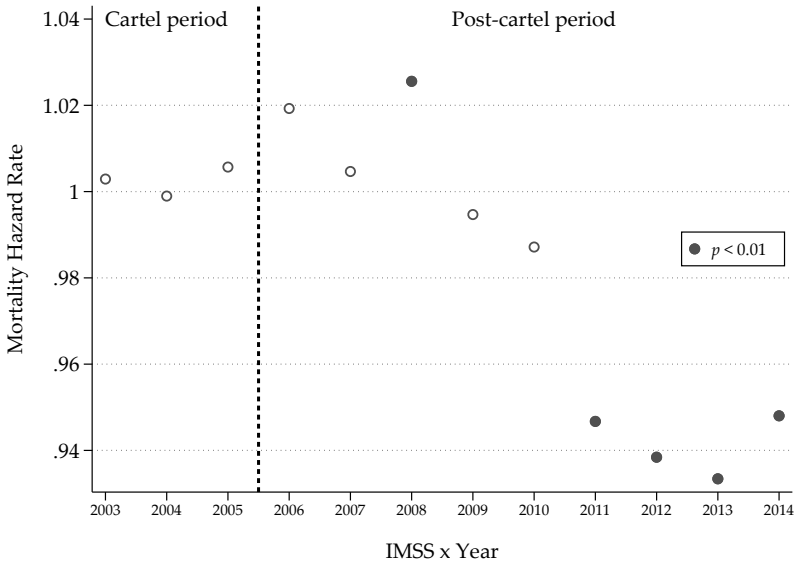
until at least the following calendar year had the cartel never operated. This number is calculated by applying the per-year reduction estimate in column (1) of Table 6 to the total IMSS diabetes deaths occurring over this period. From 2003 through 2005, there were 452,795 total deaths among IMSS beneficiaries, of which 85,692 were due to diabetes. Applying the proportional reduction of 0.966 to these diabetes deaths yields the prediction that 82,778 deaths would have occurred in the same year absent the cartel. The difference between this prediction and realized diabetes deaths implies that the lack of insulin availability created by the cartel caused 2,913 premature deaths or 971 premature deaths per year of the cartel's operation.

Finally, I re-estimate the model of column (1) of Table 6 with separate IMSS $\times$ Year interaction terms to examine the evolution of the effect on mortality over time and to test for the presence of pre-trends in diabetes mortality hazard rates. Figure 3 displays these estimated hazard ratios for 2003 to 2014, using the pre-cartel period as the base category. The first three years correspond to the cartel period, during which there is no observable trend or statistically significant effect. Diabetes mortality increased in the years after the cartel's collapse before a pronounced downward trend in mortality rates emerged in 2009. The lag between the collapse of the cartel and the decline in diabetes mortality is consistent with the long-term nature of outcomes associated with poor management of diabetes.

4.4 Discussion

The utilization and diabetes complications results are large relative to previous studies that focus on developed countries, while the increased mortality risk estimates are comparable to the existing literature on increased pharmaceutical availability. Many studies on how expanded access to pharmaceuticals affects utilization, health outcomes, and mortality use the enactment of Medicare Part D in the United States, which expanded health care coverage to include prescription pharmaceuticals for in-

Figure 3: IMSS diabetes mortality hazard rates, 2003 – 2014



dividuals 65 and older starting in 2006. Estimates for the effect of this program on the increase in utilization in Lichtenberg and Sun (2007) and Yin et al. (2008) suggest that Medicare Part D increased utilization by 13 percent and 5.9 percent, respectively, well below the 42 percent increase in insulin utilization associated with the cartel's collapse.

The effects of the increased utilization on health are also large relative to existing studies. Again drawing upon the enactment of Medicare Part D, Hanlon et al. (2013) find no improvement in cholesterol levels despite increased utilization of cholesterol-lowering medications. Specifically related to diabetes complications, Simpson et al. (2016) finds a 4 percent decrease in the risk of developing new diabetes complications associated with medication adherence in the United States.

Previous studies on how access to pharmaceuticals affects mortality have provided mixed evidence. The most related study for insulin availability on diabetes mortality is Américo and Rocha (2020), which studies the effect of subsidies for insulin in Brazil and finds evidence of a decline in hospitalizations but only weak effects on mortality. In studies using Medicare Part D, Kaestner et al. (2019) find no effect on mortality, while Huh and Reif (2017) estimate a lower mortality risk driven

by reduced risk of cardiovascular death. Dunn and Shapiro (2019) echo this finding of reduced cardiovascular mortality and estimate that Medicare Part D prevented between 7,000 and 26,000 premature deaths out of 34.53 million individuals over 18 months. These estimates imply reduced deaths per million of between 205 and 764. The additional 569 deaths per million over the same period implied by the IMSS mortality estimates lies in the middle of this range.[35] One caveat is that the nature of Medicare Part D requires a focus on individuals age 65 and older. In contrast, the mortality analysis for the IMSS diabetic patients applies across the entire age distribution. Restricting attention to individuals above age 65 may yield a different rate of additional premature deaths.

The benefits of eliminating the IMSS insulin cartel were amplified by institutional factors in Mexico, including the high prevalence of diabetes, low insulin utilization relative to high-income countries, and other factors. Market design changes similar to those implemented by IMSS are likely to have the most significant impact in countries facing similar circumstances, such as the treatment of AIDS in many African countries. However, they may have smaller effects in high-income countries where treatment availability is high.

4.5 Placebo, Robustness, and Selection tests

Placebo tests and parallel trends robustness

Testing for pre-trends in insulin utilization: Using data from the 2000 ENSA survey, a precursor to the ENSANUT survey, I conduct a placebo test that categorizes 2000 as the pre-intervention period and 2006 as the post-intervention period.[36] This test investigates whether insulin usage among IMSS beneficiaries was already increasing

[35] This figure is reached by dividing the 2913 total deaths over three years into 18 months, yielding 1456.5 total deaths, and dividing this figure across the estimated number of IMSS diabetic patients in 2005 calculated from the ENSANUT survey data.

[36] Specifications which add the 2000 ENSA survey to the full data set and include Year$\times$IMSS interactions generate similar results; see Appendix E.

relative to other insurance groups in the years leading up to the collapse of the cartel.[37] A positive and significant coefficient would indicate that existing trends likely drove increases in insulin usage in the post-cartel period among IMSS diabetics rather than the price change resulting from the cartel's collapse. The results of these tests are reported in Panel A of Table 7, where column (1) includes base controls and column (2) adds health controls. The estimated coefficients are both low in magnitude and statistically insignificant, suggesting that the main results are not due to differences in pre-trends leading up to the fall of the cartel.

Table 7: Placebo tests

Panel A: Insulin usage 2000 vs 2006		
	(1)	(2)
IMSS × 2006	0.009	0.009
p-value	(0.709)	(0.739)
95% CI	$[-0.16, 0.03]$	$[-0.14, 0.04]$
Base controls	X	X
Health controls		X
Observations	4,145	4,145
Panel B: Other treatment		
	(3)	(4)
DiD coeff.	-0.004	-0.004
p-value	(0.898)	(0.901)
95% CI	$[-0.04, 0.21]$	$[-0.04, 0.19]$
Base controls	X	X
Health controls		X
Observations	5,773	5,773

Notes: Difference-in-differences coefficients for placebo tests on insulin utilization (Panel A) and adherence to nutrition plans (Panel B). For control definitions see Table 4. Wild cluster bootstrap p-values and confidence intervals are reported below each coefficient.

Possible contamination from other policy changes: My DiD estimation strategy exploits the collapse of a cartel due to market design changes. One issue that needs to be ad-

[37] It is not possible to perform a similar test using complications as the dependent variable as complications from diabetes are not recorded in the 2000 edition of the ENSA survey.

dressed is whether these results might be due to other policies overlapping with the period covered in the data. While restricting the control group to consist only of other social security programs eliminates many sources of policy contamination, such as the *Seguro Popular* expansion, the presence of other policies which had differential effects across the various social security programs constitute a potential threat to identification.

The primary health care policy change affecting diabetes patients in the social security system during the sample period was the introduction of national diabetes clinical guidelines issued by the Secretary of Health in 2008 (Secretaría de Salud (2008)), which included specific updates to treatment recommendations (e.g., Kuri Morales et al. (2007)). These clinical guidelines aimed to reducing adverse health outcomes resulting from diabetes, cardiovascular disease, and other non-communicable diseases and were published in 2008 with the goal to improve outcomes by 2012. All clinical recommendations issued by the Secretary of Health are national, unified guidelines authored by physicians from all leading public health care organizations. The main identifying assumption is that these clinical guidelines affected social security health care programs in the same way; that is, this program did not interact with IMSS differently than with other social security programs.

To investigate the suitability of this assumption, I perform a placebo test that estimates the DiD specification using another diabetes treatment, adherence to a nutrition plan, as the outcome variable. The use of nutrition plans are included in clinical guidelines for effectively managing diabetes, and the use of nutrition plans increased from 29 percent in 2006 to 36 percent in 2012. The recommendation of these plans by physicians and other medical professionals is unlikely to have been affected by the collapse of the insulin cartel. A significant increase in the adherence to these plans among IMSS beneficiaries may signal that overall improvements to IMSS diabetes care relative to other health organizations drive the main results. Specifications (3) and (4) in Panel B of Table 7 report the tests of this hypothesis, where specification (3)

includes base controls and specification (4) adds health controls. The estimated coefficients are neither large in magnitude nor statistically significant, providing evidence that the results are not due to overall increases in IMSS diabetes treatment quality.

Robustness to functional form: An additional way to examine parallel trends is to test the robustness of the results to different functional form specifications of the parallel trends assumption. As noted in Kahn-Lang and Lang (2019), different functional form assumptions in the regression specification effectively change the formulation of the parallel trends assumption. For instance, when the outcome variable has a log specification, the associated assumption is that trends are parallel as a proportion. In contrast, with a linear specification, the parallel trends assumption requires that the trends are parallel in levels. Varying the functional form used in estimation examines the robustness of the results to different versions of the parallel trends assumption. Table 8 shows the results of tests which vary the functional form of the regression for each outcome variable of Table 4. Column (1) presents the DiD coefficient with insulin use as the outcome variable when using a probit specification. [38] Column (2) shows the results with a logit specification. Finally, columns (3) and (4) show similar tests varying the functional form for the number of complications from diabetes, with column (3) showing the results using Poisson regression and column (4) using a log specification.[39] The results show that the main results are robust to different formulations of the parallel trends assumption.

Other robustness checks

Table 9 displays the results of other robustness checks, which include the addition of medical variables correlated with diabetes severity, separate effects by survey wave, and restring the sample to individuals diagnosed with diabetes prior to the cartel's

[38]The probit specification assumes that in the counterfactual of no intervention, the treatment and control groups would have moved by the same number of standard deviations of the normal standard error.

[39]Specifically, the transformed outcome variable is $\log(1+$ Number of Complications).

Table 8: Robustness tests – functional form

	Insulin		Complications	
	(1) Probit	(2) Logit	(3) Poisson	(4) Log
DiD coeff.	0.296	0.473	-0.314	-0.152
p-value	(0.032)	(0.040)	(0.047)	(0.023)
Base controls	X	X	X	X
Health controls	X	X	X	X
Observations	5,307	5,307	5,773	5,773

Notes: Difference-in-differences coefficients for the effect on insulin utilization and diabetes complications that mirrors Table 4 with changes to functional form. For control definitions see Table 4. Score bootstrap p-values (columns (1) - (3)) or wild cluster bootstrap p-values (column (4)) are reported below each coefficient.

collapse.

Inclusion of health care and pharmaceutical utilization controls: To avoid the inclusion of potentially endogenous variables, the specifications of Table 4 include only patient-level demographic and health status variables and do not include other factors relating to diabetes care and treatment. However, unobserved factors influencing diabetes severity may be correlated with the treatment group. To examine this, I add diabetes treatment variables correlated with the severity of diabetes to the main specifications. These include the frequency of diabetes-related medical visits and the use of oral anti-diabetic medications. Table 9 reports the results of these tests. The estimates remain statistically significant and similar in magnitude to the main results.

Separate time effects: Columns (2)-(3) and (6)-(7) show of Table 9 shows the estimated effects for the 2012 and 2016 ENSANUT waves separately, first with base controls and health controls and then adding diabetes medical controls defined above. The most precise estimates are obtained for the 2012 wave, the first survey wave after the cartel's collapse. The point estimate on insulin usage for 2016 is much higher but is only marginally significant at 10 percent. The effect on complications is similar across the 2012 and 2016 surveys, but as with the effect on insulin utilization, the

estimate becomes less precise for the latter year.

Table 9: Robustness checks for medical variables, time effects, and diabetes duration

	Insulin				Complications			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
DiD coeff.	0.056				-0.314			
	(0.031)				(0.021)			
IMSS × 2012		0.040	0.049	0.056		-0.305	-0.316	-0.321
		(0.030)	(0.022)	(0.026)		(0.034)	(0.029)	(0.024)
IMSS × 2016		0.090	0.083	0.064		-0.276	-0.305	-0.153
		(0.098)	(0.052)	(0.429)		(0.150)	(0.112)	(0.279)
Base controls	X	X	X	X	X	X	X	X
Health controls	X	X	X	X	X	X	X	X
Diabetes controls	X		X	X	X		X	X
Pre-collapse diagnosis				X				X
Observations	5,618	5,773	5,618	4,079	5,618	5,773	5,618	4,079

Notes: Difference-in-differences coefficients for robustness checks that include diabetes medical controls for the base specification (columns (1) and (5)), separate year effects (columns (2)-(4) and (6)-(8)), and restricting the sample to individuals diagnosed with diabetes prior to the collapse of the cartel (columns (4) and (8)). For base and health control definitions see Table 4. Diabetes controls are the use of oral diabetes medication and the number of diabetes-related doctor visits per year. Wild cluster bootstrap p-values are reported below each coefficient.

Restricting to diabetes patients with pre-cartel collapse diagnosis: One potential threat to identification is that IMSS responded to the collapse of the cartel by increasing resources dedicated to detecting and diagnosing diabetes. If newly diagnosed cases within IMSS are less severe than previously diagnosed cases, the main results of Table 4 might reflect this compositional change rather than the direct effects of the cartel's collapse.

While the subsequent section tests for additional diagnoses directly using MXFLS data, it is also possible to test for the effects of newly diagnosed diabetes patients on the main results using the ENSANUT data by restricting the sample to cases diagnosed before the cartel's collapse. Because this sample consists of those already having a diabetes diagnosis when the cartel collapses, the effects cannot be due to compositional effects resulting from newly diagnosed patients. Columns (4) and (8)

of Table 9 show the results from this specification with estimates similar to the main results, suggesting that new diagnoses are not driving the results.

Additional robustness checks: Appendix E contains further robustness checks. Robustness checks on insulin utilization and diabetes complications include dropping all individuals affiliated with SSPS or the private health care system in the main specifications of Table 4 and adding the 2000 ENSA data to the full sample in the placebo analysis of Table 7.

For the mortality analysis, Appendix E examines the sensitivity of the results to incorporating competing causes of death. This specification adds cardiovascular disease as a competing mortality risk following the model of Fine and Gray (1999). None of the results are significantly affected by these specifications.

Patient selection, diabetes diagnoses, and out-of-pocket expenditures

Lastly, I perform a series of tests on the assumptions of the DiD models estimated in previous sections using the longitudinal data from MXFLS. Specifically, I test for patient selection to examine whether diabetes patients were more likely to switch to IMSS following the cartel's collapse, changes to diabetes diagnoses to test whether IMSS became more likely to diagnose diabetes after the cartel, and how out-of-pocket expenditures for diabetes medication changed for individuals in IMSS relative to other social security groups.

Although the results are robust to controlling for observable individual characteristics, including additional diabetes treatment variables, I also examine whether diabetes patients were more likely to switch to IMSS coverage following the cartel's collapse. This test tracks individuals with non-IMSS coverage before the collapse and assigns a dependent variable equal to one if the individual switched to IMSS after the collapse. The DiD framework for this specification compares individuals with diagnosed diabetes prior to the fall of the cartel to those never diagnosed with dia-

betes and hence tests whether diabetic patients with non-IMSS social security coverage were more likely to switch to IMSS coverage than non-diabetics. A positive and significant effect would suggest that individuals with diabetes selected into IMSS coverage following the cartel's collapse, likely by finding employment in the formal sector. Column (1) of Table 10 gives the result of this test, which shows a statistically insignificant effect of having diabetes on switching to IMSS coverage. The result suggests that selection into IMSS coverage is not common; this is perhaps not surprising because changing to IMSS requires a change in employment by a household member, meaning that a change in job, employment sector, or location is required.

Secondly, I also test whether individuals within IMSS were more likely to be diagnosed with diabetes conditional on individual characteristics. This test uses the sample of all individuals without diagnosed diabetes in 2005 and compares individuals in IMSS to those with non-IMSS social security insurance. A positive and significant effect would suggest that the composition of individuals within IMSS changed due to, for example, the reallocation of resources previously spent on high-priced insulin toward additional diabetes testing and diagnosis efforts. This constitutes a potential threat to identification, as those diagnosed with diabetes due to these new efforts may have unobservable factors correlated with diabetes severity. Column (2) of Table 10 displays the results of this test. I find no significant effect of those with IMSS being more likely to be diagnosed with diabetes.

Finally, I test whether individuals in IMSS saw their out-of-pocket expenditures for diabetes medications decline after the cartel's collapse.[40] Given the paucity of information on procurement outcomes for other public health care providers, this serves as a check that the increase in insulin usage for IMSS diabetes patients is due to increased availability and not changes to prescribing behavior by IMSS physicians. Because medication shortages may prompt individuals covered by public health in-

[40]The MXFLS data contains the amount spent on all diabetes medications, not insulin specifically. Because this amount also includes any expenditures on oral anti-diabetic medication, this serves as a noisy measure of insulin availability.

Table 10: Effect of cartel collapse on insurance switches and diabetes diagnoses

	(1) DV: Switch to IMSS Sample: non-IMSS beneficiaries	(2) DV: Diabetes diagnosis Sample: non-diabetics
Diabetes × Post	0.023	
IMSS × Post		0.010
p-value	(0.492)	(0.260)
95% CI	$[-0.04, 0.09]$	$[-0.18, 0.13]$
Base controls	X	X
Health controls	X	X
Observations	11,349	10,148

Notes: Difference-in-differences coefficients which test for effects on the cartel's collapse to cause diabetic patients covered by other insurers to switch to IMSS coverage (column (1)) and whether individuals within IMSS were more likely to be diagnosed with diabetes relative to other insurance groups after the cartel's collapse (column (2)). Base controls are age, sex, height, weight, waist circumference, and fixed effects for insurance, survey wave, employment, education, and municipality. Health controls are smoking, hypertension, heart disease, and alcohol use fixed effects. Wild cluster bootstrap p-values and confidence intervals are reported below each coefficient.

surance to purchase medication from the private sector (Gidi (2010)), a negative effect on out-of-pocket diabetes medication expenditures among IMSS diabetes patients would indicate an increase in medication availability. Table 11 presents the results of this test, where column (1) uses a sample consisting of individuals who used diabetes medication in 2005, while the sample used in the specification for column (2) consists of all diabetic patients. The negative coefficients for IMSS out-of-pocket expenditures following the collapse of the cartel indicate that medication availability increased relative to those with other public social security health insurance, reinforcing the results of Section 4.2.

5 Conclusion

In this paper, I show that the market power wielded by a pharmaceutical cartel restricted the supply of insulin to a significant public health care provider and con-

Table 11: Effect of cartel collapse on diabetes medication expenditures

	(1) Used diabetes medication in 2005	(2) All diabetic patients
DiD coeff.	-230.015	-56.180
p-value	(0.041)	(0.037)
95% CI	$[-1092.46, -172.74]$	$[-559.77, -11.92]$
Base controls	X	X
Health controls	X	X
Observations	917	1,547

Notes: Difference-in-differences coefficients with the inclusion of diabetes treatment variables. Dependent variable is quarterly diabetes expenditures in Mexican pesos. For control definitions see Table 10. Wild cluster bootstrap p-values and confidence intervals are reported below each coefficient.

tributed to adverse health outcomes. Straightforward policy changes motivated by economic theory successfully stopped the cartel and improved access to diabetes treatment. Estimates of diabetes-specific mortality indicate that the shortage of insulin caused by the cartel contributed to 971 premature deaths annually.

Broadly, this study informs the evaluation of damages caused by cartels. Evaluating direct consumer harm, such as worsened health outcomes and increased mortality risk, provides a new way to measure the detrimental effects of collusion beyond price-theoretic welfare evaluations for intermediate goods that currently dominate the literature. While the direct monetary effects of the insulin cartel were substantial, including detrimental health effects and premature deaths significantly increased the appraisal of the damages generated by the cartel.

The effectiveness of IMSS policy changes in stopping collusion also informs the debate on how best to achieve equitable outcomes in lower- and middle-income countries. Markets in these countries are often beset by the problem of weak institutions, such as weaker competition authorities relative to developed nations (Bradford and Chilton (2018)). Market design is gaining attention as a means to combat weak institutions and alleviate inequality (Kominers et al. (2017), Roth (forthcoming)). Recent

discussions on the role of contracts and institutions in the allocation of health care resources within developing nations, particularly vaccines for COVID-19 (Phelan et al. (2020)), further enforce the importance of market design. The empirical results of this paper provide evidence that well-designed markets are crucial in achieving equitable outcomes.

While the ability of changes in market design to stop collusion is encouraging, the results paint a bleak picture of the potential for market power to disrupt the health and well-being of individuals. Much less is known about the functioning of markets in developing countries than in developed nations, often due to limited data availability. However, concerns of market disruption due to corruption and collusion are rife. Better understanding the propensity for these market inefficiencies to generate shortages in such goods as medicines, food, and housing will inform policies that enhance access to these necessities.

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Supplementary Appendix

Table of contents

A Cartel appendix

A.1 Theoretical framework

Consider the following repeated market for a homogeneous good. There are $I \geq 2$ identical firms, each with constant marginal costs c. There is a single consumer who demands multiple units of the good: all units up to q are valued at $v > c$, and any additional units have value 0. Firms engage in Bertrand competition to sell to the consumer, with the firm selling the lowest price selling q units to the firm provided $\min\{p_i\} \leq v$. If two or more firms are tied for the lowest price, they equally split the sale. Let $N^w = \#\{k \ : \ p_k = \min p_i\}$ denote the number of winning firms. The per-period profits for each firm i are

$$\pi_i(p_i) = \begin{cases} \frac{q(p_i - c)}{N^w} & \text{if } p_i = \min p_i \\ 0 & \text{otherwise} \end{cases}$$

Time is discrete, and the market repeats every period. Firms discount future profits at rate $\delta \in (0, 1)$. The optimal collusive equilibrium in grim trigger strategies sets $p_i = v$ for all firms, and each firm obtains a profit of $\pi^C = q(v - c)/I$. Should any firm deviate from playing $p_i = v$ in any period, firms play static Nash equilibrium strategies forever and earn no profits. The incentive compatibility constraint for the cartel is:

$$\sum_{t=0}^{\infty} \delta^t \pi^C = \frac{\pi^C}{1 - \delta} \geq q(v - c) \quad \Rightarrow \quad \frac{q(v - c)}{I(1 - \delta)} \geq q(v - c) \tag{2}$$

Renegotiation

When renegotiation is possible but costly, the ability of the cartel to collude will be determined by the cost of punishment. This is the prohibitive reneogitation cost γ, determined as

$$\gamma = \pi^C \left(\frac{1 - \delta^T}{1 - \delta} \right).$$

If renegotiation costs exceed the cost of punishing cheating, then firms will not cheat and collusion will continue; thus, γ is the prohibitive renegotiation cost that prevents renegotiation altogether. If γ is small, then even low renegotiation costs will be too costly for firms' to incur, and collusion will continue uninterrupted.

There are two components to the prohibitive renegotiation cost: the per-period collusive profits π^C, and the multiplicative punishment factor $\rho \equiv \left(\frac{1-\delta^T}{1-\delta}\right)$. The punishment factor changes non-monotonically with consolidation through its effect on the minimum punishment duration T. As N increases and T stays constant, the punishment factor decreases. However, when δ has becomes sufficiently small that an increase in the punishment length T is required to deter cheating, the punishment factor jumps up. Absent a change in the per-period collusive profits π^C, changes in the discount factor may increase or decrease prohibitive renegotiation costs depending on the change in the punishment length T.

In addition to frequency reduction, consolidation also affects per-period collusive profits, with N-period consolidation changing the per-period profit to $\tilde{\pi}_N^C = N\pi^C$. This means that consolidation will always increase the prohibitive renegotiation cost, as expressed in the following proposition.

Proposition 1 *For a fixed number of firms I, N-period consolidation strictly increases the prohibitive renegotiation cost:*

$$\gamma(\pi^C, \delta) < \gamma(\tilde{\pi}_N, \tilde{\delta}_N) \qquad \forall\, N \geq 2.$$

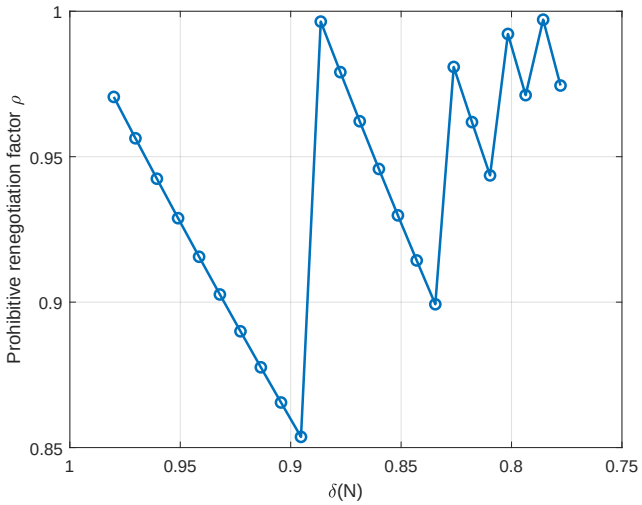
Proof. The inequality can be expressed as

$$\pi^C \left(\frac{1-\delta^{T(\delta)}}{1-\delta}\right) < N\pi^C \left(\frac{1-\tilde{\delta}_N^{T(\tilde{\delta}_N)}}{1-\tilde{\delta}_N}\right)$$

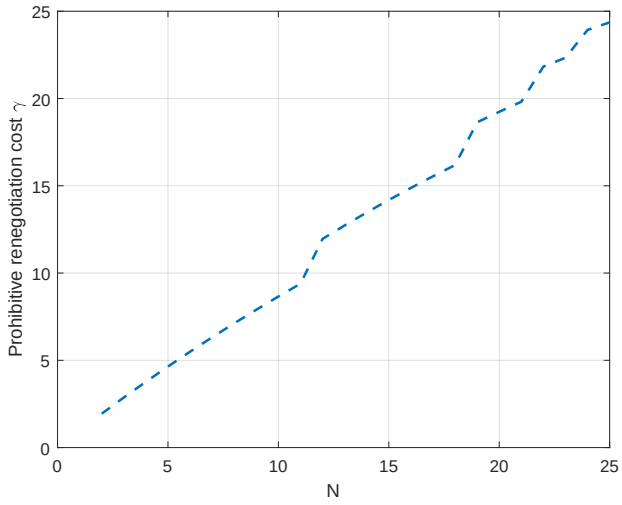
which requires that

$$N > \frac{(1-\delta^{T(\delta)})(1-\delta^N)}{(1-\delta)(1-\delta^{NT(\delta^N)})}.$$

Figure A.1: Prohibitive renegotiation under frequency reduction and consolidation



(a) Frequency reduction



(b) Consolidation

It is straightforward to show that the right hand side is always bounded above by N. First, we have that $T(\delta)$ is weakly decreasing: as δ increases, the punishment length T decreases. Recall that the punishment length T is the smallest natural number such that $(1-\frac{1}{I}) \leq \delta(1-\frac{1}{I}\delta^T)$, which means that $T(\delta)$ is the smallest positive integer such that

$$T \geq \frac{\log(I - \frac{I-1}{\delta})}{\log(\delta)}.$$

The right hand side is strictly decreasing in δ, which means that the minimum punishment period T is weakly decreasing in δ. This implies that $T(\delta^N) \geq T(\delta)$ for $N \in \mathbb{N}$, so that we have that $\frac{1-\delta^{T(\delta)}}{1-\delta^{NT(\delta^N)}} < 1$ for all N. Hence, we have

$$\frac{(1-\delta^{T(\delta)})(1-\delta^N)}{(1-\delta)(1-\delta^{NT(\delta^N)})} < \frac{1-\delta^N}{1-\delta} < N \qquad \forall \delta \in (0,1)$$

as $\frac{1-\delta^N}{1-\delta}$ is the N-th partial sum of $\sum_{t=0}^{\infty} \delta^t$. ■

Figure A.1 shows the effects of frequency reduction and the total effect of consolidation on the prohibitive renegotiation cost when $I = 4$ and a base discount factor of $\delta = 0.99$. Frequency reduction by itself, shown in Figure A.1a with δ^N on the x-axis, has a non-monotonic effect as N increases. Lower discount factors decrease punish-

ment costs for a fixed punishment length, thereby lowering the prohibitive renegotiation cost. However, once punishment costs are too low to deter cheating, another period of punishment is required and the prohibitive renegotiation cost increases.

Once the increase in per-period quantity is also considered, punishment costs increase monotonically, expressed in Figure A.1b as a multiple of the original per-period profits π^C. While increases to the discount factor can lower punishment costs by reducing present-time discounted costs, this reduction is always lower in magnitude than the effect of increasing per-period profits by a factor of N.

Price leadership and tacit collusion

While the repeated Bertrand model discussed above assumes that firms collude explicitly, consolidation can also interfere with efforts to collude tacitly via price leadership. The empirical evidence of Byrne and De Roos (2019) shows how firms can use prices as signals to other firms to coordinate price increases. Frequency of market interaction plays a key role in the viability of price leadership strategies. In the retail gasoline setting of Byrne and De Roos (2019), one firm used higher daily prices in a specific pattern to signal to other firms' their intent to raise markups. This facilitated a gradual transition to a higher price equilibrium. Communication via price signaling at lower frequencies, such as at a weekly or monthly level, may slow the pace of the equilibrium transition and make this coordination less profitable for the price leader.

The importance of frequency arises in theoretical price leadership frameworks as well, such as the oligopoly model of Miller et al. (2021) in which markups above the competitive level are determined by a timing parameter η that depends on the per-period discount factor:

$$\eta = \frac{\delta^{\tau_1} - \delta^{\tau_1+\tau_2}}{1 - \delta^{\tau_1+\tau_2}}$$

where τ_1 is the number of periods in which deviation profits are realized and τ_2 is the length of the punishment period during which firms obtain Bertrand profits. This tim-

ing parameter generates greater supermarkups for more patient firms: as δ increases, prices and markups increase. Consolidation decreases δ which, holding punishment and deviation periods fixed, lowers η and decreases supermarkups. As with explicit collusion, reducing frequency lowers the capacity for firms to coordinate on higher prices.

Other potential changes to reduce collusion damages

While IMSS made changes to the number of auctions and possibility of entry, there are other changes they might have considered to combat collusion. Once IMSS realized that a cartel was likely operating, lowering the reserve price would be the most direct way to limit the damages caused by the cartel. While the cartel may still have been able to operate for any reserve price $v > c$ within the context of the model above, this lower price would clearly limit cartel damages and may have induced IMSS to increase insulin purchases. Another alternative might have been to suppress information available to the cartel members. As each firm knew the bids submitted by all other firms, monitoring within the cartel was made easy. Withholding this information, such as not revealing the identity of the winner, may have undermined the cartel as it encourages cheating on the cartel agreement. However, this policy is difficult to implement in practice, as many procurement laws require public release of contract details and firms operating in the same industry are likely aware of rival firms being awarded large government contracts even without public release of this information.

A.2 Collusion implementation and legal proceedings

This appendix provides additional details on the IMSS insulin procurement market, discussing the susceptibility of the market to collusion, the pricing strategies of the firms involved in the cartel, and a timeline of events leading to the cartel's investigation and prosecution.

IMSS procurement auctions are first price sealed bid auctions. During the cartel period, procurement procedures stipulated that bids would be revealed in the presence of representatives of all participating firms for each procurement auction, which allowed each firm to monitor the bids placed by that firm's rivals. Each procurement auction had the potential for the contract to be split among multiple winners: if this provision was in place, all eligible bidders within 1.5 percent of the lowest bid would split the contract. If multiple winners were not permitted, a winner would be selected at random from the set of all bidders within 1.5 percent of the lowest bid.

There are several factors that made the auction markets for IMSS pharmaceuticals susceptible to collusion. Bidding information was publicly available to firms, but was not aggregated and shared across the 52 procurement units of IMSS. This meant that each firm was able to monitor other firms' bidding behavior for deviations from the collusive agreement, but IMSS authorities were not able to directly discern the high pricing patterns that prevailed across the 52 units. High reserve rates also contributed to cartel formation: the cartel set prices around the IMSS reserve price for insulin of Mex$155 per unit, and as evidenced by prices from 2007 onward this was far above firm marginal costs. Moreover, no changes to the reserve price were made in conjunction with the other policies enacted by IMSS. Barriers to entry, such as numerous regulatory requirements and restrictions on eligible firms, kept the number of bidders low. Finally, as discussed in the main text auction frequency was extremely high with up to several auctions every month.

While no direct evidence of firm pricing strategies was ever released, either in the form of sworn witness testimony or wiretap evidence, the cartel appears to have followed a bid rotation strategy. In this framework firms take turns placing the lowest bid in the auction, with the other firms in the cartel submitting "decoy" bids intentionally higher than the bid of the winner. In the insulin auctions, the winning bid was routinely placed at or just below Mex$155, while the bids of the other firms were nearly always between Mex$157.50 and Mex$158.50. The CFC also alleged that firms

used the possibility to split the auction award as a means to divide market share. Prior to consolidation, the insulin sale could be split among multiple firms if the bids were within 5 percent of the lowest bid. This presented a mechanism for firms to more evenly allocate market share in cases where there was variation in quantity across auctions. According to the CFC, cartel participants made frequent but not exhaustive use of this policy, indicating that it may have played a role in facilitating collusion.

The CFC further alleged that cartel participants used shared membership in a pharmaceutical industry association, CANIFARMA, and phone calls between cartel participants to coordinate the bid rotation. To support these assertions, the CFC presented evidence that phone calls were frequently placed between individuals implicated in the cartel's operation just prior to auctions being held, and that representatives of the cartel firms often jointly attended CANIFARMA events. While the contents of these communications remain unknown, it is clear that the firms were frequently communicating during the cartel period.

Finally, limited information is available on the activities of non-cartel firms during this period. According to figures presented by the CFC in the collusion case documents, non-cartel members would sometimes bid similarly to the cartel (e.g., per-unit prices around Mex$155). In other instances, they would submit bids noticeably lower than the cartel price but still well above the more competitive prices reached in 2006 (e.g., per-unit prices around Mex$155). Why these firms did not enter more auctions and further disrupt the cartel is not entirely clear. The CFC posits that these firms were too small to compete on a national scale, and so would only participate in auctions held by nearby procurement divisions, such as those within their state, and would forgo other auctions. This limited geographic scope would reduce their impact on the cartel's ability to operate in other areas.

Table A.1 details the timeline of events surrounding the insulin cartel's discovery, prosecution, and eventual conviction. No other substantial changes, such as a change to reserve price policy, were made during this period. A formal investigation into

bid manipulation was initiated in August of 2006, after the change to entry regulations had led to a substantial price decline. Charges were brought and a decision was reached in 2010; the case number was IO-03-2006. All bid information related to the four participants of the insulin cartel and the 2006 entrant Dimesa were obtained from the court documents of this case.

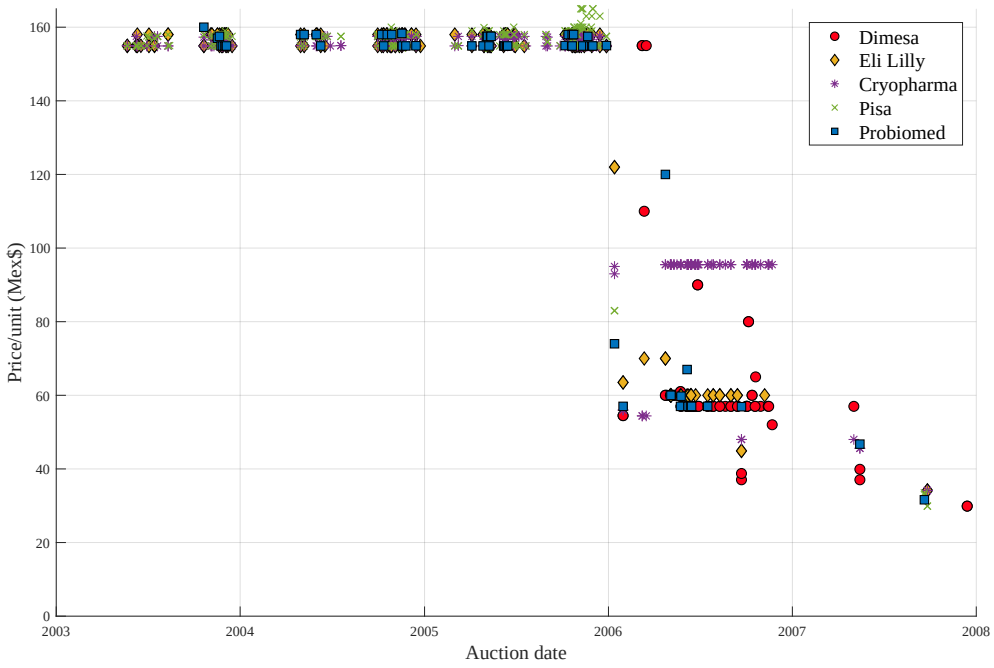
Table A.1: Timeline of Events, 2002-2010

2002	*April 17*: The CFC fines multiple companies for manipulation of bids in procurement auctions for radiographic materials. *April 30*: The CFC gives recommendations to IMSS to adjust the bidding procedures for procurement auctions to better facilitate competitive bidding.
2005	The IMSS decides upon changes to its bidding regulations, which include relaxing barriers to entry and future consolidation of procurement auctions.
2006	*Jan 1*: Reductions to barriers to entry take effect. *Jan 30*: Dimesa participates in its first auction for insulin. *August 15*: CFC begins official investigation into bid rigging in IMSS procurement auctions.
2007	IMSS centralizes procurement auctions.
2010	CFC concludes investigation, resulting in fines and criminal charges for six companies and eight individuals.

A.3 Bidding analysis

This appendix describes additional features related to the cartel's operation and collapse. A comparison to the other drug categories that experienced collusion in the IMSS procurement auctions is also provided to highlight the disruptive effects of entry and to provide additional evidence for the effects of consolidation on collusion

Figure A.2: All insulin auction bids, 2003 - 2007



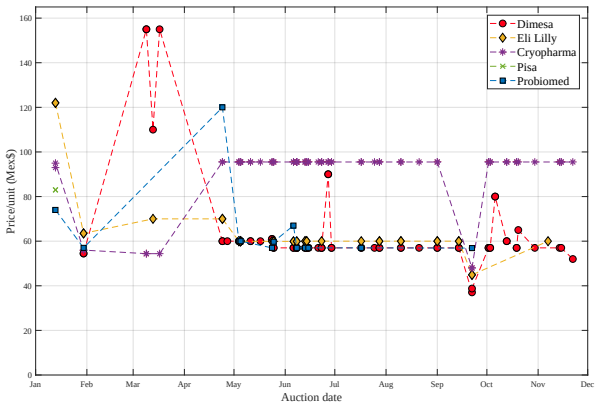
breakdown.

Figure A.2 shows all bids placed in IMSS insulin auctions by the four cartel members and Dimesa from May 2003 through the end of 2007. As in Figure 1a, there are three relevant time periods: 2003 through 2005, after the new entrant arrived in 2006, and the 2007 consolidation. Observing all bids provides additional insight into the cartel's operation: as mention in the previous section, the cartel appears to have used a bid rotation scheme, witch losing bids between $157.50 and $158.50 while winning bids were submitted near the reserve price of $155.00. Figure A.2 provides graphical support for this statement, displaying a narrow range of bids placed during the cartel period with extremely low variation. At the start of 2006 there is a sudden price decline. This period is notable for displaying not only lower prices but also increased variance in bids both across firms and over time. Finally, a further bid reduction occurs during 2007.

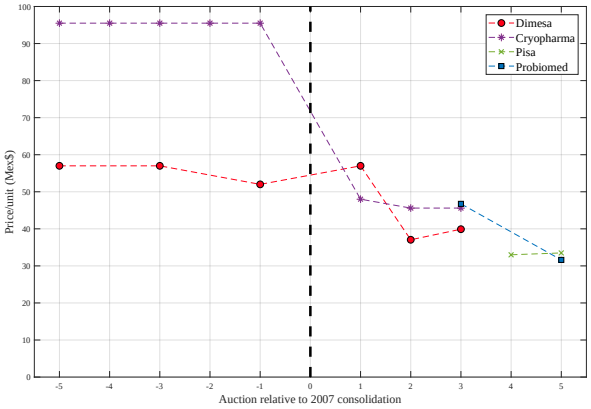
The bidding patterns for the period of the cartel's collapse from 2006 through 2007

Figure A.3: Insulin auction bids, 2006 – 2007

(a) 2006



(b) Late 2006 - Early 2007



are shown in more detail in Figure A.3. Panel (a) shows all bids placed during 2006. The bid levels of the incumbent firms drops well below the established cartel price in the first auction of 2006, possibly in anticipation of the entry of Dimesa. Dimesa subsequently enters at the end of January, winning the auction with a bid just under Mex$60. This suggests that the impending entry of Dimesa was responsible for the initial cartel breakdown and price decline.

Next, Dimesa submits very high bids in the auctions immediately following its entry, on two occasions submitting bids of exactly Mex$155.00, the previous collusive price, and on another submitting a bid of Mex$110.00, well above it's previous winning bid at the end of January. This indicates a willingness to price above the competitive level. Given the previous bids submitted by the other firms up to that point in 2006, it is unlikely that Dimesa expected to win these auctions with these high bids. Rather, these bids represent signals to the other firms of a willingness to engage in supracompetitive pricing strategies.

While two of the other firms, Probiomed and Cryopharma, use their own bids to signal a willingness to engage in these high-bid strategies, no other firms follow. Hence, the winning bid for most of the rest of 2006 stabilizes around Mex$60/unit. However, this price signalling by Dimesa may have prevented further price declines.

These further price declines eventually occurred following the consolidation of procurement in 2007. In the first auction of the year, Cryopharma, who up to that point had placed bids of Mex$95.00 in nearly all auctions, undercuts Dimesa by submitting a bid of Mex$48.00. This instigates further reductions from Dimesa and the other firms, eventually causing winning bids to fall below Mex$40.00.

A.4 Indirect monetary costs of the cartel

The direct monetary costs associated with higher insulin prices paid by IMSS, approximately Mex$610 million (US$49 million) were substantial. However there are also indirect economic consequences resulting from increased cost of care for diabetes complications. Recent cost estimates for diabetes care for patients within the IMSS health system indicate total annual costs for treating diabetes complications are US$296.3 million (Arredondo and Reyes (2013)). Here, I perform a back-of-the-envelope calculation to examine how the additional costs of treating diabetes complications relates to the direct monetary costs of the cartel.

Weighting each complication's total treatment cost in Arredondo and Reyes (2013) by the point estimate of individual complication effects (see Figure F.1) implies a total increase in annual treatment costs of US$54.75 million as a result of the increase in complications resulting from the cartel. This large increase is due to the fact that many of the most expensive complications to treat also saw substantial declines due to the cartel's collapse: retinal damage, blindness, and dialysis are among the most expensive complications within IMSS according to Arredondo and Reyes (2013), and these complications all experienced declines after the cartel's collapse.

This cost increase is substantial relative to the direct monetary costs: the annual cost of increased care for diabetes complications exceeds the entire, three-year direct monetary cost of the cartel. This suggests that direct monetary costs may be substantially downward-biased if they do not take into account the downstream effects on

consumers.

A.5 Comparison to other collusive IMSS pharmaceutical markets

As noted in Section 2, a total of 20 drug categories were found to exhibit collusive pricing practices by the CFC. Insulin represented two of these categories (intermediate and rapid acting insulin), while 18 varieties of saline solutions accounted for the remaining categories. According to the CFC's resolution on the bidding rings (Comisión Federal de Competencia (2010)), the saline solution markets did not experience entry of a major competitor between 2003 and 2007. Moreover, the set of firms involved in the bidding rings for saline solutions differed from the insulin market: only one firm, Pisa, that was active in the insulin bidding ring was also active in the market for saline solutions. The other two firms fined in the saline markets were Baxter and Fresenius. Table A.2 presents summary statistics for these markets, displaying the averaging winning bid in 2005 and 2007 and the number of auctions per year from 2003 to 2007.

Comparing the price dynamics of the saline solution markets to the insulin market gives insight into the effects of the market design changes implemented by IMSS. Figure A.4 plots annual mean price indices for each drug. The index is constructed by setting the average winning bid in 2005 equal to 100 for each drug category. Two features are notable. First, only in the insulin market is there a significant decline in price in 2006. As the insulin market was the only market to experience entry, and the regulatory environment was constant across all markets during this time, this strongly suggests that the entry of Dimesa was the primary cause of the insulin price decline in 2006.

Second, all drug categories experience a significant price decline in 2007. While it is difficult to account for all external factors affecting procurement markets during this time period, the fact that procurement consolidation had a similar effect on all

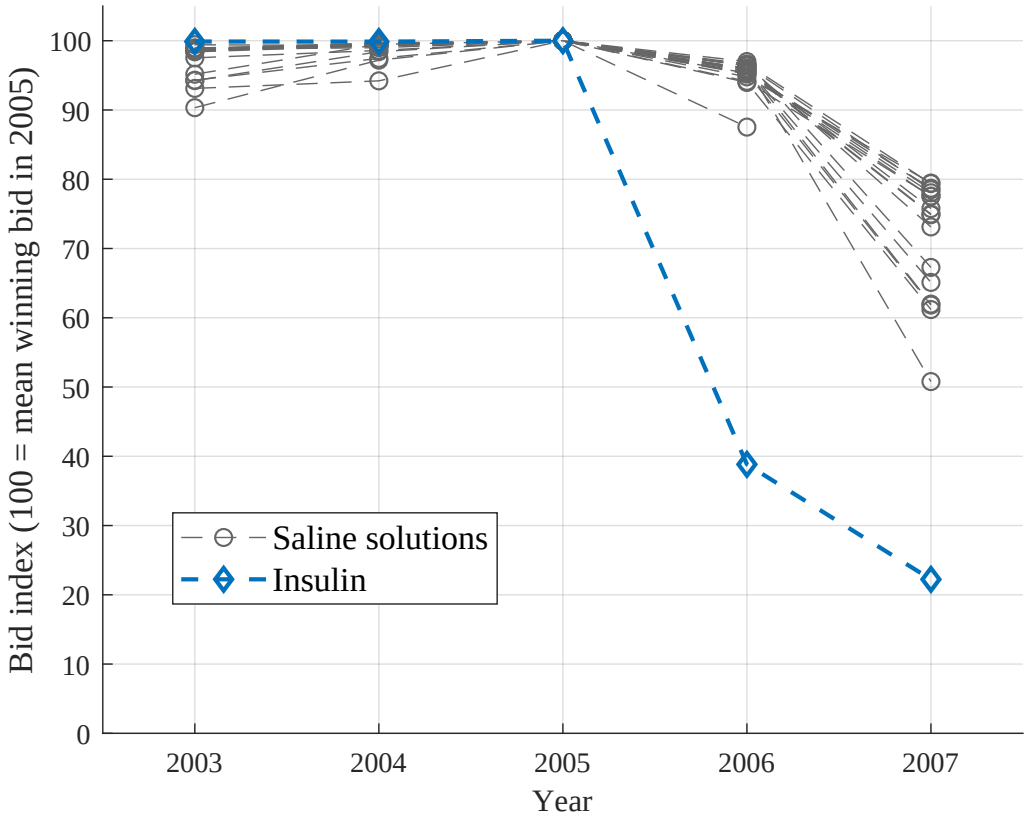
Table A.2: Summary Statistics, saline solution auctions

	Number of Auctions						
Drug ID	2003	2004	2005	2006	2007	Mean Price 2005	Mean Price 2007
3601	23	36	68	27	1	9.40	7.12
3603	24	37	64	27	2	14.72	11.49
3604	23	39	63	22	4	12.60	8.47
3605	21	31	60	20	2	14.76	11.45
3608	23	35	70	32	1	9.39	5.82
3609	23	33	65	33	1	12.59	9.44
3610	23	36	67	33	2	14.71	9.57
3611	11	17	20	11	0	12.08	-
3612	22	33	58	36	2	12.58	9.87
3613	24	37	68	34	3	14.70	11.57
3614	24	31	54	25	1	9.40	7.46
3615	23	33	66	33	3	12.58	6.39
3616	25	34	67	37	1	14.76	11.05
3624	16	35	55	23	3	6.60	5.24
3625	6	15	21	13	1	8.30	5.08
3626	24	36	58	32	2	6.59	5.12
3627	12	19	25	16	1	8.22	5.08
3675	24	35	65	30	2	9.61	7.03

Notes: Summary statistics for the non-insulin drug categories which contained collusive bidding practices according to the CFC's ruling. Each drug ID represents a type of saline solution. Mirroring the procurement market for insulin, the number of procurement auctions for each drug declined dramatically in 2007 following the procurement consolidation efforts of IMSS.

drug categories, despite being different markets with different sets of colluding firms across the drug categories, strongly suggests that procurement consolidation was the main impetus for the rapid reduction in prices across markets.

Figure A.4: Comparison of insulin and saline solution prices, 2003-2007



B Data appendix

B.1 ENSANUT data

The ENSANUT survey contains a section related to diabetes in each wave of the survey. These questions are reached via a gateway question that determines whether the individual has been diagnosed with diabetes or high blood sugar. Specifically, the question, taken from the ENSANUT 2006 questionnaire, reads "Have you been told by a doctor that you have diabetes or high blood sugar?".[41] If the response to this question is yes, the remaining questions in the diabetes section, pertaining to diabetes treatment and health outcomes, are answered. All respondents who answered yes to this question are included in the diabetes sample used in the analysis of ENSANUT data, subject to having completed responses to other health and demographic fields. The diabetes questionnaire does not distinguish between Type I and Type II diabetes, so it is not possible to break down the health effects across these two diabetes categories.

The "Insulin" variable is recorded as one if the individual reports using insulin to control diabetes and zero otherwise. Specifically, the questionnaire asks if individuals use insulin, oral medications, both, or no diabetes medication. If the individual responds "insulin" or "both," the insulin variable is recorded as one for that individual and is zero otherwise.[42]

The "Complications" variable is constructed as the sum of the eight individual complications associated with poor long-term management of diabetes contained in the data: diminished visual acuity, retinal damage, blindness, loss of sensation, ulcers, amputation, heart attack, and dialysis. The questionnaire asks each complication separately within the same section, with each question specifying that the complica-

[41] Original questionnaire text in Spanish: "¿Algún médico le ha dicho que tiene diabetes o alta el azúcar en al sangre?"

[42] Original questionnaire text in Spanish: "¿Actualmente toma pastillas o le aplican insulina para controlar su azúcar?" with responses "1. Insulina, 2. Pastillas, 3. Ambas, 4. Ninguno".

tion is brought on by diabetes. For example, the blindness complication is recorded as one if an individual answered "Yes" to the question "Due to diabetes, have you lost your sight?" and is zero otherwise.[43]

The controls used are age, height, weight, waist measurement, sex, diabetes duration, insurance provider, municipality, year, education, employment, hypertension, cholesterol, smoking, and alcohol use. Smoking is recorded as one if the individual reported ever having smoked in their life. Alcohol is recorded as one if the individual reported that they currently drink alcohol (with any frequency). For employment variables, individuals were recorded as "Working" if they reported working within the last two weeks, "Retired" if they reported being retired or on a pension, and "Not working" otherwise. While direct measures of income are available, these are frequently missing and would result in a large decrease in the number of observations if used. The final sample consists of all individuals with non-missing entries to each of the controls above plus insulin utilization and complications from diabetes.

B.2 Procurement and insulin price data

Data on procurement auctions held by IMSS comes from two sources. The first are court documents related to the legal proceedings against the four cartel members (Comisión Federal de Competencia (2010)); these proceedings are discussed in Appendix A. All data related to bidding during the years 2003 - 2007 are obtained from the court documents related to the case published on the (now-defunct) CFC website. Table 1 uses information published in the main text of these documents. Bid information for the four cartel participants in the insulin cartel and the 2006 entrant Dimesa are contained in appendices; these data are used in the construction of Figure 1a. Each appendix contains the bids placed by the relevant parties for every drug category for which bid manipulation was alleged. In the case of insulin, this consists of two cat-

[43]Original questionnaire text in Spanish: "¿Debido a la diabetes ha perdido la vista?".

egories, 1050 and 1051, which correspond to intermediate and rapid-acting insulin, respectively.

The second source of data is the IMSS purchase portal.[44] This is a web resource that documents purchases made by IMSS dating back to 2011. Because some contracts issued in previous years were still active during 2011, data on insulin purchases can be obtained back to 2009. I collected all contracts labeled as public tenders for the two insulin categories affected by the cartel, 1050 and 1051, from the earliest contracts available up through the end of 2018. These data are used in Figure C.1 for auctions occurring from 2009 onward (note that no data is available for auctions occurring in 2008).

Finally, data on aggregate IMSS insulin purchases (presented in Figure 1 and Table 1), are the same as the data used in Estrada and Vazquez (2013). Bounds are generated by a discretionary budget that permits procurement authorities to increase insulin purchases up to a threshold. For example, in the post-consolidation period IMSS generally holds one or two large-quantity insulin auctions per year. They may subsequently decide to increase insulin purchases either by exercising an option in the contract of a previous auction winner that permits further units to be purchased at the same price or by holding another procurement auction. The price and quantity data suggest that while prices and quantities varied substantially over this period, the budget range, or difference in cost between the upper and lower quantity limits, was relatively stable. The average annual budget range for 2003 through 2005 (assuming prices of Mex$155 per unit) was Mex$92 million, while in 2007 at an average price of Mex$34.35 the budget range is Mex$91 million.

B.3 INEGI data

This section contains additional information on the INEGI mortality data. The data were obtained from the INEGI data portal (`https://en.www.inegi.org.mx/datos/`).

[44] The IMSS purchasing portal can be accessed at compras.imss.gob.mx.

Cause of death is indicated by a four character alpha-numeric code, where the first character is a letter that indicates a specific category of causes and the following three characters are numbers that give the specific cause of death within that category. I classify deaths as caused by diabetes if the codebook that gives descriptions of each cause contains the word "diabetes." This corresponds to category E100 - E149. Other categories have different classifications. In the competing risk analysis of Appendix E, I classify cardiovascular disease as a competing risk.

Deaths are classified according to International Classification of Diseases (ICD) codes using the 10th edition of these classifications, or ICD-10. The purpose of this system in determining the cause of death is to assign a code corresponding to the underlying cause of death; in other words, the conditions that started the chain of events that resulted in death. In the case of diabetes, many of these codes include other conditions or causes. For example, many diabetes deaths result from kidney failure. If diabetes was identified as the primary cause of kidney failure, the cause of death would be coded as diabetes and assigned a diabetes ICD-10 code that listed kidney failure as an associated cause. One example code for the above scenario is E11.2, described as "Type 2 diabetes mellitus with kidney complications".

Finally, I categorize education and occupation as follows. Education is separated into the following categories: No formal schooling, some primary school, completed primary school, completed secondary school, completed at least some college, and has a professional or graduate degree. Occupation is also categorized into groups using the first digit of the two-digit classification system used by INEGI until 2013. These categories are: not working, professional and technical services, education and art, managerial roles, agriculture and livestock, industrial production and machinery operators, administrative workers, sales, and personal and professional services.

Table B.1: INEGI mortality statistics

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Sex (pct. female)	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.44	0.44	0.44	0.44	0.44	0.45
	(0.50)	(0.50)	(0.50)	(0.50)	(0.50)	(0.50)	(0.50)	(0.50)	(0.50)	(0.50)	(0.50)	(0.50)	(0.50)	(0.50)	(0.50)
Age at death	65.29	65.65	66.65	66.31	66.49	66.71	66.63	66.74	66.71	66.93	66.78	66.61	66.85	67.37	68.06
	(19.16)	(19.09)	(19.09)	(18.94)	(18.85)	(18.84)	(18.79)	(18.76)	(18.87)	(19.06)	(19.20)	(19.15)	(18.99)	(18.77)	(18.60)
IMSS	0.36	0.36	0.36	0.36	0.35	0.35	0.35	0.35	0.34	0.34	0.34	0.34	0.35	0.35	0.35
	(0.48)	(0.48)	(0.48)	(0.48)	(0.48)	(0.48)	(0.48)	(0.48)	(0.48)	(0.47)	(0.47)	(0.47)	(0.48)	(0.48)	(0.48)
Diabetes cause of death (pct.)	0.12	0.13	0.14	0.14	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.16	0.16
	(0.33)	(0.34)	(0.34)	(0.35)	(0.36)	(0.36)	(0.36)	(0.36)	(0.36)	(0.36)	(0.36)	(0.36)	(0.36)	(0.36)	(0.37)
Observations	378681	386626	402427	417543	419477	442437	442690	462931	488702	514288	541891	538507	551704	573652	574423

Notes: This table displays summary statistics by year for the INEGI mortality data. Means are listed in the table with standard deviations in parentheses below.

B.4 MXFLS data

Summary statistics for individuals with diagnosed diabetes are contained in Table B.2. The table is separated by survey round, with Round 1 surveys being held in 2002, Round 2 surveys held in 2005-2006, and Round 3 surveys held over 2009-2012. For the empirical analysis using the MXLFS data in Section 4.5, I treat all Round 2 survey responses as occurring during the cartel phase, i.e. before the collapse of the cartel. This is motivated by the fact that the majority of surveys that occurred during 2006 were conducted during the first three months of the year and changes to the variables measured by the MXFLS survey, namely IMSS insurance coverage, diabetes diagnosis, and out-of-pocket diabetes medication expenditures, were unlikely to react instantaneously to the cartel's collapse. Round 3 surveys were primarily conducted in 2009 and early 2010: approximately 60 percent of visits were completed by the end of 2009, and 78 percent were completed by the end of Feb 2010.

The variables follow the same definition conventions as the ENSANUT data. The only variable that appears in MXFLS that does not appear in the ENSANUT data is "Diabetes expenditures," which represents out-of-pocket diabetes medication expenditures. This variable gives the amount spent on diabetes medication during the previous three months. This variable increases from Round 1 to Round 2, possibly reflecting an increase in average diabetes severity, before falling during the 2009-2012 surveys.

Table B.2: MXFLS diabetes summary statistics

	Round 1	Round 2	Round 3
Fraction of adults with diabetes	0.068	0.069	0.080
	(0.25)	(0.25)	(0.27)
Ever smoked	0.22	0.15	0.18
	(0.42)	(0.36)	(0.38)
Drinks alcohol	0.35	0.26	0.28
	(0.48)	(0.44)	(0.45)
Hypertension	0.36	0.34	0.36
	(0.48)	(0.47)	(0.48)
Heart disease	0.08	0.06	0.06
	(0.27)	(0.23)	(0.23)
Age	55.96	56.15	56.62
	(12.18)	(12.52)	(12.87)
Sex (male)	0.35	0.44	0.39
	(0.48)	(0.50)	(0.49)
Height (cm)	155.74	159.60	156.43
	(9.56)	(10.79)	(9.88)
Weight (kg)	70.25	72.32	71.99
	(14.25)	(14.40)	(15.31)
Waist circumference (cm)	92.41	98.32	1.05
	(11.33)	(12.14)	(0.32)
Employed	0.37	0.45	0.42
	(0.48)	(0.50)	(0.49)
Less than primary school	0.20	0.14	0.17
	(0.40)	(0.35)	(0.37)
Primary school	0.61	0.60	0.55
	(0.49)	(0.49)	(0.50)
Secondary school	0.14	0.20	0.21
	(0.35)	(0.40)	(0.41)
Some college or more	0.05	0.06	0.06
	(0.21)	(0.24)	(0.24)
IMSS	0.42	0.45	0.42
	(0.49)	(0.50)	(0.49)
Diabetes expenditures	433.17	516.64	304.15
	(1580.96)	(1737.58)	(1241.66)
Observations	648	454	1411

Notes: This table presents summary statistics for adult diabetic patients in the Mexican Family Life Survey for each survey round. Round 1 surveys were conducted in 2002, Round 2 surveys in 2005-2006, and Round 3 surveys in 2009-2012. Means are listed in the table with standard deviations in parantheses below.

C Procurement in other sectors

This appendix discusses insulin procurement in other sectors to examine how the collapse of the IMSS insulin cartel might have affected insulin availability outside of IMSS beneficiaries. As noted in Section 2, the presence of such spillovers would complicate the interpretation of the main results. However, available data on prices and purchases after the cartel's collapse and institutional details of the changes implemented by IMSS suggest these spillovers are unlikely to impact the results significantly. Appendix D supplements this discussion by examining the robustness of the main results in designating privately insured individuals, who are unlikely to be affected by spillovers across public procurement programs, as the control group.

There are several ways in which the IMSS insulin cartel collapse might have had spillover effects on other markets. Some of these potential spillover effects are positive. For example, if firm conduct changes in IMSS procurement also impacted conduct in other markets and generated lower prices and markups, then insulin availability in other markets would have increased due to the cartel's collapse. Because positive spillovers will generally lead to underestimation of the health effects of the cartel, I focus most of the discussion on potential negative spillovers from the cartel's collapse, i.e., spillover effects that would have decreased insulin availability in other markets.

Spillovers to other markets that might have reduced insulin availability could be generated by production capacity constraints, increasing industry marginal costs of producing insulin, or market conduct. If there are production limits to insulin supply or firms face increasing marginal costs of insulin production, increased purchases by IMSS may have lowered availability and raised prices in other sectors. Additionally, firms that participate in IMSS procurement auctions may be present in other markets, and changes in the IMSS market might cause changes in pricing strategy or firm conduct in other markets.

C.1 Capacity constraints and marginal costs

There is little evidence that firms faced capacity constraints on insulin production during this period. Overall insulin utilization, discussed in Section 3 below, increased dramatically during this period, increasing from 7 percent of diabetes patients in 2005 to 19 percent in 2015. Much of this increase is driven by the expansion of *Seguro Popular*, which enrolled over 50 million beneficiaries during this period. Moreover, the reduction in entry barriers implemented by IMSS in 2006 may have increased insulin supply to the public health sector. The regulation change allowed importers and distributors of insulin to participate in IMSS auctions. This change facilitated the entry of Dimesa into the IMSS procurement auctions and permitted the entrant and incumbent multinational firms, such as Eli Lilly, to supply imported insulin to IMSS.

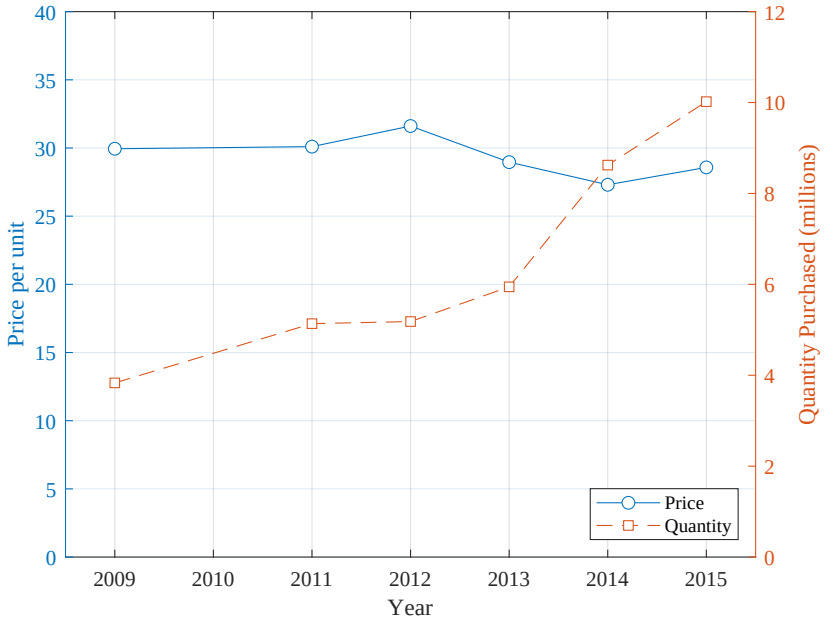
Marginal costs appear to have stayed constant despite large increases in purchase quantities. Data from contracts for insulin issued by IMSS between 2009 and 2015, displayed in Figure C.1, shows that despite significant increases to purchase quantities in the years following the cartel collapse, the per-unit cost paid by IMSS remains level during this period. Because theories of bidding in first-price sealed-bid auctions predict that winning bids should be increasing in both own and rivals' costs, this suggests that average costs per unit have not increased. Without increasing marginal costs of insulin production, negative spillovers on other markets due to increased demand from IMSS are unlikely.[45]

C.2 Firm conduct

Finally, firms may have altered their market conduct in response to the IMSS cartel collapse. Two scenarios are of central concern. First, firms may have initiated anticompetitive price increases in other markets. Available evidence suggests this was

[45]Constant marginal costs is also consistent with assumptions employed elsewhere in the empirical literature on pharmaceutical pricing; see Chaudhuri et al. (2006) and Dubois and Lasio (2018) for examples.

Figure C.1: Prices and quantities of IMSS insulin, 2009 - 2015



not the case. Following the IMSS insulin case, other procurement programs instituted reviews of their procurement policies and data, including two reviews of the ISSSTE market published by the OECD (OECD (2013, 2016)). The CFC alleged no collusive conduct in these markets, and no firms or individuals faced charges for price-fixing of insulin.

Second, firms may also have internalized the price effects of IMSS purchase changes in other markets. Because evidence suggests that switching between social security programs is rare (Table 10), the primary issue is whether firms active in the private market changed their prices in response to increased public-sector purchases. To the extent that individuals affiliated with IMSS previously relied on out-of-pocket private sector purchases to acquire insulin, firms' pricing decisions in the private market may have changed depending on how residual demand for private insulin is affected by the increased availability of IMSS insulin.[46]

[46] Analysis of market power in the private market is complicated by the difference in product availability across sectors, as within the public health system, typically only generic insulin is available,

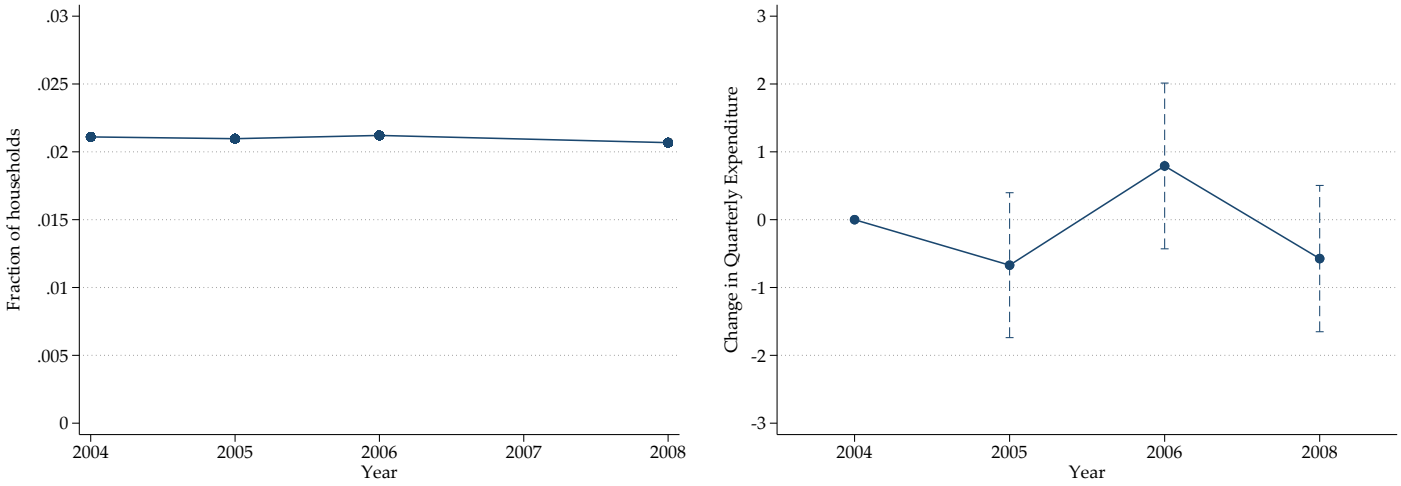
Previous empirical results suggest that prices should have decreased, rather than increased, in the private market following public procurement expansion. Brugués (2020) studies the market for pharmaceuticals in Ecuador consisting of a public procurement auction market and a private market, a similar structure to the Mexico pharmaceutical market.[47] The estimated model predicts that price increases in the private sector are generated by *decreases*, not increases, in public purchase quantities. Moreover, the predicted price increases are small (1.9 percent) relative to the magnitude of public quantity decreases examined in which the public sector is entirely absent from the market. To examine whether private prices and household out-of-pocket expenditures in Mexico are consistent with this result, I assess private market prices using two data sources. The first is a large household expenditure survey that tracks diabetes-related expenditures. The second is survey data on insulin prices gathered by the World Health Organization and Health Action International.

Using a large Mexican household expenditure survey (ENIGH) that collects information on specific health care expenditures, I investigate whether out-of-pocket diabetes expenditures changed as the cartel collapsed. The ENIGH survey is conducted more frequently than other surveys that track diabetes information, which allows for analyzing diabetes expenditures around a narrow window of the cartel's collapse. I use diabetes expenditure data from the 2004, 2005, 2006, and 2008 surveys (no survey was released in 2007). This provides a small window around the cartel's collapse to measure changes in diabetes-related expenditures. Substantial changes in insulin prices should be detectable through these expenditures, as decreases in prices due to demand declines from exiting IMSS beneficiaries should cause out-of-pocket expenditures to fall on a per-person basis. In contrast, increases in prices from anti-

while the private system offers branded and patented insulin.

[47] Other studies of pharmaceutical pricing decisions across markets focus on reference pricing (e.g., Dubois et al. (2019)), which sets prices in one market as a function of prices in other markets. This mechanism mechanically links pricing decisions across markets even if consumers in each market cannot access other markets. Because reference pricing was not present within Mexico at this time, this type of cross-market pricing coordination by insulin retailers is unlikely.

Figure C.2: Diabetes expenditures over time for non-IMSS households



(a) Pct. of households with diabetes expenditures

(b) Yearly change in diabetes expenditures

competitive conduct should cause them to increase.

Figure C.2 shows how diabetes expenditures evolved from 2004 to 2008 by showing the proportion of non-IMSS households that reported out-of-pocket expenditures and the yearly change in average quarterly expenditure level relative to 2004 (shown in hundreds of 2004 pesos). These measures are level over time and indicate that there were no substantive changes in pricing and availability of medications in the private market around the collapse of the cartel.

Lastly, I examine how insulin prices in private markets evolved after the collapse of the cartel by examining survey data on insulin prices. The World Health Organization and Health Action International gathered information on insulin prices and availability in Mexico City in 2009 (World Health Organization (2009)) and insulin prices by brand in 2015 (Ewen et al. (2016)). These prices are listed in Table C.1. Panel A shows the cost of 30 days of treatment for the lowest cost generic insulin in Mexico City in 2009. From this price, I estimate a price per 10mL vial of insulin, the same unit sold to IMSS.[48] This price is similar to the cartel's price per unit in IMSS insulin

[48]Insulin dosage levels taken from `https://www.pdr.net/drug-summary/Humulin-N-NPH--human-insulin-isophane--rDNA-origin--2911.4411`. For calculating the price per 10mL, I assume a daily dosage of 0.75 IU/kg for a 75kg adult.

auctions from 2003 through 2005.

Panel B of Table C.1 shows the price of 10mL NPH insulin vials by firm from (Ewen et al. (2016)). Prices are converted from 1996 USD, the standardized monetary value used in the report. The lowest cost product is similar to the price of the lowest-cost generic in the 2009 WHO report. Stability in the price of the lowest-cost generic insulin is consistent with level out-of-pocket diabetes expenditures for non-IMSS households in Figure C.2 and suggests no large changes in private sector insulin prices in the years following the cartel's collapse.[49]

Table C.1: Insulin prices, 2009 and 2015

Panel A: 2009 *Generic insulin, Mexico City*		
	30 day treatment (Mex$)	**Price per 10mL (Mex$)**
Lowest price generic	287.50	170.40
Panel B: 2015 *Insulin price by brand*		
Product name	**Manufacturer**	**Price (Mex$)**
Gi Insulina Intermediate®	AMSA Laboratorios	173.03
Glinux N®	Probiomed	262.95
Humulin N®	Eli Lilly	569.44
Insulex N®	PiSA	191.30
Novolin N®	Novo Nordisk	265.82

Notes: Insulin prices in Mexico obtained from World Health Organization (2009) and Ewen et al. (2016). Panel A lists the lowest price generic insulin available in Mexico City in 2009 as surveyed by the World Health Organization. Panel B gives quoted prices for NPH insulin gathered in 2015 by Health Action International; a full list of all insulin prices is given in Appendix B.

[49]The fact that the public procurement price during the cartel period was similar to the private market price was already suggestive of high firm market power in the auctions, as in general we expect the price in public procurement auctions to be lower (Atal et al. (2021)).

D Alternative empirical specifications

The main results use a difference-in-differences specification to assess how diabetes treatment and health outcomes changed following the collapse of the insulin cartel using other social security programs as the control group. This appendix investigates the sensitivity of the results to this empirical specification by estimating three different empirical specifications. The first two of these specifications incorporate use matching as part of the difference-in-differences estimation or as a nearest neighbor matching estimator on the post-cartel sample. The last specification keeps the main difference-in-differences specification from Section 4 but uses a different group, privately insured individuals, as the control group. This specification helps to assess the effect of potential spillovers from cartel collapse in IMSS procurement onto other public procurement programs.

Propensity score weighted difference-in-differences: The main specifications of Table 4 are valid under the assumption that unobserved factors affecting treatment are uncorrelated with observed characteristics of diabetes patients. To investigate the sensitivity of the results to this assumption, I perform a propensity score weighted difference-in-differences specification for repeated cross-sections following Blundell and Dias (2009). Table D.1 shows the results of this specification, which are similar to the results of the main specifications in Table 4

Nearest neighbor matching estimator: As a second way to incorporate matching into the empirical analysis, I conduct a nearest neighbor matching estimator on the post-cartel period. This specification uses one-to-one matching based on Mahalanobis distance to assign each IMSS member a corresponding control member from the set of non-IMSS social security beneficiaries. Individuals are matched on characteristics associated with IMSS insurance coverage and diabetes treatment and health outcomes. These characteristics are age, height, weight, sex, diabetes duration, employment status, alcohol use, smoking, high cholesterol, and hypertension. The primary identify-

Table D.1: Propensity score weighted difference-in-differences estimates

	Insulin		Complications	
	(1)	(2)	(3)	(4)
DiD coeff.	0.056	0.056	-0.278	-0.278
p-value	*(0.037)*	*(0.037)*	*(0.016)*	*(0.016)*
Base characteristics	X	X	X	X
Health characteristics		X		X
Observations	2,880	2,880	2,880	2,880

Notes: Difference-in-differences estimates using propensity score weighting based on observed diabetic patient characteristics. The sample consists of all individuals in the treatment and control group in the main specifications of Section 4: individuals in IMSS, and individuals in other social security programs. Specifications (1) and (3) generate weights based on base demographic characteristics of age, height, weight, waist circumference, diabetes duration, and sex. Specifications (2) and (4) add medical history characteristics, which are smoking, alcohol use, high cholesterol, and hypertension.

ing assumption is that no unobserved factors influence selection into the treatment group after matching on the observed characteristics.

The results are displayed in Table D.2, where the sample consists of the set of social security beneficiaries in the post-cartel period. The results are similar to the main specifications of Table 4, with slightly lower magnitudes for the point estimates and slightly lower p-values.

Assigning private insurance as the control group: One concern addressed in Appendix C is that the increased insulin purchase quantities of IMSS following the cartel's collapse may have disrupted insulin supply to the public procurement system more generally. This disruption has the potential to create spillovers to the procurement of other social security programs that may have decreased insulin availability.

While Appendix C discusses why such spillovers are unlikely to be a significant concern in this setting, I also conduct an empirical test for these spillovers by re-estimating the main empirical specifications of Table 4 with privately insured indi-

Table D.2: Matching estimator results

	Insulin (1)	Complications (2)
IMSS	0.048	-0.210
p-value	*(0.015)*	*(0.001)*
Observations	1,909	1,909

Notes: Average treatment effect estimates of IMSS diabetes treatment in the post-cartel period using nearest neighbor matching based on Mahalanobis distance. Individuals within social security health care programs are matched on the following demographic and health characteristics: age, height, weight, sex, diabetes duration, employment status, alcohol use, smoking, high cholesterol, and hypertension. Bias correction and p-value calculation follow Abadie and Imbens (2011).

viduals designated as the control group. Individuals who obtain health care exclusively through the private market are likely to be insulated from disruptions to public procurement programs. Furthermore, available insulin price and expenditure data (Figure C.2 and Table C.1) indicate little change to private market insulin prices during this period. Hence, if the main results of Table 4 are driven primarily by negative spillovers on the control group, then the effect size should be smaller in magnitude when using the privately insured as the control group.

The results are shown in Table D.3. The results are largely consistent with the estimates of the main specification of Table 4, albeit with a slight loss in precision. This constitutes evidence that procurement spillovers onto other social security programs are unlikely to be the main driver behind the results.

Table D.3: Effects when designating privately insured patients as the control group

	Insulin		Complications	
	(1)	(2)	(3)	(4)
DiD coeff.	0.039	0.039	-0.344	-0.338
p-value	(0.032)	(0.048)	(0.057)	(0.032)
Base controls	X	X	X	X
Health controls		X		X
Observations	5,773	5,773	5,773	5,773

Notes: Effect of cartel collapse on insulin utilization and diabetes complications when privately insured individuals are designated as the control group. For control definitions see Table 4. Wild cluster p-values are shown below each coefficient.

E Additional robustness tests

This section presents the results of additional robustness checks. Specifically, these are robustness of the results of Table 4 to dropping individuals with private health insurance and SSPS insurance and robustness of the results of Table 6 to considering cardiovascular disease as a competing cause of death.

Drop SSPS and private health insurance: The specifications reported in Table 4 include all insured individuals and use time interactions with *Seguro Popular* and private health insurance to isolate the control group of other individuals insured through social security to provide more precise estimates of the effects of covariates on insulin usage and complications from diabetes; however, it is possible that these covariates influence the treatment and control groups in different ways, or that state-level fixed effects are different for these groups compared with those insured through *Seguro Popular* or private health insurance. To investigate this, Table E.1 re-estimates the main specifications excluding all individuals not in the treatment or control groups.

Table E.1: Robustness tests – drop private health insurance and *Seguro Popular*

	Insulin		Complications	
	(1)	(2)	(3)	(4)
DiD coeff.	0.046	0.046	-0.333	-0.333
p-value	(0.030)	(0.034)	(0.043)	(0.030)
95% CI	$[0.01, 0.20]$	$[0.01, 0.19]$	$[-0.49, -0.06]$	$[-0.50, -0.21]$
Base controls	X	X	X	X
Health controls		X		X
Observations	2,880	2,880	2,880	2,880

Notes: Difference-in-differences coefficients replicating the specification of Table 4 where individuals with private health insurance or SSPS insurance are excluded from the sample. For control definitions see Table 4. Wild cluster bootstrap p-values and confidence intervals are reported below each coefficient.

Add ENSA 2000 in pre-trends test: Table E.2 combines the ENSA 2000 survey data with the ENSANUT 2006, 2012, and 2016 surveys as a robustness test for both the main results and the test for pre-trends in insulin utilization presented in Section 4.5.

The results are similar to those presented in the main text: the small and statistically insignificant coefficient on IMSS×2006 suggests that there is no evidence that insulin utilization among IMSS diabetes patients increased in 2006 relative to 2000, but utilization increased after the cartel's collapse.

Table E.2: Robustness tests – add ENSA 2000 to ENSANUT surveys

	Insulin	
	(1)	(2)
IMSS × 2006	-0.002	-0.004
p-value	(0.908)	(0.816)
95% CI	$[-0.17, 0.02]$	$[-0.16, 0.02]$
IMSS × 2012	0.047	0.045
p-value	(0.039)	(0.037)
95% CI	$[0.00, 0.11]$	$[0.01, 0.11]$
IMSS × 2016	0.108	0.107
p-value	(0.104)	(0.106)
95% CI	$[-0.09, 0.19]$	$[-0.09, 0.18]$
Base controls	X	X
Health controls		X
Observations	7,898	7,898

Notes: Difference-in-differences coefficients replicating specifications (1) and (2) of Table 4 with the ENSA 2000 survey data combined with the ENSANUT 2006-2016 surveys and Year×IMSS coefficients. A similar analysis using complications from diabetes as the dependent variable is not possible as this information is not recorded in the ENSA 2000 survey. For control definitions see Table 4. Wild cluster bootstrap p-values and confidence intervals are reported below each coefficient.

Competing risk mortality model: The specifications of Table 6 use a Cox proportional hazards model to estimate diabetes-specific mortality hazard rates as a function of the DiD parameter. This model treats other causes of death as independent censoring. To examine the robustness of this assumption, I estimate a competing risk model, or proportional subhazard model, following Fine and Gray (1999) and treat cardiovascular disease as a competing cause of death. Because of the computational burden of estimating this model on the full sample, I use a 10 percent random subsample of the original dataset in estimation. The results are contained in Table E.3, which

finds qualitatively similar results but reports smaller magnitude on the hazard rate associated with the cartel's collapse.

Table E.3: Effect of cartel collapse on mortality hazard rates, competing risk model

	(1)	(2)
DiD hazard ratio	0.987	0.984
p-value	(0.000)	(0.000)
Education		X
Occupation		X
Observations	405,493	306,113

Notes: Difference-in-differences hazard ratio for diabetes-specific mortality risk with cardiovascular disease as a competing cause of death. Included controls are as in Table 6. Due to computational burden each specification is run on a random 10 percent sample of the full data. Score bootstrap p-values are reported below each estimated hazard ratio.

F Other tables and figures

This section presents other figures not contained in the main text or other appendices. Figure F.1 shows the DiD coefficient and confidence intervals (generated by wild cluster bootstrap) for each diabetes complication. The effects are largest for vision-related complications and dialysis: the effects on loss of visual acuity, retinal damage, blindness, and dialysis are each significant at the 10 percent level.

Table F.1 expands Table C.1 to include branded and patented insulins. These products are not available through IMSS but can be purchased through the private health care market.

Table F.2 shows additional summary statistics for the ENSANUT survey data, including a breakdown of age into ten-year categories and the proportion of individuals using oral medications, such as metformin, as part of their diabetes treatment.

Figure F.1: Separate effect by complication

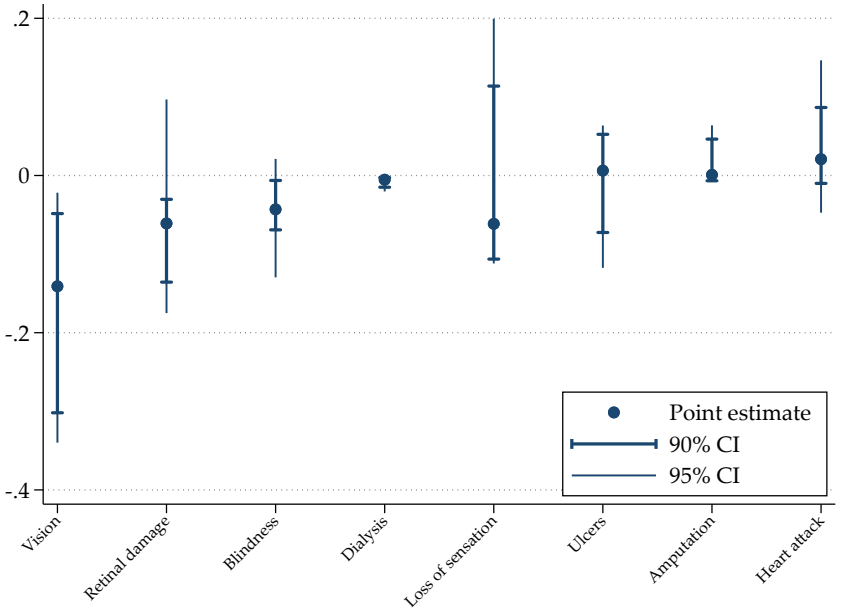


Table F.1: Insulin prices in Mexico by brand, 2015

Product name	Manufacturer	Price (1996 USD)	Price (2003 Mex$)
Gi Insulina Intermediate®	AMSA Laboratorios	9.66	173.03
Gi Insulina Rapid®	AMSA Laboratorios	4.77	85.44
Glinux 30®	Probiomed	13.85	248.09
Glinux N®	Probiomed	14.68	262.95
Glinux R®	Probiomed	13.95	249.88
Humulin 30®	Eli Lilly	30.37	544.00
Humulin N®	Eli Lilly	31.79	569.44
Humulin R®	Eli Lilly	26.53	475.22
Insulex 30®	PiSA	10.68	191.30
Insulex N®	PiSA	10.68	191.30
Insulex R®	PiSA	10.68	191.30
Novolin 30®	Novo Nordisk	21.54	385.83
Novolin N®	Novo Nordisk	14.84	265.82
Humalog®	Eli Lilly	47.7	854.42
Humalog Mix 25®	Eli Lilly	53.55	959.21
Humalog Mix 50®	Eli Lilly	57.72	1033.90
Lantus®	Sanofi	65.2	1167.89
Levemir®	Novo Nordisk	56.39	1010.08
NovoMix 30®	Novo Nordisk	44.87	803.73
NovoRapid®	Novo Nordisk	37.33	668.67
Tresiba®	Novo Nordisk	85.42	1530.08

Notes: This table supplements Table C.1 and gives a full list of all insulin prices in Mexico obtained by Health Action International (Ewen et al. (2016)).

Table F.2: Summary statistics: age by group and oral diabetes medication

	ENSANUT survey wave		
	2006	2012	2016
Age group:			
20-29	0.015	0.015	0.010
30-39	0.097	0.075	0.061
40-49	0.195	0.187	0.156
50-59	0.264	0.280	0.271
60-69	0.238	0.247	0.301
70-79	0.147	0.145	0.149
80+	0.043	0.051	0.047
Pct. using oral medication	0.880	0.824	0.819

Notes: This table displays additional summary statistics by age and oral diabetes medication usage for each survey wave of the ENSANUT survey. Each entry shows the proportion of diabetics in that category.