Colluding Against Import Competition *

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Abstract

Using a unique census of sugar manufacturers matched to firm characteristics in Guangxi, China's largest sugar-producing province, we provide novel causal evidence that import competition can induce defensive collusion among domestic firms. We estimate a structural model with market power in the refined sugar and sugarcane procurement markets that separately identifies sugar demand, cane supply, technology, and firms' conduct. The estimates show that import penetration strengthens coordination among domestic producers: as imported sugar becomes a closer substitute and domestic market shares shrink, firms face stronger incentives to coordinate. By limiting substitution toward cheaper imports, this response reduces consumers' gains from trade while shielding sugar manufacturers and cane suppliers from import competition. Counterfactuals show that defensive collusion operates much like an endogenous increase in import tariffs, redistributing welfare along the supply chain.

Keywords: Defensive collusion; Import competition; Oligopsony power; Vertically related markets

JEL Classification: F14; L13; L41; Q13

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1 Introduction

Global trade liberalization has profoundly reshaped product markets, firm behavior, and welfare. A large literature documents how import competition disciplines domestic producers, lowers prices, and reallocates resources toward more productive firms. Yet much less is known about how firms strategically respond on the conduct margin when exposed to sustained foreign competition, especially in environments where market power is already present on both the output and input sides. This paper argues that import competition can induce a defensive response in the form of collusive behavior among domestic firms, altering not only prices and quantities in downstream product markets, but also the transmission of trade shocks to upstream suppliers and aggregate welfare.

We study this mechanism in the context of China' s sugar industry. Sugar provides a particularly revealing setting. Despite China' s persistent trade surplus since WTO accession, sugar manufacturing has long been internationally uncompetitive. Beginning around 2010, a sharp and persistent decline in world sugar prices triggered a surge in imports that far exceeded the tariff-rate quota. Domestic producers faced intense pressure as imported sugar became a close substitute for domestic varieties. In response, industry associations coordinated actions across firms and regions, culminating in the 2017–2019 safeguard tariffs that imposed additional duties of up to 45 percent on out-of-quota imports. These highly visible policy interventions were preceded by quieter, firm-level coordination in pricing, production, and procurement, making sugar an ideal laboratory to study collusion as an endogenous response to import competition.

Our central question is how import competition reshapes firms' incentives to collude, and how such conduct feeds back into upstream input markets. We develop and estimate a structural model of a vertically linked industry in which downstream sugar manufacturers compete imperfectly in the product market while exercising oligopsony power in the procurement of sugarcane from farmers. On the demand side, domestic sugar varieties compete with each other and with imported sugar in a nested CES structure. On the supply side, sugarcane farmers choose whether to grow cane and which manufacturer to supply, generating upward-sloping firm-specific supply curves. Firms internalize rivals' profits to varying degrees, summarized by a conduct (profit-internalization) parameter that captures the extent of collusion.

This framework delivers a key insight. When imports expand and substitute away from domestic sugar, the perceived demand elasticity facing each firm increases, compressing markups and threatening profitability. Collusion partially offsets this force by internalizing business-stealing incentives among domestic producers. Unlike textbook models in which

collusion simply raises prices and reduces welfare, in our setting collusion primarily operates by dampening firms' quantity responses to import competition and by reshaping marginal incentives in the upstream input market. As a result, collusive behavior changes not only downstream prices and quantities, but also sugarcane demand, procurement prices, and farmer incomes.

We take this model to rich micro data covering the universe of sugar manufacturers in Guangxi province—which accounts for roughly two thirds of China' s sugar output—combined with customs data on sugar imports and detailed household- and village-level information on sugarcane planting and income. We structurally estimate product demand, production technology, and sugarcane supply, and recover firm-year measures of output markups, input markdowns, and collusive conduct. We then exploit spatial variation in exposure to import to study how firms and farmers adjust along both the output and input margins.

Our empirical results yield three main findings. First, we document substantial and economically meaningful collusion among domestic sugar manufacturers. The estimated conduct parameter is significantly greater than zero, and it increases with exposure to import competition. Firms located closer to ports experiencing faster growth in sugar imports exhibit stronger profit internalization, consistent with collusion emerging as a defensive response to foreign competition.

Second, import competition has adverse effects on domestic manufacturers and upstream sugarcane farmers, even as it lowers sugar prices for consumers. Higher import exposure reduces firm markups, compresses procurement prices, and lowers farmer participation and income from sugarcane cultivation. These effects propagate through local economies, leading to declines in agricultural activity at the village level.

Third, counterfactual simulations show that collusion materially alters the transmission of trade shocks. Relative to a non-collusive Cournot benchmark, collusive conduct mitigates the contractionary effects of import competition on domestic output and sugarcane demand, partially stabilizing farmer incomes and producer surplus. At the same time, collusion reallocates welfare away from consumers and toward producers, highlighting a fundamental trade-off between competitive discipline from trade and strategic firm responses that blunt its impact. Additionally, we explore how alternative trade policies, such as changes in tariffs and subsidies, influence market outcomes. In scenarios with reduced tariffs, the positive effects of import competition on consumer welfare are amplified, but domestic producers and farmers suffer even greater losses. In contrast, increasing tariffs or introducing subsidies for domestic manufacturers attenuates some of the negative effects on domestic output and sugarcane prices, while also stabilizing farmer incomes. However, such policies also lead to higher

consumer prices and reduced consumer surplus. These findings underscore the nuanced interactions between trade liberalization, competition policy, and strategic firm behavior, emphasizing the importance of considering both market conduct and policy responses in evaluating the welfare effects of trade shocks.

This paper contributes to three literatures. First, we contribute to the literature on firms' collusive behavior. A classic starting point is the theory of tacit collusion under imperfect monitoring. Green and Porter (1984) examine cartel self-enforcement in the presence of demand uncertainty and show how imperfect monitoring can generate recurrent reversionary episodes, so that collusive conduct may be accompanied by temporary punishment phases rather than stable monopoly pricing throughout. Relatedly, Rotemberg and Saloner (1986) show that collusion may become harder to sustain when demand is high, as firms' temptation to deviate is stronger in booms, leading to more competitive outcomes and price wars during high-demand states. Building on this foundation, an important line of work studies the forces that shape the stability and sustainability of collusion. Some papers emphasize how market conditions such as demand fluctuations, entry, and institutional constraints affect cartel durability (Chassang and Ortner, 2019; Igami and Sugaya, 2022; Iossa et al., 2024; Starc and Wollmann, 2025; Kawai et al., 2026). Others highlight how collusion can be sustained in environments with heterogeneous firms through implicit transfers, dynamic adjustments, and vertical arrangements, as in Clark and Houde (2013) and Gilo and Yehezkel (2020). More recent work shows that new technologies and institutions can themselves facilitate collusion by improving monitoring and coordination, including through algorithmic pricing and communication-based coordination. In particular, Calvano et al. (2020), Calvano et al. (2021), and Klein (2021) show that pricing algorithms can learn or sustain supracompetitive outcomes, while Ortner et al. (2024) analyze how mediated coordination can help firms sustain collusion, and Harrington and Ye (2019) and Aryal et al. (2022) show that public communication can serve as a coordination device. In this paper, we highlight a new source of collusive stability: defensive coordination in response to import competition. When domestic firms are confronted with fierce external competition and occupy a disadvantaged position, they may be more inclined to collude in order to protect market share and limit losses.

More broadly, the paper speaks to the literature developing empirical approaches to detect collusive conduct and evaluating the effects of collusion on market outcomes and welfare. An important benchmark in this literature is Genesove and Mullin (1998), who study conduct and market power in the U.S. sugar refining industry and compare direct measures of conduct with those recovered from a static conduct-parameter approach. They show that the latter tracks market power reasonably well, though it somewhat understates the direct benchmark. This also connects to Corts (1998), who argues that when conduct is dynamic, a

parameter recovered from a static pricing equation may capture the sensitivity of markups to demand shocks rather than the underlying level of market power. This concern is especially relevant in our setting, so we estimate a structural demand-and-supply model rather than infer conduct from a reduced-form static pricing rule. Empirical studies also document substantial distortions in prices, quantities, and allocation across a range of settings (Bergquist and Dinerstein, 2020; Ale-Chilet et al., 2021; Clark et al., 2022, 2024; Barkley, 2023; Chaves et al., 2026). Beyond standard price effects, collusion can also shape labor market outcomes and long-run firm behavior. Delabastita and Rubens (2025) show that firms may coordinate to exploit labor when they internalize competitors' costs, while Gross (2020) highlight that coordination can sometimes facilitate value creation, for instance through standardization. Consistent with this broader perspective, Kang (2025) show that cartel episodes can have persistent effects on firms' innovation outcomes. There is also another strand of the literature proposes increasingly granular detection methods in procurement settings, including distribution-based screens (Conley and Decarolis, 2016; Chassang et al., 2022), tests based on bid rotation and complementary bidding patterns (Kawai et al., 2023; Clark et al., 2025), and structural approaches that recover collusive links across firms (Baránek et al., 2025). Recent work has also explored combining these economic insights with machine learning techniques to improve detection performance and to identify cartel participants even in the absence of labeled data (Huber and Imhof, 2019; Silveira et al., 2023; Huber and Imhof, 2023). Distinct from these studies, we study a setting in which firms coordinate in the presence of downstream oligopsony power and by modeling collusion along an intensive margin through a firm-year-specific internalization parameter, rather than treating firms as either fully collusive or fully competitive. And our paper contributes to the literature on the effects of collusion by showing that collusion may arise not only to restrict output or raise prices, but also as a defensive response to import competition, with distinct implications for equilibrium quantities, prices, and welfare.

Second, we supplement to the literature examining how import competition shapes domestic market conduct. Whereas the effects of import penetration have been extensively documented—on firms' productivity (Bloom et al., 2016; Fieler and Harrison, 2023), innovation (Autor et al., 2020; Liu et al., 2021; Matano and Naticchioni, 2025), oligopoly power (Caselli and Schiavo, 2020; Curzi et al., 2021; De Loecker et al., 2014), and labor market outcomes (Autor et al., 2013; Chakraborty et al., 2024; Ahlquist and Downey, 2023)—much less is known about how import shocks alter the strategic interaction among domestic firms. Amiti and Heise (2024) document that greater import exposure has been associated with rising market concentration among U.S. producers. And Naylor and Soegaard (2022) show that when import competition induces upstream suppliers to cut input prices, downstream

firms may sustain or even raise profits through cost pass-through, partially offsetting the intended pro-competitive effects of trade. These studies offer valuable initial evidence on structural adjustment under import competition, yet they provide only a partial view of firms' strategic responses. We go beyond this emerging evidence by analyzing in greater depth whether heightened import competition modifies manufacturers' incentives to collude, and how such shifts in downstream conduct transmit upstream agricultural suppliers.

Third, our work adds to the literature on monopsony power.A growing body of research estimates firms' market power in input markets, particularly in labor markets((Morlacco, 2019; Brooks et al., 2021b; Mertens, 2020; Azar et al., 2022; Yeh et al., 2022; Lamadon et al., 2022; Rubens et al., 2025)). Much less attention, however, has been paid to monopsony power in material input markets.Rubens (2023) documents the allocative effects of oligopsony power of cigrate manufacturers on tobacco leaf. But in his context, manufacturers are price takers and the industry has been shielded from international competition. We extend his framework to a more common setting where manufacturers engage in monopolistic competition, faced with import competition, and thus collude.

The remainder of this paper is structured as follows. Sections 2 describe the industry background, data, and stylized facts. Section 3 presents the model. Section 4 discusses estimation and identification of the model. Section 5 simulates counterfactual outcomes under alternative assumptions and policies, and Section 6 concludes.

2 Background and Data Description

China is one of the world's largest sugar consumers, yet domestic production has persistently fallen short of demand, leaving the country heavily reliant on imports.[1] Despite this sizable demand, China's role in the global sugar market remains limited.[2] Within the domestic sector, sugarcane overwhelmingly dominates production, with Guangxi alone contributing more than half of national output. As both the geographic and industrial center of the industry, Guangxi provides a representative setting for examining the sector's organization, performance, and policy challenges. The next section introduces the institutional background and the data on which our analysis is based.

[1]Between 2008 and 2016, China's sugar output trended downward with intermittent fluctuations, while consumption remained broadly stable. At no point did production meet demand, and imports consistently filled the gap. In 2016, China accounted for about 9.04% of global sugar consumption—the third-largest share worldwide—but its output in the 2016/2017 season represented only 5.6% of global production.

[2]Its share of world output is under 10 percent, which gives it little influence over international prices and leaves it functioning primarily as a price taker. For example, in 2010 China produced 10.45 million tons of sugar, compared with a global total of 162 million tons.

2.1 Institutional Background of China's Sugar Industry

Although the industry is formally a dual-crop system, it is in practice overwhelmingly cane-based.[3] Cane production relies on smallholder farming, close ties to local mills, and high transport costs that bind farmers to processors—conditions typical of Guangxi, Yunnan, and Guangdong. Because these provinces dominate supply, their dynamics matter far more than those of the smaller beet sector in the north and northwest. Despite sizable production, consumption regularly outpaces output, leaving China structurally dependent on imports.[4] Among the cane-producing regions, Guangxi is by far the largest supplier, and it is on this province that our empirical analysis focuses.

2.1.1 Guangxi's Central Role in China's Sugar Industry

Guangxi occupies a dominant position in China's sugar industry, consistently supplying 60–70 percent of national output, a share that has remained stable over time.[5] Beyond its favorable endowment, Guangxi's sugar sector is unusually well organized: it hosts a dense network of processing plants, supported by provincial government initiatives and coordinated through the Guangxi Sugar Industry Association. Virtually all of China's leading sugar-processing firms operate in the province, making it the only region where the entire value chain—from cane farming to large-scale industrial processing—functions at such scale.

This central role is reinforced by Guangxi's exposure to international trade. Its proximity to major southern ports means that foreign sugar often enters through Guangxi, making the province the first to face import competition. At the same time, as China's dominant supplier, Guangxi's output and pricing decisions transmit directly to national market conditions, ensuring that local dynamics have economy-wide consequences for China's sugar market.

2.1.2 Sugar Supply Chain

The sugar supply chain in China consists of three key stages: sugarcane cultivation, processing into sugar, and downstream distribution and sales. Each stage is influenced by China's unique agricultural practices, economic conditions, and policy environment.

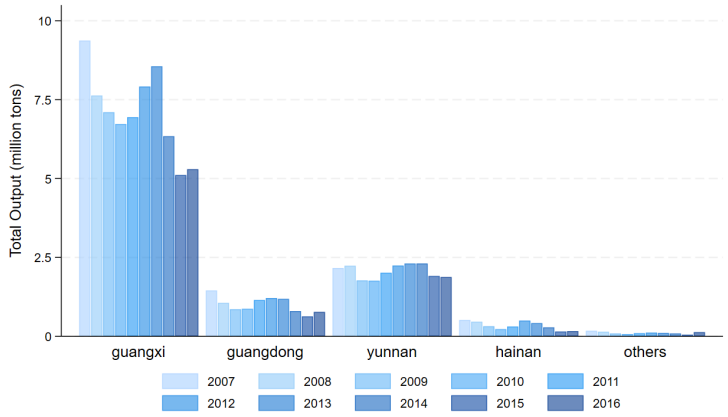
[3] Sugarcane, cultivated mainly in Guangxi, Yunnan, and Guangdong, contributes roughly 85–88 percent of national output, while sugar beet, grown in Inner Mongolia, Xinjiang, and Heilongjiang, makes up the remainder.

[4] A tariff-rate quota system regulates this dependence, while strong state involvement through quotas, reserves, and border enforcement coexists with limited market mechanisms, such as white-sugar futures on the Zhengzhou Commodity Exchange, which play only a supplementary role in pricing and risk management.

[5] Guangxi's subtropical climate and extensive cane-growing area provide natural advantages unmatched by other provinces such as Yunnan, Guangdong, or Hainan, where production is smaller and more fragmented.

Sugarcane Farming and Farmers' Livelihoods Sugarcane is the upstream input in the sugar production process, with its cultivation forming the foundation of the entire industry. Sugarcane cultivation in China is primarily concentrated in the southern provinces of Guangxi, Yunnan, Guangdong, and Hainan.[6] Cane sugar dominates China's sugar industry, accounting for roughly 93% of total production, while beet sugar makes up only about 7%. The crop's specific climatic needs limit its cultivation to China's southern provinces, with Guangxi being the leading producer, contributing more than 60% of the nation's total sugar output. Figure 1 summarizes the sugar output across the key sugarcane-growing provinces from 2007 to 2016. Guangxi consistently produced the highest output, far surpassing other provinces such as Guangdong, Yunnan, and Hainan. While production in these provinces remained relatively modest and variable, Guangxi's output showed a steady increase.

Figure 1: Sugarcane Production in Key Provinces of China (2007-2016)



Notes: The figure plots sugar output (million tons) from 2007 to 2016 across China's major sugarcane-producing provinces. Data are drawn from the Census of Sugar Manufacturers in Guangxi, compiled by the Guangxi Sugar Industry Association.

Sugarcane farming plays a vital role in the livelihoods of farmers in Guangxi, offering a stable source of income.[7] Moreover, farming remains a flexible income source in rural

[6]Sugarcane is a versatile crop, thriving in both temperate and tropical climates, and can be grown as either an annual or perennial. In China, the sugar production cycle runs from October 1 to September 30 of the following year, which constitutes a single production season. This cycle is the basis for statistical reporting on sugar production, distinct from the conventional calendar year. The timing of crushing and procurement seasons varies by region, with sugar companies adjusting the start of operations based on planting cycles, market prices, and government policies.

[7]In 2009, the sugarcane planting area in the province reached 15.56 million mu, yielding 63.98 million tons of cane. During the 2009/2010 crushing season, 55.69 million tons of raw sugarcane were processed into 7.118 million tons of sugar. By 2010, the planting area had increased slightly to 15.67 million mu, with total output rising to 68.80 million tons. Sugarcane farming spans 751 towns and townships across 56 counties in Guangxi, involving around 12 million farmers. In fact, sugarcane production accounts for more than 70% of the total output of major cash crops in the region, with a commodity rate as high as 90%.

China, where land ownership is collective, and usage rights are allocated according to the Household Registration System (Hukou). Rural residents typically retain land usage rights in their household registration area, which can be transferred. Over the past two decades, urbanization has led to a significant migration of workers from the agricultural sector to other industries. Simultaneously, the relaxation of land circulation policies has allowed non-farming workers to engage in sugarcane farming by renting land usage rights, thus further integrating farming and non-farm work in rural China.

Sugar Manufacturers In 2010, Guangxi's sugar industry comprised 33 companies operating 103 mills, a scale that remained largely stable over the study period. Private enterprises accounted for 67 percent of mills, state-owned enterprises for 18 percent, and foreign-invested firms for 15 percent. The geographic distribution of mills was highly uneven, with production concentrated in four prefecture-level cities—Nanning, Chongzuo, Laibin, and Liuzhou—which together formed the core of Guangxi's sugar-processing base.[8] By contrast, a number of counties in other prefectures had no sugar manufacturers at all. Figure 2 illustrates this spatial pattern, comparing the distribution of sugar manufacturers in 2008 and 2015. The maps make clear that while mills are densely clustered in a few cities, the overall geography of production remained remarkably stable over time. Importantly, the total number of companies and mills during our sample period changed very little, even as ownership and corporate affiliations became more consolidated. The organization of Guangxi's sugar industry further reinforces this picture of concentration. Many mills are not stand-alone entities but are part of larger corporate groups that oversee multiple plants under a common ownership structure.[9] As a result, competition in Guangxi's sugar industry seems to depend less on the operations of individual mills and more on the strategies of a handful of dominant corporate groups, which exert considerable influence through their scale and market presence.

During the harvest season, sugar manufacturers set up local purchasing stations to procure cane directly from farmers.[10] Sugar manufacturing in China operates under a strict regulatory framework designed to preserve order in procurement and stabilize farmer in-

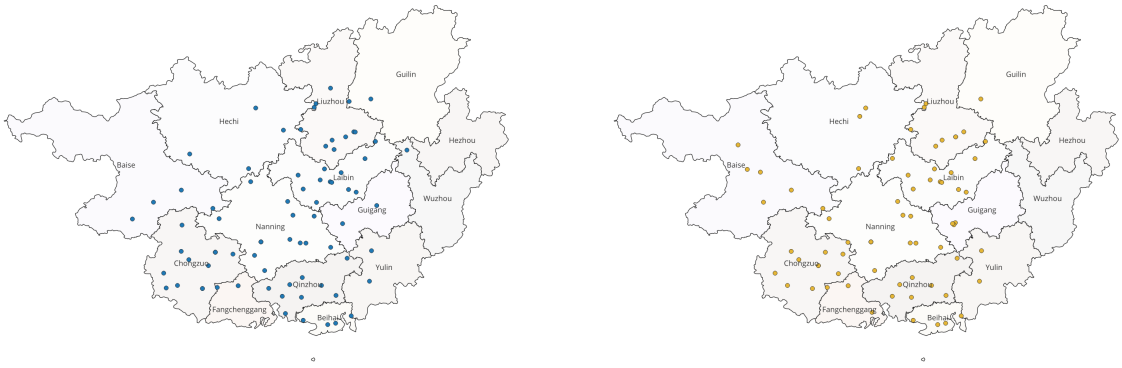
[8] In 2010, these four cities accounted for 57.2% of Guangxi's sugar enterprises and an even larger share, 72.0%, of total sugar output. Within this cluster, Chongzuo and Laibin stand out as the densest hubs of production, with multiple mills operating in many counties.

[9] Of the 682 firm-year observations in our sample, 582 are affiliated with 17 such corporate groups, with the largest eight groups accounting for more than 70% of the sample.

[10] Once received at the mill, the cane follows a standardized sequence of processing steps: it is cleaned, cut, and crushed, after which mechanical pressing extracts the juice from the stalks. This "mixed juice" is then filtered to remove impurities, concentrated through evaporation, and crystallized into refined sugar. At each stage, both labor and machinery are indispensable. Farmers and workers remain critical for harvesting, transport, and preliminary handling, while increasingly sophisticated equipment drives the crushing, filtration, and crystallization processes.

comes.[11] The regulation prohibits mills from purchasing cane outside designated zones, restricts unauthorized transport across regions, and limits procurement to licensed manufacturers.[12]In practice, however, these restrictions have not eliminated cross-regional trade. Investigations, penalties, and widespread reports suggest that cane is still transacted across district boundaries despite formal prohibitions.[13]

Figure 2: Geographic Distribution of Sugar Manufacturers in Guangxi, 2008 and 2015



(a) Distribution in 2008 (b) Distribution in 2015

Notes: Panels (a) and (b) show the locations of sugar manufacturers in Guangxi in 2008 and 2015. Each dot represents a sugar mill. Most manufacturers are clustered in a handful of prefecture-level cities—particularly Chongzuo, Laibin, Nanning, and Liuzhou—while many other counties across the province lack any processing capacity. This spatial pattern underscores the highly uneven distribution of industrial activity, with a few regions emerging as the core of Guangxi's sugar industry. Firm location data are drawn from the Chinese Firm Tax Survey, and geographic base maps are provided by MapWorld, China's national geographic information service platform.

[11]See the Interim Measures for Sugar Crop Management (Order No. 23, issued jointly on June 28, 2002 by the State Development Planning Commission, the State Economic and Trade Commission, the Ministry of Agriculture, and the State Administration for Industry and Commerce).

[12]The regulation contains three central provisions: (i) sugar-processing enterprises are prohibited from purchasing sugarcane outside their designated production zones, preventing cross-regional competition for raw cane; (ii) transportation operators are barred from moving or selling sugarcane across regions without authorization, insulating local markets; and (iii) only licensed sugar manufacturers are permitted to procure cane, with all other enterprises or individuals barred from doing so.

[13]See "Guangxi: Why Has Cross-Region Cane Poaching Intensified?" (China Economic Times, via Sina Finance, June 22, 2006) for documented evidence of widespread sugarcane "cross-region buying" in Guangxi despite regulatory prohibitions. The article reports that rising sugar prices between 2003–2006 nearly doubled, incentivizing manufacturers to source cane outside their designated zones. Local governments responded by deploying police, militia, and roadblocks to prevent cane from leaving production districts. Investigations and penalties were imposed: over 30 enterprises were ordered to suspend or limit operations for engaging in cross-region procurement. These cases illustrate that formal restrictions are frequently violated in practice.

Downstream Uses of Sugar. Once processed into refined sugar, the bulk of output —about 70 percent—is sold directly to industrial clients such as beverage, food, confectionery, and pharmaceutical producers under annual or quarterly contracts. Retail distribution through provincial and municipal dealers accounts for roughly 20 percent, supplemented by interregional traders who balance supply across producing and consuming regions.

Refined sugar in China is traded largely on market terms, with futures on the Zhengzhou Commodity Exchange serving as the national benchmark. Yet several frictions create scope for market power, even in what appears to be a homogeneous good. Regional segmentation generates persistent basis differences between producing and consuming areas: high transport costs and uneven local inventories allow mills and traders to price above the benchmark when regional supplies are tight. Quality distinctions also matter.[14] Timing further reinforces these margins. During the crush season, mills actively manage inventories, forward sales, and basis contracts to exploit short-run scarcity, thereby influencing spot prices. Finally, buyer concentration creates asymmetries in bargaining power. Large beverage and food companies negotiate long-term, high-volume contracts with strict quality and delivery clauses, leaving limited discretion to suppliers, whereas smaller industrial users and retail distributors typically purchase at posted prices that incorporate local costs and markups.

2.1.3 Growing Reliance on Sugar Imports

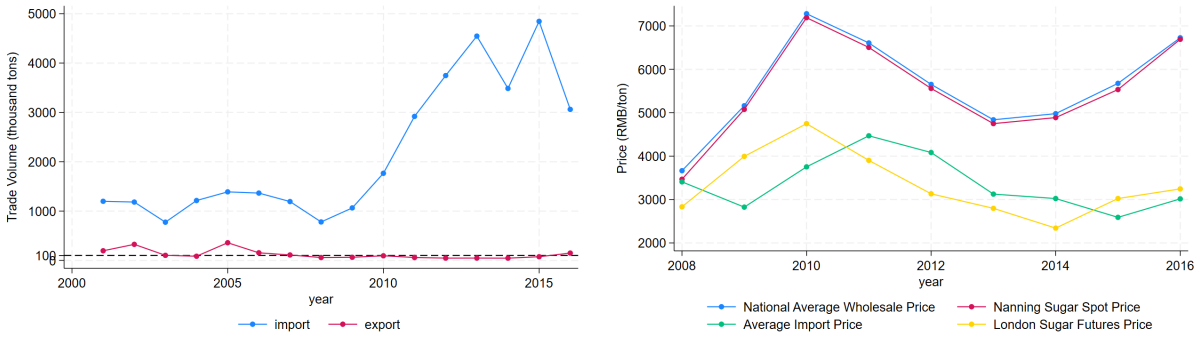
China's sugar trade has been governed by the tariff-rate quota (TRQ) system introduced at WTO accession in 2001.[15] Throughout the 2000s, imports remained stable and largely within the quota, serving mainly to cover temporary production shortfalls and replenish national reserves.

After 2010, however, this balance quickly unraveled. During five consecutive production years from 2011/12 to 2015/16, world sugar prices declined sharply, remaining well below China's domestic wholesale prices. This persistent gap created strong arbitrage incentives, making imports profitable far beyond the tariff-rate quota, even when domestic output was

[14]Variations in polarity and ICUMSA color, along with specialized grades such as pharmaceutical sugar, create meaningful price premia. Beverage producers, for example, demand high-polarity, low-color sugar to ensure consistent taste and appearance, and are often willing to pay several hundred RMB per ton above the standard grade. Pharmaceutical firms require even stricter purity, purchasing only refined grades that meet medical specifications. Mills capable of delivering these higher standards not only obtain price premiums but also secure stable, long-term contracts with downstream buyers.Appendix Figure A.1 documents these patterns. Panel (a) shows the distribution of refined sugar prices across producers, while Panel (b) reports the distribution of sugarcane purchase prices. Both panels reveal substantial dispersion, underscoring the heterogeneity in product quality, procurement practices, and firm capabilities.

[15]By 2004 the quota was fixed at 1.945 million tons, with an in-quota tariff of 15 percent and an out-of-quota tariff of 50 percent. The level has remained unchanged since, with 70 percent allocated to state trading enterprises and the remainder distributed to approved firms based on past import performance and commercial capacity.

Figure 3: China's Sugar Trade and Price Gaps, 2000–2016



(a) Imports and Exports

(b) Sugar Prices

Notes: Panel (a) plots China's annual sugar imports and exports (thousand tons). Panel (b) reports sugar prices (RMB per ton), comparing domestic and international benchmarks: the national wholesale average (blue), the Nanning Commodity Exchange spot price (red), the average landed import price (green), and the London futures price (yellow). The widening gap after 2010 underscores the profitability of "price difference–driven" imports, even under the 50 percent out-of-quota tariff. Data are from the Census of Sugar Manufacturers in Guangxi, compiled by the Guangxi Sugar Industry Association.

broadly in line with demand. As a result, import dependence rose markedly—from about 15 percent before 2010 to roughly 25 percent thereafter. Figure 3 illustrates these dynamics. Panel (a) shows the surge in imports after 2010, while Panel (b) documents the widening wedge between Chinese wholesale prices and international reference prices. The sustained premium of domestic prices over both London futures and landed import costs explains why imports remained attractive despite the prohibitive 50 percent out-of-quota tariff.[16] In effect, what had once been a quota-constrained mechanism of market stabilization transformed into a conduit through which global oversupply and falling world prices increasingly shaped China's domestic sugar market.

[16]Customs data show that the bulk of China' s imports take the form of raw sugar, predominantly from Brazil, supplemented by smaller shipments of refined sugar from South Korea and Thailand. Once landed, raw sugar is almost entirely processed in China into white granulated sugar, which enters the same downstream channels—beverage producers, candy manufacturers, food processors, and wholesale markets—as domestically produced sugar. The refining stage serves several purposes. It shields buyers from the pronounced volatility in world white sugar prices, provides scope to adjust product quality and specifications to domestic market demand, and ensures compliance with national food safety standards. Importantly, the refining margin is modest—roughly 500 RMB per ton—when set against the much larger wedge between landed import costs and domestic wholesale prices. As a result, the profitability of imports depends overwhelmingly on international price conditions, not on the relatively minor costs of refining. Industry reports further document that refiners have strong incentives to integrate imported raw sugar seamlessly into existing distribution networks, where it is indistinguishable from local output. These factors together explain why developments in global raw sugar markets transmit so directly and immediately into China' s wholesale and retail sugar prices.

Anecdotal Evidence of Collusion. In the context of intensifying import competition, Guangxi's sugar industry presents several anecdotal cases of coordinated behavior that extend beyond routine information exchange. First, coordination through the Guangxi Sugar Association (GSA) has long been central. All major firms are members, and the GSA's seasonal meetings and notices on staggered factory schedules, though framed as protecting farmers, served as a platform for collective decision-making that curtailed competition. Second, in 2016 the GSA joined Yunnan and Guangdong associations to petition for safeguard tariffs, pooling data on imports, costs, and losses. The 2017–2019 duties—an extra 45 percent on out-of-quota imports—cut inflows by more than half, a visible outcome of lobbying rooted in earlier, quieter collusion against import competition. Third, institutionalized cooperation further cemented this collective stance. In 2015, 81 Guangxi firms, including Nanhua and Nanning Sugar, founded the Bagui Sugar Industry Chamber of Commerce. Publicly presented as promoting consensus and "fair competition," it became another vehicle for pooling resources, enforcing discipline, and presenting a united front, extending collusive practices into broader initiatives such as the Belt and Road.[17]

These episodes highlight how collective arrangements repeatedly emerged in Guangxi's sugar industry when import competition intensified. Their persistence and institutionalization suggest that such practices may have significantly influenced market outcomes, making it essential to move beyond anecdote and rigorously quantify the degree of collusion and its aggregate implications for China's sugar economy.

2.2 Data Description

Our analysis draws on four complementary sources. At the core is a census of all sugar manufacturers in Guangxi (2008–2016), China's leading cane-producing region. We link these plant-level records to firm tax filings to measure inputs, merge them with Chinese Customs data to capture import competition, and use village and census surveys to approximate the upstream pool of cane farmers. Detailed descriptions follow below.

Census of Sugar Manufacturers in Guangxi We draw on a unique census of all sugar manufacturers in Guangxi province, China, covering the years 2008-2016. These data come from a micro-level enterprise survey organized by the Guangxi Sugar Industry Association, a province-wide body that coordinates between government agencies and industry stakeholders. Every processing plant in Guangxi is required to report its operations to the Association, which compiles and verifies the information under the supervision of the provincial Ministry

[17]Detailed anecdotal evidence of collusion is provided in Appendix A.1.

of Agriculture. The resulting dataset is then used as an important statistical input for national reporting. This makes the data both comprehensive, covering the complete universe of sugar-processing plants in Guangxi, and highly reliable as an official statistical source. The establishment-by-year panel is far richer than standard sources such as the Annual Survey of Industrial Firms. In addition to detailed output and price information for both refined sugar and sugarcane, it reports production capacity, input usage, energy consumption, efficiency, costs, sales, and profitability at the plant level. Such a micro-level enterprise survey, with census coverage and official verification, is rarely accessible in Chinese industry studies and provides an exceptionally authoritative basis for analyzing firm behavior in the sugar sector.

Chinese Firm Tax Survey. To complement the industry census, we use administrative records from the State Administration of Tax (SAT) covering the years 2008–2016. The SAT is the Chinese counterpart of the U.S. Internal Revenue Service and is responsible for nationwide tax collection and auditing. The dataset is drawn from enterprise income tax filings, which provide verified, firm-level information on employment, capital stock, and other financial indicators. Because these filings are based on mandatory reporting for tax purposes, the data are both highly reliable and nationally standardized.

For our purposes, the SAT records serve two key functions. First, they allow us to track the evolution of factor inputs, labor and capital, alongside the detailed production outcomes from the Guangxi Sugar Industry Association census. Second, the SAT data are essential for production function estimation: by combining input data from the tax filings with output and cost data from the industry census, we can estimate plant-level productivity and quantify how exposure to trade shocks influences the efficiency of sugar producers.

China Customs Data. We incorporate Chinese Customs data, which provide transaction-level records of all import shipments, including quantity, value, HS code, and the consignee's location. Because sugar is a relatively homogeneous product, we aggregate imports to the HS 2-digit category and then construct province-year totals of import value and quantity. These aggregates capture both the scale and geographic distribution of sugar imports across China. To translate these flows into local exposure for Guangxi, we develop a distance-weighted measure of import penetration. Specifically, we combine a distance matrix of provincial capitals with prefecture-level distances within Guangxi to compute the effective proximity of each prefecture city to external sources of sugar. Each province's sugar imports are then weighted by these distances, yielding a prefecture-by-year index of import exposure that varies across space and time. In our research design, this measure provides the key source of variation: an exogenous import shock that captures the intensity of foreign competition

faced by local producers. It allows us to examine how trade liberalization affects domestic sugar output, pricing, and input demand, and to quantify how the resulting adjustments are transmitted through the value chain to consumers, producers, and cane farmers.

China Fixed Point Village Survey. Finally, to link sugar-processing plants with their upstream suppliers, we use demographic data to estimate the pool of farmers available to each mill. Our main source is the China Fixed Point Village Survey, complemented by the Sixth National Census (2000), which reports agricultural employment, total employment, and the working-age population at the county level. The Fixed Point Survey follows rural households and villages over time, providing detailed information on farm employment, land allocation, and demographic characteristics at the village level. Combining these data with census tabulations enables us to approximate the number of cane farmers in each locality and to map their potential supply relationship to nearby mills. These data serve two important purposes. First, they allow us to estimate the local supply curve for sugarcane by connecting shifts in processing demand to the availability of farm labor across counties and villages. Second, they provide the basis for analyzing how collusion alters the balance of power between downstream processors and upstream farmers.

3 Theoretical Framework

This section begins with a simple diagram illustrating how potential collusion modifies firm behavior in response to import competition. We then develop a supply-and-demand model for sugar, treated as a homogeneous product, to identify collusive conduct among Chinese sugar manufacturers and to examine its aggregate implications.

3.1 A General Framework

Marginal revenue under collusion. Consider a set of domestic firms $d = \{1, \ldots, N\}$ that compete in quantities. Let firm f's profit be

$$\pi_{ft} = p_{ft} q_{ft} - C_{ft}(q_{ft}),$$

and suppose its collusive objective internalizes the profits of the other domestic firms:

$$W_{ft} \equiv \pi_{ft} + \lambda_t \sum_{v \neq f} \pi_{vt}, \qquad \lambda_t \geq 0. \tag{1}$$

The first-order condition with respect to q_{ft} is

$$\begin{aligned}\frac{\partial W_{ft}}{\partial q_{ft}} &= \frac{\partial \pi_{ft}}{\partial q_{ft}} + \lambda_t \sum_{v \neq f} \frac{\partial \pi_{vt}}{\partial q_{ft}} \\ &= \left[p_{ft} + q_{ft} \frac{\partial p_{ft}}{\partial q_{ft}} - C'_{ft}(q_{ft}) \right] + \lambda_t \sum_{v \neq f} q_{vt} \frac{\partial p_{vt}}{\partial q_{ft}} = 0.\end{aligned} \tag{2}$$

To isolate the strategic revenue side, define

$$MR_{ft}^{\text{Cournot}} \equiv p_{ft} + q_{ft} \frac{\partial p_{ft}}{\partial q_{ft}}, \qquad MR_{ft}^{\text{coll}} \equiv MR_{ft}^{\text{Cournot}} + \lambda_t \sum_{v \neq f} q_{vt} \frac{\partial p_{vt}}{\partial q_{ft}}. \tag{3}$$

Then the collusive wedge relative to Cournot is

$$MR_{ft}^{\text{coll}} - MR_{ft}^{\text{Cournot}} = \lambda_t \sum_{v \neq f} q_{vt} \frac{\partial p_{vt}}{\partial q_{ft}}. \tag{4}$$

Let rival domestic revenue be

$$R_{-f,t} \equiv \sum_{v \neq f} p_{vt} q_{vt}.$$

Since q_{vt} is fixed when firm f changes its own output,

$$\frac{\partial R_{-f,t}}{\partial q_{ft}} = \sum_{v \neq f} q_{vt} \frac{\partial p_{vt}}{\partial q_{ft}}, \tag{5}$$

so that

$$MR_{ft}^{\text{coll}} - MR_{ft}^{\text{Cournot}} = \lambda_t \frac{\partial R_{-f,t}}{\partial q_{ft}}. \tag{6}$$

Decomposition of the spillover on rival revenues. Let aggregate expenditure on domestic goods be

$$E_{dt} \equiv \sum_{j \in d} p_{jt} q_{jt},$$

and define firm f's expenditure share within the domestic sector as

$$s_{ft} \equiv \frac{p_{ft} q_{ft}}{E_{dt}}.$$

Then rival domestic revenue can be written as

$$R_{-f,t} = (1 - s_{ft}) E_{dt}.$$

Now consider a unilateral output expansion by firm f, so that $dq_{ft} > 0$. Totally differentiating yields

$$\begin{aligned} dR_{-f,t} &= d\Big[(1 - s_{ft})E_{dt}\Big] \\ &= -E_{dt}\, ds_{ft} + (1 - s_{ft})\, dE_{dt}. \end{aligned} \tag{7}$$

Hence

$$\boxed{dR_{-f,t} = \underbrace{-E_{dt}\, ds_{ft}}_{\text{negative domestic term}} + \underbrace{(1 - s_{ft})\, dE_{dt}}_{\text{positive import term}}}. \tag{8}$$

The first term is the standard business-stealing effect: a higher output by firm f raises its share within the domestic sector, so $ds_{ft} > 0$ and therefore $-E_{dt}ds_{ft} < 0$. The second term captures import recapture: if higher domestic output shifts expenditure away from imports and toward domestic goods, then $dE_{dt} > 0$, which offsets part of the loss borne by rival domestic firms.

The canonical cartel model as a special case. If there is no import margin, or more generally if a unilateral output change by firm f does not affect aggregate domestic expenditure, then $dE_{dt} = 0$. Equation (8) then collapses to

$$dR_{-f,t} = -E_{dt}\, ds_{ft} < 0. \tag{9}$$

Thus, in the classical case, an aggressive unilateral move by firm f imposes a purely negative spillover on the rest of the cartel. Our framework nests this benchmark and adds an additional import-recapture channel.

A necessary condition for our mechanism. For any rival domestic firm $v \neq f$, write

$$p_{vt} = \frac{p_{vt}q_{vt}}{q_{vt}} = \frac{s_{vt}E_{dt}}{q_{vt}}.$$

Since q_{vt} is fixed when firm f changes its own output,

$$d\ln p_{vt} = d\ln s_{vt} + d\ln E_{dt}. \tag{10}$$

Therefore the cross inverse-demand elasticity can be written as

$$\kappa_{vft} \equiv \frac{\partial \ln p_{vt}}{\partial \ln q_{ft}} = \underbrace{\frac{\partial \ln s_{vt}}{\partial \ln q_{ft}}}_{\substack{\text{within-domestic reallocation} \\ \text{holding } E_{dt} \text{ fixed}}} + \underbrace{\frac{\partial \ln E_{dt}}{\partial \ln q_{ft}}}_{\text{domestic-versus-import margin}}. \tag{11}$$

18

To relate this condition directly to the MR wedge in (4), note that

$$MR_{ft}^{\text{coll}} - MR_{ft}^{\text{Cournot}} = \lambda_t \sum_{v \neq f} q_{vt} \frac{\partial p_{vt}}{\partial q_{ft}} = \lambda_t \frac{1}{q_{ft}} \sum_{v \neq f} p_{vt} q_{vt} \kappa_{vft}, \tag{12}$$

where

$$\kappa_{vft} \equiv \frac{\partial \ln p_{vt}}{\partial \ln q_{ft}}.$$

Using $p_{vt} q_{vt} = s_{vt} E_{dt}$, this can be rewritten as

$$MR_{ft}^{\text{coll}} - MR_{ft}^{\text{Cournot}} = \lambda_t \frac{E_{dt}}{q_{ft}} \sum_{v \neq f} s_{vt} \kappa_{vft}. \tag{13}$$

Hence the sign of the collusive MR wedge is governed by the sign of $\sum_{v \neq f} s_{vt} \kappa_{vft}$.

Now define the within-domestic component

$$\tilde{\kappa}_{vft}^{d} \equiv \left. \frac{\partial \ln p_{vt}}{\partial \ln q_{ft}} \right|_{E_{dt}} = \frac{\partial \ln s_{vt}}{\partial \ln q_{ft}} < 0, \tag{14}$$

and let aggregate import expenditure be

$$E_{mt} \equiv P_{mt} q_{mt},$$

where q_{mt} denotes aggregate import quantity and P_{mt} is the import price index. If total expenditure Y_t is fixed and P_{mt} is unaffected by firm f's output choice, then

$$E_{dt} = Y_t - E_{mt}.$$

Hence

$$\frac{\partial \ln E_{dt}}{\partial \ln q_{ft}} = -\frac{E_{mt}}{E_{dt}} \frac{\partial \ln q_{mt}}{\partial \ln q_{ft}}. \tag{15}$$

Define the cross elasticity of aggregate import demand with respect to firm f's output as

$$\theta_{ft}^{m} \equiv -\frac{\partial \ln q_{mt}}{\partial \ln q_{ft}} > 0. \tag{16}$$

[18] This is the quantity-setting analogue of the price-setting decomposition. In the canonical cartel model, the aggressive unilateral move is an output expansion, so collusion internalizes the harm imposed on partner firms and therefore restrains output. In our setting, the first term in (11) captures exactly this classical force: a unilateral output expansion by firm f lowers rival firms' prices through within-domestic business stealing. The difference is the additional import-substitution margin, which may raise aggregate domestic expenditure by shifting demand away from imports. When sufficiently strong, this force can overturn the standard output-restraining logic of collusion.

Then

$$\frac{\partial \ln E_{dt}}{\partial \ln q_{ft}} = \frac{E_{mt}}{E_{dt}}\theta^m_{ft}. \tag{17}$$

Substituting (14) and (17) into (11) gives, for each rival $v \neq f$,

$$\kappa_{vft} = \tilde{\kappa}^d_{vft} + \frac{E_{mt}}{E_{dt}}\theta^m_{ft}. \tag{18}$$

And $\sum_{v \neq f} s_{vt} = 1 - s_{ft}$, therefore,

$$\sum_{v \neq f} s_{vt}\kappa_{vft} = \sum_{v \neq f} s_{vt}\tilde{\kappa}^d_{vft} + (1 - s_{ft})\frac{E_{mt}}{E_{dt}}\theta^m_{ft}. \tag{19}$$

Then the relevant sign condition becomes

$$\boxed{\sum_{v \neq f} s_{vt}\kappa_{vft} > 0 \quad \Longleftrightarrow \quad (1 - s_{ft})\frac{E_{mt}}{E_{dt}}\theta^m_{ft} > -\sum_{v \neq f} s_{vt}\tilde{\kappa}^d_{vft}.} \tag{20}$$

Equation (20) shows that collusion raises marginal revenue relative to Cournot only if the foreign-demand elasticity is sufficiently strong, relative to the within-domestic business-stealing force, once rival spillovers are aggregated using rivals' expenditure shares.

Under a symmetric equilibrium, $s_{jt} = 1/N$ for all $j \in d$, so that $1 - s_{ft} = (N-1)/N$, and $\tilde{\kappa}^d_{vft} = \tilde{\kappa}^d_t$ for all $v \neq f$. In that case, (20) simplifies to

$$\boxed{\frac{E_{mt}}{E_{dt}}\theta^m_{ft} > -\tilde{\kappa}^d_t.} \tag{21}$$

That is, under symmetry, collusion raises marginal revenue relative to Cournot if and only if the foreign-demand elasticity is strong enough to outweigh the within-domestic business-stealing term for a representative rival.[19]

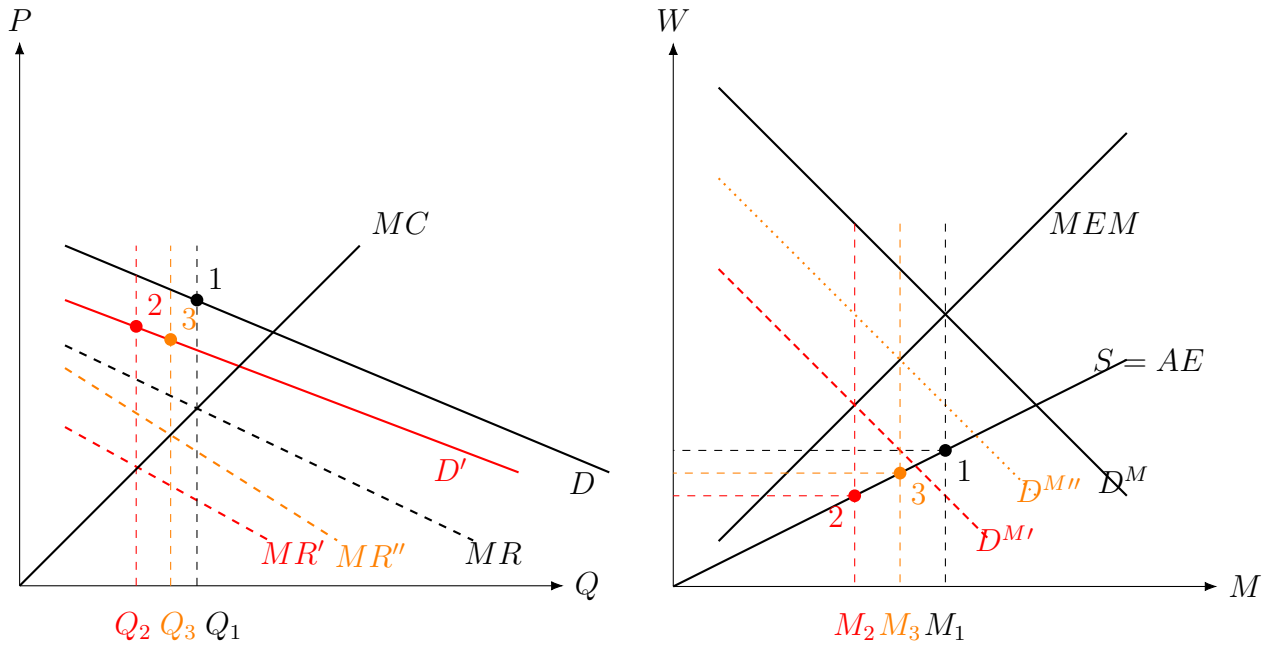
3.2 Conceptual Framework for Collusion and Import Competition

Collusion can fundamentally alter how domestic firms respond to import competition. When lower-priced foreign goods enter the market, domestic producers face two options: compete head-to-head and accept steep profit losses, or coordinate output decisions to soften the blow. Panel (a) of Figure 11 illustrates this mechanism in the product market. The arrival of imports shifts demand inward from D to D'. Under Cournot competition, the corresponding marginal revenue curve shifts from MR to MR', and equilibrium output falls from Q_1 to Q_2

[19] We also do the comparative static to formally show this pattern in Appendix B.1

(point 1 to point 2). With collusion, however, the effective marginal revenue curve is MR''. Because collusion internalizes the impact of output reductions across the industry, MR'' is flatter and lies above MR'. The resulting equilibrium, at Q_3, is larger than Q_2 (point 1 to point 3). Thus, collusion sustains higher output and helps firms defend market share. The trade-off, however, is that the markup shrinks: with greater output at Q_3, prices remain closer to marginal cost than under Cournot competition, so firms accept lower price–cost margins in exchange for preserving sales.

Figure 4: Potential Impact of Collusion on Market Outcomes



Notes: This figure illustrates how collusion shapes equilibrium outcomes in the presence of an import shock. Panel (a) depicts the product market. The initial demand curve, D, shifts inward to D' following the import shock, reflecting the reduction in domestic demand for sugar. The line labeled MC is the marginal cost curve. The dashed curves represent the associated marginal revenue schedules: MR under Cournot competition, and MR' and MR'' under collusion, before and after the import shock. The intersections of each marginal revenue curve with MC determine the equilibrium quantities Q_1, Q_2, and Q_3, marked by points 1, 2, and 3. Panel (b) shows the input (sugarcane) market. The upward-sloping curve $S = AE$ denotes the supply of sugarcane, while MEM is the marginal expenditure curve faced by the buyer of the input. The downward-sloping curves D^M, $D^{M'}$, and $D^{M''}$ are the derived input demand schedules under Cournot competition, collusion after the import shock, and collusion before the import shock, respectively. Their intersections with MEM determine the equilibrium employment levels M_1, M_2, and M_3, with the corresponding equilibrium wages read along the horizontal axis.

Panel (b) turns to the input market. The curves now represent derived demand for factors under different regimes. Initially, demand is D^M. Once imports arrive, Cournot behavior shifts this inward to $D^{M'}$, reducing equilibrium input use from M_1 to M_2. With collusion, however, input demand becomes $D^{M''}$, which lies above $D^{M'}$ since sustaining higher output requires greater use of inputs. The resulting equilibrium is M_3, with $M_3 > M_2$. Collusion

therefore affects the input market in two distinct ways. First, it dampens the contraction in factor demand by maintaining higher output. Second, by acting jointly, firms consolidate their monopsony power, enabling them to negotiate lower input prices from suppliers.

Therefore, collusion does more than alter prices and quantities - it shifts the balance of market power. On the product side, firms absorb thinner markups in order to stabilize output and defend market share. On the input side, however, the same coordination amplifies their monopsony leverage, allowing them to discipline suppliers more forcefully. The net effect is a reallocation of power from consumers to suppliers, reshaping how the gains and losses of import competition are distributed. To quantify the magnitude of these shifts, we need more than qualitative diagrams. A fully structured model can disentangle technology and demand from firm conduct, recover the underlying fundamentals, and estimate the degree of collusion implied by the data. It also quantifies how market power is redistributed between product and input markets, motivating the model developed in the next section.

3.3 Quantification Model

To establish the causal link between import competition and collusion, we first estimate the extent of collusion during periods of rapid import penetration and then quantify its implications for market power. Our focus is on both the pricing behavior of sugar manufacturers and the monopsony power these firms may exercise over sugarcane farmers. Following Rubens (2023); Rubens et al. (2025), we separately estimate the supply of sugarcane, the production function for sugar, and the demand for sugar among Chinese consumers.

3.3.1 Sugar Demand

We model sugar demand at the national level, assuming an aggregate market for sugar products across China.[20] The representative consumer's preferences are modeled using a nested constant elasticity of substitution (CES) structure, a standard approach in international trade to capture substitution across varieties, as in Feenstra (1994) and Atkeson and Burstein (2008). This framework accommodates both domestic and imported sugar products and allows for flexible estimation of substitution patterns within and across these groups.

[20]Several factors justify this national aggregation. First, our transaction-level data do not distinguish firm-level sugar sales across regions, and observed price dispersion more likely reflects differences in product quality than geographic segmentation. Second, China's sugar retail market is increasingly integrated, with major firms such as COFCO and Yunnan Tin operating broad distribution networks that span urban supermarkets and rural shops alike. This results in relatively uniform availability and pricing nationwide. In addition, government regulation of sugar prices and distribution has long sought to minimize regional disparities and ensure market stability. Taken together, these features support the plausibility of a unified national market for sugar.

Let F_{dt} represent the set of sugar varieties sold by domestic firms in time t, where each firm is a single-product producer. The sub-utility derived from domestic sugar products is then expressed as:

$$U_t = \left(\sum_{m \in \{d,e\}} X_{mt}^{(\eta-1)/\eta} \right)^{\eta/(\eta-1)}, \quad X_{dt} = \left(\sum_{f \in F_d} \left(b_{ft} x_{ft} \right)^{(\sigma-1)/\sigma} \right)^{\sigma/(\sigma-1)}, \quad \sigma, \eta > 0 \tag{22}$$

where σ represents the elasticity of substitution between varieties offered by domestic firms, and b_{ft} denotes the taste parameters associated with each variety, which may vary across firms. η indicates the elasticity of substitution between domestic and foreign sugar products, reflecting the fact that consumers perceive imperfect substitution between domestic (d) and foreign (e) sugar products. As in Hottman et al. (2016), we don't a priori impose the restriction that $\sigma > \eta > 1$. Instead, we only assume the necessary condition for positive markups,$\sigma, \eta > 0$. We would expect (but do not impose) that the elasticity of substitution of sugar across firms is larger than between domestic and imported sugar, i.e. $\sigma > \eta$. When the two elasticities are equal, our system will collapse to a standard CES at the firm level. Given the utility structure, the demand faced by Chinese sugar manufacturer f in time t is:

$$x_{ft} = b_{ft}^{\sigma-1} p_{ft}^{-\sigma} P_{dt}^{\sigma-\eta} P_t^{\eta-1} Y_t \tag{23}$$

where Y_t represents total sugar sales, including both domestic and foreign imported sugars. P_{dt} and P_t are the price indices for domestic sugar products and the overall sugar consumption price index in China, respectively. The overall price index P_t nests both domestic (P_{dt}) and foreign (P_{et}) sugar prices, which are defined as follows:

$$P_{dt} = \left(\sum_{f \in F_d} \left(p_{ft}/b_{ft} \right)^{1-\sigma} \right)^{\frac{1}{1-\sigma}}, \quad P_t = \left(\sum_{m \in \{d,e\}} P_{mt}^{1-\eta} \right)^{\frac{1}{1-\eta}} \tag{24}$$

where P_{et}, the price of foreign sugar, is determined exogenously by global sugar markets. A key advantage of the above demand system is that it yields firm-specific demand elasticities that depend on both the estimated elasticity parameters and each firm's market share. In particular, we obtain the demand elasticity for an individual domestic sugar producer (ε_{ft}), the elasticity of aggregate domestic sugar consumption (ε_{dt}), and the cross-price elasticity of demand (ε_{fvt}) as follows:

$$\begin{aligned} &\varepsilon_{ft} = \left[(\sigma - \eta) + (\eta - 1) S_{dt} \right] s_{ft} - \sigma, \qquad \varepsilon_{dt} = -\eta + (\eta - 1) S_{dt}, \\ &\varepsilon_{fvt} = \left[\sigma - \eta + (\eta - 1) S_{dt} \right] s_{vt} \end{aligned} \tag{25}$$

where s_{ft} and S_{dt} represent the expenditure share of firm f in domestic markets and the total expenditure share on domestic sugar products in time t, respectively. Specifically, $s_{ft} = p_{ft}x_{ft}/\sum_{v\in F_d} p_{vt}x_{vt}$ and $S_{dt} = \sum_{v\in F_d} p_{vt}x_{vt}/Y_t$. According to equation (25), sugar manufacturers with larger sales shares tend to have lower demand elasticities, which translates to greater market power in the sugar market. Similarly, the higher the total expenditure on domestic sugar brands, the greater the overall market power of domestic sugar manufacturers. This demand system is subsequently employed to estimate firm-specific demand elasticities, which are central to evaluating the extent of collusion among Chinese sugar manufacturers. The detailed derivation of these elasticities is provided in Appendix B.2.

3.3.2 Sugar Manufacturing Firms

Sugar manufacturers f produce Q_{ft} tons of sugar using sugarcane M_{ft}, labor L_{ft}, and capital input K_{ft}, all expressed in quantities. The sugarcane generates raw sugar, which, as in Genesove and Mullin (2006), cannot be substituted with labor or capital. The production function is given by the following equation:

$$Q_{ft} = \min\left\{\beta_{ft}^{M} M_{ft}, \quad \Omega_{ft} H(L_{ft}, K_{ft}, \beta)\right\}. \tag{26}$$

The production is governed by a Leontief production function, where output is determined by the minimum of two factors: the amount of sugarcane available, $\beta_{ft}^{M} M_{ft}$, and the firm's capacity to process it using labor L_{ft} and capital K_{ft}, represented by $\Omega_{ft} H(L_{ft}, K_{ft}, \beta)$. The parameter β_{ft}^{M} is a firm-specific efficiency parameter that determines how much sugarcane is needed to produce one unit of sugar, and Ω_{ft} reflects the firm-specific production capacity. The function $H(L_{ft}, K_{ft}, \beta)$ captures the firm's technology in converting labor and capital into sugar, with β adjusting for technological factors. In particular, we allow the efficiency of converting sugarcane into sugar, captured by $1/\beta_{ft}^{M}$, to differ across firms. This flexibility arises from our ability to observe both the quantity of sugarcane used and the amount of sugar produced.[21]

Choice of Inputs Sugarcane is grown by farmers, and we assume it is a variable input: its quantity is chosen by manufacturers in the same period it is used in sugar production. This assumption treats sugarcane as a static input, meaning it only affects current profits and excludes any adjustment costs related to output or inventories. Similarly, labor is assumed to be both a variable and static input. Sugar manufacturing facilities primarily

[21] We assume that $H(\cdot)$ is twice differentiable with respect to both labor and capital. Equation (26) nests production functions where all inputs are substitutable; in such a case, the marginal product of the sugarcane parameter β_{ft} would be zero, and sugarcane would become an additional substitutable input within $H(\cdot)$.

rely on production workers, for whom this assumption is more plausible than for white-collar workers. In contrast, capital is treated as dynamic and fixed; the capital stock at time t can only be adjusted through investment made in the prior period, $t-1$. The prices of sugarcane and labor are denoted by W_{ft}^M and W_{ft}^L, respectively. The extent of oligopsony power that a manufacturer f exerts over an input $V \in \{L, M\}$ is captured by the inverse elasticity of input supply $\phi_{ft}^M = \frac{\partial W_{ft}^M}{\partial M_{ft}} \frac{M_{ft}}{W_{ft}^M}$, following Rubens (2023). We assume the labor market is competitive, so firms have no market power over manufacturing workers. This is plausible in the context of rural China, where workers can migrate freely across counties and non-agricultural employment has become the main source of off-farm income in recent decades (Wang et al., 2017; Zhang et al., 2018). By contrast, we allow manufacturers to exercise oligopsony power over sugarcane farmers, reflecting the localized, relationship-driven nature of agricultural input procurement.

Profit Maximization A distinctive feature of profit maximization for Chinese sugar manufacturers, in contrast to traditional models, is the consideration of potential collusion. In such a setting, firms not only optimize their own profits but also account for the profits of other firms, as highlighted in Bergquist and Dinerstein (2020). In each period, firms choose labor and sugarcane inputs to minimize current variable costs. Given that labor and sugarcane are used in a Leontief production function, cost minimization implies that the quantity of labor chosen directly determines the amount of sugarcane, and by extension, the level of output. The firm's ability to influence sugarcane prices stems from its oligopsony power in the sugarcane market. Specifically, by increasing demand for labor and sugarcane, firms drive up sugarcane prices due to the upward-sloping supply curve, reflecting their oligopsony power in that market. In contrast, labor is competitively supplied, so wages are uniform across firms (i.e., $W_j^L = W_k^L$), and firms have no pricing power over labor.

In a collusive market structure, firms can respond to increasing foreign competition by strategically restricting sugar production to raise domestic prices. This deliberate underproduction helps sustain profit margins despite the increased pressure of lower-priced imported sugar. However, reducing sugar output also lowers the firms' demand for sugarcane, which in turn diminishes their oligopsony power in the input market. As a result, sugar manufacturers extract a smaller surplus from sugarcane farmers, as the reduced input demand limits their ability to suppress sugarcane prices. This behavior illustrates a trade-off: while firms mitigate the adverse effects of foreign competition by boosting product prices, they forgo some of the surplus they could otherwise capture from upstream suppliers. Ultimately, this strategy preserves firm profitability but shifts part of the adjustment burden to both consumers-who face higher sugar prices-and farmers, who may temporarily benefit from slightly improved

terms of trade. We express sugar manufacturer f's profit maximization problem as:

$$\max_{Q_{ft},L_{ft},M_{ft}} p_{ft}Q_{ft} - W^L_{ft}L_{ft} - W^M_{ft}M_{ft} + Z_{ft} \cdot \frac{\sum_{v\neq f}\left(p_{vt}Q_{vt} - W^L_{vt}L_{vt} - W^M_{vt}M_{vt}\right)}{N-1} \tag{27}$$

where p_{ft} and Q_{ft} denote the price and quantity of sugar produced by firm f, with output Q_{ft} determined by the production function given in equation (26). The last term in equation (27) captures the average profits of competing firms, scaled by the internalization parameter $Z_{ft} \in [0, 1]$. The parameter N represents the total number of sugar manufacturers in the industry. When $Z_{ft} = 0$, the firm maximizes its own profit independently, consistent with Cournot competition. When $Z_{ft} = 1$, the firm fully internalizes the profits of its rivals, aligning its decisions with joint profit maximization as in full collusion. Intermediate values of Z_{ft} reflect partial internalization and allow for a continuum between competition and collusion. [22]

This formulation captures the interdependent nature of firm behavior in oligopolistic markets, where each firm's actions affect not only its own outcome but also the performance of others. Differentiating equation (27) with respect to labor input L_{ft} yields the first-order condition that characterizes the firm's optimal input choice under this objective.

$$1 + \frac{1}{\varepsilon_{ft}} + \frac{Z_{ft}}{N-1}\sum_{v\neq f}\frac{1}{\varepsilon_{fvt}}\frac{s_{vt}}{s_{ft}} = \frac{1}{p_{ft}} \cdot \left[\frac{w^L_{ft}}{MP^L_{ft}} + \frac{w^M_{ft}(1+\phi^M_{ft})}{MP^M_{ft}}\right] \tag{28}$$

where $MP^L_{ft} \equiv \partial Q_{ft}/\partial L_{ft}$ and $MP^M_{ft} \equiv \partial Q_{ft}/\partial M_{ft}$ denote the marginal products of labor and sugarcane, respectively. The terms s_{ft} and s_{vt} represent the market shares of firm f

[22] A central critique in Corts (1998) is that the traditional conduct–parameter method (CPM) "can measure only equilibrium variation, which cannot be mapped into the equilibrium values of interest *in the absence of a theoretical model of competitive interaction*" (p. 231). His critique applies to settings where one estimates a reduced–form product–market supply slope—i.e., the responsiveness of output to demand shifters—and then *interprets* that slope as an elasticity–adjusted price–cost margin or as a measure of conduct. In such cases, equilibrium variation is mechanically (and often incorrectly) mapped into equilibrium market power.

Our empirical strategy is fundamentally different. Firms interact in a fully specified static model: they face a nested CES demand system, we structurally identify the resulting demand elasticities, we estimate a production function to recover marginal costs, and we estimate an *input–market* (farmer) supply elasticity to recover markdowns in the cane market. All primitives entering the firm's first–order condition—demand elasticities, marginal products, and input supply elasticities—are therefore *independently and structurally identified* within a coherent model of competitive interaction. The internalization parameter Z_{ft} is then *computed* by imposing the theoretical FOC, as an *as–if* accounting construct summarizing the degree of markup internalization consistent with the estimated primitives, rather than as an estimated conjecture based on any product–market supply–side quantity coefficient.

Moreover, our analysis focuses on *over–time* variation in Z_{ft} rather than its absolute level. Because Z_{ft} is a reduced–form object implied by structurally estimated demand and supply elasticities, it should be interpreted as a summary of how observed pricing behavior aligns with the static benchmark as import exposure changes, not as a literal measure of dynamic collusive beliefs. For these reasons, our approach lies outside the class of CV–based conduct estimators criticized by Corts (1998).

and rival firm v, while ε_{ft} and ε_{fvt} denote the own- and cross-price elasticities of demand for firm f's product, i.e., $\varepsilon_{fvt} \equiv \partial \ln Q_{ft} / \partial \ln p_{vt}$. The full derivation of the first-order condition is provided in Appendix B.3.

The right-hand side of the first-order condition summarizes both the marginal cost of production and the degree of market power, as it reflects the firm's marginal cost relative to price. It incorporates the costs of labor and sugarcane inputs, with the latter adjusted for oligopsony power. Specifically, the term ϕ_{ft}^M captures the sensitivity of sugarcane prices to the firm's own purchasing behavior, reflecting the fact that sugarcane is procured in a market with an upward-sloping supply curve. Beyond input costs, the markup also depends on the firm's strategic interaction with rivals in the output market. On the left-hand side, the conduct parameter Z_{ft} measures the extent to which firm f internalizes the profits of competing firms. As Z_{ft} increases, firms behave less competitively and more like a coordinated cartel, widening the wedge between price and marginal cost. Importantly, this collusive behavior in the output market can reinforce market power in the input market. As firms raise output prices through coordination, they may simultaneously exert downward pressure on input prices, extracting more surplus from suppliers. In other words, higher degrees of collusion may mask or justify more aggressive pricing strategies toward upstream sugarcane farmers. Thus, collusion does not merely affect consumer prices-it also shapes how value is split along the supply chain.

To quantify this, we define a firm's market power in the sugarcane market through the concept of a markdown, which measures the extent to which firms are able to suppress the price paid for sugarcane below its marginal benefit. Formally, the markdown is defined as:

$$Markdown_{ft} = \frac{MBM_{ft} - w_{ft}^M}{MBM_{ft}} \tag{29}$$

where MBM_{ft} is the marginal benefit of sugarcane to the firm, and w_{ft}^M is the price the firm pays. In our setting, firms internalize not only their own marginal revenue from sugarcane but also a share of the marginal revenues earned by their competitors. As a result, the marginal benefit incorporates both components.[23]. Following a similar derivation to the first-order condition, we obtain:

$$MBM_{ft} = MP_{ft}^M \cdot p_{ft} \left[\left(1 + \frac{1}{\varepsilon_{ft}} \right) + \frac{Z_{ft}}{N-1} \sum_{v \neq f} \frac{1}{\varepsilon_{fvt}} \cdot \frac{s_{vt}}{s_{ft}} \right], \tag{30}$$

where MP_{ft}^M is the marginal product of sugarcane. This expression makes clear that the

[23]Because of this internalization, we cannot obtain a concise expression for the markdown and the inverse supply elasticity of sugarcane, such as $Markdown_{ft} = 1 - 1/\phi_{ft}^M$ in Rubens et al. (2025).

degree of collusion in the output market, measured by Z_{ft}, can raise the perceived marginal benefit of sugarcane, thereby expanding the gap between that benefit and the actual price paid. As a result, the markdown is not only a measure of input market power but also a reflection of strategic behavior in the product market. A full derivation of the first-order condition and the marginal benefit expression is provided in Appendix B.3.[24]

In addition to markdowns, firms' oligopoly power can also be assessed on the output side of the sugar market through markups. By definition, the price markup is given by $p_{ft}/mc_{ft} - 1$, where mc_{ft} denotes marginal cost. In our context, marginal cost is the sum of the incremental costs of labor and sugarcane required to produce one more unit of sugar. This yields:

$$Markup_{ft} = \frac{p_{ft}}{\frac{w_{ft}^L}{MP_{ft}^L} + \frac{w_{ft}^M(1+\phi_{ft}^M)}{MP_{ft}^M}} - 1, \tag{31}$$

Markdowns and markups provide complementary measures of firms' market power, the former from their ability to suppress input prices, the latter from their ability to raise output prices above marginal cost.

3.3.3 Supply of Sugarcane

To estimate the degree of collusion, we require the inverse supply elasticity of sugarcane, which we obtain by introducing a structural supply model. Sugarcane in China is cultivated and supplied by individual farmers. To model their supply decisions, we adopt a discrete-choice nested logit framework, following Berry (1994) and recent applications such as Rubens (2023); Rubens et al. (2025).[25] In each period, farmers choose between growing sugarcane or selecting an outside option, such as working in non-agricultural sectors or cultivating alternative crops. The elasticity of substitution between these two broad options is denoted by ζ. Conditional on choosing to grow sugarcane, a farmer must then decide which manufacturer f to sell to. Choosing not to grow sugarcane is modeled as selecting the outside option, indexed by $f = 0$. The utility of the outside option is normalized to zero, $U_{j0t} = 0$. The

[24] In practice, once we estimate the parameters needed to calculate the internalization parameter Z_{ft}, we can directly compute the marginal revenue benefit of materials. This approach avoids relying on marginal cost expressions derived from a cost-minimization framework, which is not appropriate here. Because firms in our context explicitly internalize rivals' profits and solve a joint profit maximization problem, the duality between cost minimization and profit maximization that holds in non-cooperative models no longer applies.

[25] We adopt a discrete-choice model to represent the supply of sugarcane because the available data does not allow us to observe the quantities or prices at which individual firms purchase sugarcane from each farmer. Instead, we can only observe the number of farmers supplying to each firm, which limits our ability to directly estimate how much sugarcane each firm purchases and at what price.

utility that farmer j derives from supplying sugarcane to firm f at time t is given by:

$$U_{jft} = \underbrace{\gamma_t W_{ft}^M + \gamma^X \mathbf{X}_{ft} + \xi_{ft}}_{\equiv \delta_{ft}} + \sum_n \left(d_{fn}\zeta_{jn}\right) + (1-\sigma_s)u_{jft},$$

where W_{ft}^M is the price offered by firm f, $\mathbf{X}_{ft}$ is a vector of observed firm characteristics, and ξ_{ft} captures unobserved firm attributes. The term d_{fn} is an indicator for whether firm f belongs to sector n, allowing for sector-specific taste heterogeneity ζ_{jn}. The idiosyncratic utility component u_{jft} is assumed to follow a Type-I extreme value distribution. All firm characteristics-observed and unobserved-are treated as exogenous to the firms. The nesting parameter $\sigma_s \in (0,1)$ governs the correlation of unobserved preferences within the sugarcane nest.[26] The market share of firm f, denoted $s_{ft}^M \equiv L_{ft}^M / \sum_f L_{ft}^M$, where L_{ft}^M is the number of farmers supplying to firm f, follows the nested logit formula:$s_{ft}^M = \frac{\exp\left(\frac{\delta_{ft}}{1-\sigma_s}\right)}{D_{nt}^{\sigma_s}\left[\sum_g D_{gt}^{1-\sigma_s}\right]}$ where $D_{nt} \equiv \sum_{f\in\mathcal{F}_{nt}} \exp\left(\frac{\delta_{ft}}{1-\sigma_s}\right)$ and $\mathcal{F}_{nt}$ denotes the set of firms in sector n at time t. Taking logs, the market share equation, which represents the supply curve, becomes:

$$\ln s_{ft}^M - \ln s_{0t}^M = \gamma_t W_{ft}^M + \sigma_s \ln s_{ft}^{M,n} + \gamma^X \mathbf{X}_{ft} + \xi_{ft}, \tag{32}$$

where $s_{ft}^{M,n}$ represents the firm's market share within the sugarcane nest, capturing the firm's relative position within the sector. This equation illustrates how the number of farmers supplying to firm f, denoted by L_{ft}^M, is influenced by several factors. A higher price W_{ft}^M increases the utility of farmers, making them more likely to supply to the firm f. Similarly, a firm's larger market share $s_{ft}^{M,n}$ attracts more farmers, as a stronger presence in the market boosts its appeal. Observable firm characteristics $\mathbf{X}_{ft}$, such as reputation and stability, further influence farmers' choices. Unobserved preferences, captured by ξ_{ft}, introduce additional variability in decisions. Therefore, we derive the inverse supply elasticity of sugarcane supply for firm f from equation (32) as follows:

$$\phi_{ft}^M \equiv \left(\frac{d\ln s_{ft}^M}{d\ln W_{ft}^M}\right)^{-1} = \frac{1-\sigma_s}{\gamma_t \cdot W_{ft}^M \cdot \left[1-\sigma_s s_{ft}^{M,n} - (1-\sigma_s)s_{ft}^M\right]} \tag{33}$$

[26] A key advantage of this nested structure is its ability to capture realistic substitution patterns: the top-level decision between sugarcane farming and the outside option is governed by ζ, while the within-nest choice across manufacturers is governed by the nesting parameter $\sigma_s \in (0,1)$. This setup allows us to relax the restrictive Independence of Irrelevant Alternatives (IIA) assumption inherent in standard logit models, better reflecting the decision-making process of rural households facing heterogeneous opportunities.

This inverse supply elasticity ϕ_{ft}^M captures how sensitive the share of farmers supplying to firm f is to changes in the price paid for sugarcane, W_{ft}^M. A lower value of ϕ_{ft}^M implies that farmers are more responsive to price changes-meaning that even a small reduction in price would lead to a noticeable decline in the firm's supplier base. In this case, the firm faces a relatively elastic supply curve and has limited ability to depress input prices, weakening its oligopsony power. This inelastic response enhances the firm's market power over suppliers and increases its ability to impose a markdown.

4 Empirical Estimation

With the model structure outlined above, we now turn to estimate the key parameters governing the production function, the markdown of sugarcane prices, and the parameter capturing the degree of collusion. In the following analysis, we adopt lowercase variables for all logarithmic-level variables, except for market shares.

4.1 Production Function

Taking the logarithm of the production function in equation (26), we note that sugarcane, being a non-substitutable input and a linear function of the sugar output, does not directly enter the estimable production function. Instead, we focus on identifying the coefficients of the production function $\boldsymbol{\beta}$, which are crucial for understanding how labor and capital inputs influence sugar production. The production function is expressed as: $q_{ft} = h(l_{ft}, k_{ft}, \boldsymbol{\beta}) + \omega_{ft}$.

Measurement Several measurement errors arise in estimating the production function. First, white granulated sugar, the final product of sugar manufacturers, is differentiated from sugarcane, with quality differences playing a key role in production. This differentiation can introduce an "output price bias," as discussed in De Loecker et al. (2016) and Rubens (2023). However, we observe output in physical units of granulated sugar, which helps mitigate this bias. On the input side, we observe the number of employees ($\tilde{l}_{ft}$) rather than effective labor hours (l_{ft}), leading to potential errors in labor input measurement. Similarly, capital is recorded in monetary terms ($\tilde{k}_{ft}$) instead of physical units (k_{ft}), meaning that variations in labor intensity and capital prices, driven by technological differences, are not directly captured. These unobserved variations can result in "input price bias," especially if they are correlated with sugar quality. To address these biases, we introduce a control function $a(\cdot)$ that incorporates both wages per worker and coal consumption per 100 tons of sugarcane extraction. The coal consumption variable (c_{ft}) serves as a proxy for capital

quality , thereby helping to control for potential input price bias.[27] Variation in coal use may capture differences in energy efficiency during sugar production or reflect heterogeneity in equipment efficiency across firms. In Rubens (2023), output price is used in the control function to adjust for input quality. In our case, however, output price is endogenous to firms, whereas Rubens (2023) treat it as exogenous. With these adjustments, we estimate the following production function:

$$q_{ft} = h(\tilde{l}_{ft}, \tilde{k}_{ft}, \boldsymbol{\beta}) + a(c_{ft}, w^L_{ft}) + \omega_{ft}. \tag{34}$$

Identification To identify the key parameters of the model, we follow the timing assumptions on firms' input choices proposed by Olley and Pakes (1996), combined with a functional form assumption for the productivity transition process. In order to capture the impact of foreign competition, we allow the productivity evolution of domestic sugar manufacturers to depend on the volume of sugar imports X_{et}. Specifically, we model productivity as following a first-order Markov process with an unanticipated innovation v_{ft}, as in De Loecker (2013), Braguinsky et al. (2015), and Rubens (2023):

$$\omega_{ft} = g(\omega_{ft-1}, \mathbf{X}_{et-1}) + v_{ft}. \tag{35}$$

We assume that labor is a static input chosen in period t, after the realization of the productivity shock v_{ft}, while capital is a dynamic input determined in period $t-1$, before the shock is observed. Worker quality, proxied by average wages, is assumed to be strictly exogenous from the perspective of the firm. As discussed in Section 2.1.3, sugar imports are largely driven by fluctuations in global sugar markets, with little change in domestic trade policy, and are not influenced by firm-level decisions. We therefore treat China's total imports of foreign sugar X_{et} as exogenous to individual domestic manufacturers. These timing and exogeneity assumptions lead to a set of exclusion restrictions that allow us to identify the parameters of interest. Specifically, the productivity shock is assumed to be orthogonal to current capital usage, lagged labor input, lagged standard coal consumption per 100 tons of sugarcane, lagged wages, and the lagged values of sugar imports:

$$E\left[v_{ft} \middle| \left(\tilde{l}_{fr-1}, \tilde{k}_{fr}, c_{fr-1}, w^L_{fr}, \mathbf{X}_{er}\right)_{r\in[2,\ldots,t]}\right] = 0. \tag{36}$$

Since exposure to foreign imports may directly affect production efficiency, we follow Dhyne et al. (2017) and specify firm productivity as a linear function of a firm's location-specific exposure to sugar imports. We decompose productivity into two components: an

[27] De Loecker et al. (2016) also note that market share can be used to account for input price variation.

observable component driven by sugar imports at the city level, and a residual unobserved component, denoted $\tilde{\omega}_{ft}$. We further assume that the unobserved component $\tilde{\omega}_{ft}$ follows an AR(1) process with serial correlation parameter ρ, as follows:

$$\omega_{ft} = \beta^X \mathbf{X}_{c,et} + \tilde{\omega}_{ft}, \qquad \tilde{\omega}_{ft} = \rho \tilde{\omega}_{ft-1} + v_{ft}. \tag{37}$$

where $\mathbf{X}_{c,et}$ captures the logarithm total volume of sugar imported into city c at time t, and β^X reflects how this import exposure shapes firm-level productivity.[28]

In the main specification, we adopt a Cobb-Douglas functional form for both the production function $h(\cdot)$ and the control function $a(\cdot)$. The production function is given by $h(\tilde{l}_{ft}, \tilde{k}_{ft}) = \beta^L \tilde{l}_{ft} + \beta^K \tilde{k}_{ft} + \beta^0$, and the control function is expressed as $a(w^L_{ft}, c_{ft}) = \beta^w w^L_{ft} + \beta^c c_{ft}$, where β^L and β^K represent the output elasticities of labor and capital, respectively. To estimate these parameters, we utilize the moment conditions implied by the AR(1) productivity process, using lagged instruments up to one period. The resulting orthogonality condition is given by equation (38):

$$\begin{aligned} E\Big[q_{ft} - \rho q_{ft-1} - \beta^0(1-\rho) - \beta^K(\tilde{k}_{ft} - \rho \tilde{k}_{ft-1}) - \beta^L(\tilde{l}_{ft} - \rho \tilde{l}_{ft-1}) \\ - \beta^w(w^L_{ft} - \rho w^L_{ft-1}) - \beta^c(c_{ft} - \rho c_{ft-1}) \\ - \beta^X(\mathbf{X}_{et} - \rho \mathbf{X}_{et-1}) | (\tilde{l}_{ft-1}, \tilde{k}_{ft}, \tilde{k}_{ft-1}, w^L_{ft}, w^L_{ft-1}, c_{ft-1}, \mathbf{X}_{et}) \Big] = 0. \end{aligned} \tag{38}$$

This step recovers the vector of parameters $(\beta^L, \beta^K, \beta^0, \beta^w, \beta^c, \beta^X, \rho)$, which includes output elasticities, input-quality proxies, the effect of import exposure on productivity, and the persistence of productivity shocks.

4.2 Supply of Sugarcane

The supply curve of sugarcane to each firm is derived from the structural equation (32). Estimating this supply relationship allows us to recover the inverse supply elasticity using equation (33), which plays a central role in inferring the firm-specific markdown on sugarcane inputs.

[28] As discussed in Rubens (2023), the control function approach of Levinsohn and Petrin (2003) assumes that productivity is the sole latent, serially correlated input shifter, making it less suitable under imperfect competition where input demand also depends on firm-specific markups and markdowns (Doraszelski and Jaumandreu, 2018). We therefore follow the dynamic panel approach with timing assumptions from Olley and Pakes (1996) to estimate the production function. Although the AR(1) assumption on productivity limits flexibility and does not fully address selection from endogenous entry and exit, prior work suggests that using an unbalanced panel largely mitigates these concerns (De Loecker et al., 2016).

Measurement We define the outside option based on population census data. As described above, the "inner nest" comprises farmers who choose to grow sugarcane and sell it to a manufacturer. In contrast, the outside option includes individuals who either (i) cultivate alternative crops or (ii) are employed in non-agricultural sectors. To convert sugarcane quantities in the manufacturing data into the number of supplying farmers, we use the statistics from Guangxi's 12th Five-Year Plan for the Development of Sugarcane Industry. In 2010, the sugarcane planting area across the region reached 15.67 million mu, producing approximately 55.66 million tons of sugarcane, with participation from 12 million farmers. This implies that, on average, one farmer supplies about 4.64 tons of sugarcane per year, or equivalently, one ton corresponds to 0.2156 farmers. We assume this ratio is constant over time. Accordingly, the number of sugarcane farmers supplying to firm f in year t is given by $N_{ft} = Q_{ft} \times 0.2156$, where Q_{ft} denotes total sugarcane purchased by the firm. To measure the full choice set, we define the total pool of potential and actual sugarcane farmers N_{ct} as the working-age population (aged 15 and above) in county c, including those employed or actively seeking employment. On average, the market share of the outside option, S_{0t}, is 86.4% (standard deviation 14.2%), indicating that the vast majority of the working population does not engage in sugarcane farming.

Identification While manufacturer characteristics $\mathbf{X}_{ft}$ are assumed to be exogenous, both sugarcane prices and within-nest market shares are potentially endogenous. Manufacturers recognize that their unobserved characteristics ξ_{ft} affect farmers' utility and therefore influence supply. As a result, firms may adjust sugarcane prices in response to their latent attributes, making price endogenous in the supply equation.

To isolate the causal relationship between sugarcane prices and supply decisions-separately from the firm's input demand-we require at least two valid instruments. We employ two groups of instruments: the first is two firm-level measures of production efficiency: (i) the actual number of crushing days, and (ii) the total recovery rate, calculated as the percentage of sucrose content recovered from processed cane. These instruments are strongly correlated with the firm's demand for sugarcane and thus satisfy relevance. Moreover, they are plausibly exogenous to the supply equation, as they reflect production technology and operational efficiency rather than factors affecting farmers' outside options. As noted by Rubens (2023) and Seegmiller (2023), such productivity-related variables shape firms' labor and input demand, but are unlikely to be influenced by supply-side decisions-supporting their validity as instruments.

The key exclusion restriction is that these efficiency measures do not directly affect the utility of farmers, conditional on the offered price and observable firm characteristics. In

other words, the instruments are assumed to be orthogonal to the supply function residual ξ_{ft}. This assumption is plausible in our context: farmers are not employed by the manufacturers but engage in arm's-length transactions through spot markets. Conditional on price and observable attributes, it is reasonable to assume that farmers do not factor in how efficiently the buyer converts cane into sugar. Productivity differences-driven by, for example, managerial skill or technology-may affect firm behavior but are unlikely to enter the farmer's decision problem.

Second, we further exploit exogenous variation in local weather conditions, including temperature, rainfall, and sunshine, which are key determinants of sugarcane growth and sucrose accumulation (Manzoor et al., 2023; Dao et al., 2023). Weather data are sourced from the China Meteorological Administration and aggregated at the city-year level. Following the logic of the "BLP instruments" used in Berry et al. (1995), Nevo (2001), and Berry and Haile (2014), we construct instruments using the average weather conditions in other cities. These variables affect sugarcane supply elsewhere, which in turn shifts demand for a given firm's sugar product, thereby indirectly influencing its input prices. Crucially, these instruments are unlikely to affect a farmer's manufacturer choice beyond the impact mediated through price, supporting their validity.

4.3 Consumer Demand for Sugar

We now turn to estimating consumer demand elasticities for sugar, as described in equation (25), which relates demand to substitution elasticities and market shares. Our goal in this section is to identify two key parameters: the elasticity of substitution across sugar products, σ, and the elasticity of substitution between domestic and imported sugar, η.

Measurement We draw on detailed data on sugar prices and quantities at the firm level, along with import data from Chinese Customs. Since we only observe aggregate sugar quantities per firm, we adopt the simplifying assumption that sugar products differ across manufacturers-captured by the taste parameter b_{ft}-but are homogeneous within each manufacturer. This assumption is justified for two reasons. First, the quality and value of sugar are closely linked to sucrose content, which is ultimately reflected in the price. Second, the dominant product in the Chinese market is first-grade white granulated sugar, which is widely used in both industrial and household applications. In practice, white granulated sugar accounts for over 90% of total domestic sugar production, and most of it falls into the first-grade or higher categories. Similarly, we aggregate all imported sugar products and treat them as a homogeneous composite that competes with the domestic market. As the

Customs data report import values in US dollars, we convert these into RMB using the annual average exchange rate corresponding to each year.

Identification To identify the elasticity of substitution σ, we follow the double-differencing strategy in Feenstra (1994) and Hottman et al. (2016), which eliminates unobserved firm- and time-specific effects from the log-linearized demand equation (23). The resulting estimating equation is:

$$\Delta_{t,f} \ln x_{ft} = -\sigma \cdot \Delta_{t,f} \ln p_{ft} - (1-\sigma) \cdot \Delta_{t,f} \ln b_{ft}, \tag{39}$$

where the operator $\Delta_{t,f}$ denotes the difference relative to a benchmark firm across time. In particular, $\Delta_{t,f} \ln p_{ft} = \Delta_f \ln p_{ft} - \Delta_f \ln p_{f,t-1}$, and $\Delta_f \ln p_{ft} = \ln p_{ft} - \ln p_{\bar{f}t}$, with $\bar{f}$ denoting the firm with the highest sales in year t. This transformation eliminates time-specific shocks common across firms as well as firm-specific factors that do not vary over time, both of which could otherwise confound the identification of σ. To further address concerns about simultaneity bias, we instrument prices using firm productivity and energy consumption per unit of output, variables that are predetermined from the perspective of demand and thus valid instruments.

With the estimated elasticity of substitution σ, we recover the relative demand shifter for firm f compared to the reference firm as used in the estimation: $\tilde{b}_{ft} \equiv b_{ft}/b_{\bar{f}t} = (s_{ft}/s_{\bar{f}t})^{1/(\sigma-1)}(p_{ft}/p_{\bar{f}t})$ where $\tilde{b}_{\bar{f}t} = 1$ by construction. Having recovered the firm-level demand shifters, we compute the domestic price index P_{dt} according to equation (24). Finally, we estimate η, the elasticity of substitution between domestic and imported sugar, using the following specification:

$$\ln S_{dt} = (1-\eta) \ln P_{dt} + \delta_t \tag{40}$$

where S_{dt} denotes the expenditure share on domestic sugar, and $\delta_t = (1-\eta) \ln P_t$ captures time fixed effects representing overall sugar demand regardless of origin. To address potential endogeneity of the domestic price index, we instrument $\ln P_{dt}$ using the average firm-level productivity and average energy consumption per unit of output. This step allows us to recover the preference parameters σ and η, which govern substitution across products and between domestic and imported sugar, respectively. With these parameters and firm-level market shares, we then compute the firm-specific demand elasticities ε_{ft} using equation (25).

4.4 Degree of Collusion Across Sugar Manufacturers

With all structural parameters estimated, we now return to the first-order condition to recover the firm-level profit internalization parameter Z_{ft}. This parameter captures the extent to which each firm takes into account the profits of its competitors when setting

prices. Using the estimated primitives, we can compute a firm-year specific value of Z_{ft} for each manufacturer in each period, based on the following expression:

$$\frac{Z_{ft}}{N-1} = \frac{\left[\frac{w_{ft}^L}{MP_{ft}^L} + \frac{w_{ft}^M(1+\phi_{ft}^M)}{MP_{ft}^M}\right] - p_{ft}\left(1+\frac{1}{\varepsilon_{ft}}\right)}{\sum_{v\neq f}\frac{1}{\varepsilon_{fvt}}\frac{s_{vt}}{s_{ft}}} \tag{41}$$

In this expression, MP_{ft}^L and MP_{ft}^M denote the marginal products of labor and sugarcane, derived from the estimated production function in Section 4.1. The inverse supply elasticity of sugarcane input, ϕ_{ft}^M, comes from the supply-side estimates in Section 4.2, and the demand elasticity ε_{ft} is obtained from Section 4.3.

The estimation of Z_{ft} relies on observing how a firm's price-cost margin deviates from what would be expected under purely competitive behavior, once we account for its cost structure, market demand, and strategic environment. Several sources of variation are key to identifying this parameter. A firm facing more elastic demand has less pricing power and, all else equal, will charge a lower markup. The term $p_{ft}\left(1+\frac{1}{\varepsilon_{ft}}\right)$ captures this relationship, linking the firm's price to the responsiveness of demand. If the observed markup is lower than what the demand elasticity would suggest, it may reflect deliberate price restraint to avoid triggering competitive responses-an indication of collusive behavior. On the cost side, firms with greater bargaining power in input markets tend to face lower marginal costs, reflected in a smaller value of $\frac{w_{ft}^L}{MP_{ft}^L} + \frac{w_{ft}^M(1+\phi_{ft}^M)}{MP_{ft}^M}$. This advantage is particularly pronounced when the inverse supply elasticity ϕ_{ft}^M is low. If such firms choose not to pass their cost advantage into higher markups, it suggests pricing coordination with rivals-a sign of stronger profit internalization. Finally, the denominator $\sum_{v\neq f}\frac{1}{\varepsilon_{fvt}}\cdot\frac{s_{vt}}{s_{ft}}$ captures the extent of strategic interdependence. When rival firms hold larger market shares s_{vt} and demand is more sensitive to cross-price changes, the potential impact of one firm's pricing on others becomes more substantial. In such environments, where firms are similarly sized or offer close substitutes, there is a stronger incentive to internalize the profits of competitors, resulting in a higher estimated degree of collusion.

4.5 Estimation Results

This section reports the key parameters that shape our structural analysis. We first estimate the production technology of domestic sugar manufacturers, followed by demand elasticities across varieties and against imports. We then turn to sugarcane supply, identifying how farmers allocate output across buyers. Building on these estimates, we recover firms' degree of collusion and the implied markdowns on sugarcane. Finally, we assess how rising import

competition influenced productivity and revenue shares, highlighting the broader industry adjustments at work.

4.5.1 Production Function

Table 1 reports the estimated output elasticities of labor and capital from our production function specification. Our preferred estimates come from the dynamic panel approach, which accounts for the persistence of firm-level productivity and addresses endogeneity in input choices, including time-invariant unobservables. The estimated elasticities for labor (0.54) and capital (0.55) are nearly identical, indicating a balanced reliance on both inputs-a pattern consistent with the mechanical intensity of sugar manufacturing.[29] The estimated returns-to-scale parameter of 1.091 suggests mild increasing returns. For comparison, we also present OLS estimates. As expected, the OLS results overstate the elasticity of labor (0.655) and understate that of capital (0.166), likely due to simultaneity bias arising from unobserved productivity shocks that influence firms' input choices.

Finally, the direct effect of import competition-captured by the coefficient β^X in the law of motion for TFP (equation (37))-is statistically insignificant. As shown in Figure 5, the simple average of firm-level TFP in the sugar industry remained largely stable despite the sharp rise in sugar imports after 2010. This pattern indicates that imports did not exert an immediate, industry-wide effect on productivity. However, this does not mean import competition is inconsequential. Competitive pressure can reshape aggregate outcomes through indirect channels, such as altering firms' market power or redistributing output shares across producers. These forces, in turn, affect the overall efficiency of the domestic sugar industry.

4.5.2 Demand Elasticities

Panel B of Table 1 reports the estimated demand system elasticities. The elasticity of substitution across domestic sugar varieties, σ, is estimated at 4.665, while the elasticity between domestic and imported sugar, η, is 3.890. These results are intuitive and consistent with prior expectations: domestic products are closer substitutes for one another than for imported sugar, as indicated by $\sigma > \eta > 1$. In addition to these system-level parameters, we compute firm-specific demand elasticities. The average across firms is estimated at -4.616, suggesting that a 1% increase in price by a given firm leads, on average, to a 4.6% decline

[29] Notably, the food manufacturing sector was traditionally classified as labor-intensive, but capital deepening in China has shifted its dependence increasingly toward machinery and equipment (Zheng, 2012; Jin and Cheng, 2015). In the case of sugar production, key stages such as cane crushing, cutting, and filtration require specialized machines.

Table 1: Key Parameter Estimates: Production, Demand, and Supply

Panel A. Production Function	OLS		Dynamic Panel	
	Est.	S.E.	Est.	S.E.
Output Elasticity of Labor (β^L)	0.655	0.151	0.540	0.029
Output Elasticity of Capital (β^K)	0.166	0.039	0.551	0.039
Scale Parameter	0.821	0.132	1.091	0.068
Wage (β^w)	0.395	0.089	0.143	0.031
Coal Use (β^c)	-1.399	0.358	-0.192	0.006
Import Effect (β^X)	-0.186	0.071	0.317	0.050

Panel B. Demand System	Elasticity of Substitution		Demand Elasiticity ($\lvert\varepsilon_{ft}\rvert$)	
Across Domestic Sugar Varieties (σ)	4.665		Mean	4.616
Between Domestic and Imported Sugar (η)	3.890		Median	4.631

Panel C. Sugarcane Supply	All Industries		Non-agricultural	
	Est.	S.E.	Est.	S.E.
Sugarcane Price (γ_t)	0.0312	0.008	0.0406	0.011
Nested Parameter(σ_s)	0.886	0.688	1.015	2.757
Sugar Price	-0.002	0.0004	-0.002	0.0006
1(SOE)	-0.256	0.362	-0.373	0.541
1(Export)	-1.828	1.042	0.0733	1.829
Average Wage	-0.034	0.009	-0.052	0.015

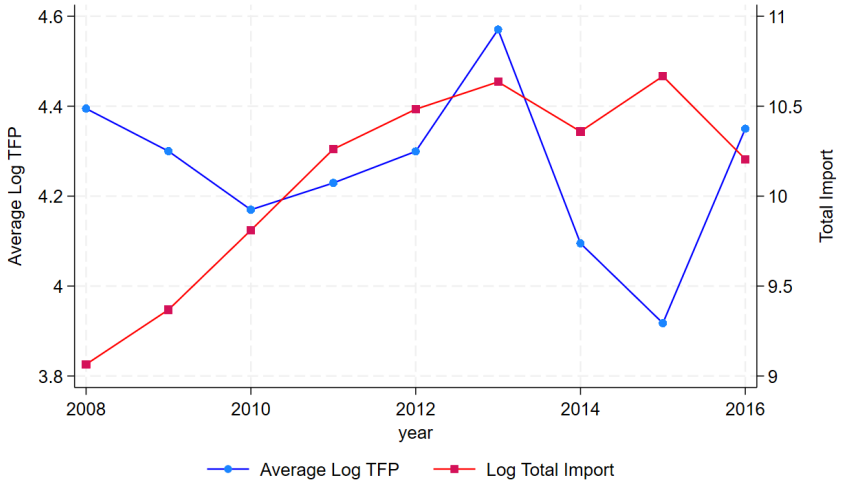
Notes: This table summarizes key parameter estimates used in the structural model. Panel A reports the estimated output elasticities from both OLS and dynamic panel specifications of the production function.Standard errors are computed using a firm-level block bootstrap with 200 replications. Panel B presents estimates from the demand system. The elasticity of substitution across domestic sugar varieties (σ) and between domestic and imported sugar (η) are reported, along with the mean and median of the estimated firm-specific demand elasticities ($|\varepsilon_{ft}|$). Panel C shows the estimated coefficients from the inverse sugarcane supply equation. The dependent variable is the log of sugarcane quantity supplied. Column (I) assumes that farmers' alternative employment options span all industries; Column (II) restricts the outside option to non-agricultural sectors. The dummy variable **1**(SOE) indicates whether the purchasing firm is a state-owned enterprise, and **1**(Export) identifies whether the firm is actively engaged in export markets.

in the quantity demanded for its sugar products. Figure 6 plots the distribution of these firm-level elasticities, revealing a relatively concentrated pattern across producers-indicative of similar demand conditions faced by most firms in the industry.

4.5.3 Sugarcane Supply Parameters

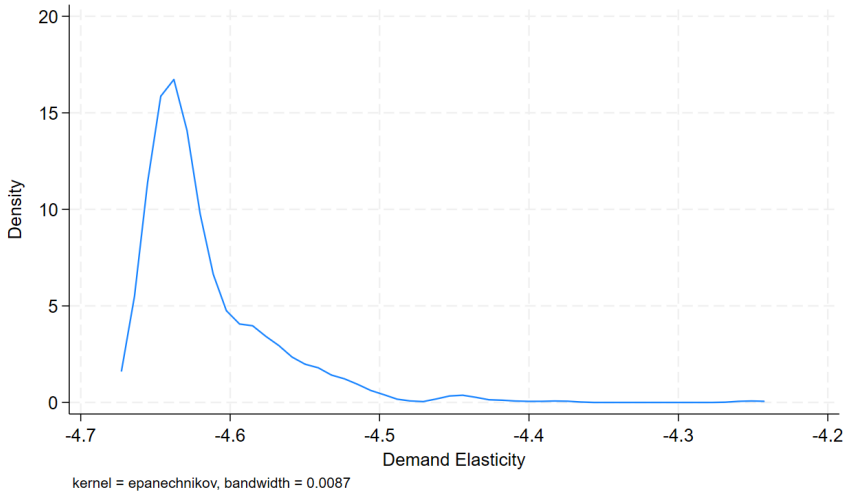
Panel C of Table 1 reports the estimation results from the sugarcane supply model. The first specification assumes that farmers' outside employment options span all industries, which we treat as the preferred benchmark. The alternative specification restricts these outside options to non-agricultural sectors. Focusing on the preferred specification, the estimated semi-elasticity of sugarcane supply with respect to price is positive and statistically significant, consistent with upward-sloping supply. The estimated nesting parameter is close to

Figure 5: Trends in TFP and Sugar Imports



Notes: Notes: This figure plots the annual trends in the simple average of log(TFP) across sugar manufacturers alongside the log of total sugar imports.

Figure 6: Distribution of Estimated Firm-Level Demand Elasticities



Notes: This figure displays the distribution of own-price demand elasticities across domestic sugar manufacturers. The estimates are derived from the nested CES demand system, showing a relatively concentrated pattern around the mean elasticity of -4.616.

one, suggesting that working in other industries is an imperfect substitute for sugarcane farming. When the outside option is limited to non-agricultural sectors, the nesting parameter rises above one, although the estimate is imprecise and not statistically distinguishable from unity. Across both specifications, we also observe consistent patterns in the determinants of supply allocation across manufacturers. Farmers tend to sell more to private firms, to manufacturers that pay lower wages to their factory workers, and to those offering lower downstream sugar prices. These patterns may seem counterintuitive at first glance, but they are consistent with the structure of interlinked contracts and market power in input procurement. First, private firms may face fewer procurement frictions or offer more flexible payment terms compared to state-owned enterprises, making them more attractive trading partners. Second, lower factory wages may signal weaker labor protections or looser regulation-conditions under which manufacturers may pass a greater share of rents to input suppliers. Finally, manufacturers with lower sugar prices may operate at larger scale or higher efficiency, providing more stable and predictable demand for farmers' output.

4.5.4 Degree of Collusion

With all model parameters estimated, we now return to the firms' first-order condition to back out the profit internalization parameter Z_{ft}, which reflects the extent to which each firm incorporates competitors' profits into its own objective function. If the model correctly identifies this parameter, and assuming that each firm places a consistent, idiosyncratic weight on the profits of all other firms, we can compute a firm-year-specific value of Z_{ft} using equation (41).

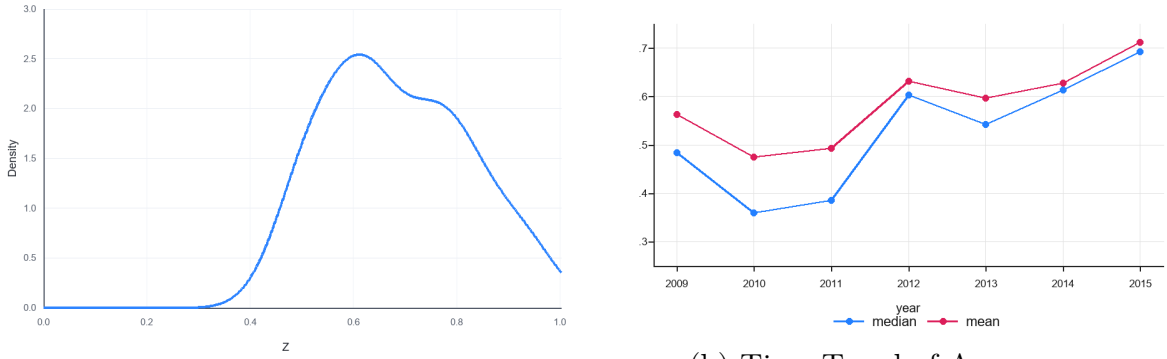
The first column of Table 2 reports the mean Z_{ft} across all firm-year observations. In the baseline specification, the average firm internalizes approximately 72.6% of the average profits of its competitors when making pricing decisions, an economically meaningful degree of collusive behavior.And the standard error is block-bootstrapped with 200 iterations. Figure 7 illustrates the distribution and evolution of Z_{ft} of the baseline setting. Panel (a) shows that the distribution is right-skewed and significantly shifted away from zero, indicating that while most firms internalize a modest share of rival profits, a subset engages in stronger collusion. Panel (b) depicts a rising trend in average Z_{ft} over time, with a notable uptick beginning around 2010. This increase coincides with a period of accelerated growth in foreign sugar imports, suggesting that heightened import competition may have induced domestic firms to coordinate more closely as a defensive response. Due to being at a disadvantage in price competition, exposure to foreign rivals appears to have prompted greater strategic alignment among incumbent producers.

Table 2: Estimated Collusion via Internalization Parameter Z_{ft}

Parameter	(1) Uniform Collusion	(2) Differentiated Collusion	(3) $H_0 : Z^2_{ft} = 0$	(4) $H_0 : \begin{matrix} Z^1_{ft} = Z^1_t \\ Z^2_{ft} = Z^2_t \end{matrix}$
Panel A: Within- vs. Outside-City Collusion				
$\bar{Z}_{ft}$	0.726			
	(0.038)			
$\bar{Z}^1_{ft}$		0.417	0.710	0.225
		(0.010)	(0.018)	(0.010)
$\bar{Z}^2_{ft}$		0.032		0.075
		(0.009)		(0.005)
Panel B: Within- vs. Outside-Upstream Ownership Links				
$\bar{Z}_{ft}$	0.726			
	(0.038)			
$\bar{Z}^1_{ft}$		0.263	0.627	0.560
		(0.011)	(0.017)	(0.010)
$\bar{Z}^2_{ft}$		0.111		0.003
		(0.009)		(0.007)

Notes: This table reports the estimated mean values $\bar{Z}_{ft}$, $\bar{Z}^1_{ft}$ and $\bar{Z}^2_{ft}$ of the internalization parameter Z_{ft}, Z^1_{ft} and Z^2_{ft} under different assumptions. Panel A compares collusion between firms located within the same city and those outside the city. Panel B compares firms that share upstream ownership links with those that do not. Column (1) presents the baseline estimates, assuming firms collude uniformly with all others, regardless of location or ownership ties. Column (2) allows the degree of collusion to differ depending on whether other firms are in the same city or share ownership links. Column (3) imposes the restriction that firms only collude with others in the same city or ownership network ($Z^2_{ft} = 0$). Column (4) assumes that all firms share the same degree of collusion within and outside the city (or ownership link), removing firm-level heterogeneity while still allowing differences across location or ownership categories.

Figure 7: Estimated Degree of Collusion Among Sugar Manufacturers



(a) Distribution of z_{ft} Across Firms

(b) Time Trend of Average z_{ft}

Notes: Panel (a) displays the distribution of the firm-year-specific profit internalization parameter Z_{ft}, and Panel (b) plots its annual trend, showing the simple average of Z_{ft} across firms in each year.

Extended Results. The degree of collusion may differ systematically across firms, influenced by factors such as geographic proximity and ownership structure. Firms located in the same city are exposed to similar competitive pressures, which can strengthen their incentives to coordinate behavior.[30] Similarly, firms under common corporate ownership are more likely to internalize one another's profits, as strategic decisions are often guided by centralized management and aligned financial interests.[31] This distinction is particularly salient in our setting. Of the 682 firm-year observations in our sample, 582 belong to 17 distinct corporate ownership networks, with the largest eight networks accounting for over 70% of the sample. Firms operating under the same ownership umbrella also often coordinate production and pricing decisions at the parent-company level.

To account for this heterogeneity in coordination intensity, we extend the model to allow firms to place different weights on the profits of others depending on whether they are within the same city or share common ownership. Specifically, Z^1_{ft} captures the degree of profit internalization toward firms within the same city or ownership network, while Z^2_{ft} captures internalization toward firms outside that boundary. The revised first-order condition under differentiated collusion weights is:

$$1+\frac{1}{\varepsilon_{ft}}+\frac{Z^1_{ft}}{N_G-1}\sum_{v\in G, v\neq f}\frac{1}{\varepsilon_{fvt}}\frac{s_{vt}}{s_{ft}}+\frac{Z^2_{ft}}{N-N_G}\sum_{v\notin G}\frac{1}{\varepsilon_{fvt}}\frac{s_{vt}}{s_{ft}}=\frac{1}{p_{ft}}\cdot\left[\frac{w^L_{ft}}{MP^L_{ft}}+\frac{w^M_{ft}(1+\phi^M_{ft})}{MP^M_{ft}}\right] \quad (42)$$

Columns (2) through (4) in Table 2 shed light on how collusive behavior varies depending on whether firms are located in the same city or are tied through upstream ownership. Starting with Panel A, we allow firms to place different weights on the profits of nearby versus distant peers. The results are striking: firms internalize profits more heavily from those located in the same city ($\bar{Z}^1_{ft} = 0.417$) than from those outside ($\bar{Z}^2_{ft} = 0.032$). This pattern is intuitive-firms that operate in close geographic proximity are more likely to interact, monitor each other's behavior, and form implicit or explicit arrangements. In other words, local connections matter. [32] When we go a step further and assume that firms only consider

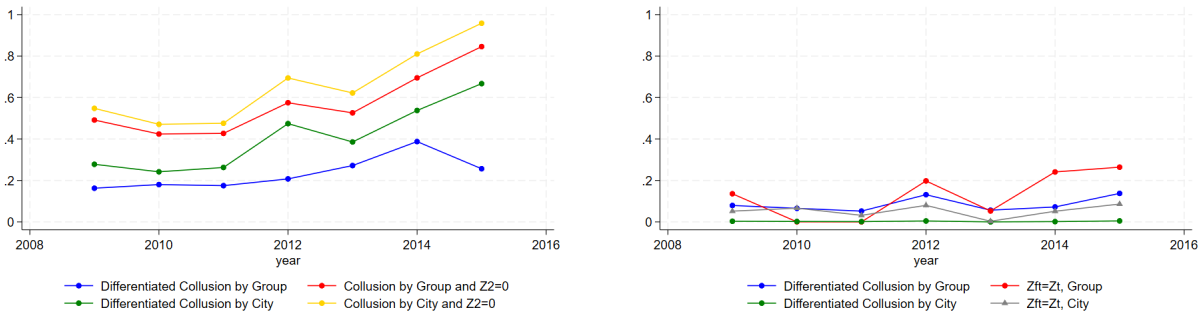
[30] For example, Brooks et al. (2021a) document that firms in Chinese special economic zones exhibit cooperative pricing almost three times as frequently as firms outside these zones. Similarly, Gan and Hernandez (2013) show that hotels located in close geographic clusters are significantly more likely to fall within the collusive regime.

[31] As emphasized by Khanna and Palepu (1997, 2000); Gopalan et al. (2007), business groups can mitigate market failures, buffer environmental shocks, and offset survival threats to affiliates through internal cooperation. They also provide ongoing benefits to group-affiliated firms, including information on market opportunities and reputation signaling (Lamin, 2013), as well as superior capabilities for sensing and seizing growth opportunities (Manikandan and Ramachandran, 2015).

[32] It is important to note that this does not imply that the baseline conduct parameter Z_{ft} must lie between Z^1_{ft} and Z^2_{ft}. As shown in Appendix B.5, Z_{ft} is not a convex combination of the group-specific terms and

others in the same city in their profit calculations (Column 3), the intensity of internalization increases markedly to $\bar{Z}^1_{ft} = 0.710$. This suggests that when collusive attention is concentrated solely on local peers, the depth of coordination deepens-likely because local firms face similar market conditions and may have greater trust or repeated interactions. Even when we restrict the model further in Column 4-assuming that all firms internalize profits with the same weight but still allowing for a distinction between inside and outside the city-the results hold steady ($\bar{Z}^1_{ft} = 0.225$, $\bar{Z}^2_{ft} = 0.075$), confirming that local ties consistently play a stronger role in shaping collusive incentives. Panel B tells a parallel story, this time focusing

Figure 8: Estimated Differentiated Degree of Collusion



(a) Time Trend of Average Z^1_{ft}

(b) Time Trend of Average Z^2_{ft}

Notes: Panels (a) and (b) display the yearly average of the estimated collusion parameters Z^1_{ft} and Z^2_{ft}, respectively, across all firms in each year. The parameter Z^1_{ft} reflects the degree of profit internalization within firm groups, while Z^2_{ft} captures potential coordination across groups.

on organizational ties rather than geography. Here, we ask: do firms that share upstream ownership-such as being part of the same corporate network-collude more strongly with each other? The answer is yes. Column (2) shows that firms within the same ownership network internalize each other's profits more ($\bar{Z}^1_{ft} = 0.263$) than firms that do not share ownership links ($\bar{Z}^2_{ft} = 0.111$). These ties may reflect formal or informal coordination mechanisms, shared strategic interests, or even centralized decision-making within corporate groups. This interpretation is reinforced in Column (3), where we restrict firms to only internalize profits within the ownership network. The estimated $\bar{Z}^1_{ft}$ rises to 0.627, indicating a more focused and potentially deliberate coordination among affiliated firms. Even under the assumption of uniform behavior in Column (4), the internalization parameter for affiliated firms remains higher than for unaffiliated ones ($Z^1_{ft} = 0.560$ vs. $Z^2_{ft} = 0.164$), highlighting the persistent role of ownership structure in facilitating collusion. Overall, the results reveal that collusion is far from uniform. It clusters along lines of proximity and affiliation: firms are more

may fall outside their range.

likely to coordinate with those nearby or within the same ownership network. We further display the evolution of collusive behavior by plotting the annual averages of the estimated internalization parameters Z^1_{ft} and Z^2_{ft} in Figure 8, Panels (a) and (b). On average, Z^2_{ft} is markedly smaller than Z^1_{ft}, providing clear evidence that collusion is largely concentrated within firm groups rather than across them. Panel (a) shows a pronounced upward trend in Z^1_{ft}, indicating a growing tendency for firms to internalize the profits of their affiliated peers- a pattern consistent with increasing within-group coordination over time. In contrast, Panel (b) shows that the average value of Z^2_{ft}, which captures the degree of profit internalization across different groups, remains relatively flat, suggesting limited evolution in cross-group collusive behavior.

4.5.5 Sugarcane Markdown

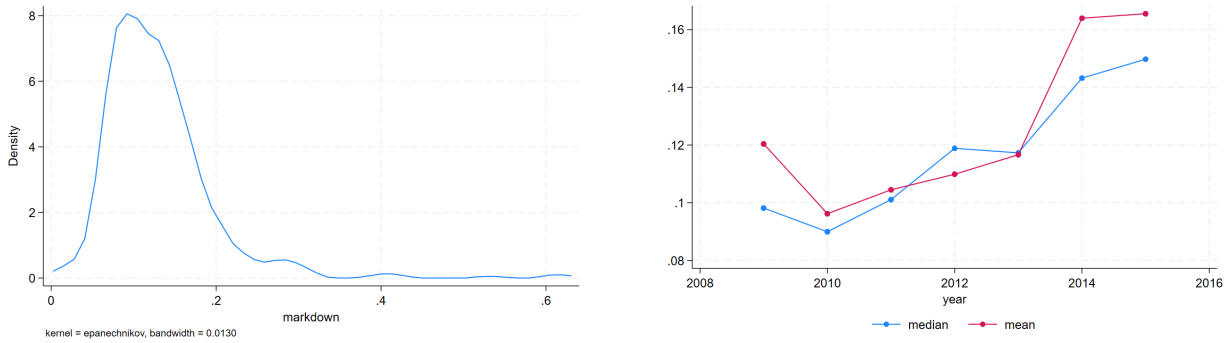
Using the internalization parameter Z_{ft}, we can compute the implied markdown on sugarcane purchases according to equation (29). The estimated mean markdown is 0.130, indicating that, on average, firms acquire sugarcane at a cost roughly 13% below the marginal benefit it generates.[33] Figure 9 presents the distribution and temporal evolution of sugarcane markdowns. Panel (a) shows the cross-sectional distribution of markdowns, with most firms purchasing sugarcane at prices below its marginal value. Panel (b) traces the evolution of markdowns over time: both the median and average rose steadily after 2010, peaking around 2014. The upward trend suggests that domestic producers increasingly exercised market power over cane suppliers, widening the gap between procurement prices and marginal value. Facing intensifying import competition, firms may have coordinated to avoid destructive price wars, thereby protecting margins. Such coordination can, in turn, support higher aggregate output, which naturally requires greater use of inputs, consistent with the observed increase in markdowns.

4.5.6 Sugar Markup

Using labor and sugarcane prices together with the estimated output elasticities, we compute the implied sugar price markup from equation (31). The mean markup is 0.202, indicating that firms sell sugar at prices roughly 20.2% above marginal cost. Figure 10 illustrates both the cross-sectional distribution and the time-series pattern of markups. Panel (a) shows that most firms price above marginal cost, though a non-negligible share record negative markups, implying short-term losses. Panel (b) highlights the sharp decline in both the

[33] Our estimate is lower than the average markdown on cigarette leaf reported by Rubens (2023). The possible reason could be to the instituional difference between the two sectors in China.

Figure 9: Sugarcane Markdown Among Domestic Sugar Producers



(a) Distribution of Sugarcane Markdown (b) Trend of Average Sugarcane Markdown

Notes: Panel (a) shows the cross-sectional distribution of sugarcane markdowns across firms. Panel (b) plots the annual evolution of markdowns, reporting both the median and simple average. A higher markdown indicates greater buyer power, as firms purchase sugarcane at prices further below its marginal value.

mean and median markups after 2010, pointing to a steady erosion of market power. The timing of this decline coincides with a surge in sugar imports, which intensified competition and weakened the ability of Guangxi producers to sustain monopoly pricing. Under growing import pressure, firms appear to have sought implicit coordination to limit destructive price wars, thereby preserving margins. Such coordination, while restraining price cuts, also facilitated continued expansion of aggregate output, requiring greater use of inputs, even as markups fell.

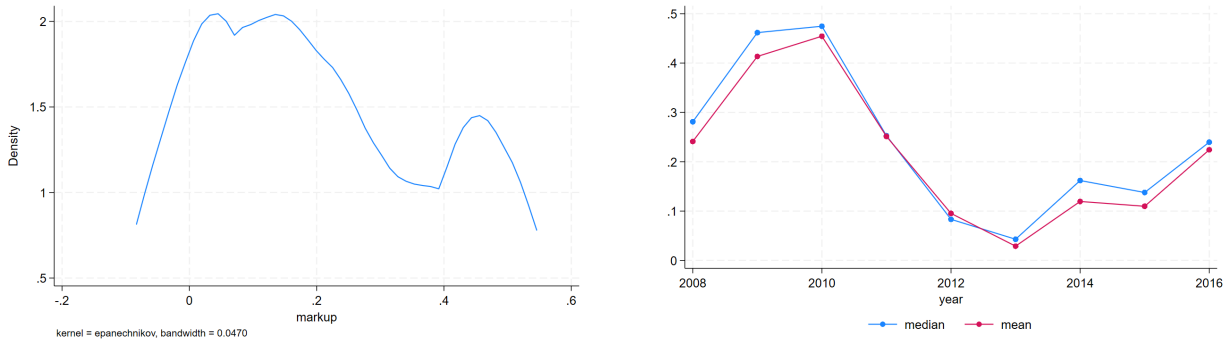
5 Reduced-Form Evidence

This section presents reduced-form evidence on how rising import competition reshaped firm organization and performance in China's sugar industry. We examine two key margins: first, how sugar manufacturers responded in terms of collusive behavior, production decisions, and evolving market power in both input and output markets; and second, how upstream sugarcane farmers adjusted in response.

5.1 Specification

To analyze firm responses, we examine estimated firm-year outcomes, such as outputs, markups, and demand for sugarcane, to identify the causal impact of import-driven competitive pressure on domestic industry performance. Specifically, we estimate the following

Figure 10: Sugar Markup Among Domestic Sugar Producers



(a) Cross-Sectional Distribution of Sugar Markups

(b) Time Trend of Average and Median Markups

Notes: Panel (a) shows the distribution of estimated sugar markups across firms. Markups are calculated as the percentage difference between price and marginal cost; values above zero imply that firms price above marginal cost, while negative values indicate short-term losses. Panel (b) traces the annual evolution of markups from 2005 onward, reporting both the simple average and the median. A higher markup corresponds to stronger seller market power and greater ability to extract margins from production.

specification:

$$y_{ft} = \beta \ln IM_{ct} + \mathbf{Z}'_{ct}\gamma + \delta_t + \delta_f + \epsilon_{ft}, \tag{43}$$

where y_{ft} denotes an outcome of interest (e.g., output, input prices, markup) for firm f in year t; $\ln IM_{ct}$ captures city-level exposure to sugar import at time t. We construct $\ln IM_{ct}$ as a distance-weighted sum of sugar imports across all provinces:

$$IM_{ct} = \sum_j \frac{1}{D_{jc}} \cdot \text{Imp}_{jt}, \tag{44}$$

where D_{jc} is the geodesic distance from city c to city j, and Imp_{jt} denotes the volume of sugar imported by city j in year t. This formulation reflects the notion that firms are more exposed to import competition the closer they are to regions with large inflows of imported sugar. The vector $\mathbf{Z}_{ct}$ includes time-varying city-level controls such as population, GDP per capita, and employment composition (e.g., public vs. private sector share). We include year fixed effects δ_t to capture common time-specific shocks, and firm fixed effects δ_f to absorb all time-invariant heterogeneity across firms. The residual term ϵ_{ft} captures unexplained firm-year variation, and standard errors are clustered at the firm level to account for serial correlation in unobserved firm-specific shocks.

To corroborate our firm-level findings, we examine how rising import competition affects upstream suppliers by drawing on detailed household and village surveys conducted

annually by the Ministry of Agriculture of the People's Republic of China (MOA).[34] These data provide a unique lens into how trade shocks transmit upstream, influencing sugarcane-producing households and revealing shifts in the monopsony power of downstream processors. We construct household-level measures of cultivated land, fixed asset investment, and total income, along with village-level indicators of sugarcane activity, land transfer income, and population. To quantify the upstream effects of trade, we estimate a reduced-form specification parallel to the firm analysis, relating household outcomes to city-level exposure to rising sugar imports. Import exposure is measured using the same distance-weighted index of trade flows, enabling consistent identification across the supply chain. The specification includes a rich set of time-varying city-level controls, such as employment structure, to capture local labor market conditions, alongside village and year fixed effects to absorb unobserved heterogeneity and common shocks. Standard errors are clustered at the village level. We focus on households engaged in sugarcane cultivation, and replicate the analysis for non-cultivating households as a placebo test of exposure specificity.

5.2 Results

Firm-level Adjustments Table 3 presents the effects of rising sugar imports on firms' production decisions and market conduct. Column (1) shows that the internalization parameter Z_{ft}, which captures the extent of collusive behavior, increases significantly with greater import exposure. This suggests that firms respond to intensified foreign competition by tightening coordination, effectively colluding more, to buffer against margin pressure and maintain industry stability. Column (2) shows that firms' output shrinks in response to the import shock. However, with more efficient coordination, firms collectively increase production to preserve market share. This output expansion is consistent with heightened collusion: by coordinating their supply responses, firms can avoid destructive price wars while still mounting a unified defense against foreign rivals. However, this strategy entails a trade-off. As shown in column (3), firms experience a decline in markups, indicating a willingness to sacrifice pricing power in exchange for volume gains. The loss in pricing margin underscores the intensity of the competitive environment, even under coordinated behavior. Besides, a higher coordination efficiency is accompanied by larger "pricing power exchanging for volume". Finally, column (4) reveals that the decrease in output also lowers the derived demand for sugarcane, and higher coordination efficiency help to maintain relative larger sugarcane demand. This pass-through highlights the upstream effects of downstream adjustment.

[34]The MOA survey, initiated in 1984, covers all provincial-level regions in China. Each year, it samples roughly 200,000 rural households and 350 administrative villages, yielding nationally representative data.

Robustness Check of Confounding Effect In December 2009, the People's Government of the Guangxi Zhuang Autonomous Region issued the *Opinions on Accelerating the Development of the Circular Economy in the Sugar-Manufacturing Industry*. The document proposed prioritizing the development of sugar-manufacturing enterprise groups with annual sugar production capacity exceeding 500,000 tons, or with strong potential for comprehensive utilization. It emphasized fostering large-scale enterprise groups by encouraging and supporting existing sugar manufacturers to engage in deep integration through asset linkages, thereby establishing larger and more competitive industry groups. The policy also explicitly promoted mergers led by stronger firms and the integration or exit of smaller firms. In particular, it called for expanding the production scale of individual sugar mills and eliminating or consolidating mills that lacked a stable sugarcane supply, relied on outdated production technologies and equipment, or had a daily crushing capacity below 3,000 tons.[35]

To account for the potential impact of this consolidation policy on market competition and to alleviate concerns about confounding effects, we construct a difference-in-differences indicator, *Post_Consolidation*. This variable equals one if a firm is located in a county where at least one sugar mill has a daily crushing capacity below 3,000 tons and the year is after 2009, and zero otherwise. We then re-estimate the effects of city-level import exposure ($\ln IM_{ct}$) on firm-level outcomes, as well as its heterogeneous effects interacting with the city-level average internalization parameter Z_{ct}, while controlling for *Post_Consolidation*. The results are reported in Table B.2. The estimated coefficients on import exposure remain quantitatively similar and statistically significant after controlling for *Post_Consolidation*, suggesting that our main results are not driven by the consolidation policy.

Evidence of Subsidies Beyond firms' adjustments in production and market conduct, we find additional evidence that import competition affects government support received by sugar manufacturers. Because a substantial share of firms receive zero subsidies or tax benefits, we estimate these specifications using a Tobit model with left censoring at zero. Table B.3 reports the estimated effects of import exposure on several subsidy-related outcomes, including tax reductions on agricultural intermediate inputs, income tax concessions, and direct fiscal subsidies. Columns (1), (3), and (5) show that greater import exposure significantly increases firms' access to direct subsidies as well as tax reductions related to agricultural inputs and income. Moreover, the interaction term reported in columns (2) indicates that these effects are amplified in cities with a higher degree of collusion, suggesting that collusive conduct enhances firms' ability to obtain policy support in response to import

[35] Detailed information on the document is provided at http://gxt.gxzf.gov.cn/xxgk/gfxwj/t3663280.shtml

competition.

Table 3: Effects of Import Exposure on Firm Outcomes

Dep var:	(1) $\ln Z_{ft}$	(2) $\ln Q_{ft}$	(3) $\ln Markup_{ft}$	(4) $\ln M_{ft}$
$\ln IM_{ct}$	0.488*	-1.259***	-0.239***	-1.257***
	(0.23)	(0.19)	(0.07)	(0.19)
$\ln IM_{ct} \times lnZ_{ft}^{2010}$		0.022***	-0.007**	0.022**
		(0.00)	(0.00)	(0.00)
Controls	Yes	Yes	Yes	Yes
County FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Cluster	City	City	City	City
adj. R^2	0.462	0.862	0.891	0.848
N	236	497	414	513

Notes: This table reports the estimated effects of city-level import exposure ($\ln IM_{ct}$) on firm-level outcomes, as well as the heterogenous effects with city-level simple average internalization parameter, Z_{ct} . Column (1) uses the log internalization parameter, $\ln Z_{ft}$, as a proxy for the extent of collusion. Column (2) examines the log of sugar output quantity, $\ln Q_{ft}$, capturing production responses. Column (3) measures changes in pricing power via the log markup, while column (4) evaluates input market behavior using the log of sugarcane quantity purchases. All regressions include county fixed effects, year fixed effects, and a standard set of control variables (not shown). Standard errors, clustered at the city level, are reported in parentheses. Significance levels are denoted as follows: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

6 Quantitative Analysis

To quantify the aggregate macroeconomic impact of collusion triggered by import competition, we conduct a series of counterfactual simulations that trace how collusive behavior alters the transmission of trade shocks to market structure. We begin by contrasting two benchmark scenarios: (i) non-collusive Cournot competition, where firms compete independently, and (ii) full collusion, where firms maximize joint profits. This comparison isolates the role of collusion in shaping industry outcomes. We then extend the analysis to examine how alternative trade policies, in particular those that expand sugar imports, affect both market structure and firm conduct. To further disentangle mechanisms, we simulate a case in which import prices remain unchanged, thereby focusing on the quantity effects of increased imports. Finally, we explore a policy experiment in which the Chinese government introduces a per-unit subsidy for domestic sugar manufacturers, which allows us to evaluate how industrial policy interacts with trade shocks and collusive behavior.

Simulation Procedures In the counterfactual simulations, equilibrium outcomes are obtained by solving a system of five equations that jointly determine sugar output (Q_{ft}), prices

(p_{ft}), sugarcane prices (W_{ft}^M), sugarcane input (M_{ft}), and labor demand (L_{ft}). The system is built from the structural model described in Appendix B.8.1. First, firms' optimal pricing is given by the first-order condition in equation (28), which links equilibrium prices to marginal costs of labor and sugarcane inputs. Second, the sugarcane supply response is captured by the market-clearing condition in equation (32), where prices adjust to balance supply with firm characteristics and shocks. Third, demand is governed by the CES system in equation (B.42), with the corresponding domestic and aggregate price indices (P_{dt}, P_t). Finally, production technology imposes the joint conditions in equation (B.43), ensuring that labor and sugarcane inputs are simultaneously consistent with output. Together, these equilibrium conditions form a $5n$ system of equations in $5n$ unknowns (where n is the number of domestic firms), which we solve to map any exogenous policy or parameter change, such as shifts in trade policy or subsidies, into endogenous industry outcomes. Using the resulting equilibrium values, we compute consumer surplus (CS), producer surplus (PS), and total welfare (TW) under each scenario. The detailed procedures for calculating these surplus measures are provided in Appendix B.8.3.

For comparison, we report the changes in equilibrium outcomes implied by the observed data between 2010 and 2014, a period spanning the sharp rise in import competition. We summarize (i) aggregate outcomes—the domestic market share of sugar, total consumer surplus in sugar, total producer surplus (sugar mills plus sugarcane farmers), total revenue of sugar manufacturers, total cane payments, government's net income, and total welfare in the sector—and (ii) simple averages of key firm-level variables, including sugar output, sugar prices, sugarcane input use, sugar price markups, sugarcane procurement prices, and the corresponding markdowns. We refer to these observed 2010–2014 changes as the Status Quo, reported in the first column of Table 4. We then take the 2014 economy as the baseline and recompute equilibrium outcomes under alternative conduct and policy scenarios; the remaining columns report differences relative to the 2014 Status Quo.

6.1 Perfect Cournot Competition

As a benchmark, we consider the case in which collusion among Chinese sugar manufacturers is absent. Firms compete à la Cournot, choosing output independently to maximize profits. Solving the system under this assumption yields the counterfactual equilibrium of the key endogenous variables. The firm's first-order condition, with $z_{ft} = 0$, is:

$$p_{ft}\left(1 + \frac{1}{\varepsilon_{ft}}\right) = \left[\frac{w_{ft}^L}{MP_{ft}^L} + \frac{w_{ft}^M(1+\phi_{ft}^M)}{MP_{ft}^M}\right]$$

In this setup, firms internalize the effect of their own output on the market price but take rivals' quantities as given, consistent with the standard Cournot framework. We calibrate the counterfactual by allowing the decline in foreign sugar prices to mirror the empirical magnitude observed in the data. This provides a natural reference point for evaluating the effects of collusion on market outcomes.

Column (1) reports the counterfactual under Cournot competition, where firms act independently rather than coordinating their output. Relative to the 2014 Status Quo, real activity contracts more sharply: in addition to the 12.55% decline observed from 2010 to 2014, domestic sugar output is 84.95% lower under Cournot, and sugarcane use is 84.92% lower. On the product side, prices would be much larger [36] (domestic prices are 136.38% higher relative to the Status Quo), and the domestic market share erodes further (an additional 29.76% decline relative to the Status Quo in 2014). These patterns reflect a standard free-rider logic in the presence of import substitution. Facing cheaper imports, an individual Cournot firm has weaker incentives to expand output to "defend" the domestic segment, because much of the gain from such expansion is dissipated through lower own margins and does not internalize the business-stealing effect across domestic rivals. By contrast, under the Status Quo—which embeds partial profit internalization—firms coordinate their quantities so as to sustain domestic scale *vis-à-vis imports*. This defensive coordination can imply lower domestic prices and markups relative to the Cournot counterfactual, not because firms compete more aggressively against domestic rivals, but because they jointly choose a larger domestic quantity response to mitigate substitution toward imports.

These differences carry through to input markets. With weaker production incentives under Cournot, demand for sugarcane is lower, driving a sharper fall in cane prices (-28.16% further) and a dramatic increase in markdowns (+226.77%),which is in line with the theoretical model's graphical analysis results in panel b of figure 11 [37]. In our framework, the markdown is jointly determined by (i) the scale of input demand and (ii) the perceived marginal benefit of inputs, which itself depends on output-market conduct. Although the overall scale of input demand shrinks, the higher perceived marginal revenue product strengthens firms' incentives to exercise buyer power. The net effect is an expansion of upstream oligopsony

[36] As shown in panel a of figure 11,under Cournot competition, the corresponding marginal revenue curve shifts from MR to MR',which drops faster with output and has a larger slope, and equilibrium output falls from Q_1 to Q_2 (point 1 to point 2),the price turns out higher. With collusion, however, the effective marginal revenue curve is MR''. Because collusion internalizes the impact of output reductions across the industry, MR'' is flatter and lies above MR'. The resulting equilibrium, at Q_3, is larger than Q_2 (point 1 to point 3).

[37] Conduct also affects the effective marginal-expenditure schedule. In the figure, stronger coordination shifts the relevant MEM curve downward, vice versa. As a result, although cane purchases decrease under Cournot competition, the equilibrium cane price is relatively lower compared to the marginal value of cane than under stronger collusion. The gap between marginal benefit and the input price therefore expands, implying a larger markdown under Cournot competition.

distortion, reflected in the sharp increase in markdowns. By contrast, under the Status Quo with partial internalization, firms expand output to defend the domestic segment against imports. This coordinated response sustains cane demand, supports input prices, and moderates the exercise of buyer power upstream. Thus, conduct shapes not only downstream pricing but also the extent to which import shocks are transmitted to farmers.

Welfare outcomes highlight the second-best nature of the environment. Consumer surplus rises more under Cournot (+36.48%) because buyers benefit from import expansion and the weaker domestic response. However,total firm revenue and sugarcane expenditures decline much more sharply (-63.61% and -89.41%, respectively), leading to a substantial reduction in producer surplus. Relative to the Status Quo, producer surplus falls by 94.25%, and total producer surplus (mills plus farmers) is a further 38.21% lower. This pronounced loss reflects the severe contraction of domestic production and the associated decline in upstream economic activity, which can not be compensated by the increased consumer surplus and tariff income. As a result, total welfare is 20.60% lower than in the Status Quo. In short, the Cournot counterfactual delivers larger gains to consumers but triggers a sharper collapse of domestic and upstream surplus; with both output-market power and input-market distortions present,the net welfare ranking depends on how the import shock reallocates surplus across consumers, domestic producers, and upstream suppliers, as well as on the associated tariff or subsidy components.

6.2 Complete Collusion

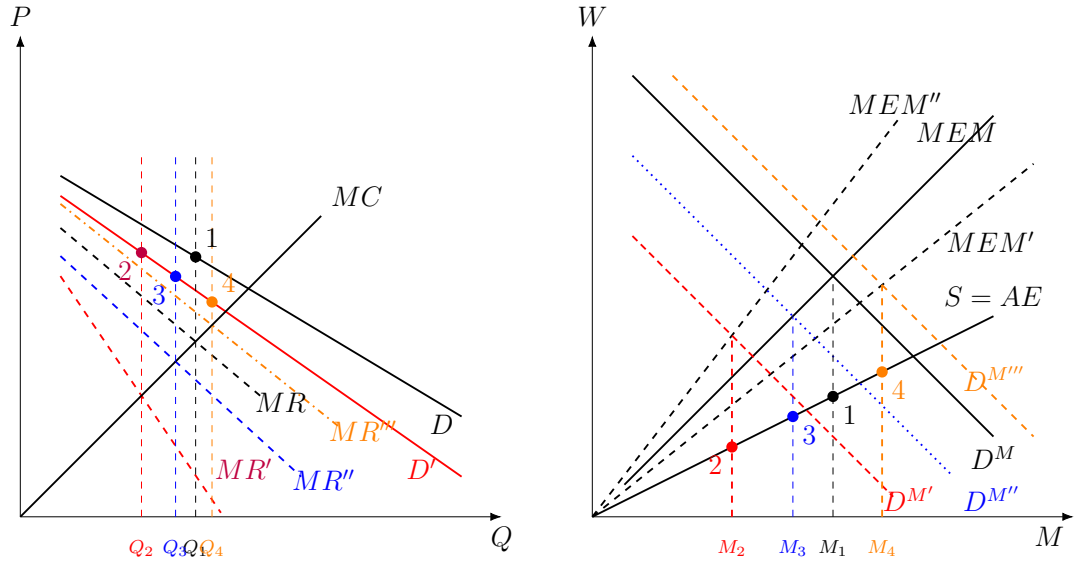
We now turn to the opposite extreme, in which firms collude fully by maximizing joint industry profits. Compared with Cournot competition, this regime introduces an additional term in the first-order condition, capturing that each firm fully internalizes the profits of all others ($Z_{ft} = N - 1$). In effect, the strategic interdependence that is only partial under Cournot becomes complete under collusion, and firms choose output as if they were a single monopolist:

$$1 + \frac{1}{\varepsilon_{ft}} + \sum_{v \neq f} \frac{1}{\varepsilon_{fvt}} \frac{s_{vt}}{s_{ft}} = \frac{1}{p_{ft}} \cdot \left[\frac{w_{ft}^L}{MP_{ft}^L} + \frac{w_{ft}^M (1 + \phi_{ft}^M)}{MP_{ft}^M} \right]. \tag{45}$$

Compared with Cournot competition, the collusive regime adds the summation term on the left-hand side, which captures how firms internalize the external effects of their output on the profitability of their rivals.

The results, reported in Column (2) of Table 4, indicate that the observed Status Quo lies between the two extremes: Cournot competition and complete collusion. Under full collusion, firms choose quantities to internalize the domestic business-stealing effects and

Figure 11: Potential Impact of Market Conduct on Market Outcomes



Notes:This figure further illustrates how different conducts shape equilibrium outcomes in the presence of an import shock based on figure 4. Panel (a) depicts the product market. The initial demand curve D shifts inward to D' following the import shock, reflecting a reduction in domestic demand for sugar. The upward-sloping line labeled MC is the marginal-cost curve. The dashed curves show the associated marginal-revenue schedules: MR (pre-shock), MR' (Cournot, post-shock), MR'' (partial collusion, post-shock), and MR''' (full collusion, post-shock). The intersections of each marginal-revenue curve with MC determine the equilibrium quantities Q_1, Q_2, Q_3, and Q_4, marked by points 1–4. Panel (b) shows the input (sugarcane) market. The upward-sloping curve $S = AE$ denotes the supply of sugarcane; the dashed curves are the marginal-expenditure schedules faced by the buyer under alternative conduct: MEM (partial collusion), MEM' (Cournot), and MEM'' (complete collusion). The downward-sloping curves D^M, $D^{M'}$, $D^{M''}$, and $D^{M'''}$ are the derived input-demand schedules before the import shock, under Cournot after the shock, under partial collusion after the shock, and under complete collusion after the shock, respectively. Their intersections with the corresponding marginal-expenditure curves determine the equilibrium employment levels M_1, M_2, M_3, and M_4; the associated equilibrium wages are read on the vertical axis.

thereby mount a stronger *defensive* response against import substitution. Relative to the Status Quo, they cut more prices to expand output. This implies a larger domestic quantity response and lower domestic markups, which raises sugarcane demand and pushes input prices upward. The welfare consequences reflect a reallocation rather than a first-best improvement. Consumers gain less than in the Status Quo because some expenditure is shifted from cheaper imports toward domestic varieties. Producers (mills plus farmers) gain more because domestic scale and upstream activity are better preserved. In this second-best setting—with both output-market power and input-market distortions—the net effect on total welfare can be positive even though consumer surplus falls, because full coordination mitigates the contraction on the sugarcane side.

6.3 Liberalization Policy: Lower Import Tariffs

Our estimates suggest that the observed Status Quo reflects some degree of collusive behavior, as firms already coordinate to defend market share in the presence of import competition. Current tariffs nonetheless provide partial protection by limiting the extent of foreign entry. A natural question, then, is what happens if this protection is reduced further. We simulate a tariff cut that lowers the price of imported sugar by 10 percent and compute the new equilibrium outcomes, reported in Column (3) of Table 4.

The results indicate that liberalization intensifies import competition under partial collusion. Compared with the Status Quo, domestic output and prices fall further (-0.04% and -0.94%), leading to a markedly lower domestic market share (-3.10%). And sugarcane demand declines slightly further (-0.04%), leading to a reduction in the sugarcane price and the corresponding markdown (-0.01% and -0.86%, respectively). Markups also decrease (-0.93%), consistent with a more competitive market environment.

On the demand side, the tariff cut lowers the effective price index faced by consumers—primarily through cheaper imports and the induced adjustment of domestic prices—so total consumer surplus rises by 1.45% relative to the Status Quo.Total Producer surplus (mills plus farmers) declines by 1.67% as lower domestic scale and weaker upstream demand compress revenues and rents. And taking the reduced tariff income into consideration, aggregate welfare is 1.97% less than in the Status Quo.

6.4 Protectionism Policy

Higher Import Tariffs While tariff liberalization highlights the potential gains from greater openness, many countries also consider protectionist measures when domestic industries face mounting import pressure. Exploring the consequences of higher tariffs is therefore

not only a useful theoretical benchmark but also a realistic policy scenario. By simulating a 10 percent increase in the import price of sugar, we can assess whether protectionism stabilizes domestic production and supports upstream suppliers, or whether it reduces overall efficiency and welfare.

As reported in Column (4) of Table 4, higher tariffs raise domestic output, market share, and sugarcane demand relative to the Status Quo. In our framework, this policy partly redirects demand away from imports and toward domestic varieties. Given partial internalization in the domestic industry, firms respond predominantly through quantities: they expand domestic supply to absorb the redirected demand, which can put downward pressure on domestic prices even as imported varieties become more expensive observed at the border. Consistent with this adjustment, markups fall further.

The distributional implications are straightforward. Consumers benefit less than in the Status Quo because the policy reduces access to low-priced imported sugar and shifts consumption toward domestic varieties. Producers and sugarcane farmers gain as domestic scale expands and cane demand increases, raising input prices and improving upstream revenues. Accounting for tariff revenue, total welfare increases slightly relative to the Status Quo, though the gain is driven by producer-side improvements rather than consumer surplus.

Manufacturing Subsidies In addition to tariffs, governments frequently rely on production subsidies as an alternative form of protection. Whereas tariffs restrict foreign competition directly, subsidies lower domestic producers' effective costs, enabling them to compete more aggressively against imports.[38] We consider a case in which the government provides an ad valorem subsidy of 10 percent on output. The corresponding first-order condition is:

$$(1+\tau)\left[1+\frac{1}{\varepsilon_{ft}}+\frac{Z_{ft}}{N-1}\sum_{v\neq f}\frac{1}{\varepsilon_{fvt}}\frac{s_{vt}}{s_{ft}}\right]=\frac{1}{p_{ft}}\cdot\left[\frac{w_{ft}^{L}}{MP_{ft}^{L}}+\frac{w_{ft}^{M}(1+\phi_{ft}^{M})}{MP_{ft}^{M}}\right] \tag{46}$$

where the ad valorem subsidy is set at $\tau = 10\%$.

The subsidy enters as a $(1+\tau)$ multiplier on the left-hand side of the first-order condition, effectively relaxing the pricing constraint implied by demand elasticities. Equivalently, the policy lowers firms' effective marginal cost of serving the market, allowing them to sustain lower prices (and/or larger quantities) for a given conduct parameter.In practice, this means firms can profitably charge lower prices. The results in Column (5) of Table 4 show how subsidies change the adjustment to import competition. By lowering effective costs, subsidies

[38]This policy instrument is particularly relevant in China, where industrial subsidies have been widely deployed to shield strategic sectors from external shocks(Kalouptsidi (2018); Lashkaripour and Lugovskyy (2023); Barwick et al. (2025); Hu et al. (2025)).

allow firms to cut prices more aggressively and expand output far beyond the Status Quo. This expansion drives a sharp increase in sugarcane demand and raises input prices, while markups fall as firms sacrifice margins to gain scale. Importantly, total producers' surplus rises dramatically (+31.22%), not only because firms and upstream cane growers sell more at the subsidized price, but also because the subsidy itself acts as a direct transfer from the government. Consumer surplus, by contrast, is lower than in the Status Quo (-0.5%), because the subsidy induces substitution away from imported sugar toward domestic varieties that, despite the price cut, are still relatively more expensive, thereby limiting the net gains to consumers. Once the fiscal cost of the subsidy is taken into account, the overall policy performance deteriorates further. Compared with a tariff increase, the production subsidy delivers weaker aggregate gains, and total welfare is 25.22% lower than in the Status Quo. This highlights the distortionary nature of production-based support in a setting characterized by both output- and input-market power.

Interpreting the Counterfactual Mechanisms. After presenting the full set of counterfactual exercises, it is useful to synthesize the mechanisms underlying the results. The economy we study is inherently second-best: market power is present on both the output side (imperfect competition in sugar) and the input side (oligopsonistic procurement with an endogenous sugarcane supply). Because imports are close substitutes for domestic sugar in the nested CES demand system, import shocks operate primarily through substitution between domestic and imported bundles. Changes in firms' conduct therefore matter not only for domestic markups, but also for how strongly firms adjust quantities to defend the domestic segment *vis-à-vis* imports.

This perspective helps rationalize several results that differ from standard one-market intuition. In a textbook oligopoly without upstream distortions, collusion typically raises prices and reduces welfare. In our setting, however, collusion is not a instrument to extract more profit from downstream consumer, but for defending against import competition. And partial (or full) profit internalization can strengthen the domestic quantity response to import competition, lowering domestic prices and markups relative to a Cournot counterfactual, conditional on the same import shock. This "defensive coordination" reflects firms' internalization of business-stealing incentives, leading them to coordinate quantities so as to limit cannibalization among domestic producers and respond more aggressively to import competition. These adjustments propagate upstream through the sugarcane market, so that differences in domestic scale translate into sizable changes in upstream activity and surplus. Consequently, welfare rankings across scenarios reflect the balance between consumer gains from import competition, producer-side adjustments along the supply chain, and the

associated fiscal components.

Table 4: Comparison for the Change of Key Variables Across Market Scenarios

	Change from 2010 to 2014	Difference of market scenarios compared to Status Quo in 2014				
				Liberalization Policy	Protectionism Policy	
Indicator/ Scenario	Status Quo	(1) Non-coordinated Cournot	(2) Complete Collusion	(3) Reduction in Tariffs	(4) Increase in Tariffs	(5) Production Subsidy
Domestic Sugar Output	-12.55%	-84.95%	+20.88%	-0.04%	+0.02%	+8.36%
Domestic Sugar Price	-30.86%	+136.38%	-12.15%	-0.94%	+0.67%	-3.86%
Domestic Share	-14.05%	-29.76%	+0.99%	-3.10%	+1.49%	+0.74%
Sugarcane Quantity	-13.07%	-84.92%	+21.55%	-0.04%	+0.02%	+8.36%
Sugarcane Price	-16.57%	-28.16%	+5.20%	-0.01%	+0.01%	+1.98%
Markup	-33.32%	+271.61%	-21.33%	-0.93%	+0.67%	-6.37%
Markdown	-16.91%	+226.77%	-17.61%	-0.86%	+1.13%	-9.74%
CS	+25.68%	+36.48%	-1.22%	+1.45%	-1.05%	-0.50%
PS	-61.62%	-94.25 %	+27.73%	+0.09%	-0.08%	+9.00%
Total PS	-26.73%	-38.21 %	-27.73%	-1.67%	+1.19%	+31.22%
Revenue	-22.84%	-63.61%	+11.34%	-0.98%	+0.69%	+4.15%
Canecost	-8.11%	-89.41%	+22.94%	-0.06%	+0.03%	+10.92%
TW	-11.83%	-17.82%	-22.98%	-2.08 %	+1.32%	-25.22%
Tariff/ Subsidy (% TW)	0.53%	7.37%	0.40%	1.75%	0.33%	-15.05%

Notes: This table compares the percentage changes in key variables across the observed Status Quo (Column 1) and five counterfactual scenarios. The counterfactuals include: (i) non-coordinated Cournot competition (Column (1)), where firms act independently; (ii) complete collusion (Column (2)), where firms maximize joint profits; (iii) a tariff reduction of 10 percent on imported sugar (Column (3)); (iv) a tariff increase of 10 percent (Column (4)); and (v) a production subsidy equal to 10 percent of output value (Column (5)). Changes reported in the Status Quo column are measured between the pre-shock period (2010) and the post-shock period (2014). Statistics in Columns (1)–(5) represent percentage changes in 2014 under each counterfactual scenario relative to the 2014 Status Quo. All figures are expressed as simple percentage differences. The reported indicators include average domestic sugar output, average domestic sugar prices, the domestic market share, average sugarcane input use and prices, the price markup on sugar, and the markdown on sugarcane. Welfare measures comprise consumer surplus (CS), producer surplus (PS), total producer surplus (mills plus farmers), total firm revenue, total sugarcane expenditure, and total welfare (TW), where TW incorporates tariff revenues and subsidy expenditures. The final row reports the fiscal component—government net income (tariff revenue plus subsidy expenditure)—expressed as a share of total welfare.

7 Conclusion

This paper studies how import competition reshapes firms' conduct in a vertically related market with imperfect competition on both the output and input sides. Using the Chinese sugar industry as a laboratory, we document that rising import pressure does not simply discipline domestic producers through lower prices and reduced markups. Instead, it induces manufacturers to internalize rivals' profits to a greater extent, leading to stronger collusive behavior in the downstream market.

We develop and estimate a structural framework that integrates a nested CES demand system, a production technology featuring a non-substitutable sugarcane input, and a nested-logit sugarcane supply model, which together allow us to recover downstream conduct (profit internalization) and upstream oligopsony distortions in a unified setting.

The estimated conduct parameter reveals substantial profit internalization among firms, and its magnitude increases with exposure to import competition. This behavioral response alters the transmission of trade shocks: while imports reduce domestic prices and expand consumer surplus, they simultaneously depress manufacturers' profits and upstream sugarcane producers' income.

Counterfactual simulations highlight the importance of endogenous conduct adjustments. When firms are allowed to collude more intensively, they expand output and partially offset the contractionary effects of import competition on upstream demand. As a result, collusion mitigates income losses for sugarcane farmers and cushions manufacturers against import pressure, albeit at the cost of higher market power distortions. In contrast, these trade-policy counterfactuals are designed to compare welfare consequences across policy instruments, showing that policies which expand import access generate large consumer gains but impose substantial losses on domestic producers and upstream farmers, while protective measures and production subsidies redistribute surplus in the opposite direction, with markedly different implications for total welfare.

Our findings suggest that the conventional empirical literature may underestimate the adverse impacts of import competition on domestic producers and upstream suppliers by treating market conduct as fixed. In environments where firms can coordinate, observed outcomes already reflect endogenous mitigation through collusion. From a policy perspective, this implies that trade liberalization, competition policy, and industrial policy cannot be evaluated in isolation. Understanding how firms adjust their conduct in response to trade shocks is essential for accurately assessing both welfare effects and distributional consequences along the value chain.

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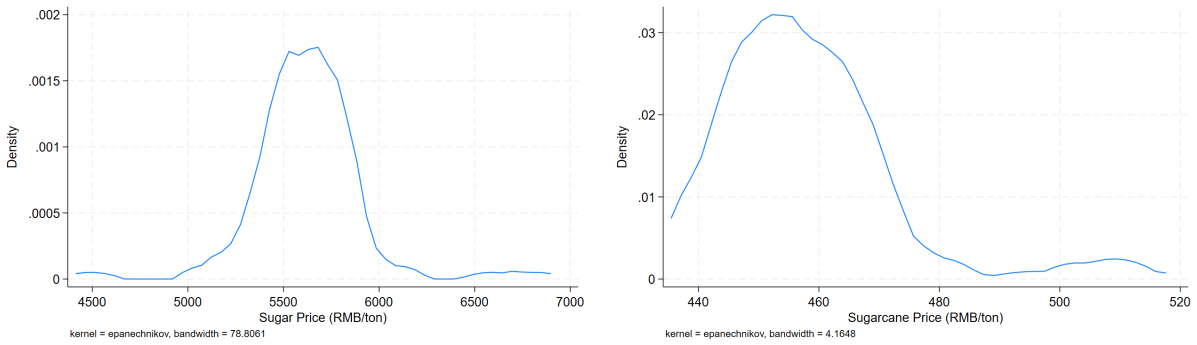
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Appendix A Empirical Appendix

Figure A.1: Distribution of Sugar and Sugarcane Prices among Domestic Producers in 2015(RMB per ton)



(a) Sugar Prices (b) Sugarcane Purchase Prices

Notes: Panel (a) shows the distribution of sugar prices (RMB per ton) reported by domestic sugar manufacturers. Panel (b) displays the distr sugarcane purchase prices (RMB per ton) offered by the same manufacturers. Data are from the Census of Sugar Manufacturers in Guangxi by the Guangxi Sugar Industry Association, which covers the complete universe of sugar-processing firms in the province and provides a rel for documenting these patterns.

A.1 Anecdotal Evidence of Collusion

Producers in Guangxi repeatedly relied on collective arrangements that softened rivalry and kept firms moving in step. The following cases illustrate how this unfolded in practice.

Coordination through the Guangxi Sugar Association (GSA). In Guangxi, all major sugar producers are members of the Guangxi Sugar Association (GSA), an industry body that encompasses state-owned firms such as Nanhua and Nongtou, foreign-invested enterprises like Dongya and Nanpu, and a wide range of private companies. The GSA plays a central role in organizing the industry's seasonal rhythm. Each year, as the crushing season approaches, the association convenes meetings where firms exchange information on cane planting areas, crop conditions, and expected yields. More importantly, before the start of each season, the GSA issues formal notices recommending staggered schedules for mill operations. Officially, the rationale is to avoid premature bidding for cane, which could undermine sugar recovery rates and erode farmers' long-term incentives. Yet the effect of these notices is to ensure mills move in step rather than racing against one another, a rhythm that has quietly shaped procurement practices across the province. [39]

[39]More information of the GSA can be found at https://baike.baidu.com/item/%E5%B9%BF%E8%A5%BF%E7%B3%96%E4%B8%9A%E5%8D%8F%E4%BC%9A/5766322

Collective Petition for a Safeguard Investigation. The industry's capacity to act in concert became most visible during the safeguard investigation of 2016. In July of that year, the GSA joined with its counterparts in Yunnan and Guangdong to compile a comprehensive petition to the Ministry of Commerce. The application drew upon detailed evidence—import statistics, cost reports, and documented operating losses—that required pooling data across firms and provinces. By formally submitting the "Application for a Safeguard Investigation on the Sugar Industry of the People's Republic of China," the associations sought protective measures against the surge in low-priced imports. The petition succeeded: in 2017, safeguard tariffs of 45 percent on out-of-quota imports were imposed, remaining in place until 2019. These measures had an immediate impact, cutting imports in 2017 by 56 percent relative to 2015. The speed and effectiveness of this collective petition suggest that the habits of coordination cultivated in seasonal operations had already extended into the political arena.[40]

Signing the 2013/2014 Crushing Season Cane Area Self-Discipline Convention In November 2013, executives from 18 major sugar groups in Guangxi jointly signed the 2013/2014 Crushing Season Cane Area Management Industry Self-Discipline Convention. The move was prompted by an industry-wide crisis: sugar prices had remained depressed since the start of the crushing season, and the Guangxi sugar sector was projected to suffer losses of 1.5 billion yuan that year. Against this backdrop, the convention called on firms to strengthen solidarity, "weather the winter together," and strictly prohibit cross-regional competition for sugarcane. By formalizing a collective pledge to avoid poaching cane from one another, the agreement effectively established an industry-wide restraint mechanism at a time of acute financial pressure.[41]

Establishment of the Guangxi Bagui Sugar Industry Chamber of Commerce. The institutionalization of collective action was further reinforced by the creation of new organizational structures. In 2015, eighty-one Guangxi-based enterprises—including leading firms such as Nanhua Sugar Industry and Nanning Sugar Industry—jointly founded the Guangxi Bagui Sugar Industry Chamber of Commerce. The chamber's stated mission was to strengthen consensus, safeguard common interests, and promote cooperative development. In practice, it offered a permanent organizational framework through which firms could

[40]Detailed information on the safeguard investigation is provided in an official announcement by the Ministry of Commerce, available at https://www.mofcom.gov.cn/zcfb/dwmygl/art/2016/art_630cbe7dbd204eca8b39b5061961edef.html.

[41]As reported by the CPC' s official platform, the Guangxi Sugar Industry Association convened major firms—including state-owned, private, and joint-venture enterprises—to sign the convention, with the explicit goal of preventing disorderly cane procurement. Source: https://news.12371.cn/2013/11/13/ARTI1384324410440202.shtml.

coordinate resources, exchange strategic information, and impose a degree of self-discipline on the industry. By presenting itself as a champion of "fair competition" and by aligning with national initiatives such as the Belt and Road, the chamber lent a veneer of legitimacy to practices that subtly reduced rivalry. Over time, this new body provided not only stability but also continuity, allowing cooperative patterns to harden into enduring institutions.[42]

[42]Further details about the chamber are available in an online report published by China Chemicals Network, accessible at http://www.cnchemicals.com/Detail/Readonline.aspx?id=4936&type=n&cid=20879600708.

Appendix B Model Derivation

B.1 Comparative Static Analysis of Output under Collusion

Consider domestic firms $d = \{1, \ldots, N\}$ that compete in quantities. Firm f's objective is

$$W_{ft}(q_t, \lambda_t) \equiv \pi_{ft}(q_t) + \lambda_t \sum_{v \neq f} \pi_{vt}(q_t), \qquad \pi_{ft}(q_t) \equiv p_{ft}(q_t) q_{ft} - C_{ft}(q_{ft}),$$

where $\lambda_t \geq 0$ indexes the degree of collusion.

Firm f's first-order condition is

$$F_{ft}(q_t, \lambda_t) \equiv \frac{\partial W_{ft}}{\partial q_{ft}} = \underbrace{\frac{\partial \pi_{ft}}{\partial q_{ft}}}_{MR_{ft} - MC_{ft}} + \lambda_t \sum_{v \neq f} \frac{\partial \pi_{vt}}{\partial q_{ft}} = 0.$$

At the Cournot benchmark $\lambda_t = 0$, let q_t^C satisfy

$$F_{ft}(q_t^C, 0) = 0 \qquad \Longleftrightarrow \qquad MR_{ft}^{\text{Cournot}} = MC_{ft}.$$

Step 1: Envelope theorem (direct value effect).

For fixed rivals $q_{-f,t}$, define the optimized value

$$V_{ft}(\lambda_t; q_{-f,t}) \equiv \max_{q_{ft}} W_{ft}(q_{ft}, q_{-f,t}; \lambda_t).$$

Then the envelope theorem implies

$$\left.\frac{dV_{ft}}{d\lambda_t}\right|_{\lambda_t = 0} = \left.\sum_{v \neq f} \pi_{vt}(q_t)\right|_{q_t = q_t^C}.$$

Thus, a marginal increase in λ_t has a first-order payoff effect. But this does *not* yet tell us whether firm f wants to *raise output*.

Step 2: Implicit function theorem (output effect).

Let $q_{ft}^*(q_{-f,t}, \lambda_t)$ denote firm f's best response. Differentiating the FOC gives

$$\left.\frac{\partial q_{ft}^*}{\partial \lambda_t}\right|_{(q_{-f,t}^C, 0)} = -\frac{\left.\dfrac{\partial F_{ft}}{\partial \lambda_t}\right|_{(q_t^C, 0)}}{\left.\dfrac{\partial F_{ft}}{\partial q_{ft}}\right|_{(q_t^C, 0)}}.$$

The numerator is

$$\left.\frac{\partial F_{ft}}{\partial \lambda_t}\right|_{(q_t^C,0)} = \sum_{v\neq f} \left.\frac{\partial \pi_{vt}}{\partial q_{ft}}\right|_{q_t=q_t^C}.$$

The denominator is

$$\left.\frac{\partial F_{ft}}{\partial q_{ft}}\right|_{(q_t^C,0)} = \left.\frac{\partial^2 \pi_{ft}}{\partial q_{ft}^2}\right|_{q_t=q_t^C} = \left.\frac{\partial MR_{ft}^{\text{Cournot}}}{\partial q_{ft}}\right|_{q_t=q_t^C} - \left.\frac{\partial MC_{ft}}{\partial q_{ft}}\right|_{q_t=q_t^C}.$$

Under the standard second-order condition,

$$\left.\frac{\partial^2 \pi_{ft}}{\partial q_{ft}^2}\right|_{q_t=q_t^C} < 0,$$

so

$$\left.\frac{\partial q_{ft}^*}{\partial \lambda_t}\right|_{(q_{-f,t}^C,0)} > 0 \iff \sum_{v\neq f} \left.\frac{\partial \pi_{vt}}{\partial q_{ft}}\right|_{q_t=q_t^C} > 0.$$

B.1.1 Spillover

Under separable costs,

$$\pi_{vt}(q_t) = p_{vt}(q_t)q_{vt} - C_{vt}(q_{vt}), \qquad \frac{\partial C_{vt}}{\partial q_{ft}} = 0 \quad (v \neq f),$$

so for any allied firm $v \neq f$,

$$\frac{\partial \pi_{vt}}{\partial q_{ft}} = q_{vt}\frac{\partial p_{vt}}{\partial q_{ft}}.$$

Hence the spillover internalized by firm f is purely demand-side:

$$\sum_{v\neq f} \frac{\partial \pi_{vt}}{\partial q_{ft}} = \frac{Y_t}{q_{ft}}\left[S_{Dt}\sum_{v\neq f} s_{vt}\tilde{\kappa}_{vft}^d + (1-S_{Dt})(1-s_{ft})\theta_{ft}^m\right].$$

Here

$$\tilde{\kappa}_{vft}^d \equiv \left.\frac{\partial \ln p_{vt}}{\partial \ln q_{ft}}\right|_{E_{Dt}} = \frac{\partial \ln s_{vt}}{\partial \ln q_{ft}} < 0$$

captures the within-domestic business-stealing effect, while

$$\theta_{ft}^m \equiv -\frac{\partial \ln q_{mt}}{\partial \ln q_{ft}} > 0$$

captures import substitution.

Therefore,

$$\left.\frac{\partial q_{ft}^*}{\partial \lambda_t}\right|_{(q_{-f,t}^C, 0)} > 0 \iff S_{Dt} \sum_{v \neq f} s_{vt} \tilde{\kappa}_{vft}^d + (1 - S_{Dt})(1 - s_{ft}) \theta_{ft}^m > 0.$$

Equivalently,

$$\left.\frac{\partial q_{ft}^*}{\partial \lambda_t}\right|_{(q_{-f,t}^C, 0)} > 0 \iff \theta_{ft}^m > -\frac{S_{Dt}}{(1 - S_{Dt})(1 - s_{ft})} \sum_{v \neq f} s_{vt} \tilde{\kappa}_{vft}^d.$$

Interpretation. Starting from the Cournot benchmark, a marginal increase in collusive conduct raises firm f's output iff the gain from shifting demand away from imports outweighs the loss imposed on allied domestic firms through within-domestic business stealing.

Role of costs. Cost curvature enters only through the denominator

$$\frac{\partial^2 \pi_{ft}}{\partial q_{ft}^2} = \frac{\partial MR_{ft}^{\text{Cournot}}}{\partial q_{ft}} - \frac{\partial MC_{ft}}{\partial q_{ft}},$$

so it affects the *magnitude* of the output response, not the *sign*, under separable costs.

B.2 Demand Elasticities

We have the demand function for each firm

$$b_{ft} x_{ft} = \left[\left(\frac{p_{ft}}{b_{ft}} \right) / P_{dt} \right]^{-\sigma} X_{dt} \tag{B.1}$$

Multiplying by $\left(\frac{p_{ft}}{b_{ft}}\right)$ and using the definition for X_{dt}, we find that spending on each variety is,

$$p_{ft} x_{ft} = P_{dt} X_d \left(\frac{p_{ft}/b_{ft}}{P_{dt}} \right)^{1-\sigma} = Y_t \left(\frac{p_{ft}/b_{ft}}{P_{dt}} \right)^{1-\sigma} \left(\frac{P_{dt}}{P_t} \right)^{1-\eta} \tag{B.2}$$

Then the expenditure share of firm f within the domestic firm set d is:

$$s_{ft} = \frac{p_{ft} x_{ft}}{\sum_{v \in m} p_{vt} x_{vt}} = \frac{\left(p_{ft}/b_{ft}\right)^{1-\sigma}}{\sum_{v \in d} \left(p_{vt}/b_{vt}\right)^{1-\sigma}} = \frac{d \ln P_{dt}}{d \ln p_{ft}} \tag{B.3}$$

We are now in a position to compute the elasticity of demand for an individual firm:

$$
\begin{aligned}
\varepsilon_{ft} = \frac{d\ln x_{ft}}{d\ln p_{ft}} &= \frac{d\ln(p_{ft}x_{ft})}{d\ln p_{ft}} - 1 \\
&= (1-\sigma) + \left[(\sigma-\eta) + (\eta-1)\frac{d\ln P_t}{d\ln P_{dt}}\right]\frac{d\ln P_{dt}}{d\ln p_{ft}} - 1 \\
&= \left[(\sigma-\eta) + (\eta-1)S_{dt}\right]s_{ft} - \sigma \\
&= \underbrace{-1}_{\text{mechanical quantity effect}} + \underbrace{\left[-(\sigma-1)(1-s_{ft})\right]}_{\text{within-domestic share loss}} + \underbrace{\left[-(\eta-1)(1-S_{dt})s_{ft}\right]}_{\text{aggregate domestic expenditure loss}} .
\end{aligned}
\tag{B.4}
$$

$$
\begin{aligned}
\varepsilon_{fvt} = \frac{\mathrm{d}\ln x_{ft}}{\mathrm{d}\ln p_{vt}} &= -\frac{\mathrm{d}\ln P_t}{\mathrm{d}\ln p_{vt}} + (\sigma-\eta)\frac{\mathrm{d}\ln P_{dt}}{\mathrm{d}\ln p_{vt}} + \eta\frac{\mathrm{d}\ln P_t}{\mathrm{d}\ln p_{vt}} \\
&= (\eta-1)\frac{\mathrm{d}\ln P_t}{\mathrm{d}\ln p_{vt}} + (\sigma-\eta)\frac{\mathrm{d}\ln P_{dt}}{\mathrm{d}\ln p_{vt}} \\
&= (\eta-1)S_{dt}s_{vt} + (\sigma-\eta)s_{vt} \\
&= \left[\sigma-\eta+(\eta-1)S_{dt}\right]s_{vt} \\
&= \underbrace{(\sigma-1)s_{vt}}_{\text{within-domestic business stealing}} - \underbrace{(\eta-1)(1-S_{dt})s_{vt}}_{\text{offset from domestic-sector expansion}}
\end{aligned}
\tag{B.5}
$$

where $s_{ft} = \frac{d\ln P_{dt}}{d\ln p_{ft}}$ is the share of expenditure on firm f within the firm set d, and $S_{dt} = \frac{d\ln P_t}{d\ln P_{dt}}$ is the share of total sales of firm set d. The aggeregate demand for domestic sugar products equals:

$$
\begin{aligned}
\ln X_{dt} &= \ln\left(\frac{Y_t}{P_t}\right) - \eta\ln P_{dt} + \eta\ln P_t \\
&= \ln Y_t + (\eta-1)\ln P_t - \eta\ln P_{dt}
\end{aligned}
\tag{B.6}
$$

Then the elasticity of demand for an firm set $d \in \{d, e\}$ is:

$$
\begin{aligned}
\varepsilon_{dt} = \frac{d\ln X_{dt}}{d\ln P_{dt}} &= -\eta + (\eta-1)\frac{\mathrm{d}\ln P_t}{\mathrm{d}\ln P_{dt}} \\
&= -\eta + (\eta-1)S_{dt}
\end{aligned}
\tag{B.7}
$$

where Y_t denotes total expenditure, $P_t = \left(\sum_{d\in\{d,e\}} P_{dt}^{1-\eta}\right)^{1/(1-\eta)}$ is the overall CES price index.

Elasticity of import demand with respect to a domestic firm's price. We now derive the elasticity of aggregate import demand with respect to the price charged by domestic

firm f. Recall that imported sugar demand is given by

$$X_{et} = P_{et}^{-\eta} P_t^{\eta-1} Y_t, \tag{B.8}$$

where P_{et} is the price index of imported sugar, P_t is the overall sugar price index, and Y_t denotes total expenditure on sugar.

Taking logs gives

$$\ln X_{et} = -\eta \ln P_{et} + (\eta - 1) \ln P_t + \ln Y_t. \tag{B.9}$$

Differentiating with respect to $\ln p_{ft}$ yields

$$\frac{d \ln X_{et}}{d \ln p_{ft}} = (\eta - 1) \frac{d \ln P_t}{d \ln p_{ft}}, \tag{B.10}$$

since P_{et} and Y_t do not depend on firm f's price.

By the chain rule,

$$\frac{d \ln P_t}{d \ln p_{ft}} = \frac{d \ln P_t}{d \ln P_{dt}} \cdot \frac{d \ln P_{dt}}{d \ln p_{ft}}. \tag{B.11}$$

Using the same CES price-index properties as above,

$$\frac{d \ln P_t}{d \ln P_{dt}} = S_{dt}, \qquad \frac{d \ln P_{dt}}{d \ln p_{ft}} = s_{ft}, \tag{B.12}$$

where s_{ft} is firm f's expenditure share within the domestic sugar nest and S_{dt} is the expenditure share of domestic sugar in total sugar expenditure.

Substituting equation (B.12) into equation (B.10), we obtain

$$\varepsilon_{eft} \equiv \frac{d \ln X_{et}}{d \ln p_{ft}} = (\eta - 1) S_{dt} s_{ft}. \tag{B.13}$$

This elasticity is positive when $\eta > 1$: an increase in the price charged by domestic firm f raises the domestic price index, making imported sugar relatively more attractive and thereby increasing aggregate import demand.

A condition for import substitution to dominate domestic reallocation. To study when a price cut by domestic firm f expands its sales primarily by attracting demand away from imports rather than by stealing demand from other domestic firms, it is useful to compare two elasticities.

From the nested CES demand system, the absolute value of firm f's own-price demand

elasticity is

$$|\varepsilon_{ft}| = \sigma - \Big[(\sigma - \eta) + (\eta - 1)S_{dt}\Big]s_{ft}, \tag{B.14}$$

while the elasticity of aggregate import demand with respect to firm f's price is

$$\varepsilon_{eft} = (\eta - 1)S_{dt}s_{ft}. \tag{B.15}$$

The increase in firm f's own demand following a price cut can be viewed as consisting of two parts: demand diverted from imports and demand diverted from other domestic firms. A natural sufficient condition for the import-substitution component to be at least as important as the within-domestic reallocation component is

$$\varepsilon_{eft} > \sigma s_{ft} - \varepsilon_{eft}. \tag{B.16}$$

Rearranging gives

$$2\varepsilon_{eft} > \sigma s_{ft}. \tag{B.17}$$

Substituting equation (B.15) into equation (B.17), we obtain

$$2(\eta - 1)S_{dt}s_{ft} > \sigma s_{ft}. \tag{B.18}$$

For $s_{ft} > 0$, this simplifies to

$$2(\eta - 1)S_{dt} > \sigma. \tag{B.19}$$

Condition (B.19) is not necessary for firm-level output to rise after a price cut. Rather, it is a sufficient condition for the import-substitution channel to dominate the within-domestic reallocation channel in the expansion of firm f's demand.

B.3 Profit Maximization

From the profit maximization problem of sugar manufacturer f:

$$\max_{Q_{ft},L_{ft},M_{ft}} p_{ft}Q_{ft} - W^L_{ft}L_{ft} - W^M_{ft}M_{ft} + Z_{ft} \cdot \frac{\sum_{v \neq f}\left(p_{vt}Q_{vt} - W^L_{vt}L_{vt} - W^M_{vt}M_{vt}\right)}{N-1} \tag{B.8}$$

The corresponding first-order condition for the manufacturer is given by:

$$\begin{aligned}\frac{\partial p_{ft}(Q_{ft})}{\partial Q_{ft}} \cdot \frac{\partial Q_{ft}}{\partial L_{ft}} \cdot Q_{ft} + p_{ft}(Q_{ft}) \cdot \frac{\partial Q_{ft}}{\partial L_{ft}} - W_{ft}^{M} \frac{\partial M_{ft}}{\partial L_{ft}} - W_{ft}^{L} - M_{ft} \cdot \frac{\partial W_{ft}^{M}}{\partial M_{ft}} \frac{\partial M_{ft}}{\partial L_{ft}} \\ + \frac{Z_{ft}}{N-1} \sum_{v \neq f} \frac{\partial p_{vt}(Q_{ft})}{\partial Q_{ft}} \cdot \frac{\partial Q_{ft}}{\partial L_{ft}} \cdot Q_{vt} \\ = 0\end{aligned} \tag{B.9}$$

Define the inverse elasticity of sugarcane supply as $\phi_{ft}^{M} = \frac{\partial W_{ft}^{M}}{\partial M_{ft}} \frac{M_{ft}}{W_{ft}^{M}}$ Substituting this expression into the first-order condition yields:

$$\begin{aligned}\left(\frac{\partial Q_{ft}}{\partial L_{ft}}\right) \left[\frac{\partial p_{ft}}{\partial Q_{ft}} \cdot Q_{ft} + p_{ft} + \frac{Z_{ft}}{N-1} \sum_{v \neq f} \frac{\partial P_{vt}}{\partial Q_{ft}} \cdot Q_{vt}\right] &= W_{ft}^{L} + W_{ft}^{M} \frac{\partial M_{ft}}{\partial L_{ft}} (1 + \phi_{ft}^{M}) \\ &= W_{ft}^{L} + W_{ft}^{M} \frac{\frac{\partial Q_{ft}}{\partial L_{ft}}}{\frac{\partial Q_{ft}}{\partial M_{ft}}} (1 + \phi_{ft}^{M})\end{aligned} \tag{B.10}$$

Dividing both sides by the marginal product of labor gives the compact expression:

$$\left[\frac{\partial p_{ft}}{\partial Q_{ft}} \cdot Q_{ft} + p_{ft} + \frac{Z_{ft}}{N-1} \sum_{v \neq f} \frac{\partial P_{vt}}{\partial Q_{ft}} \cdot Q_{vt}\right] = \frac{W_{ft}^{L}}{\frac{\partial Q_{ft}}{\partial L_{ft}}} + \frac{W_{ft}^{M}}{\frac{\partial Q_{ft}}{\partial M_{ft}}} (1 + \phi_{ft}^{M}) \tag{B.11}$$

where $MP_{ft}^{L} = \frac{\partial Q_{ft}}{\partial L_{ft}}$ and $MP_{ft}^{M} = \frac{\partial Q_{ft}}{\partial M_{ft}}$ denote the marginal products of labor and material input, respectively.

We have $\frac{1}{\varepsilon_{fvt}} = \frac{\partial p_{vt}}{\partial Q_{ft}} \cdot \frac{Q_{ft}}{p_{vt}}$ for any $f, v \in F_d$ and substitute $\frac{Q_{vt} p_{vt}}{Q_{ft} p_{ft}}$with $\frac{s_{vt}}{s_{ft}}$ Therefore,

$$p_{ft}(1 + \frac{1}{\varepsilon_{fft}}) + Z_{ft} \sum_{v \neq f} \frac{Q_{vt} p_{vt} / Q_{ft}}{\varepsilon_{fvt}(N-1)} = \frac{w_{ft}^{L}}{\partial Q_{ft} / \partial L_{ft}} + \frac{w_{ft}^{M}}{\partial Q_{ft} / \partial M_{ft}} \cdot (1 + \phi_{ft}^{M}) \tag{B.12}$$

$$1 + \frac{1}{\varepsilon_{ft}} + \frac{Z_{ft}}{N-1} \sum_{v \neq f} \frac{1}{\varepsilon_{fvt}} \frac{s_{vt}}{s_{ft}} = \frac{1}{p_{ft}} \cdot \left[\frac{w_{ft}^{L}}{MP_{ft}^{L}} + \frac{w_{ft}^{M}(1 + \phi_{ft}^{M})}{MP_{ft}^{M}}\right] \tag{B.13}$$

where the left-hand side reflects the markup condition—capturing own-price elasticity, strategic interactions, and market shares—while the right-hand side represents the marginal cost,

i.e., the additional input expenditure required to produce one more unit of output.

$$\begin{aligned} MBM_{ft} &= \frac{\partial \left[p_{ft} Q_{ft} + \frac{Z_{ft}}{N-1} \cdot \sum_{v \neq f} \left(p_{vt} Q_{vt} \right) \right]}{\partial M_{ft})} \\ &= \left(\frac{\partial Q_{ft}}{\partial M_{ft}} \right) \left[\frac{\partial p_{ft}}{\partial Q_{ft}} \cdot Q_{ft} + p_{ft} + \frac{Z_{ft}}{N-1} \sum_{v \neq f} \frac{\partial p_{vt}}{\partial Q_{ft}} \cdot Q_{vt} \right] \\ &= MP_{ft}^{M} p_{ft} \left[\left(1 + \frac{1}{\varepsilon_{ft}} \right) + \frac{Z_{ft}}{N-1} \sum_{v \neq f} \frac{1}{\varepsilon_{fvt}} \frac{s_{vt}}{s_{ft}} \right] \end{aligned} \tag{B.14}$$

B.4 Why Collusion Can Increase Aggregate Output

This subsection explains why, in our environment, collusion may increase aggregate domestic output relative to Cournot competition. The key mechanism is that, although a firm's price cut reallocates demand within the domestic nest, it also expands aggregate domestic demand by shifting expenditure away from imports. The former is purely redistributive within the domestic sector, while the latter is a genuine market-expansion effect.

From firm demand to the decomposition of firm sales. Starting from the firm-level demand in equation (23) and equation (B.2)

$$x_{ft} = b_{ft}^{\sigma-1} p_{ft}^{-\sigma} P_{dt}^{\sigma-\eta} P_t^{\eta-1} Y_t,$$

$$p_{ft} x_{ft} = P_{dt} X_d \left(\frac{p_{ft}/b_{ft}}{P_{dt}} \right)^{1-\sigma} = Y_t \left(\frac{p_{ft}/b_{ft}}{P_{dt}} \right)^{1-\sigma} \left(\frac{P_{dt}}{P_t} \right)^{1-\eta}$$

And recall that the within-domestic expenditure share of firm f is

$$s_{ft} = \frac{\left(p_{ft}/b_{ft} \right)^{1-\sigma}}{\sum_{v \in d} \left(p_{vt}/b_{vt} \right)^{1-\sigma}}. \tag{B.15}$$

Since the domestic CES price index satisfies

$$P_{dt}^{1-\sigma} = \sum_{v \in d} \left(\frac{p_{vt}}{b_{vt}} \right)^{1-\sigma}, \tag{B.16}$$

it follows that

$$s_{ft} = \left(\frac{p_{ft}}{b_{ft}} \right)^{1-\sigma} P_{dt}^{\sigma-1}. \tag{B.17}$$

Substituting this into the expression for firm sales gives

$$p_{ft}x_{ft} = s_{ft}P_{dt}X_{dt}, \tag{B.18}$$

or equivalently,

$$x_{ft} = \frac{s_{ft}P_{dt}X_{dt}}{p_{ft}}. \tag{B.19}$$

Equation (B.19) is useful because it decomposes firm-level demand into a within-group market-share component, s_{ft}, and an aggregate domestic-market component, X_{dt}.

Firm-level demand: business stealing and market expansion. Taking logs of (B.19),

$$\ln x_{ft} = \ln s_{ft} + \ln P_{dt} + \ln X_{dt} - \ln p_{ft}. \tag{B.20}$$

A change in a firm's price therefore affects its demand through two distinct channels:

1. a *within-group reallocation effect* through s_{ft}, which captures business stealing among domestic firms;

2. a *between-group demand effect* through X_{dt}, which captures substitution between domestic goods and imports.

To see this, consider the effect of firm v's price on rival firm $f \neq v$. Using the demand system derived above,

$$\varepsilon_{fvt} = \frac{\mathrm{d}\ln x_{ft}}{\mathrm{d}\ln p_{vt}} = \left[\sigma - \eta + (\eta-1)S_{dt}\right] s_{vt} = \underbrace{\sigma s_{vt}}_{\text{within-group business stealing}} + \underbrace{\left[-\eta + (\eta-1)S_{dt}\right] s_{vt}}_{\text{between-group demand effect}}. \tag{B.21}$$

The first term reflects the standard business-stealing effect: when firm v lowers its price, it attracts demand away from other domestic firms. Under nested CES preferences with $\sigma > \eta$, this within-group substitution is strong at the firm level.

Aggregate domestic demand. However, business stealing is purely redistributive within the domestic sector. It changes how domestic demand is allocated across firms, but it does not change the total size of domestic demand. Formally, because expenditure shares sum to one within the domestic nest,

$$\sum_{v \in d} ds_{vt} = 0. \tag{B.22}$$

Hence, when summing across firms, the within-group reallocation terms cancel out.

Aggregate domestic demand is given by

$$\ln X_{dt} = \ln Y_t + (\eta - 1) \ln P_t - \eta \ln P_{dt}. \tag{B.23}$$

Differentiating with respect to $\ln p_{ft}$ yields

$$\frac{\partial \ln X_{dt}}{\partial \ln p_{ft}} = \frac{\partial \ln X_{dt}}{\partial \ln P_{dt}} \frac{\partial \ln P_{dt}}{\partial \ln p_{ft}} = [-\eta + (\eta - 1) S_{dt}] \, s_{ft}. \tag{B.24}$$

This expression contains no within-group business-stealing term. The reason is exactly that business stealing is internal redistribution within the domestic nest and therefore sums to zero in the aggregate.

Why collusion can increase output. The implication is that the relevant externality for coalition-wide output is not business stealing, but import substitution. Although a price cut intensifies competition within the domestic nest, it also shifts demand from imports to domestic products. The key distinction is that business stealing is purely redistributive within the domestic sector, whereas import substitution expands the total size of the domestic market. **As collusion internalizes this expansion effect, it can lead to higher aggregate output, and higher average output in the absence of firm exit**. In a symmetric environment, this implies that each firm produces more under collusion than under Cournot.

Under Cournot competition, an individual firm takes into account how its price affects its own demand, but it does not internalize the positive effect of a lower domestic price on the sales and profits of other domestic firms through an increase in X_{dt}. By contrast, under collusion, firms maximize joint profits and therefore internalize this demand-expansion effect at the level of the domestic group.

In standard cartel models, collusion reduces output because firms internalize within-group business stealing and raise markups. In our environment, by contrast, within-group business stealing is only a redistribution within the domestic nest and does not reduce coalition profits in the aggregate. What matters for coalition-wide output is the expansion of domestic demand through substitution away from imports. Consequently, collusion may induce more aggressive pricing and higher aggregate domestic output than Cournot competition.

B.5 Relation between Z_{ft}, Z^1_{ft} and Z^2_{ft}

The first order condition in the main text with a uniform conduct parameter Z_{ft} is

$$1+\frac{1}{\varepsilon_{ft}}+\frac{Z_{ft}}{N-1}\sum_{v\neq f}\frac{1}{\varepsilon_{fvt}}\frac{s_{vt}}{s_{ft}}=\frac{1}{p_{ft}}\cdot\left[\frac{w^L_{ft}}{MP^L_{ft}}+\frac{w^M_{ft}(1+\phi^M_{ft})}{MP^M_{ft}}\right]. \tag{B.25}$$

When we allow for differential conduct within and outside a reference group G (e.g., firms in the same city or sharing an ownership link), the first order condition becomes

$$1+\frac{1}{\varepsilon_{ft}}+\frac{Z^1_{ft}}{N_G-1}\sum_{v\in G,v\neq f}\frac{1}{\varepsilon_{fvt}}\frac{s_{vt}}{s_{ft}}+\frac{Z^2_{ft}}{N-N_G}\sum_{v\notin G}\frac{1}{\varepsilon_{fvt}}\frac{s_{vt}}{s_{ft}}=\frac{1}{p_{ft}}\cdot\left[\frac{w^L_{ft}}{MP^L_{ft}}+\frac{w^M_{ft}(1+\phi^M_{ft})}{MP^M_{ft}}\right]. \tag{B.26}$$

Both (B.25) and (B.26) share the same right-hand side, so the difference between the two specifications lies entirely in how strategic interactions are summarized on the left-hand side.

For notational convenience, define

$$A_{ft}\equiv\frac{1}{N_G-1}\sum_{v\in G,v\neq f}\frac{1}{\varepsilon_{fvt}}\frac{s_{vt}}{s_{ft}}, \tag{B.27}$$

$$B_{ft}\equiv\frac{1}{N-N_G}\sum_{v\notin G}\frac{1}{\varepsilon_{fvt}}\frac{s_{vt}}{s_{ft}}, \tag{B.28}$$

$$C_{ft}\equiv\frac{1}{N-1}\sum_{v\neq f}\frac{1}{\varepsilon_{fvt}}\frac{s_{vt}}{s_{ft}}. \tag{B.29}$$

By construction,

$$\sum_{v\neq f}\frac{1}{\varepsilon_{fvt}}\frac{s_{vt}}{s_{ft}}=\sum_{v\in G,v\neq f}\frac{1}{\varepsilon_{fvt}}\frac{s_{vt}}{s_{ft}}+\sum_{v\notin G}\frac{1}{\varepsilon_{fvt}}\frac{s_{vt}}{s_{ft}}=(N_G-1)A_{ft}+(N-N_G)B_{ft}, \tag{B.30}$$

so that the average interaction term in the uniform-conduct specification can be written as

$$C_{ft}=\frac{(N_G-1)A_{ft}+(N-N_G)B_{ft}}{N-1}=\lambda_{ft}A_{ft}+(1-\lambda_{ft})B_{ft},\qquad \lambda_{ft}\equiv\frac{N_G-1}{N-1}\in(0,1). \tag{B.31}$$

Equating the left-hand sides of (B.25) and (B.26) and subtracting $1+1/\varepsilon_{ft}$ from both sides yields

$$Z_{ft}\,C_{ft}=Z^1_{ft}A_{ft}+Z^2_{ft}B_{ft}, \tag{B.32}$$

or, using (B.31),

$$\boxed{Z_{ft}=\frac{Z^1_{ft}A_{ft}+Z^2_{ft}B_{ft}}{\lambda_{ft}A_{ft}+(1-\lambda_{ft})B_{ft}}}. \tag{B.33}$$

Equation (B.33) makes clear that the scalar conduct parameter Z_{ft} in the uniform specification is *not* generally a convex combination of the group-specific parameters Z^1_{ft} and Z^2_{ft}. In particular, nothing in (B.33) guarantees that

$$Z_{ft} \in \Big[\min\{Z^1_{ft}, Z^2_{ft}\},\ \max\{Z^1_{ft}, Z^2_{ft}\}\Big].$$

To see this more explicitly, consider the case $Z^1_{ft} > Z^2_{ft}$ and suppose that the within-group interaction term A_{ft} is much larger in magnitude than the outside-group term B_{ft}. Using (B.33),

$$Z_{ft} = \frac{Z^1_{ft}A_{ft} + Z^2_{ft}B_{ft}}{\lambda_{ft}A_{ft} + (1-\lambda_{ft})B_{ft}} \approx \frac{Z^1_{ft}A_{ft}}{\lambda_{ft}A_{ft}} = \frac{Z^1_{ft}}{\lambda_{ft}} > Z^1_{ft} \qquad \text{since } \lambda_{ft} \in (0,1). \tag{B.34}$$

In this case the uniform conduct parameter Z_{ft} strictly exceeds the within-group parameter Z^1_{ft}, and hence lies *outside* the interval spanned by Z^1_{ft} and Z^2_{ft}. Symmetric examples can be constructed where Z_{ft} falls below both Z^1_{ft} and Z^2_{ft}.

Therefore, while Z_{ft} can be interpreted as a coarser, "average" conduct index aggregating strategic interactions with all rivals, it should not be viewed as a simple midpoint between the within-group and outside-group conduct parameters (Z^1_{ft}, Z^2_{ft}).

B.6 Sugarcane Supply Elasticity

The utility that farmer j derives from supplying sugarcane to firm f at time t is given by:

$$U_{jft} = \underbrace{\gamma_t W^M_{ft} + \gamma^X \mathbf{X}_{ft} + \xi_{ft}}_{\equiv \delta_{ft}} + \sum_n \Big(d_{fn}\zeta_{jn}\Big) + (1-\sigma_s)u_{jft},$$

We normalize the utility of the outside option to zero, $U_{j0t} = 0$. Using the nested logit formula, the market share of firm f in time t follows the nested logit formula:$s^M_{ft} = \frac{\exp\left(\frac{\delta_{ft}}{1-\sigma_s}\right)}{D^{\sigma_s}_{nt}\left[\sum_g D^{1-\sigma_s}_{gt}\right]}$, where $D_{nt} \equiv \sum_{f\in\mathcal{F}_{nt}} \exp\left(\frac{\delta_{ft}}{1-\sigma_s}\right)$ and $\mathcal{F}_{nt}$ denotes the set of firms in sector n at time t. And $s^{M,n}_{ft} = \frac{\exp\left(\frac{\delta_{ft}}{1-\sigma_s}\right)}{D_{nt}}, \quad \delta_{ft} = \gamma_t W^M_{ft} + \gamma^X \mathbf{X}_{ft} + \xi_{ft}$

Thus, we obtain

$$\begin{aligned}\frac{\partial s^M_{ft}}{\partial W^M_{ft}} &= \gamma_t \frac{\frac{1}{1-\sigma_s}\exp\left(\frac{\delta_{ft}}{1-\sigma_s}\right) D^{\sigma_s}_{nt}\left(\sum_g D^{1-\sigma_s}_{gt}\right) - \exp\left(\frac{\delta_{ft}}{1-\sigma_s}\right)\frac{1}{1-\sigma_s}\exp\left(\frac{\delta_{ft}}{1-\sigma_s}\right)\left[\sigma D^{\sigma-1}_{nt}\left(\sum_g D^{1-\sigma_s}_{gt}\right) + 1 - \delta\right]}{D^{2\sigma}_{nt}\left(\sum_g D^{1-\sigma_s}_{gt}\right)^2} \\ &= \gamma_t s^M_{ft}\left(\frac{1}{1-\sigma_s} - \frac{\sigma_s}{1-\sigma_s}s^{M,n}_{ft} - s^M_{ft}\right)\end{aligned}$$

Hence, the inverse elasticity of sugarcane supply is given by

$$\phi_{ft}^{M} \equiv \left(\frac{d \ln s_{ft}^{M}}{d \ln W_{ft}^{M}} \right)^{-1} = \frac{1 - \sigma_s}{\gamma_t \cdot W_{ft}^{M} \cdot \left[1 - \sigma_s s_{ft}^{M,n} - (1 - \sigma_s) s_{ft}^{M} \right]}$$

B.7 Sugarcane Price Markdown

B.7.1 Stardard non-cooperative Cost minimization problem

In a noncooperative competition model and firms choose variable inputs, labor and sugarcane, to make cost minimization decision, we can derive the marginal cost as follows: First, we defined input inverse elasticity:

$$\psi_{ft}^{L} - 1 = \phi_{ft}^{L} = \frac{\partial W_{ft}^{l}}{\partial L_{ft}} \frac{L_{ft}}{W_{ft}^{l}}, \ \psi_{ft}^{M} - 1 = \phi_{ft}^{M} = \frac{\partial W_{ft}^{m}}{\partial M_{ft}} \frac{M_{ft}}{W_{ft}^{m}} \tag{B.35}$$

and assume output elasticity:

$$\theta_{ft}^{L} \equiv \frac{\partial G(\ .\ )}{\partial L_{ft}} \frac{L_{ft}}{G(\ .)}, \ \theta_{ft}^{M} \equiv \frac{\partial G(\ .\ )}{\partial M_{ft}} \frac{M_{ft}}{G(\ .)} \tag{B.36}$$

Input Revenue share:

$$\alpha_{ft}^{L} \equiv \frac{W_{ft}^{L} L_{ft}}{p_{ft} Q_{ft}}, \ \alpha_{ft}^{M} \equiv \frac{W_{ft}^{M} M_{ft}}{p_{ft} Q_{ft}} \tag{B.37}$$

Firms' cost minimization problem:

$$\min_{L_{ft}, M_{ft}} W_{ft}^{L} L_{ft} + W_{ft}^{M} M_{ft} - \lambda_{ft} \left(Q_{ft} - \Omega_{ft} G(\ .\ ) \right)$$

The first-order condition with respect to material input yields

$$\frac{\partial W_{ft}^{M}}{\partial M_{ft}} M_{ft} + W_{ft}^{M} = \lambda_{ft} \frac{\partial Q_{ft}}{\partial M_{ft}}$$

Rearranging gives

$$W_{ft}^{M} (1 + \phi_{ft}) = \lambda_{ft} \theta_{ft}^{M} \frac{Q_{ft}}{M_{ft}}$$

so that

$$\lambda_{ft} = \frac{(1 + \phi_{ft}) p_{ft} \alpha_{ft}^{M}}{\theta_{ft}^{M}} \tag{B.38}$$

where ϕ_{ft}^{M} denotes the inverse supply elasticity of material input, θ_{ft}^{M} the cost share of ma-

terial, and α_{ft}^M its output elasticity. We define the price markup as

$$\mu_{ft}^P = \frac{p_{ft} - \lambda_{ft}}{\lambda_{ft}} \Rightarrow \mu_{ft}^P + 1 = \frac{\theta_{ft}^L}{\alpha_{ft}^L(\phi_{ft}^L + 1)} = \frac{\theta_{ft}^M}{\alpha_{ft}^M(\phi_{ft}^M + 1)}$$

This implies

$$\Rightarrow \phi_{ft}^M + 1 = \frac{\theta_{ft}^L}{\theta_{ft}^M}\frac{\alpha_{ft}^M}{\alpha_{ft}^L}(\phi_{ft}^L + 1)$$

Assuming $\psi_{ft}^M = 1$, we can write the marginal revenue products of labor and material as

$$MPPL_{ft} = \frac{\partial R_{ft}}{\partial Q_{ft}}\frac{\partial Q_{ft}}{\partial M_{ft}} = W_{ft}^L, MPPM_{ft} = \frac{\partial R_{ft}}{\partial Q_{ft}}\frac{\partial Q_{ft}}{\partial M_{ft}} = W_{ft}^L\frac{\partial Q_{ft}/\partial M_{ft}}{\partial Q_{ft}/\partial L_{ft}}$$

Finally, the markdown for material input is

$$Markdown_{ft}^M \equiv \frac{MRPM_{ft} - W_{ft}^M}{MRPM_{ft}} = 1 - \frac{W_{ft}^M}{MRPM_{ft}} = 1 - \frac{\theta_{ft}^L}{\theta_{ft}^M}\frac{\alpha_{ft}^M}{\alpha_{ft}^L} = 1 - \frac{1}{\phi_{ft}^M + 1} \quad \text{(B.39)}$$

B.8 Counterfactual Simulations

B.8.1 Algorithm

In the counterfactual simulations, our goal is to compute the new equilibrium values of the key endogenous variables: sugar output (Q_{ft}), sugar prices (p_{ft}), the domestic sugar price index (P_{dt}), the aggregate price index (P_t), sugarcane prices (W_{ft}^M), sugarcane input (M_{ft}), and labor demand (L_{ft}).T o solve the equilibrium, we assume that consumer preferences for sugar remain stable, so that sugar' s share of GDP expenditure is constant over time. Specifically, let the ratio of sugar expenditure to GDP in 2014 be the reference share. By applying this share to GDP in each year, we back out the corresponding level of sugar expenditure—for example, multiplying the 2010 GDP by the 2014 sugar expenditure share yields the implied sugar expenditure in 2010.

In the counterfactual simulations, our objective is to compute the new equilibrium values of the key endogenous variables: sugar output (Q_{ft}), sugar prices (p_{ft}), the domestic sugar price index (P_{dt}), the aggregate price index (P_t), sugarcane prices (W_{ft}^M), sugarcane input (M_{ft}), and labor demand (L_{ft}). To solve for the equilibrium, we assume that consumer preferences for sugar remain stable, such that the expenditure share of sugar in GDP is constant. Taking 2014 sugar expenditure as the numeraire, we then use the expenditure share of sugar and GDP in each year to back out total sugar expenditure in 2010.

The structural parameters of the model-including the production function coefficients, the inverse elasticity of sugarcane supply, and the elasticity of substitution across firms-

have been estimated in the preceding sections and serve as the foundation for solving the counterfactual system.

Several variables are treated as exogenous in the simulations. Labor markets are assumed to remain competitive, so wages are fixed at the levels observed in the data and directly enter as exogenous inputs. Likewise, both observed and unobserved firm-specific characteristics ($\mathbf{X}_{ft}$ and ξ_{ft}) are taken as given. The world price of sugar (P_{et}) and the total market size of Chinese sugar consumption (Y_t) are also treated as exogenous when solving the equilibrium system. The counterfactual equilibrium is determined by solving simultaneously the following system of equations:

i) Firm pricing condition. We begin with the firms' first-order condition, which pins down the equilibrium sugar price p_{ft} as a function of marginal costs and market power:

$$1 + \frac{1}{\varepsilon_{ft}} + \frac{Z_{ft}}{N-1} \sum_{v \neq f} \frac{1}{\varepsilon_{fvt}} \frac{s_{vt}}{s_{ft}} = \frac{1}{p_{ft}} \cdot \left[\frac{w_{ft}^L}{MP_{ft}^L} + \frac{w_{ft}^M (1 + \phi_{ft}^M)}{MP_{ft}^M} \right] \tag{B.40}$$

where the right-hand side reflects marginal production costs, composed of labor and sugarcane inputs. The demand elasticity for an individual domestic sugar producer (ε_{ft}), the elasticity of aggregate domestic sugar consumption (ε_{dt}), and the cross-price elasticity of demand (ε_{fvt}) as follows:

$$\begin{aligned} &\varepsilon_{ft} = \left[(\sigma - \eta) + (\eta - 1) S_{dt} \right] s_{ft} - \sigma, \qquad \varepsilon_{dt} = -\eta + (\eta - 1) S_{dt}, \\ &\varepsilon_{fvt} = \left[\sigma - \eta + (\eta - 1) S_{dt} \right] s_{vt} \end{aligned}$$

ii) Sugarcane market clearing. Next, the sugarcane supply equation links sugarcane prices (W_{ft}^M) and sugarcane input (M_{ft}). Supply responds to prices, firm characteristics, and shocks as:

$$\ln s_{ft}^M - \ln s_{0t}^M = \gamma_t W_{ft}^M + \sigma_s \ln s_{ft}^{M,n} + \gamma^X \mathbf{X}_{ft} + \xi_{ft}, \tag{B.41}$$

iii) Sugar demand and price indices. We then solve for sugar price (p_{ft}) and firm-level sales by using the CES demand system:

$$p_{ft} x_{ft} = P_{dt} X_d \left(\frac{p_{ft}/b_{ft}}{P_{dt}} \right)^{1-\sigma} = Y_t \left(\frac{p_{ft}/b_{ft}}{P_{dt}} \right)^{1-\sigma} \left(\frac{P_{dt}}{P_t} \right)^{1-\eta} \tag{B.42}$$

with the corresponding domestic (P_{dt}) and aggregate (P_t) price indices defined by:

$$P_{dt} = \left(\sum_{f \in F_d} \left(p_{ft} / b_{ft} \right)^{1-\sigma} \right)^{\frac{1}{1-\sigma}}, \quad P_t = \left(\sum_{m \in \{d,e\}} P_{mt}^{1-\eta} \right)^{\frac{1}{1-\eta}}$$

iv) Production and labor demand. Finally, the production technology determines the link between sugarcane input, labor, and output:

$$Q_{ft} = \min \left\{ \beta_{ft}^{M} M_{ft}, \quad \Omega_{ft} H(L_{ft}, K_{ft}, \beta) \right\}.$$

In equilibrium, firms choose M_{ft} and L_{ft} such that both constraints are simultaneously satisfied:

$$\beta_{ft}^{M} M_{ft} = \Omega_{ft} H(L_{ft}, K_{ft}, \beta), \qquad Q_{ft} = \beta_{ft}^{M} M_{ft}. \tag{B.43}$$

We use equation (B.40), equation (B.41), equation (B.42), together with the two conditions in (B.43), to form a system of five equilibrium conditions. Taken together, these conditions generate a system of $5n$ equations-covering prices, quantities, and factor demands-for $5n$ unknowns: sugar output (Q_{ft}), sugar prices (p_{ft}), sugarcane prices (W_{ft}^{M}), sugarcane input (M_{ft}), and labor demand (L_{ft}). Here, n denotes the number of firms in the domestic sugar industry. Solving this system yields the counterfactual equilibrium allocation under any given policy or parameter change, providing a consistent mapping from exogenous shocks to endogenous outcomes within the model.

B.8.2 Derivation of Consumer and Producer Surplus

Consumer Surplus We begin by considering the inverse demand function derived from a nested CES utility framework. For any domestic sugar-producing firm f, the consumer demand is given by:

$$x_{ft} = b_{ft}^{\sigma-1} \cdot p_{ft}^{-\sigma} \cdot P_{dt}^{\sigma-\eta} \cdot P_t^{\eta-1} \cdot Y_t,$$

where x_{ft} is the quantity of sugar purchased from firm f, p_{ft} is the price charged by the firm, and b_{ft} is a taste or quality parameter that captures firm-specific appeal. The elasticity of substitution across domestic varieties is denoted by $\sigma > 1$, while $\eta > \sigma$ governs substitution between domestic and imported sugar. The term P_{dt} is the CES price index across domestic firms, and P_t is the aggregate sugar price index (including both domestic and imported varieties). Finally, Y_t is total expenditure on sugar in period t. Solving for the inverse

demand function gives us the price as a function of quantity demanded:

$$p_{ft} = b_{ft}^{\frac{\sigma-1}{\sigma}} \cdot P_{dt}^{\frac{\sigma-\eta}{\sigma}} \cdot P_t^{\frac{\eta-1}{\sigma}} \cdot Y_t^{\frac{1}{\sigma}} \cdot x_{ft}^{-\frac{1}{\sigma}}.$$

This expression shows that the price is decreasing in quantity. It also reveals how price depends on the general equilibrium variables P_{dt}, P_t, and Y_t, as well as firm-specific characteristics b_{ft}. Next, we turn to imported sugar. Under the outer CES aggregator over domestic and imported sugar, the total demand for imports is:

$$X_{et} = \left(\frac{Y_t}{P_t}\right) \cdot \left(\frac{P_{et}}{P_t}\right)^{-\eta} = Y_t \cdot P_t^{\eta-1} \cdot P_{et}^{-\eta},$$

where P_{et} is the price of the imported sugar bundle. Solving for the inverse demand function for imports, we obtain:

$$P_{et} = \left(Y_t \cdot P_t^{\eta-1} \cdot X_{et}^{-1}\right)^{\frac{1}{\eta}} = Y_t^{\frac{1}{\eta}} \cdot P_t^{\frac{\eta-1}{\eta}} \cdot X_{et}^{-\frac{1}{\eta}}.$$

This equation also implies a downward-sloping demand curve, with the elasticity governed by η, and prices decreasing in total import quantity. We now compute the consumer surplus from purchasing sugar from a domestic firm f. Consumer surplus is defined as the area under the inverse demand curve, up to the consumed quantity x_{ft}^*, minus total expenditure:

$$CS_{ft} = \int_0^{x_{ft}^*} p(x_{ft})\, dx_{ft} - p_{ft}^* x_{ft}^*.$$

Substituting in the expression for the inverse demand curve, we obtain:

$$CS_{ft} = \int_0^{x_{ft}^*} b_{ft}^{\frac{\sigma-1}{\sigma}} \cdot P_{dt}^{\frac{\sigma-\eta}{\sigma}} \cdot P_t^{\frac{\eta-1}{\sigma}} \cdot Y_t^{\frac{1}{\sigma}} \cdot x_{ft}^{-\frac{1}{\sigma}}\, dx_{ft} - p_{ft}^* x_{ft}^*.$$

Evaluating the integral yields:

$$\begin{aligned}
CS_{ft} &= b_{ft}^{\frac{\sigma-1}{\sigma}} \cdot P_{dt}^{\frac{\sigma-\eta}{\sigma}} \cdot P_t^{\frac{\eta-1}{\sigma}} \cdot Y_t^{\frac{1}{\sigma}} \cdot \left[\frac{\sigma}{\sigma-1} x_{ft}^{\frac{\sigma-1}{\sigma}}\right]_0^{x_{ft}^*} - p_{ft}^* x_{ft}^* \\
&= \frac{\sigma}{\sigma-1} \cdot b_{ft}^{\frac{\sigma-1}{\sigma}} \cdot P_{dt}^{\frac{\sigma-\eta}{\sigma}} \cdot P_t^{\frac{\eta-1}{\sigma}} \cdot Y_t^{\frac{1}{\sigma}} \cdot (x_{ft}^*)^{\frac{\sigma-1}{\sigma}} - p_{ft}^* x_{ft}^* \\
&= \frac{\sigma}{\sigma-1} p_{ft}^* x_{ft}^* - p_{ft}^* x_{ft}^* \\
&= \frac{1}{\sigma-1} p_{ft}^* x_{ft}^*.
\end{aligned}$$

This expression captures the consumer's net gain from buying sugar from firm f under CES preferences. The term in front reflects the composite price index and expenditure, while the exponent $(\sigma-1)/\sigma$ represents the degree of curvature in demand. We perform an analogous derivation for imported sugar. The consumer surplus from import purchases X^*_{et} is:

$$\begin{aligned} CS_{et} &= \int_0^{X^*_{et}} P_{et}(x_{et})\, dx_{et} - P_{et} \cdot X^*_{et} \\ &= \int_0^{X^*_{et}} Y_t^{\frac{1}{\eta}} \cdot P_t^{\frac{\eta-1}{\eta}} \cdot x_{et}^{-\frac{1}{\eta}}\, dx_{et} - P_{et} \cdot X^*_{et}. \end{aligned}$$

Solving the integral, we obtain:

$$\begin{aligned} CS_{et} &= Y_t^{\frac{1}{\eta}} \cdot P_t^{\frac{\eta-1}{\eta}} \cdot \left[\frac{\eta}{\eta-1} x_{et}^{1-\frac{1}{\eta}}\right]_0^{X^*_{et}} - P_{et} \cdot X^*_{et} \\ &= \frac{\eta}{\eta-1} \cdot Y_t^{\frac{1}{\eta}} \cdot P_t^{\frac{\eta-1}{\eta}} \cdot (X^*_{et})^{1-\frac{1}{\eta}} - P_{et} \cdot X^*_{et} \\ &= \frac{\eta}{\eta-1} P_{et} \cdot X^*_{et} - P_{et} \cdot X^*_{et} \\ &= \frac{1}{\eta-1} P_{et} \cdot X^*_{et} \end{aligned}$$

This provides the consumer surplus from imported sugar, and like the domestic case, depends on expenditure, relative prices, and demand elasticity. Finally, to compute total consumer surplus in the market, we aggregate across all domestic firms and add the surplus from imported sugar:

$$CS_t = \sum_{f \in d} CS_{ft} + CS_{et},$$

where d denotes the set of all domestic firms. This total surplus reflects the overall welfare consumers derive from access to both domestic and imported sugar varieties.

Producer Surplus We now turn to the derivation of producer surplus. Each domestic firm f produces sugar using a Cobb-Douglas production function with two inputs, labor and capital:

$$Q_{ft} = \Omega_{ft} \cdot L_{ft}^{\beta_L} \cdot K_{ft}^{\beta_K},$$

where Q_{ft} is output, L_{ft} is labor input, K_{ft} is capital input, Ω_{ft} is a firm-specific productivity term, and β_L and β_K are the output elasticities of labor and capital, respectively. Solving

the production function for labor as a function of output and capital, we get:

$$L_{ft} = \left(\frac{Q_{ft}}{\Omega_{ft} \cdot K_{ft}^{\beta_K}} \right)^{\frac{1}{\beta_L}}.$$

We are interested in the average labor productivity, expressed as output per unit of labor:

$$\begin{aligned} \frac{Q_{ft}}{L_{ft}} &= Q_{ft} \cdot \left(\frac{Q_{ft}}{\Omega_{ft}} \right)^{-\frac{1}{\beta_L}} \cdot K_{ft}^{\frac{\beta_K}{\beta_L}} \\ &= Q_{ft}^{1-\frac{1}{\beta_L}} \cdot \Omega_{ft}^{\frac{1}{\beta_L}} \cdot K_{ft}^{\frac{\beta_K}{\beta_L}}. \end{aligned}$$

This expression will be useful in constructing the marginal cost function. Next, we derive marginal cost. Assuming constant input prices, the marginal cost of producing one unit of output consists of two components: the marginal labor cost and the marginal material cost. Under the Cobb-Douglas form and cost minimization, the marginal cost is given by:

$$\begin{aligned} MC_{ft} &= \frac{W_{ft}^L}{\beta_L} \cdot \frac{L_{ft}}{Q_{ft}} + \frac{W_{ft}^M}{\beta_{ft}^M} \\ &= \frac{W_{ft}^L}{\beta_L} \cdot Q_{ft}^{\frac{1}{\beta_L}-1} \cdot \Omega_{ft}^{-\frac{1}{\beta_L}} \cdot K_{ft}^{-\frac{\beta_K}{\beta_L}} + \frac{W_{ft}^M}{\beta_{ft}^M}, \end{aligned}$$

where W_{ft}^L and W_{ft}^M denote the prices of labor and materials, respectively, and β_{ft}^M is the cost share parameter associated with materials. Producer surplus for firm f is defined as the difference between total revenue and total variable cost:

$$PS_{ft} = p_{ft}^* \cdot x_{ft}^* - \int_0^{x_{ft}^*} MC_{ft}(x)\, dx.$$

Substituting the marginal cost expression:

$$\begin{aligned} PS_{ft} &= p_{ft}^* \cdot x_{ft}^* - \int_0^{x_{ft}^*} \left(\frac{W_{ft}^L}{\beta_L} \cdot x^{\frac{1}{\beta_L}-1} \cdot \Omega_{ft}^{-\frac{1}{\beta_L}} \cdot K_{ft}^{-\frac{\beta_K}{\beta_L}} + \frac{W_{ft}^M}{\beta_{ft}^M} \right) dx \\ &= p_{ft}^* \cdot x_{ft}^* - \left[W_{ft}^L \cdot x^{\frac{1}{\beta_L}} \cdot \Omega_{ft}^{-\frac{1}{\beta_L}} \cdot K_{ft}^{-\frac{\beta_K}{\beta_L}} + \frac{W_{ft}^M}{\beta_{ft}^M} \cdot x \right]_0^{x_{ft}^*} \\ &= p_{ft}^* \cdot x_{ft}^* - \left(W_{ft}^L \cdot {x_{ft}^*}^{\frac{1}{\beta_L}} \cdot \Omega_{ft}^{-\frac{1}{\beta_L}} \cdot K_{ft}^{-\frac{\beta_K}{\beta_L}} + \frac{W_{ft}^M}{\beta_{ft}^M} \cdot x_{ft}^* \right). \end{aligned}$$

The first term is revenue, and the second term is the total variable cost of production, integrating over the marginal cost function. This formulation allows the producer surplus to

reflect firm-level heterogeneity in technology and input usage. Finally, total pro

B.8.3 Derivation of Consumer and Producer Surplus

Consumer Surplus We begin by considering the inverse demand function derived from a nested CES utility framework. For any domestic sugar-producing firm f, the consumer demand is given by:

$$x_{ft} = b_{ft}^{\sigma-1} \cdot p_{ft}^{-\sigma} \cdot P_{dt}^{\sigma-\eta} \cdot P_t^{\eta-1} \cdot Y_t,$$

where x_{ft} is the quantity of sugar purchased from firm f, p_{ft} is the price charged by the firm, and b_{ft} is a taste or quality parameter that captures firm-specific appeal. The elasticity of substitution across domestic varieties is denoted by $\sigma > 1$, while $\eta > \sigma$ governs substitution between domestic and imported sugar. The term P_{dt} is the CES price index across domestic firms, and P_t is the aggregate sugar price index (including both domestic and imported varieties). Finally, Y_t is total expenditure on sugar in period t. Solving for the inverse demand function gives us the price as a function of quantity demanded:

$$p_{ft} = b_{ft}^{\frac{\sigma-1}{\sigma}} \cdot P_{dt}^{\frac{\sigma-\eta}{\sigma}} \cdot P_t^{\frac{\eta-1}{\sigma}} \cdot Y_t^{\frac{1}{\sigma}} \cdot x_{ft}^{-\frac{1}{\sigma}}.$$

This expression shows that the price is decreasing in quantity. It also reveals how price depends on the general equilibrium variables P_{dt}, P_t, and Y_t, as well as firm-specific characteristics b_{ft}. Next, we turn to imported sugar. Under the outer CES aggregator over domestic and imported sugar, the total demand for imports is:

$$X_{et} = \left(\frac{Y_t}{P_t}\right) \cdot \left(\frac{P_{et}}{P_t}\right)^{-\eta} = Y_t \cdot P_t^{\eta-1} \cdot P_{et}^{-\eta},$$

where P_{et} is the price of the imported sugar bundle. Solving for the inverse demand function for imports, we obtain:

$$P_{et} = \left(Y_t \cdot P_t^{\eta-1} \cdot X_{et}^{-1}\right)^{\frac{1}{\eta}} = Y_t^{\frac{1}{\eta}} \cdot P_t^{\frac{\eta-1}{\eta}} \cdot X_{et}^{-\frac{1}{\eta}}.$$

This equation also implies a downward-sloping demand curve, with the elasticity governed by η, and prices decreasing in total import quantity. We now compute the consumer surplus from purchasing sugar from a domestic firm f. Consumer surplus is defined as the area under the inverse demand curve, up to the consumed quantity x_{ft}^*, minus total expenditure:

$$CS_{ft} = \int_0^{x_{ft}^*} p(x_{ft})\, dx_{ft} - p_{ft}^* x_{ft}^*.$$

Substituting in the expression for the inverse demand curve, we obtain:

$$CS_{ft} = \int_0^{x^*_{ft}} b_{ft}^{\frac{\sigma-1}{\sigma}} \cdot P_{dt}^{\frac{\sigma-\eta}{\sigma}} \cdot P_t^{\frac{\eta-1}{\sigma}} \cdot Y_t^{\frac{1}{\sigma}} \cdot x_{ft}^{-\frac{1}{\sigma}} \, dx_{ft} - p^*_{ft} x^*_{ft}.$$

Evaluating the integral yields:

$$\begin{aligned}
CS_{ft} &= b_{ft}^{\frac{\sigma-1}{\sigma}} \cdot P_{dt}^{\frac{\sigma-\eta}{\sigma}} \cdot P_t^{\frac{\eta-1}{\sigma}} \cdot Y_t^{\frac{1}{\sigma}} \cdot \left[\frac{\sigma}{\sigma-1} x_{ft}^{\frac{\sigma-1}{\sigma}} \right]_0^{x^*_{ft}} - p^*_{ft} x^*_{ft} \\
&= \frac{\sigma}{\sigma-1} \cdot b_{ft}^{\frac{\sigma-1}{\sigma}} \cdot P_{dt}^{\frac{\sigma-\eta}{\sigma}} \cdot P_t^{\frac{\eta-1}{\sigma}} \cdot Y_t^{\frac{1}{\sigma}} \cdot (x^*_{ft})^{\frac{\sigma-1}{\sigma}} - p^*_{ft} x^*_{ft} \\
&= \frac{\sigma}{\sigma-1} p^*_{ft} x^*_{ft} - p^*_{ft} x^*_{ft} \\
&= \frac{1}{\sigma-1} p^*_{ft} x^*_{ft}.
\end{aligned}$$

This expression captures the consumer's net gain from buying sugar from firm f under CES preferences. The term in front reflects the composite price index and expenditure, while the exponent $(\sigma-1)/\sigma$ represents the degree of curvature in demand. We perform an analogous derivation for imported sugar. The consumer surplus from import purchases X^*_{et} is:

$$\begin{aligned}
CS_{et} &= \int_0^{X^*_{et}} P_{et}(x_{et}) \, dx_{et} - P_{et} \cdot X^*_{et} \\
&= \int_0^{X^*_{et}} Y_t^{\frac{1}{\eta}} \cdot P_t^{\frac{\eta-1}{\eta}} \cdot x_{et}^{-\frac{1}{\eta}} \, dx_{et} - P_{et} \cdot X^*_{et}.
\end{aligned}$$

Solving the integral, we obtain:

$$\begin{aligned}
CS_{et} &= Y_t^{\frac{1}{\eta}} \cdot P_t^{\frac{\eta-1}{\eta}} \cdot \left[\frac{\eta}{\eta-1} x_{et}^{1-\frac{1}{\eta}} \right]_0^{X^*_{et}} - P_{et} \cdot X^*_{et} \\
&= \frac{\eta}{\eta-1} \cdot Y_t^{\frac{1}{\eta}} \cdot P_t^{\frac{\eta-1}{\eta}} \cdot (X^*_{et})^{1-\frac{1}{\eta}} - P_{et} \cdot X^*_{et} \\
&= \frac{\eta}{\eta-1} P_{et} \cdot X^*_{et} - P_{et} \cdot X^*_{et} \\
&= \frac{1}{\eta-1} P_{et} \cdot X^*_{et}
\end{aligned}$$

This provides the consumer surplus from imported sugar, and like the domestic case, depends on expenditure, relative prices, and demand elasticity. Finally, to compute total consumer surplus in the market, we aggregate across all domestic firms and add the surplus from imported sugar:

$$CS_t = \sum_{f \in d} CS_{ft} + CS_{et},$$

where d denotes the set of all domestic firms. This total surplus reflects the overall welfare consumers derive from access to both domestic and imported sugar varieties.

Producer Surplus We now turn to the derivation of producer surplus. Each domestic firm f produces sugar using a Cobb-Douglas production function with two inputs, labor and capital:

$$Q_{ft} = \Omega_{ft} \cdot L_{ft}^{\beta_L} \cdot K_{ft}^{\beta_K},$$

where Q_{ft} is output, L_{ft} is labor input, K_{ft} is capital input, Ω_{ft} is a firm-specific productivity term, and β_L and β_K are the output elasticities of labor and capital, respectively. Solving the production function for labor as a function of output and capital, we get:

$$L_{ft} = \left(\frac{Q_{ft}}{\Omega_{ft} \cdot K_{ft}^{\beta_K}} \right)^{\frac{1}{\beta_L}}.$$

We are interested in the average labor productivity, expressed as output per unit of labor:

$$\begin{aligned} \frac{Q_{ft}}{L_{ft}} &= Q_{ft} \cdot \left(\frac{Q_{ft}}{\Omega_{ft}} \right)^{-\frac{1}{\beta_L}} \cdot K_{ft}^{\frac{\beta_K}{\beta_L}} \\ &= Q_{ft}^{1-\frac{1}{\beta_L}} \cdot \Omega_{ft}^{\frac{1}{\beta_L}} \cdot K_{ft}^{\frac{\beta_K}{\beta_L}}. \end{aligned}$$

This expression will be useful in constructing the marginal cost function. Next, we derive marginal cost. Assuming constant input prices, the marginal cost of producing one unit of output consists of two components: the marginal labor cost and the marginal material cost. Under the Cobb-Douglas form and cost minimization, the marginal cost is given by:

$$\begin{aligned} MC_{ft} &= \frac{W_{ft}^L}{\beta_L} \cdot \frac{L_{ft}}{Q_{ft}} + \frac{W_{ft}^M}{\beta_{ft}^M} \\ &= \frac{W_{ft}^L}{\beta_L} \cdot Q_{ft}^{\frac{1}{\beta_L}-1} \cdot \Omega_{ft}^{-\frac{1}{\beta_L}} \cdot K_{ft}^{-\frac{\beta_K}{\beta_L}} + \frac{W_{ft}^M}{\beta_{ft}^M}, \end{aligned}$$

where W_{ft}^L and W_{ft}^M denote the prices of labor and materials, respectively, and β_{ft}^M is the cost share parameter associated with materials. Producer surplus for firm f is defined as the difference between total revenue and total variable cost:

$$PS_{ft} = p_{ft}^* \cdot x_{ft}^* - \int_0^{x_{ft}^*} MC_{ft}(x)\, dx.$$

Substituting the marginal cost expression:

$$
\begin{aligned}
PS_{ft} &= p^*_{ft} \cdot x^*_{ft} - \int_0^{x^*_{ft}} \left(\frac{W^L_{ft}}{\beta_L} \cdot x^{\frac{1}{\beta_L}-1} \cdot \Omega_{ft}^{-\frac{1}{\beta_L}} \cdot K_{ft}^{-\frac{\beta_K}{\beta_L}} + \frac{W^M_{ft}}{\beta^M_{ft}} \right) dx \\
&= p^*_{ft} \cdot x^*_{ft} - \left[W^L_{ft} \cdot x^{\frac{1}{\beta_L}} \cdot \Omega_{ft}^{-\frac{1}{\beta_L}} \cdot K_{ft}^{-\frac{\beta_K}{\beta_L}} + \frac{W^M_{ft}}{\beta^M_{ft}} \cdot x \right]_0^{x^*_{ft}} \\
&= p^*_{ft} \cdot x^*_{ft} - \left(W^L_{ft} \cdot {x^*_{ft}}^{\frac{1}{\beta_L}} \cdot \Omega_{ft}^{-\frac{1}{\beta_L}} \cdot K_{ft}^{-\frac{\beta_K}{\beta_L}} + \frac{W^M_{ft}}{\beta^M_{ft}} \cdot x^*_{ft} \right).
\end{aligned}
$$

The first term is revenue, and the second term is the total variable cost of production, integrating over the marginal cost function. This formulation allows the producer surplus to reflect firm-level heterogeneity in technology and input usage. Finally, total producer surplus in the market is obtained by summing across all domestic firms:

$$PS_t = \sum_{f \in d} PS_{ft},$$

where d denotes the set of all domestic sugar producers.ducer surplus in the market is obtained by summing across all domestic firms:

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where d denotes the set of all domestic sugar producers.

Appendix C Table and Figure Appendix

C.1 Table Appendix

Table B.1: Sugarcane Supply Parameters with weather IVs

	All Industries		Non-agricultural	
	Est.	S.E.	Est.	S.E.
Sugarcane Price (γ_t)	0.010	0.002	0.014	0.002
Nested Parameter(σ_s)	1.285	0.262	0.984	0.874
Sugar Price	-0.001	0.000	-0.001	0.000
1(SOE)	-0.063	0.149	-0.041	0.236
1(Export)	-0.919	0.417	-0.619	0.853
Average Wage	-0.013	0.002	-0.019	0.004

Notes: This table summarizes key parameter estimates used in the structural model. Panel A reports the estimated output elasticities from both OLS and dynamic panel specifications of the production function.Standard errors are computed using a firm-level block bootstrap with 200 replications. Panel B presents estimates from the demand system. The elasticity of substitution across domestic sugar varieties (σ) and between domestic and imported sugar (η) are reported, along with the mean and median of the estimated firm-specific demand elasticities ($|\varepsilon_{ft}|$). Panel C shows the estimated coefficients from the inverse sugarcane supply equation. The dependent variable is the log of sugarcane quantity supplied. Column (I) assumes that farmers' alternative employment options span all industries; Column (II) restricts the outside option to non-agricultural sectors. The dummy variable **1**(SOE) indicates whether the purchasing firm is a state-owned enterprise, and **1**(Export) identifies whether the firm is actively engaged in export markets.

Table B.2: Robustness: Examine the Confounding Effects of Consolidation

Dep var:	(1) $\ln Z_{ft}$	(2) $\ln Q_{ft}$	(3) $\ln Markup_{ft}$	(4) $\ln M_{ft}$
ΔIM_{ct}	1.657**	-0.378***	-0.110***	-0.374***
	(0.58)	(0.15)	(0.03)	(0.15)
$\Delta IM_{ct} \times Z_{ct}$		2.398**	-0.652*	2.415**
		(0.88)	(0.34)	(0.86)
Post_Consolidation	-0.568**	0.078	0.020*	0.077
	(0.21)	(0.11)	(0.01)	(0.11)
Controls	Yes	Yes	Yes	Yes
County FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Cluster	City	City	City	City
adj. R^2	0.462	0.862	0.891	0.848
N	196	497	414	513

Notes: This table reports when adding the potential confounding policy term *Post_Consolidation*,the estimated effects of city-level import exposure (ΔIM_{ct}) on firm-level outcomes, as well as the heterogenous effects with city-level simple average internalization parameter, Z_{ct} . Column (1) uses the log internalization parameter, $\ln Z_{ft}$, as a proxy for the extent of collusion. Column (2) examines the log of sugar output quantity, $\ln Q_{ft}$, capturing production responses. Column (3) measures changes in pricing power via the log markup, while column (4) evaluates input market behavior using the log of sugarcane quantity purchases. All regressions include county fixed effects, year fixed effects, and a standard set of control variables (not shown). Standard errors, clustered at the city level, are reported in parentheses. Significance levels are denoted as follows: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table B.3: Effects of Import Exposure on Firm Subsidies

Dep var:	(1) Subsidy	(2) Subsidy	(3) de_agr_tax	(4) de_agr_tax	(5) de_inc_tax	(6) de_inc_tax
ΔIM_{ct}	2.512***	1.667***	4.629***	3.337**	7.606**	-0.385
	(0.47)	(0.60)	(1.73)	(1.58)	(3.18)	(3.42)
$\Delta IM_{ct} \times Z_{ct}$		20.292*		30.769		150.357***
		(11.07)		(27.87)		(48.66)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Cluster	City	City	City	City	City	City
N	308	300	424	408	371	354

Notes: This table reports Tobit estimates of the effects of city-level import exposure on firm-level subsidies and tax reductions. The dependent variables include direct fiscal subsidies (columns 1–2), tax reductions on agricultural intermediate inputs (columns 3–4), and income tax reductions (columns 5–6). All dependent variables are left-censored at zero due to a large mass of zero observations. Columns with interaction terms include the interaction between import exposure and the city-level average internalization parameter. Standard errors clustered at the city level are reported in parentheses. Significance levels are denoted as follows: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.