Market access, technology adoption, and intermediation

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Abstract

Access to foreign markets can encourage technology upgrading, but realizing these gains depends on domestic intermediaries. We study how intermediary market power shapes upgrading and market access in the Brazilian beef supply chain. China pays a premium for beef but requires cattle to be slaughtered before 30 months of age and restricts licensing of eligible slaughterhouses. Meeting the age requirement encourages farmers to invest in technologies that shorten production cycles. Slaughterhouses serving China also purchase older cattle for domestic and other foreign markets. Using microdata linking farmers, slaughterhouses, and export destinations, we develop and estimate a model to quantify how slaughterhouses' joint sourcing of younger and older cattle affects technology adoption and access to China. Scarce land supply means that expanding young-cattle production raises the cost of supplying older cattle, giving slaughterhouses sourcing both types incentives to restrict China-oriented sourcing and entry to protect profits from their existing business. Counterfactual analysis shows that when sourcing and entry decisions ignore their effects on profits in the other segment, young-cattle output rises by 32%. Policies subsidizing entry of competitive slaughterhouses sourcing older cattle raise farmers' returns to producing them, potentially discouraging upgrading. At the same fiscal cost, subsidizing small buyers of older cattle generates larger gains for farmers and landowners than subsidizing China-oriented participation, but reduces participation and adoption in the China-oriented segment.

Keywords: Market access, Technology Adoption, Intermediation, Buyer Power.

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Access to foreign markets is an important avenue for firm growth, in particular in low- and middle-income countries. Higher export revenues are often associated with productivity gains and technology upgrading by exporters (Bustos 2011; Assunção, Gandour, Rocha and Rocha 2020).

Realizing these gains often requires producers to undertake costly adjustments, such as adopting new technologies or complying with foreign regulatory standards. Producers will make these investments only if they expect sufficient returns, so gains from foreign market access depend on how much additional revenue reaches them.

Producers often sell through intermediaries rather than directly to foreign buyers. As documented in agricultural contexts, these intermediaries may exercise buyer power (Atkin and Donaldson 2015; Bergquist and Dinerstein 2020), limiting how much of the export premium reaches producers and weakening their incentives to upgrade. Intermediaries also decide whether to serve a new foreign market. When they already earn rents in other domestic or foreign markets, they weigh the profits from the new opportunity against any losses it may impose on their existing business. Domestic market power can therefore shape both producers' returns to upgrading and intermediaries' willingness to provide access to foreign markets.

This paper asks: *How does domestic buyer competition shape producer upgrading and access to foreign markets?* We examine how competition affects both producers' returns to upgrading and intermediaries' incentives to provide market access. We then compare policies that strengthen competition in markets serving domestic demand with policies that support entry into foreign-oriented segments, assessing their effects on technology adoption, producer surplus, and market access.

We study this question in the context of the Brazilian beef supply chain and its exports to China, its main foreign partner. China imposes two non-tariff barriers in Brazil. First, sanitary restrictions require that beef from Brazil must come from cattle slaughtered before 30 months of age. Second, access to the Chinese market also depends on a select group of intermediaries - only slaughterhouses approved by Chinese authorities can export to China, and these approvals were initially limited before expanding over time.

Brazilian slaughterhouses receive substantial price premiums on exports to China. These premiums create scope to reward farmers for producing cattle that meet their age requirement. Doing so means bringing animals to slaughter weight earlier, which typically requires investments in improved pasture quality, supplementary feeding, or feedlot finishing.

Farmers' ability to benefit from Chinese demand therefore depends on both the returns they receive from adjusting production and access to an approved slaughterhouse. Because transporting live cattle is costly, farmers typically sell to nearby slaughterhouses and face a limited set of buyers. This gives slaughterhouses leeway to restrict purchases and pay farmers less than the marginal revenue product of their cattle.

China-approved slaughterhouses also purchase older cattle for domestic and other foreign markets, often accounting for substantial shares of local purchases. We study how this joint sourcing shapes their incentives to serve China. Expanding young-cattle production can raise land rents and the cost of supplying older cattle, increasing the prices slaughterhouses must pay in their existing business. The resulting profit loss can discourage both entry into and expansion within the China-oriented segment.

Using cattle-movement records linked to customs transactions, we document high buyer concentration in local Brazilian cattle markets and provide reduced-form evidence on their responses to increased Chinese demand. Following the 2018 African swine fever outbreak, municipalities whose existing slaughterhouse buyers relied more heavily on exports to China and Hong Kong experienced larger increases in young-cattle slaughter and its share of total slaughter. These responses were weaker where buyers accounting for larger shares of young-cattle purchases also held larger shares of older-cattle purchases, even after controlling for concentration within the young-cattle segment. This pattern motivates our focus on intermediaries' joint sourcing across segments.

Motivated by the reduced-form evidence that joint sourcing across cattle-age segments predicts weaker responses to Chinese demand, we develop a model of technology adoption and multiproduct intermediation. Farmers produce two goods, each defining a segment of the cattle market: traditional cattle produced using land-intensive technology, and modern cattle produced using technology that combines land with a material input. Slaughterhouses exercise oligopsony power and choose how much to source in each segment. Competition for land links production costs across the two technologies. Multiproduct slaughterhouses internalize these links: expanding purchases in either segment raises the cost of their purchases in the other. This cannibalization force creates an additional incentive to restrict sourcing. The model therefore provides a mechanism consistent with the weaker production responses observed in markets with greater overlap, beyond concentration within the young-cattle segment.

On the extensive margin, slaughterhouses already active in the traditional segment can pay a fixed cost to enter the modern segment and gain access to foreign demand. Modern profits must cover both this fixed cost and any loss of traditional profits induced by entry, creating an additional, endogenous barrier to modern participation. Stronger competition in the traditional segment can reduce the profits forgone by entering the modern segment, encouraging entry through an escape-from-competition effect. However, it can also raise farmers' returns to traditional production and intensify competition for land, making modern sourcing less profitable. Whether stronger traditional competition promotes more adoption therefore depends on the balance of these forces.

We extend the model quantitatively using the data in two steps. First, conditional on observed slaughterhouse participation, we use prices, quantities, and sourcing patterns to recover production, demand, and intermediary-productivity parameters. We then combine the implied operating profits alongside observed participation decisions to estimate the distribution of modern-entry costs. Following Fan and Yang (2025), we construct moment inequalities that bound entry probabilities without specifying which equilibrium is selected. This approach sidesteps repeatedly solving the full entry game during estimation, making it tractable across many local markets.

Our estimates imply substantial buyer power in both segments. Throughout municipalities with observed modern-market access, marginal revenue products exceed prices paid to farmers by an average of 76.4% in the traditional segment and 56.4% in the modern segment. On the extensive margin, the estimated model implies large differences in entry costs among observed entrants and nonentrants. Using estimated fixed costs consistent with recorded entry patterns, median annual exogenous costs are approximately R$0.48 million for entrants and R$6.8 million for nonentrants per slaughterhouse. The endogenous opportunity cost of entry, that is, the traditional profits forgone by entering the modern segment, is smaller, with medians of approximately R$110,000 and R$280,000 for entrants and nonentrants. This component is positively correlated with exogenous fixed costs within both groups: slaughterhouses with higher fixed costs also tend to have more traditional profits at stake. These patterns imply that ignoring the endogenous component could overstate the effectiveness of entry subsidies, a possibility we examine in the counterfactual analysis.

We first use the estimated model to quantify how multiproduct sourcing affects modern production and market access. Removing slaughterhouses' incentives to protect profits across segments raises modern output by 16.1% when participation is held fixed. Allowing slaughterhouses to reop-

timize their modern entry decisions increases this expansion to 32.0%, raises farmer adoption by 0.6 percentage points, and extends access to 53 additional municipalities. These responses reflect both expanded sourcing by existing slaughterhouses and entry into previously unserved markets. Removing this internalization increases surplus for farmers, landowners, and intermediaries, with intermediary profits rising by a larger proportion as slaughterhouses expand sales. These results show the importance of accounting for intermediaries' existing businesses when evaluating foreign market access. Models that abstract from joint sourcing across segments can miss an important barrier to technology adoption and market access.

We then conduct two policy counterfactuals comparing two entry subsidies with the same equilibrium fiscal cost. The first subsidizes slaughterhouses' modern participation, including those already active in the baseline. It raises modern output by 6.8% and extends access to 40 additional municipalities, while leaving markdowns largely unchanged. Because the subsidy also pays slaughterhouses that would participate without assistance, much of the spending supports inframarginal activity. The subsidy equals approximately 22% of baseline entrants' median exogenous fixed cost, but only 1.6% of nonentrants' median. Its relatively small size compared with nonentrants' estimated costs limits additional entry. After deducting government spending, net industry is effectively the same, increasing by 0.1%.

The second policy subsidizes entry by the competitive fringe in the traditional segment. It strengthens traditional competition and generates larger gains for farmers and landowners than the modern-entry subsidy, but reduces modern output by 3.8% and the number of municipalities with modern access by 21. Stronger traditional competition can reduce the profits slaughterhouses forgo by entering the modern segment. However, it also raises farmers' returns to traditional production, increasing demand for land and making modern production more costly. In this experiment, these effects outweigh the incentive to escape traditional-market competition. Despite the gains for farmers and landowners, net industry surplus falls by 0.6% after accounting for government spending.

At the same fiscal cost, the two policies therefore rank differently for adoption and producer income. Strengthening traditional competition raises farmers' returns but can discourage modern production, while supporting modern entry expands access without substantially changing buyer power. Neither policy produces significant gains in net industry surplus at the subsidy levels considered. The response to foreign opportunities depends on both intermediaries' capacity to provide

access and farmers' returns from adjusting production. Our surplus comparison excludes consumer surplus and distortionary financing costs, so it does not provide a complete welfare ranking.

Related literature

This paper relates mostly to three strands of literature.

Trade, technology and upgrading First, we contribute to the literature on trade, technology adoption, and quality upgrading. As covered in many papers and reviewed in Verhoogen (2023), trade is often associated with upgrading in various ways, like providing access to imported intermediate inputs (Fieler, Eslava and Xu 2018; Farrokhi and Pellegrina 2023), providing higher revenues that allow for covering fixed costs of adoption (Bustos 2011), or giving producers access to consumers that are more willing to pay for quality (Verhoogen 2008; Atkin, Khandelwal and Osman 2017).

We examine how domestic buyer power can weaken these incentives by compressing the additional returns producers receive from upgrading. Closely related work studies upgrading along agricultural supply chains. Macchiavello et al. (2025) emphasize contracting frictions and arrangements that transmit quality premiums to farmers. Bai et al. (2026) examine buyer power and quality investments undertaken by both producers and intermediaries. We focus on producer upgrading and jointly determine farmers' adoption decisions and intermediaries' participation in markets that reward or demand it. This allows us to study how domestic competition shapes both the returns to upgrading and the availability of market access.

Intermediation, buyer power, and market access Second, we contribute to the literature on intermediation and buyer power in agricultural markets (Bergquist and Dinerstein 2020; Chatterjee 2023; Zavala 2024). Krishna and Sheveleva (2017) jointly determine crop choices and intermediary entry under limited contracting, while Dhingra and Tenreyro (2026) connect farmer sorting across buyers, endogenous buyer power, and intermediary entry. We emphasize multiproduct buyers that jointly source across production technologies competing for land. Their sourcing and entry decisions account for how activity in one segment affects profits in the other, creating an endogenous opportunity cost of providing access to the foreign-oriented segment. Our paper also relates closely to Barrozo (2025) and Domínguez-Iino (2026), who study how agricultural intermediaries' market power shapes the effects of environmental policies. In Brazilian beef, Barrozo endogenizes slaughterhouses' entry

into local sourcing markets. We hold the presence of existing granular slaughterhouses fixed and study their decision to add young-cattle sourcing and serve China. This distinction lets us examine how profits from an incumbent traditional business affect market access and farmers' incentives to adopt modern technology.

Trade and domestic distortions Finally, we contribute to the literature on how domestic distortions shape the effects of international trade (Coşar, Guner and Tybout 2016; Bai, Jin and Lu 2024; Dix-Carneiro, Goldberg, Meghir and Ulyssea 2026). Edmond, Midrigan and Xu (2015) show how foreign competition can reduce markup distortions. Farrokhi, Lashkaripour and Pellegrina (2024) find that labor-market distortions attenuate the productivity gains from trade liberalization, but take distortions as exogenous wedges, in the tradition of Hsieh and Klenow (2009).

We study intermediaries' monopsony power as a domestic distortion and examine how it interacts with entry barriers and markdowns in the foreign-oriented segment. Strengthening competition in the traditional segment raises farmers' incomes but discourages technology adoption and participation in foreign markets. Reducing domestic market power therefore need not offset distortions that limit producers' access to foreign demand. By improving returns to traditional production, it can instead weaken incentives to enter the foreign-oriented supply chain.

The remainder of the paper continues as follows. Section 1 describes the institutional setting and data. Section 2 presents evidence on responses to Chinese demand and local market structure. Section 3 develops the model, and Section 4 explains the estimation strategy and assesses model fit. Section 5 quantifies the role of multiproduct sourcing and compares subsidies to modern entry and traditional fringe participation. Section 6 concludes.

1 Institutional setting and data

Context

Brazilian cattle farmers reach domestic and foreign consumers through slaughterhouses, which buy live animals, process them into beef, and sell to downstream buyers. Production is predominantly pasture-based, and slaughterhouses connect geographically dispersed farms to consumer markets (zu Ermgassen et al. 2020). Transporting live cattle is costly and exposes animals to weight loss and injury, limiting farmers' ability to sell to distant buyers. These are conditions conducive to buyer mar-

ket power. Studying the Brazilian Amazon, Barrozo (2025) documents substantial local monopsony power and geographic variation in competition, where exporting meatpacking plants are relatively large and concentrated. At the same time, small domestic and informal buyers provide additional competition, particularly in remote areas.

China became an increasingly important destination for Brazilian beef, with imports rising sharply after the outbreak of African swine fever in 2018.[1]. The resulting contraction in China's pork supply raised demand for alternative proteins, including beef, acting therefore as a positive demand shock for Brazilian beef exports. This expansion was accompanied by further approvals of Brazilian slaughterhouses to serve mainland China, broadening the set of plants able to supply the market. By 2019, mainland China had become Brazil's largest beef-export destination, accounting for 26.8% of export volume, compared with 18.6% for Hong Kong. As shown in Figure 1, by 2022 China accounted for more than half of Brazil's beef exports.

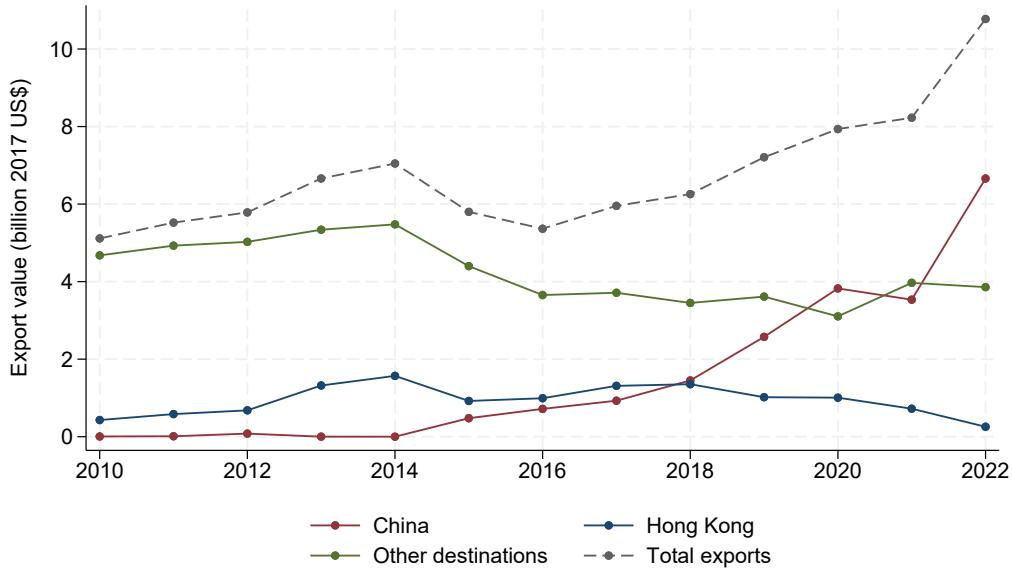


Figure 1: Brazilian beef export values by destination

In addition to the limited licensing, China also imposes a sanitary barrier on Brazilian beef exporters. Since 2015, beef had to come from cattle slaughtered before 30 months of age. These restrictions form part of the sanitary safeguards addressing bovine spongiform encephalopathy (BSE), or mad cow disease. Because BSE has a long incubation period, slaughtering younger animals reduces the risk that infected animals have developed high infectivity. Still, Brazil is listed as having negligible

[1]See ABARES on substitution toward beef following African swine fever.

BSE risk status by World Organisation for Animal Health.[2].

The aforementioned policies by China are associated with premiums in the unit values of Brazilian beef exports when compared to Brazilian beef exports to other destinations. While this has been widely reported in specialized news outlets, we also document this in the appendix using customs microdata[3]. We document this difference in the appendix using customs microdata. Brazilian slaughterhouses also pay a premium for young cattle that meet China's age requirement. In the industry's jargon, this type of animal is known as *Boi China*[4].

Meeting China's age requirement means cattle must reach slaughter weight earlier, which farmers can achieve through improved pasture management, supplementary feeding, or feedlot finishing. These investments shorten production cycles and can raise annual output per hectare on existing land. These production changes matter in a land-intensive sector that often operates at low productivity per hectare. Assunção and Bragança (2019) describe the low productivity of Brazilian pastures and the substantial scope for increasing cattle output through intensification. Historically, expanding pasture into forest areas provided another way to raise production. This margin has faced tighter environmental restrictions in the Amazon (Assunção, Gandour and Rocha 2015; Assunção, Gandour, Rocha and Rocha 2020).

Data

Our main dataset combines cattle-movement records, customs transactions, satellite land-use data, and local cattle-price quotes. We describe these sources here and defer the auxiliary data sources and additional construction details to the Appendix.

The cattle-movement data come from the *Guia de Trânsito Animal* (GTA), the administrative records accompanying animal movements in Brazil. The available records span 2012-2020, with our main linked analyses concentrating on 2014-2019. This window covers the introduction of the Chinese slaughter-age standard in 2015 and the early development of the associated supply chain. For much of this period, direct Chinese purchases were still relatively limited, with the longer customs panel described below capturing the subsequent expansion beyond the cattle-flow window.

For each recorded animal movement from either rancher to slaughterhouse or between farms, the

[2]The 2015 Brazil-China protocol, Articles 3-8, specifies BSE surveillance and safeguards, the under-30-month requirement, and establishment approval. See also WOAH's description of BSE for its long incubation period.

[3]See BrasilAgro (2019) and Scot Consultoria (2021, Figure 3)

[4]See Canal Rural (2019) and Reuters (Figueiredo, 2022)

data report the date, origin and destination, buyer and seller identifiers, and the number of animals transacted by age group and sex. See zu Ermgassen et al. (2020) and their Supplementary Appendix for a detailed description of GTA records and their use in mapping cattle supply chains. We focus on movements from farms to slaughterhouses, which reveal sourcing links and cattle sales from each producing municipality.

The data report three age bins: 1-2 years, 2-3 years, and 3 years or older. The first and last bins are unambiguous relative to China's 30-month slaughter-age requirement, as cattle aged 1-2 satisfy the age criterion, while cattle aged 3+ exceed the cutoff. The middle bin straddles the cutoff, containing animals both younger and older than 30 months, so we cannot determine their age eligibility directly from the records. We explain how we treat this ambiguous group when describing the model's quantification.

Importantly, we link GTA records to customs transactions through slaughterhouse tax identifiers. The customs data span 2010-2023 and report buyer and seller IDs, destinations, product codes, quantities, and volumes. Combining the two sources maps the export supply chain from producing farms and municipalities, through their slaughterhouse buyers, to foreign markets. We can therefore identify which buyers serve mainland China and other destinations or do not export at all, and how strongly each producing municipality is connected to these markets.

We complement these flows with MapBiomas satellite-based measures of land cover, pasture vigor, and land-use transitions (Souza et al. 2020). Our municipal land-cover panel spans 2006-2022, pasture-vigor data are available for 2010-2024. We aggregate land-cover information to the municipality level to measure pasture, cropland, and native vegetation. Pasture-vigor maps distinguish low-, medium-, and high-vigor areas, providing a proxy for pasture condition.

Finally, cattle prices come from monthly local market quotes for 2014-2019, reporting average and maximum prices. We match these quotes to producing municipalities in our GTA dataset. Because the quotes do not separately identify transactions involving cattle eligible for China, we use the maximum quoted price as a proxy for the young-cattle price. If actual prices paid for these animals are lower, this proxy overstates the young-cattle price and understates the gap between downstream beef values and upstream cattle prices.

Table 1 provides summary statistics for the 2017 GTA dataset. We focus on municipalities where we observe positive purchases of young cattle by a slaughterhouse that exports to China.

From Panel A, China exporters are very few, and so are other exporters. On average, 1.9 and 2.7 of each bought cattle in a given municipality. In contrast, the average market has many non-exporter buyers. Panel B shows that the effective number of buyers is much lower: 5.4 when considering purchases of older cattle, and 1.2 when looking at sourcing young cattle by eligible China-sellers. This suggests that the non-exporters reported in Panel A are small. We use this information as motivation to treat those slaughterhouses as a competitive fringe in the model.

Finally, Panel C shows that slaughterhouses serving China also purchase older cattle for other destinations, including the domestic market. In addition, the correlation between a slaughterhouse's market shares in the two segments (old and young cattle) is high. We thus conclude that farmers' options for selling younger and older animals are therefore linked through common buyers. This joint sourcing makes the structure of local cattle markets relevant both for access to foreign demand and for the returns to changing production practices, as the model will highlight.

Table 1: Buyer composition, concentration, and joint sourcing, 2017

	Mean	SD	P25	Median	P75
A. Buyers by export status					
Non-exporters	14.9	16.6	5.0	10.0	18.0
China exporters	1.9	1.2	1.0	1.0	2.0
Other exporters	2.7	1.9	1.0	2.0	4.0
B. Buyer choice and concentration					
Buyers of 3+ cattle	18.1	16.7	8.0	13.0	23.0
China exporters buying 1–2 cattle	1.6	0.9	1.0	1.0	2.0
Effective buyers of 3+ cattle, $1/H_O$	5.45	3.19	3.10	4.65	7.14
Effective China buyers of 1–2 cattle, $1/H_Y$	1.23	0.43	1.00	1.00	1.28
Largest buyer of 3+ cattle (%)	38.4	17.8	24.6	34.8	48.9
Largest China buyer of 1–2 cattle (%)	91.1	15.6	87.5	100.0	100.0
C. Joint sourcing across age groups					
3+ share held by China buyers of 1–2 cattle (%)	18.3	19.3	4.1	12.2	26.6
Correlation of China buyers' market shares	0.497	0.777	0.114	0.981	1.000

Notes: Equal-weight statistics across 484 municipalities with positive 3+ purchases and positive 1–2 purchases by China exporters in 2017. Buyers are tax-identifier–destination-municipality locations. Export groups are mutually exclusive: China exporters use the inherited China-export flag; other exporters have the exporter flag only; non-exporters have neither. These classifications reflect recorded export status, rather than exports in 2017 alone. All quantities are observed heads in the 1–2 and 3+ age bins; the 2–3 bin is excluded and no allocation weights or carcass-weight adjustments are used. Panel A counts buyers purchasing either included age bin. The 1–2 market includes China exporters only; the 3+ market includes all buyers. Shares use these respective totals. $H_g = \sum_i s_{ig}^2$, where $g = O$ denotes 3+ cattle and $g = Y$ denotes 1–2 cattle bought by China exporters. The final row divides 1–2 sales to China exporters by all 1–2 and 3+ sales. The correlation is computed within each municipality across China exporters buying 1–2 cattle, using their shares of the two markets; it is defined in 164 municipalities with at least two such buyers and variation in both shares. All other rows use the full sample.

2 Empirical Evidence

To motivate some features of the paper's structural model, this section presents evidence of changes in production behavior by Brazilian municipalities in response to increased foreign demand for beef from China, and how these changes interact with the degree of concentration in cattle sourcing in those municipalities.

Although China's maximum slaughter-age requirement has been in place since 2015, Chinese demand for Brazilian beef began expanding after the unexpected outbreak of African swine fever (ASF) in mid-2018. The outbreak severely reduced China's pork supply, its main source of meat, increasing demand for substitutes such as Brazilian beef. This unexpected shock pushed Brazilian beef exports to China higher and led more slaughterhouses to secure permits to export to China, which sought alternative protein sources.

From the perspective of Brazilian farmers and slaughterhouses, the resulting surge in demand for beef from younger cattle was largely unexpected. Because relatively few slaughterhouses were approved to export to China when the outbreak began, municipalities with existing sourcing links to these plants should be better positioned to respond to this positive demand shock.

We use our GTA data linked to customs microdata to test for this. In particular, we estimate the following specification:

$$Y_{rt} = \alpha_r + \delta_t + \beta E_r \times \text{Post}_t + \varepsilon_{rt}, \tag{1}$$

where Y_{rt} is an outcome in municipality r and month t, and Post_t equals one from August 2018 onward, and E_r is a measure of exposure of municipality r to Chinese beef demand, as explained below. The municipality fixed effects α_r absorb permanent differences across municipalities, while the calendar-month fixed effects δ_t absorb shocks common to all municipalities in each month. We use monthly observations from August 2017 through July 2019.

Our exposure measure combines municipalities' sourcing links with their buyers' reliance on Chinese demand before the shock:

$$E_r = \frac{1}{0.10} \sum_i s_{ir}^{\text{pre}} \theta_i^{\text{pre}}, \qquad s_{ir}^{\text{pre}} = \frac{q_{ir}^{\text{pre}}}{\sum_j q_{jr}^{\text{pre}}}, \qquad \theta_i^{\text{pre}} = \frac{X_{i,\text{China}}^{\text{pre}} + X_{i,\text{HK}}^{\text{pre}}}{X_{i,\text{World}}^{\text{pre}}}. \tag{2}$$

Here, q_{ir}^{pre} is the number of cattle sold by municipality r to buyer i over August 2017–July 2018,

so s_{ir}^{pre} is that buyer's share of the municipality's cattle sales. Using customs data, we calculate θ_i^{pre} as the share of the buyer's beef exports going to mainland China and Hong Kong over the same period. We then average these export shares using the sourcing weights. Exposure is therefore higher when a municipality sells more cattle to buyers that rely more heavily on exports to China and Hong Kong. Both components are fixed before the shock. For interpretability, we define E_r such that β captures the differential post-shock response associated with a ten-percentage-point increase in exposure.

Our main outcomes are (i) the number of cattle aged 1–2 years slaughtered from municipality r, which satisfy China's slaughter-age requirement; (ii) their share of total slaughter; and (iii) the share of slaughters aged 3 years. We estimate the first outcome with PPML to accommodate zeros, and the two shares with OLS. The regressions compare changes after the demand shock across municipalities with different baseline exposure levels. A causal interpretation requires that, absent the shock, these municipalities would have followed parallel trends.

The first columns of Tables 2, 3, and 4 report the results. Following the demand shock, a ten-percentage-point increase in baseline exposure to the China supply chain is associated with a 12.0% greater increase in slaughter of 1–2-year-old cattle. Their share of total slaughter also rises by 0.64 percentage points, while the share of cattle aged 3 years or older falls by 1.87 percentage points. These results suggest that increased Chinese demand encouraged both an expansion in young-cattle slaughter and a shift toward younger cattle in Brazil.

Beyond the overall response to the demand shock, we investigate whether its effects vary with local buyer concentration and joint sourcing across age segments. We use two measures of baseline market structure, constructed from cattle transactions over August 2017–July 2018.

First, we measure concentration in young-cattle sourcing using the HHI index among buyers that had exported to mainland China by July 2018. Let $\mathcal{C}$ denote this cohort of buyers and define

$$s_{ir}^{Y} = \frac{q_{ir}^{Y,\text{pre}}}{\sum_{j\in\mathcal{C}} q_{jr}^{Y,\text{pre}}}, \qquad H_r = \sum_{i\in\mathcal{C}} (s_{ir}^{Y})^2, \tag{3}$$

where $q_{ir}^{Y,\text{pre}}$ is the number of 1-2-year-old cattle sold from municipality r to buyer i in the baseline period. A higher H_r means that young-cattle sales to these buyers are more concentrated.

Second, we treat slaughterhouses serving China and other destinations as multiproduct buyers, distinguishing their sourcing of young cattle eligible for China from their sourcing of older cattle. Buyers active in both segments may internalize how expanding purchases in one segment raises sourcing

costs in the other. This force should be stronger when the same buyers hold larger market shares in both segments. We capture this dimension of market structure using a measure we call overlap:

$$s_{ir}^{O} = \frac{q_{ir}^{O,\text{pre}}}{Q_r^{O,\text{pre}}}, \qquad O_r = \sum_{i \in \mathcal{C}} s_{ir}^{Y} s_{ir}^{O}, \tag{4}$$

where $q_{ir}^{O,\text{pre}}$ is buyer i's purchases of cattle aged 3+ and $Q_r^{O,\text{pre}}$ is total sales of these cattle from municipality r to all buyers. Overlap is therefore the average older-cattle market share of China-linked buyers, weighted by their young-cattle shares. It is higher when buyers accounting for more young-cattle purchases also account for more older-cattle purchases, capturing joint sourcing across segments beyond concentration within the young segment.

We extend equation (1) to allow the response to exposure to vary with concentration and overlap. In the regressions, we center both indices at their baseline reference values and divide them by 0.10, retaining the notation H_r and O_r for simplicity:

$$\begin{aligned} Y_{rt} = \alpha_r + \delta_t + \beta E_r \text{Post}_t + \gamma_H E_r H_r \text{Post}_t + \gamma_O E_r O_r \text{Post}_t \\ + \lambda_H H_r \text{Post}_t + \lambda_O O_r \text{Post}_t + \varepsilon_{rt}, \end{aligned} \tag{5}$$

With this scaling, β captures the post-shock response to a ten-percentage-point increase in baseline exposure at the reference levels of concentration and overlap. The coefficients γ_H and γ_O capture how this response changes when HHI or overlap increases by 0.10, holding the other measure fixed. The separate interactions of each index with Post allow post-shock changes to vary with market structure independently of exposure. Columns (2) and (3) in Tables 2, 3, and 4introduce HHI and overlap separately, with column (4) including both, as in equation (5).

Columns (2)–(4) show that focusing on HHI alone would miss an important dimension of how market structure shapes responses to the demand shock. In column (2), the interaction between exposure, HHI, and Post is statistically insignificant for both young-cattle slaughter and its share of total slaughter. Column (3), however, reveals a clear relationship with overlap: municipalities with greater overlap experience smaller increases in young-cattle slaughter and its share, alongside smaller declines in the share of older cattle.

Column (4) includes both measures. The overlap interactions retain their signs and statistical significance. In contrast, the HHI interactions remain insignificant for the two young-cattle outcomes and are significant only at the 10% level for the older-cattle share. Taken together, these results sug-

gest that joint sourcing across segments captures variation in responses to Chinese demand beyond concentration within the young-cattle segment. These results motivate the theoretical model in the next section, which explicitly models multiproduct intermediaries' behavior.

Table 2: Chinese demand and sales of 1–2-year-old cattle

	(1)	(2)	(3)	(4)
Exposure × Post	11.361**	11.693***	7.332*	7.488*
	(4.565)	(4.499)	(3.961)	(3.873)
Exposure × HHI × Post		-0.714		0.338
		(2.292)		(2.024)
Exposure × Overlap × Post			-7.183***	-7.126***
			(2.147)	(2.175)
HHI × Post		-2.021		-5.052
		(5.841)		(5.000)
Overlap × Post			32.890***	33.693***
			(7.264)	(7.415)
Observations	15,532	15,532	15,532	15,532
Municipalities	687	687	687	687
Microregion clusters	138	138	138	138
Municipality fixed effects	Yes	Yes	Yes	Yes
Calendar-month fixed effects	Yes	Yes	Yes	Yes

Notes: The outcome is sales of cattle aged 3+ as a percentage of total cattle sales to all buyers, defined for positive total sales. OLS coefficients and standard errors are in percentage points. All specifications include municipality and calendar-month fixed effects. The sample covers August 2017-July 2019. Post equals one from August 2018. Exposure combines pre-shock cattle-sales weights and buyers' China and Hong Kong export shares and is divided by 0.10. HHI is younger-segment concentration. HHI and Overlap are centered at their baseline reference means and divided by 0.10. Columns (2)–(4) add the indicated exposure interactions and the corresponding indices interacted with Post. Microregion-clustered standard errors are in parentheses. $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.

Table 3: Chinese demand and the share of 1–2-year-old cattle

	(1)	(2)	(3)	(4)
Exposure × Post	0.639***	0.675***	0.577**	0.602**
	(0.223)	(0.233)	(0.253)	(0.257)
Exposure × HHI × Post		-0.102		-0.077
		(0.114)		(0.104)
Exposure × Overlap × Post			-0.245***	-0.241***
			(0.079)	(0.081)
HHI × Post		0.257		0.241
		(0.300)		(0.274)
Overlap × Post			0.993**	0.986**
			(0.390)	(0.390)
Observations	15,519	15,519	15,519	15,519
Municipalities	687	687	687	687
Microregion clusters	138	138	138	138
Municipality fixed effects	Yes	Yes	Yes	Yes
Calendar-month fixed effects	Yes	Yes	Yes	Yes

Notes: The outcome is sales of cattle aged 3+ as a percentage of total cattle sales to all buyers, defined for positive total sales. OLS coefficients and standard errors are in percentage points. All specifications include municipality and calendar-month fixed effects. The sample covers August 2017-July 2019. Post equals one from August 2018. Exposure combines pre-shock cattle-sales weights and buyers' China and Hong Kong export shares and is divided by 0.10. HHI is younger-segment concentration. HHI and Overlap are centered at their baseline reference means and divided by 0.10. Columns (2)–(4) add the indicated exposure interactions and the corresponding indices interacted with Post. Microregion-clustered standard errors are in parentheses. $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.

Table 4: Chinese demand and the share of cattle aged 3+

	(1)	(2)	(3)	(4)
Exposure × Post	-1.865***	-1.979***	-1.424***	-1.506***
	(0.389)	(0.395)	(0.344)	(0.349)
Exposure × HHI × Post		0.315*		0.281*
		(0.170)		(0.146)
Exposure × Overlap × Post			0.528***	0.505***
			(0.137)	(0.141)
HHI × Post		-0.804		-0.790*
		(0.487)		(0.429)
Overlap × Post			-2.638***	-2.592***
			(0.571)	(0.578)
Observations	15,519	15,519	15,519	15,519
Municipalities	687	687	687	687
Microregion clusters	138	138	138	138
Municipality fixed effects	Yes	Yes	Yes	Yes
Calendar-month fixed effects	Yes	Yes	Yes	Yes

Notes: The outcome is sales of cattle aged 3+ as a percentage of total cattle sales to all buyers, defined for positive total sales. OLS coefficients and standard errors are in percentage points. All specifications include municipality and calendar-month fixed effects. The sample covers August 2017-July 2019. Post equals one from August 2018. Exposure combines pre-shock cattle-sales weights and buyers' China and Hong Kong export shares and is divided by 0.10. HHI is younger-segment concentration. HHI and Overlap are centered at their baseline reference means and divided by 0.10. Columns (2)–(4) add the indicated exposure interactions and the corresponding indices interacted with Post. Microregion-clustered standard errors are in parentheses. $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.

3 Model

This section develops a model of technology adoption and intermediation to study how slaughterhouses'market power and entry decisions shape farmers' incentives to modernize production. The model captures a stylized representation of the beef supply chain and can be described as a vertical supply chain, consisting of i) production, ii) intermediation, and iii) consumption.

In production, a representative farmer chooses how much to produce of two goods, $g \in \{T, M\}$. Good $g = T$ is traditional and uses only land, while good $g = M$ uses modern technology that combines land with a material input. Both technologies rely on a common upward-sloping supply curve, so expanding production in either segment raises land prices and increases costs in both. In this paper, $g = T$ is older cattle, while $g = M$ is younger cattle.

In intermediation, heterogeneous granular slaughterhouses compete oligopsonistically to source cattle from farmers and sell differentiated beef varieties under monopolistic competition. Traditional output serves Home, while modern output can serve both Home and China. Access to China, therefore, creates an additional source of demand for modern production.

A slaughterhouse active in both procurement segments is multiproduct, henceforth MP, and chooses its sourcing quantities jointly. A multiproduct slaughterhouse internalizes cannibalization forces: sourcing more of good g entails moving up its supply curve while also shifting the inverse supply curve of good $-g$ upward.

Intermediary market structure is endogenous along two margins. First, a competitive fringe of slaughterhouses enters the traditional segment until a free-entry condition holds. Second, each granular slaughterhouse, already sourcing the traditional good, can pay a fixed cost f_M to enter the modern segment and become MP. When deciding whether to enter, it accounts for both this fixed cost and the change in profits in the traditional segment. The *opportunity cost of entry* is, therefore, endogenous.

After laying out the model structure in the next subsections, we highlight the main inefficiencies introduced by intermediaries. For quantification, we further expand the model to allow multiple regions and an extensive-margin adoption decision on the farmers' side.

Production - Cattle supply

Production of good $g = T$ has decreasing returns to land, $Q_T = A_T L_T^{\eta}$, while the modern good has a Cobb-Douglas aggregate of land and materials, $Q_M = A_M \left(L_M^{\alpha} X^{1-\alpha}\right)^{\eta}$, with the same degree of

returns to scale η.

We assume that materials cost p_x and are perfectly elastic. Land, by contrast, is perfectly mobile across the two uses and is supplied under an upward-sloping supply curve. Letting $L = L_T + L_M$ be total land used, we assume that land rents r satisfy

$$r = \kappa L^{\frac{1}{\varphi}}, \tag{6}$$

So κ is a supply shifter, and φ is the land supply elasticity.

Farmer optimization leads to the following inverse supply curves for each of the two goods:

$$p_T(Q_T, Q_M) \propto r(Q_T, Q_M) \cdot Q_T^{(1-\eta)/\eta}, \tag{7}$$

$$p_M(Q_T, Q_M) \propto r(Q_T, Q_M)^{\alpha} \cdot Q_M^{(1-\eta)/\eta}. \tag{8}$$

Where $r(Q_M, Q_T)$ adjust endogenously to enforce land market clearing:

$$\left(\frac{r}{\kappa}\right)^{\varphi} = \left(\frac{Q_T}{A_T}\right)^{1/\eta} + \left(\frac{Q_M}{A_M}\right)^{1/\eta} \left(\frac{\alpha p_x}{(1-\alpha)r}\right)^{1-\alpha}. \tag{9}$$

Expanding either sector therefore raises land rents and shifts the other sector's inverse supply upward, as illustrated below in figure 2.

Supply elasticities also depend on land allocation. Letting $\ell_T = L_T/(L_T + L_M)$, the inverse supply elasticity matrix is

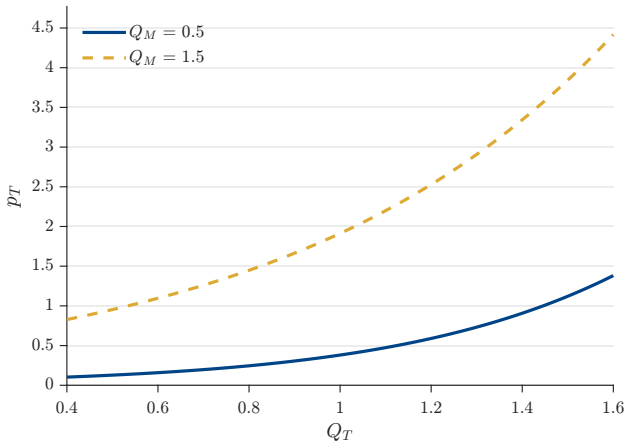
$$\varepsilon(\ell_T) = \frac{1-\eta}{\eta} I + \Gamma(\ell_T) \begin{pmatrix} \ell_T & 1-\ell_T \\ \alpha\ell_T & \alpha(1-\ell_T) \end{pmatrix}, \tag{10}$$

$$\Gamma(\ell_T) = \frac{1}{\eta[\varphi + (1-\alpha)(1-\ell_T)]}, \tag{11}$$

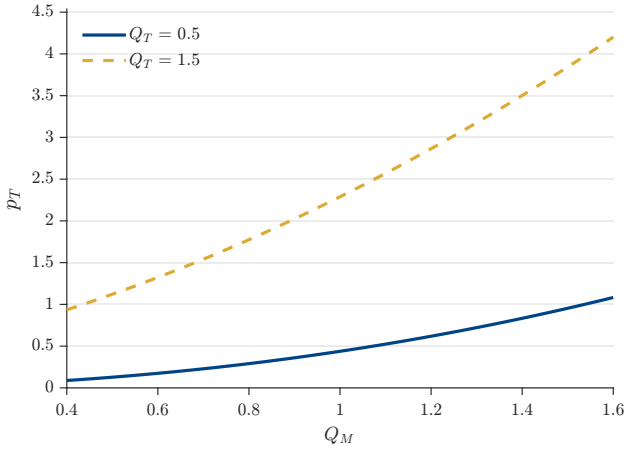
with rows indexing prices and columns indexing quantities. The first term captures decreasing returns, the second captures competition for land. A higher traditional land share ℓ_T strengthens both prices' responses to traditional output and weakens their responses to modern output. Traditional own inverse supply thus becomes steeper, while modern own inverse supply becomes flatter, in percentage terms. The mechanism is that a sector using more of the available land generates a larger rent increase when its output expands proportionally. As ℓ_T rises, this effect strengthens for traditional production and weakens for modern production, which can also substitute materials for land as rents

increase.

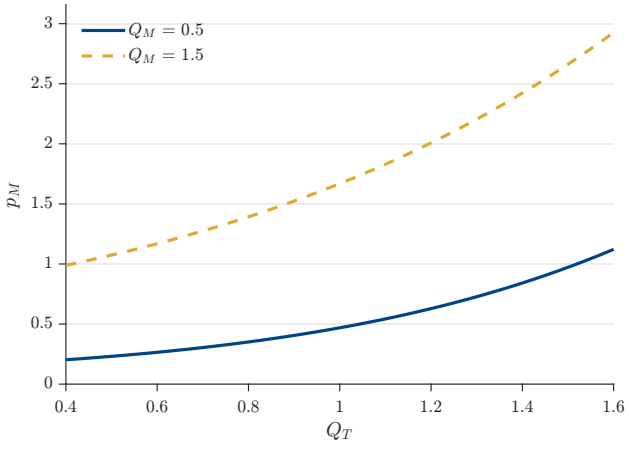
Figure 2: Supply system



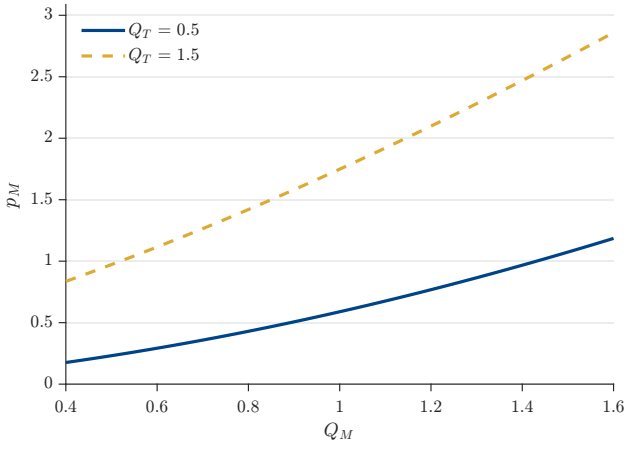
p_T and Q_T for fixed Q_M



p_T and Q_M for fixed Q_T



p_M and Q_T for fixed Q_M



p_M and Q_M for fixed Q_T

Intermediation - Slaughterhouse sourcing

We use the supply system above to characterize slaughterhouses' profit maximization. Slaughterhouses source cattle from farmers and sell differentiated beef varieties under monopolistic competition. Upstream, granular slaughterhouses internalize their effect on producer prices, while fringe slaughterhouses take these prices as given.

There are three types of slaughterhouses. Single-product (SP) granular slaughterhouses source only the traditional good. Multiproduct (MP) granular slaughterhouses source both goods and internalize how purchases in either segment affect both producer prices. Single-product fringe slaughterhouses source only the traditional good and are competitive in the upstream market. Granular slaugh-

terhouses are heterogeneous in product-specific productivity $z_g(i)$, while fringe slaughterhouses are homogeneous and have productivity $\bar{z}_T$. All three types operate in the traditional segment, while only MP slaughterhouses operate in the modern segment.

A slaughterhouse transforms cattle into beef according to $q_g^b(i) = z_g(i)q_g(i)$, where $q_g(i)$ is the quantity sourced and $q_g^b(i)$ is downstream sales. Each variety faces CES demand,

$$q_g^b(i) = B_g\big(p_g^b(i)\big)^{-\sigma}, \qquad \sigma > 1. \tag{12}$$

Traditional beef serves Home, while modern beef serves Home and China. Home consumes both goods in a single CES basket, while China consumes only modern downstream varieties. Letting E_H and E_C denote their expenditures, the demand shifters are

$$B_T = \frac{E_H}{P_H^{1-\sigma}}, \qquad\qquad B_M = \frac{E_H}{P_H^{1-\sigma}} + \frac{E_C}{P_M^{1-\sigma}}, \tag{13}$$

where P_H is Home's CES price index over both goods and P_M is the CES price index over modern varieties. Modern varieties sell at the same price in either destination. Slaughterhouses take these aggregate demand coefficients as given when choosing quantities, while internalizing their effect on upstream prices.

Single-product slaughterhouses. An SP slaughterhouse chooses how much to source in $g = T$, taking the quantities sourced by other slaughterhouses as given. Increasing its sourcing moves it up the supply curve p_T. Its problem is

$$\max_{q_T(i)} \quad \pi_T^{SP}(i) = p_T^b(i)z_T(i)q_T(i) - p_T(Q_T, Q_M)q_T(i), \tag{14}$$

subject to (12) and $Q_T = Q_{T,-i} + q_T(i)$.

Letting $s_T(i) = q_T(i)/Q_T$ be the upstream market share of slaughterhouse i, we define its markdown as the ratio of marginal revenue product to the producer price:

$$\mu_T^{SP}(i) \equiv \frac{\sigma - 1}{\sigma}\frac{z_T(i)p_T^b(i)}{p_T} = 1 + s_T(i)\varepsilon_{p_g,Q_g}. \tag{15}$$

The markdown is larger when the slaughterhouse has a larger sourcing share or faces a steeper inverse supply curve.

Multiproduct slaughterhouses. An MP slaughterhouse chooses its sourcing quantities jointly:

$$\max_{q_T(i),q_M(i)} \quad \pi^{MP}(i) = \sum_{g\in\{T,M\}} \left[p_g^b(i) z_g(i) q_g(i) - p_g(Q_T, Q_M) q_g(i)\right], \tag{16}$$

subject to (12) and $Q_g = Q_{g,-i} + q_g(i)$ for both goods. When choosing how much to source in segment g, it internalizes the effect on p_g and the resulting increase in the other good's supply price, p_{-g}.

Defining the markdown analogously gives

$$\mu_g^{MP}(i) = 1 + s_g(i)\varepsilon_{p_g,Q_g} + s_{-g}(i)\varepsilon_{p_g,Q_{-g}}. \tag{17}$$

The last term captures the cannibalization force, as sourcing more of one good raises the cost of cattle already sourced in the other segment. Relative to an SP slaughterhouse with the same sourcing share, an MP slaughterhouse therefore has an additional incentive to restrict purchases.

Fringe slaughterhouses. A fringe slaughterhouse is single-product and takes both B_T and the upstream price p_T as given. Its first-order condition implies

$$\bar{p}_T^b = \frac{\sigma}{\sigma-1}\frac{p_T}{\bar{z}_T}, \qquad\qquad \mu_T^F \equiv \frac{\sigma-1}{\sigma}\frac{\bar{z}_T \bar{p}_T^b}{p_T} = 1. \tag{18}$$

All sourcing decisions are made for a given participation profile. Slaughterhouses do not account for how changing their sourcing quantities might affect competitors' entry decisions. Fringe entry affects the equilibrium at which these first-order conditions are evaluated, but granular slaughterhouses take the prevailing fringe mass as given when choosing quantities.

Segment-level markdowns. We aggregate buyer-level markdowns using upstream sourcing shares, as in Edmond, Midrigan and Xu (2023).

Define $H_g = \sum_{i=1}^{N_g} s_g(i)^2$ as the HHI index of granular slaughterhouses in g and $O = \sum_i s_T(i) s_M(i)$ as a measure of *overlap* in market shares across MPs. In a similar spirit to the Customer Overlap in Einav, Guido and Klenow (2026), it captures whether buyers that are large in one segment tend to be large in the other. For example, under symmetry within each granular type, $O = s_T^{MP}$, where s_T^k denotes the traditional sourcing share of each buyer of type $k \in \{SP, MP\}$. When both types are present, sourcing shares across the two segments are positively correlated across granular slaughterhouses if $s_T^{MP} > s_T^{SP}$.

Aggregating the markdowns across varieties, we arrive at

$$\mu_T = 1 + \varepsilon_{p_T,Q_T} H_T + \varepsilon_{p_T,Q_M} O \tag{19}$$

$$= 1 + \frac{1-\eta}{\eta} H_T + \Gamma(\ell_T) \left[\ell_T H_T + (1-\ell_T) O\right], \tag{20}$$

$$\mu_M = 1 + \varepsilon_{p_M,Q_M} H_M + \varepsilon_{p_M,Q_T} O \tag{21}$$

$$= 1 + \frac{1-\eta}{\eta} H_M + \alpha\Gamma(\ell_T) \left[(1-\ell_T) H_M + \ell_T O\right] \tag{22}$$

Equations (19) and (21) provide theoretical motivation for the reduced-form regressions above. We see that in markets with a substantial presence of multiproduct buyers, concentration as measured by the HHI index is *not* a sufficient statistic for the markdowns in such a market, even under an assumption of Cournot competition. All else constant, overlap also matters and pushes markdowns upward, as it captures concentration *across markets*.

We plug in the supply elasticities and simplify to obtain equations (20) and (22). They are useful because they show how production-side interdependencies, captured by $\Gamma(\ell)$, and intermediation-side interdependencies, captured by overlap O, jointly shape markdowns.

Substituting the supply elasticities shows how production-side interdependencies, captured by $\Gamma(\ell_T)$, and intermediation-side interdependencies, captured by overlap O, jointly shape markdowns. The terms proportional to $(1-\eta)/\eta$ reflect decreasing returns and depend only on own-market concentration. The remaining terms reflect the common land market and combine concentration and overlap, weighted by the respective land shares. As $\Gamma(\ell_T) \to 0$, inverse supply becomes separable across goods and the cross-market component of markdowns vanishes.

Intermediary entry

We endogenize market structure along two margins. First, granular slaughterhouses simultaneously decide whether to pay a fixed cost f_M to enter the modern segment and become MP. Second, fringe slaughterhouses enter the traditional segment until operating profits equal the fixed entry cost f_T.

More precisely, we assume that the *total* number of granular buyers N_T is exogenously given. For tractability, we view this as a reasonable short-run assumption. This reflects our empirical context, in which only established slaughterhouses gained access to the Chinese market in the period covered by our data.

With this in mind, market structure is partially endogenous because we endogenize the selection

of the N_T granular slaughterhouses into MP production. That is, letting $\mathcal{I}_T$ be the set of active granular slaughterhouses, a subset $\mathcal{I}_M \subseteq \mathcal{I}_T$ becomes multiproduct, with $N_M = |\mathcal{I}_M|$.

For a candidate set $\mathcal{I}_M$ and demand shifters $\mathbf{B} = (B_T, B_M)$, let $M(\mathcal{I}_M; f_T, \mathbf{B})$ denote the equilibrium fringe mass. Define $\widehat{\Pi}^{MP}(i; \mathcal{I}_M, f_T, \mathbf{B})$ and $\widehat{\Pi}^{SP}_T(i; \mathcal{I}_M, f_T, \mathbf{B})$ as variable profits after fringe entry and sourcing quantities have adjusted.

Definition (Extensive-margin equilibrium). Given the set of granular slaughterhouses $\mathcal{I}_T$, entry costs (f_T, f_M), and demand shifters $\mathbf{B}$, an extensive-margin equilibrium is a pure-strategy Nash equilibrium of granular slaughterhouses' modern participation decisions. It consists of a set $\mathcal{I}^*_M \subseteq \mathcal{I}_T$, a fringe mass $M^* = M(\mathcal{I}^*_M; f_T, \mathbf{B})$, and associated sourcing quantities and prices such that:

1. No multiproduct slaughterhouse wishes to leave the modern segment:

$$\widehat{\Pi}^{MP}(i; \mathcal{I}^*_M, f_T, \mathbf{B}) - f_M \geq \widehat{\Pi}^{SP}_T(i; \mathcal{I}^*_M \setminus \{i\}, f_T, \mathbf{B}), \qquad i \in \mathcal{I}^*_M. \tag{23}$$

2. No single-product granular slaughterhouse wishes to enter the modern segment:

$$\widehat{\Pi}^{SP}_T(i; \mathcal{I}^*_M, f_T, \mathbf{B}) \geq \widehat{\Pi}^{MP}(i; \mathcal{I}^*_M \cup \{i\}, f_T, \mathbf{B}) - f_M, \qquad i \in \mathcal{I}_T \setminus \mathcal{I}^*_M. \tag{24}$$

3. Fringe entry yields zero net profits. Assuming a positive fringe mass,

$$\Pi^F_T\left(\mathcal{I}^*_M, M^*; \mathbf{B}\right) = f_T. \tag{25}$$

4. Given participation, the intensive-margin equilibrium satisfies (6)–(9) and (15)–(18).

In each unilateral deviation, the participation of all other granular slaughterhouses is held fixed, while fringe entry and sourcing quantities adjust. Demand shifters $\mathbf{B}$ are held fixed in these comparisons. Thus, entry and exit comparisons include the change in profits in the traditional segment. The opportunity cost of modern entry is therefore endogenous and depends on traditional competition, including fringe participation. These conditions allow for arbitrary productivity heterogeneity and may admit more than one equilibrium participation profile.

Wedges

To highlight the potential distortions in this economy caused by market power and linkages across the segments, we now compare the decentralized equilibrium with the allocation chosen by a planner that maximizes industry surplus taking downstream demand shifters as given. We organize the

comparison along three sources of wedges at the intensive margin and intermediary entry at the extensive margin. Appendix B derives the planner allocation, and Appendix C presents the full wedge derivations.

Intensive margin. Buyer power generates three intensive-margin distortions that are well understood (Hsieh and Klenow 2009; Edmond, Midrigan and Xu 2023). First, buyer-level markdown dispersion distorts cattle allocation across slaughterhouses: conditional on total output in a segment, high-markdown buyers source too little relative to their downstream productivity. Letting $\rho = (\sigma - 1)/\sigma$, equilibrium and efficient segment productivities are

$$Z_g = \left[\sum_i z_g(i)^{\sigma-1} \left(\frac{\mu_g}{\mu_g(i)}\right)^{\sigma-1}\right]^{1/(\sigma-1)}, \qquad Z_g^* = \left[\sum_i z_g(i)^{\sigma-1}\right]^{1/(\sigma-1)}. \tag{26}$$

The participation of intermediaries in each segment is held fixed. Thus $Z_g \leq Z_g^*$, and the within-segment misallocation wedge is

$$\mathcal{A}_g \equiv \left(\frac{Z_g^*}{Z_g}\right)^{\rho} \geq 1. \tag{27}$$

Buyer power affects upstream production both by lowering the price transmitted to farmers and by reducing the revenue generated by a given amount of output. One can show that we can write this as

$$\Omega_g \equiv \frac{\lambda_g^*}{p_g} = \mu_g \mathcal{A}_g, \tag{28}$$

where λ_g^* is the planner's marginal value of upstream output of segment g.

Second, differences in these segment-level wedges distort land allocation between traditional and modern technologies. This leads to a cross-segment distortion of

$$\frac{\lambda_M^* \, \partial Q_M / \partial L_M}{\lambda_T^* \, \partial Q_T / \partial L_T} = \frac{\Omega_M}{\Omega_T} = \frac{\mu_M}{\mu_T} \frac{\mathcal{A}_M}{\mathcal{A}_T}. \tag{29}$$

When $\Omega_M > \Omega_T$, the social return to land is larger at the margin in modern production, and the planner would reallocate land toward segment M. Even if the two segments have the same markdown, land composition is inefficient whenever within-sector misallocation differs across segments.

Third, the common level of these wedges distorts the scale of production, including total land use

and modern material use. If

$$\Omega_T = \Omega_M = \Omega > 1, \qquad t_Q = 1 - \frac{1}{\Omega}, \tag{30}$$

The common wedge acts as a uniform output tax t_Q.

Extensive margin: intermediary entry More novel to this paper, we examine intermediary participation decisions, focusing on the decision to become MP and enter the modern segment.

For multiproduct entry, profits associated with becoming MP must cover f_M plus any traditional profit forgone by changing status from SP to MP. Denoting such $\pi_g^k(i)$ as the variable profits in segment g under status $k \in \{SP, MP\}$, a potential entrant requires

$$\pi_M^{MP}(i) \geq f_M + \pi_T^{SP}(i) - \pi_T^{MP}(i) \equiv \widetilde{f}_M(i), \tag{31}$$

This opportunity cost is endogenous and responds in particular to market conditions in either segment. Equation (31) contrasts with the condition under which the unconstrained planner evaluates entry. She allocates entry strictly based on productivity in the modern segment $z_M(i)$. Abstracting from the integer constraints in the derivations, the marginal entrant satisfies

$$\frac{\lambda_M^* q_M^*(N_M^*)}{\sigma - 1} = f_M. \tag{32}$$

That is, the planner has no concerns about cannibalization and takes f_M as the only opportunity cost of actually entering.

When becoming multiproduct reduces traditional profits, $\widetilde{f}_M(i) > f_M$, so entry into the modern sector is relatively more costly once we account for slaughterhouses maximizing profits jointly across segments. In Appendix C.4, we see that a higher traditional markdown under MP status lowers traditional profits at a given price. The appendix derives this opportunity cost and separates it from the effects of markdowns and sourcing misallocation on modern entry.

As a result, when thinking about policies to incentivize entry and market access into the modern segment, we would *underestimate* entry costs by not accounting for cross-market interactions, as in this case.

Traditional competition therefore matters for modern entry. To make the opportunity-cost chan-

nel explicit, a first-order approximation around a common traditional markdown $\bar{\mu}_T > 1$ gives

$$\widetilde{f}_M(i) \approx f_M + \sigma(\sigma-1) f_T \left(\frac{z_T(i)}{\bar{z}_T}\right)^{\sigma-1} \frac{\bar{\mu}_T - 1}{\bar{\mu}_T^{\sigma+1}} \left[\mu_T^{MP}(i) - \mu_T^{SP}(i)\right]. \tag{33}$$

Holding markdowns fixed, a higher fringe entry cost f_T directly raises the opportunity cost when $\mu_T^{MP}(i) > \mu_T^{SP}(i)$. On the other hand, f_T also affects the markdown gap by changing the difference between the two markdowns, so the overall effect is ambiguous. Under perfect competition, the traditional opportunity cost vanishes and $\widetilde{f}_M = f_M$.

4 Quantification

We now quantify the model to assess the economic importance of intermediary market power and entry and to evaluate policy counterfactuals. We first introduce quantitative extensions that make the model amenable to empirical estimation. We then describe a two-stage estimation strategy. In the first stage, we take observed intermediary participation as given and use prices, quantities, and sourcing patterns to identify the production, demand, and intermediary-productivity parameters that govern slaughterhouse variable profits. In the second stage, we combine the resulting estimates of slaughterhouses' profit function with observed entry decisions into China to estimate the distribution of modern-entry costs using moment inequalities. This approach allows us to leave equilibrium selection unspecified during estimation, greatly simplifying computation.

Quantitative extensions

Regions. We extend the model allowing for many regions. Let a region be indexed by $r \in \{1, \ldots, R\}$. We assume upstream cattle and land markets are segmented by region, while downstream varieties remain in a single market in Home H and in China C. That is, letting $\mathcal{I}_{gr}$ denote the set of active granular varieties in segment g and region r, and M_r the mass of traditional fringe varieties in region r, the price indices are

$$P_H^{1-\sigma} = \sum_{r=1}^{R} \left[\sum_{g \in \{T,M\}} \sum_{i \in \mathcal{I}_{gr}} \left(p_{gr}^b(i)\right)^{1-\sigma} + M_r \left(\bar{p}_{Tr}^b\right)^{1-\sigma} \right], \tag{34}$$

$$P_C^{1-\sigma} = P_M^{1-\sigma} = \sum_{r=1}^{R} \sum_{i \in \mathcal{I}_{Mr}} \left(p_{Mr}^b(i)\right)^{1-\sigma}. \tag{35}$$

Here $p_{gr}^b(i)$ is the downstream price of granular variety i, and $\bar{p}_{Tr}^b$ is the common price of fringe varieties in region r. As in the baseline model, modern varieties sell at the same price in Home

and China. Because both price indices aggregate varieties across all regions, the demand shifters $B_T = E_H/P_H^{1-\sigma}$ and $B_M = E_H/P_H^{1-\sigma} + E_C/P_M^{1-\sigma}$ remain common across regions.

We define regions as Brazilian municipalities, as in Barrozo (2025). This allows the model to capture geographic differences in slaughterhouse presence, agricultural productivity, and input costs. Local upstream markets and integrated downstream markets also motivate assuming Cournot competition in the former and monopolistic competition in the latter. A slaughterhouse can account for a large share of municipal cattle purchases while representing a small share of national beef sales. We therefore allow slaughterhouses to internalize their effects on local cattle prices while taking aggregate downstream beef price indices as given.

Production and sourcing. Turning to the production side, as upstream markets clear region-by-region, the land supply curve becomes

$$r_r = \kappa \left(\frac{L_r}{\bar{L}_r} \right)^{\frac{1}{\varphi}}, \tag{36}$$

where $\bar{L}_r$ is the observed land used in agriculture in a region.

Rather than assuming a representative producer, we assume a continuum of heterogeneous farmers indexed by $\omega \in [0, N_r^f]$ who produce the traditional good $g = T$ and, upon paying a fixed cost F, may also produce the modern one. This extension allows us to speak to heterogeneity in adoption decisions across farmers in a municipality.

Farmers are heterogeneous in their productivity in both $g = T$ and $g = M$. For farmer ω in region r, productivity in segment g is $A_{gr} a_{gr}(\omega)$, where A_{gr} is a supply shifter and $a_{gr}(\omega)$ are farmer-specific components, which are jointly lognormal,

$$\begin{pmatrix} \log a_{Tr}(\omega) \\ \log a_{Mr}(\omega) \end{pmatrix} \sim \mathcal{N}\left(\begin{pmatrix} 0 \\ 0 \end{pmatrix}, \Sigma_A \right). \tag{37}$$

The farmer's production functions are

$$y_{Tr}(\omega) = A_{Tr} a_{Tr}(\omega) \ell_{Tr}(\omega)^{\eta}, \tag{38}$$

$$y_{Mr}(\omega) = A_{Mr} a_{Mr}(\omega) \left[\ell_{Mr}(\omega)^{\alpha} x_r(\omega)^{1-\alpha} \right]^{\eta}, \tag{39}$$

Productivity varies across both municipalities and farmers. The regional component A_{gr} captures

differences common to farmers producing in segment g and municipality r, while $a_{gr}(\omega)$ captures farmer-specific productivity. We decompose the regional component as

$$A_{Tr} = K_T S_{Tr}, \qquad A_{Mr} = K_M S_{Mr}. \tag{40}$$

Shifters S_{Tr} and S_{Mr} determine the spatial patterns of traditional and modern productivity. We construct them from GAEZ potential grass yields under low-input and high-input production, applying a common conversion estimated from observed cattle stocking rates and a common normalization. Appendix D.1 provides a detailed description.

The national scales K_T and K_M determine good-specific productivity levels and are estimated jointly with the farmer adoption cost to match aggregate production and participation moments.

All farmers remain active in traditional production. A farmer with access to a modern buyer can additionally produce modern cattle by paying the fixed cost F. Let $y^*_{Mr}(\omega)$ denote the farmer's optimal modern output conditional on adoption. Modern operating profits equal $(1-\eta)p_{Mr}y^*_{Mr}(\omega)$, so the farmer adopts when

$$(1-\eta)p_{Mr}y^*_{Mr}(\omega) \geq F. \tag{41}$$

Modern supply therefore responds through both adopters' input choices and changes in the mass of adopters.

Intermediation. Each region has an exogenously given pool of granular slaughterhouses $\mathcal{I}_{Tr}$ that are always active in the traditional segment. Consistent with the data, a slaughterhouse may source cattle from multiple regions. Conditional on aggregate demand shifters and entry-cost realizations, its sourcing and modern-entry problems are separable across regions.

We replace the common modern-entry cost f_M with a slaughterhouse-region-specific cost f_{Mir}:

$$\log f_{Mir} = X'_{ir}\gamma + \sigma_f \left(\sqrt{\rho_f}\, u_i + \sqrt{1-\rho_f}\, v_{ir} \right), \tag{42}$$

where u_i and v_{ir} are independent standard normal shocks, σ_f governs dispersion of fixed-cost shocks, and $\rho_f \in [0,1]$ is the correlation of costs across regions within a slaughterhouse. The vector X_{ir} is a vector of covariates to be detailed in the estimation section.

In practice, modern participation involves both obtaining access to the Chinese market and es-

tablishing procurement relationships for young cattle in particular regions. We approximate these common and local determinants through the slaughterhouse-level component u_i and the regional component v_{ir}. This allows entry costs to correlate across regions within a slaughterhouse while keeping entry decisions separable across markets. The estimation section describes how we discipline the cost parameters using observed participation decisions.

Overview of the estimation strategy

Our estimation proceeds sequentially. We treat observed prices, quantities, and slaughterhouse participation as an equilibrium realization and first estimate, calibrate, or invert the model to back out the parameters governing production, demand, and intermediary productivity. This approach, therefore, does not require fully solving the entry game or taking a stance on equilibrium selection. This avoids jointly estimating these parameters and solving the strategic entry game at every candidate parameter vector.

We then use the estimated primitives to estimate the distribution of fixed costs via moment inequalities, following Fan and Yang (2025). As in their approach, we bound entry probabilities below by the probability that entry is dominant and above by the probability that entry is undominated, leaving equilibrium selection unspecified.

Estimation of intensive margin objects

We now discuss how we quantify the intensive margin objects. Appendix A provides the model derivations underlying these objects, and Table 5 summarizes the results.

We take 2017 as the baseline year for our estimation procedure, unless otherwise noted. All monetary values are measured in annual terms in Brazilian Reais (R$). The Chinese standard was already in action in 2017, but China had not yet established itself as the most prominent importer of Brazilian beef. We pick it as our baseline year because of the wider coverage of the GTA flows data compared to other years'

Some parameters and exogenous variables come directly from the data. We identify the set of granular intermediaries as those for which we observe any positive exports in any period through 2017. Therefore, the potential entrants into the modern segment in a given region r are those for which we observe exports (to China or not) and sourcing of cattle of any age in r. We assign the remaining non-exporters to the fringe.

Table 5: Intensive margin parameters

Object	Description	Source / method	Value
Panel A. Measured and constructed inputs			
$\mathcal{I}_{Tr}$, $\mathcal{I}_{Mr}$	Intermediary participation	GTA and customs	
N_r^f	Mass of farmers	GTA	
L_r, $\bar{L}_r$	Total land use	Mapbiomas	
S_{Tr}, S_{Mr}	Regional supply shifters	FAO-GAEZ	
$p_{x,r}$	Input price index	IBGE–PAM and ICBC-SP prices; IMEA cost shares.	
E_H	Home + non-China beef expenditure	Customs and zu Ermgassen et al. (2020)	51.0 bn
θ	China-bound share of eligible young-cattle output	GTA and customs	0.7
Panel B. Externally assigned parameters			
η	Returns to scale	Pellegrina (2022)	0.9
α	Land share	Cost shares - IMEA	0.7
φ	Land supply elasticity	Barrozo (2025)	0.2
σ	Demand elasticity	Barrozo (2025)	4.4
Panel C. Internally estimated parameters			
K_T	Traditional aggregate supply shifter	GMM	156.9
K_M	Modern aggregate supply shifter	GMM	59.7
F	Farmer entry cost	GMM	83,413.8
λ_1	Modern share of $2-3$ aged cattle	GMM	0.8
λ_2	Adoption share of $2-3$ only sellers	GMM	0.1
Other estimated or calibrated objects			
Σ_A	Farm heterogeneity	Heckman correction	
$z_{Tr}(i)$, χ_z	Granular SH productivity	FOC inversion	$\chi_z = 0.8$
$\bar{z}_{Tr}$, f_T	Fringe productivity and entry cost	FOC inversion	$f_T = 438{,}038$
κ	Land cost shifter	FOC inversion	386.7
B_C	China export demand shifter	Total Brazilian beef exports to China	2.2 bn

Looking at the bottom part of panel C in 5. The granularity of the GTA data lets us observe farmer-level sales over time to different slaughterhouses across cattle age bins, which helps estimate the covariance matrix Σ_a governing farmer heterogeneity and comparative advantage in producing each cattle type.

We estimate Σ_A using a two-step Heckman correction procedure with an exclusion restriction. We use sales of cattle aged 0–2 to China-capable buyers as our young-output measure, $\widetilde{y}_{Mrt}(\omega)$, and sales of cattle aged 3+ to all buyers as our traditional-output measure, $\widetilde{y}_{Trt}(\omega)$. Define $d_{\omega rt} = 1$ when the farmer records positive young output. We use farmer-year observations from 2016–2019 with positive traditional output and observed baseline connections.

In the first step, we estimate the probit

$$d_{\omega rt} = \mathbf{1}\{a_{rt} + b \log \widetilde{y}_{Trt}(\omega) + \pi Z_{\omega rt} + \nu_{\omega rt} > 0\}, \qquad \nu_{\omega rt} \sim \mathcal{N}(0,1), \tag{43}$$

where a_{rt} are municipality-year fixed effects, controlling for market prices and other unobserved supply and demand shifters that are market-time specific. The excluded variable $Z_{\omega rt}$ equals one once a buyer to which the farmer sold cattle in 2014–2015 starts exporting to China after 2015. We include it because an existing procurement relationship should lower the cost of accessing a modern buyer. The maintained exclusion is that, conditional on traditional output and municipality-year effects, this connection affects young-output participation but has no direct effect on young output conditional on participation.

In the second step, we estimate

$$\log \widetilde{y}_{Mrt}(\omega) = c_{rt} + \beta \log \widetilde{y}_{Trt}(\omega) + \psi \frac{\phi(\widehat{v}_{\omega rt})}{\Phi(\widehat{v}_{\omega rt})} + e_{\omega rt}, \tag{44}$$

among farmers with $d_{\omega rt} = 1$ where c_{rt} are municipality-year fixed effects. The inverse Mills ratio accounts for selection into observed young-cattle sales. With the estimates, we can back out the variances and correlations in the matrix Σ_a. Our preferred specification has $\sigma_T^2 = 0.02$, $\sigma_M^2 = 0.02$, with correlation 0.24.

The GTA data bins cattle ages into $0-2$, $2-3$, and $3+$ year-old animals. Unfortunately, these do not perfectly overlap with the Chinese age cutoff of 2.5 years. We cannot simply discard the ambiguous $2-3$ bin, as that could mismeasure adoption rates and certainly make the model underpredict overall production scale. We handle this issue by assuming that a fraction λ_1 of cattle in the $2-3$ bin

is below the 2.5 cutoff. Likewise, among farmers selling only cattle in the $2-3$ bin, a fraction λ_2 of them sell eligible animals.

We estimate λ_1 and λ_2 alongside farmer adoption costs (F) and national supply shifters K_T and K_M using GMM. The moments match aggregate traditional and modern output, as well as farmer participation, together with two moments relating modern output and participation to municipal age composition. The latter two exploit variation in ambiguous-age output shares and ambiguous-supplier shares to distinguish λ_1 from λ_2. The appendix provides more details.

We jointly estimate the five parameters by matching aggregate traditional output, modern output, and farmer participation,

Finally, we estimate heterogeneity in slaughterhouse productivity. We make no distributional assumptions and instead infer them from the optimality conditions.

For a given allocation, the first-order condition implies

$$\widehat{z}_{grt}^{\text{FOC}}(i) = \frac{\sigma}{\sigma-1}\frac{p_{grt}}{p_{git}^{b}}\widehat{\mu}_{grt}(i), \tag{45}$$

where the markdowns for single-product and multi-product buyers are

$$\widehat{\mu}_{Trt}^{SP}(i) = 1 + s_{Trt}(i)\widehat{\varepsilon}_{TT,rt}, \tag{46}$$

$$\widehat{\mu}_{grt}^{MP}(i) = 1 + s_{grt}(i)\widehat{\varepsilon}_{gg,rt} + s_{hrt}(i)\frac{p_{hrt}Q_{hrt}}{p_{grt}Q_{grt}}\widehat{\varepsilon}_{hg,rt}, \qquad h \neq g. \tag{47}$$

Here $s_{grt}(i) = q_{grt}(i)/Q_{grt}$ is the buyer's sourcing share and $\varepsilon_{hg,rt} = \partial \log p_{hrt}/\partial \log Q_{grt}$ is the inverse-supply elasticity of price h with respect to quantity g. We can back out these elasticities using the previously estimated intensive-margin parameters, the observed allocations, and the model's supply side.

Starting with the inversion for granular intermediaries, we use export unit values in 2017 to non-China countries to measure the downstream price p_{Tit}^{b}, and to China to measure p_{Mit}^{b}. We control for composition and quality differences across products using HS6 fixed effects and provide validation exercises in the appendix using finer fixed effects.

We recover traditional productivity directly from (45). To specify modern productivity for potential entrants as well as observed multiproduct buyers, we impose

$$z_{Mr}(i) = \chi_z z_{Tr}(i). \tag{48}$$

Let $\mathcal{P}$ be the set of multiproduct buyer–municipality–year observations. We estimate

$$\widehat{\chi}_z = \exp\left\{\frac{1}{|\mathcal{P}|}\sum_{(i,r,t)\in\mathcal{P}}\left[\log \widehat{z}^{\text{FOC}}_{Mrt}(i) - \log \widehat{z}^{\text{FOC}}_{Trt}(i)\right]\right\}. \tag{49}$$

We use the traditional FOC inversion as the model's traditional productivity and assign modern productivity according to

$$\widehat{z}^{\text{model}}_{Tr}(i) = \widehat{z}^{\text{FOC}}_{Trt_0}(i), \tag{50}$$

$$\widehat{z}^{\text{model}}_{Mr}(i) = \widehat{\chi}_z \widehat{z}^{\text{model}}_{Tr}(i), \qquad i \in \mathcal{I}_{Tr}, \tag{51}$$

where $t_0 = 2017$. The second equation applies to both observed multiproduct buyers and single-product buyers that could enter the modern segment. Regarding observed MPs, we therefore replace the independently inverted modern productivity with the projected value $\widehat{\chi}_z \widehat{z}^{\text{model}}_{Tr}(i)$. This enforces the same relationship among traditional and modern productivity on incumbents and potential entrants.

For the homogeneous traditional fringe, we use the mean across municipal fringe buyers:

$$\widehat{\bar{z}}_{Tr} = \frac{1}{|\mathcal{F}_r|}\sum_{i\in\mathcal{F}_r} \widehat{z}^{\text{FOC}}_{Trt_0}(i), \tag{52}$$

where $\mathcal{F}_r$ denotes the set of fringe buyers in municipality r. Because the fringe does not export, we do not have direct measures of downstream prices. We proxy them with local wholesale beef prices in different municipalities provided by CONAB. We assume that each fringe member sells its output locally and therefore take the corresponding beef price.

The appendix exercises show that persistent differences across slaughterhouse–municipality links account for substantial variation in recovered productivity. For non-China sales, destination effects matter considerably more than product effects, indicating that export-market composition contributes to the measured productivity differences. Slaughterhouse and municipality effects together explain 50.7% of the variation in the estimated persistent link effects for non-China sales and 90.0% for China sales.

Estimation of of extensive margin objects

We estimate modern-entry costs from slaughterhouses' observed participation in different municipalities, taking the intensive-margin estimates as given. As discussed previously, we follow the bound-

ing approach of Fan and Yang (2025). Specifically, assuming slaughterhouses do not choose strictly dominated actions, the probability of entry is bounded below by the probability that entry is strictly dominant and above by the probability that entry is not strictly dominated. These bounds generate moment inequalities that partially identify the fixed-cost parameters. A particular advantage of the approach is that the bounds are easy to compute and do not require repeatedly solving the entry game for each parameter value or specifying an equilibrium selection rule.

We sketch the estimation algorithm below and provide a detailed description in the appendix.

Let $d_{ir} = 1$ if slaughterhouse i sources young cattle in municipality r and exports beef to China, and let $d_{-i,r}$ collect its rivals' participation decisions. Its gain in variable profits from modern participation is

$$\Delta\pi_{ir}(d_{-i,r}) = \pi_{ir}(1, d_{-i,r}) - \pi_{ir}(0, d_{-i,r}). \tag{53}$$

These profits include both traditional and modern operations, so the gain incorporates any spillovers across segments due to cannibalization.

In computing these objects, we assume slaughterhouse i takes the downstream demand shifters, as we assumed that there is monopolistic competition downstream. Accordingly, we hold those fixed when evaluating profits, while allowing region-level equilibrium objects, such as prices and quantities, to vary. This assumption matters because it lets us solve the entry game region by region rather than jointly.

We use as our sample all observed combinations of exporting slaughterhouses and municipalities that sourced cattle in 2017. Our main outcome of interest then is the indicator d_{ir}, which equals 1 if an exporter i exported to China and bought young cattle from municipality r. The estimation sample contains 5,902 potential slaughterhouse-municipality pairs, spanning 136 slaughterhouses and 1,915 municipalities.

In the cost specification in (42), we use

$$X_{ir} = \left(1, H_i^L, H_i^H, R_{ir}, C_i, C_i^{-i}, \log \widehat{z}_{Tr}(i)\right)', \tag{54}$$

and fixed costs are given by

$$\log f_{Mir} = X_{ir}'\gamma + \sigma_f \left(\sqrt{\rho_f}\, u_i + \sqrt{1-\rho_f}\, v_{ir}\right), \tag{55}$$

Here H_i^L and H_i^H indicate positive 2015 Hong Kong export shares at or below and above the median, respectively, with no Hong Kong exports as the omitted category. R_{ir} indicates past cattle sourcing from municipality r in 2015 or 2016. C_i indicates that the slaughterhouse exported to China in either year, and C_i^{-i} indicates China exports by another establishment under the same parent company as i. These variables allow costs to vary with export experience, firm-level access to China, and existing procurement relationships. Log traditional productivity allows the conditional cost mean to vary across slaughterhouse–municipality links with different recovered productivities.

Following Fan and Yang (2025), we bound participation probabilities without specifying which equilibrium is selected. Define the smallest and largest operating-profit gains across rival participation profiles as

$$L_{ir} = \min_{d_{-i,r}} \Delta\pi_{ir}(d_{-i,r}), \qquad U_{ir} = \max_{d_{-i,r}} \Delta\pi_{ir}(d_{-i,r}). \tag{56}$$

A cost below L_{ir} makes entry profitable under every competitor entry configuration, whereas a cost above U_{ir} makes it unprofitable under every configuration. When entry gains weakly decrease with rivals' participation, the extrema correspond to all rivals entering and no rivals entering, respectively. We verify in entry games in smaller markets that these bounds are correct, leaving them as approximations in markets with more potential entrants.

Let $\vartheta = (\gamma', \sigma_f, \rho_f)'$ be the vector of extensive-margin parameters. Under log-normality of the cost draws, the lower and upper bounds of entry probabilities are

$$p_{ir}^B(\vartheta) = \begin{cases} \Phi\left(\dfrac{\log B_{ir} - X_{ir}'\gamma}{\sigma_f}\right), & B_{ir} > 0, \\ 0, & B_{ir} \le 0, \end{cases} \qquad B \in \{L, U\}, \tag{57}$$

where Φ is the standard normal CDF. The entry restrictions imply $p_{ir}^L \le \mathbb{E}[d_{ir} \mid X_{ir}, L_{ir}, U_{ir}] \le p_{ir}^U$ as conditional moment inequalities. We follow Fan and Yang (2025) and transform them into unconditional moment inequalities like those in equation (58) by interacting $d_{ir} - p_{ir}^B$ with indicator functions that group the covariate vector X_{ir} and the profitability bounds (L_{ir}, U_{ir}) into bins h_{ir}, defined in the appendix.

$$\mathbb{E}\Big[(d_{ir} - p_{ir}^L)h_{ir}\Big] \ge 0, \qquad \mathbb{E}\Big[(p_{ir}^U - d_{ir})h_{ir}\Big] \ge 0. \tag{58}$$

Entries from the same slaughterhouse in different municipalities provide information about the

common cost shock u_i and the correlation ρ_f. For $r \neq s$, we have

$$q^B_{irs}(\vartheta) = \Phi_2\Big(\Phi^{-1}(p^B_{ir}), \Phi^{-1}(p^B_{is}); \rho_f\Big), \qquad B \in \{L, U\}, \tag{59}$$

where $\Phi_2(\cdot, \cdot; \rho_f)$ is the bivariate standard normal CDF with correlation ρ_f. The joint probabilities bound the probability of entry in both municipalities. Defining $h_{irs} = (h_{ir} + h_{is})/2$, we obtain

$$\mathbb{E}\Big[(d_{ir}d_{is} - q^L_{irs})h_{irs}\Big] \geq 0, \qquad\qquad \mathbb{E}\Big[(q^U_{irs} - d_{ir}d_{is})h_{irs}\Big] \geq 0. \tag{60}$$

We combine 30 individual-entry inequalities, 30 same-slaughterhouse pair inequalities, and 21 additional restrictions from markets with at most three potential entrants. These small markets are sufficiently tractable that we can enumerate every participation configuration and determine which are equilibria for each simulated vector of fixed costs.

The additional restrictions use the number of slaughterhouses participating in a municipality. Individual-entry inequalities ask whether each slaughterhouse could profitably participate under different assumptions about its competitors. Entry counts also tell us which participation decisions can occur together in equilibrium. For example, each of two slaughterhouses might individually find entry profitable when its competitor stays out, while competition makes simultaneous entry unprofitable. Observing whether neither, one, or both participate therefore provides information beyond their individual entry decisions. By comparison, the same-slaughterhouse pair inequalities provide information about cost correlation across municipalities.

We choose parameters to minimize weighted squared violations of the resulting 81 sample inequalities.

$$\widehat{\vartheta} \in \arg\min_{\vartheta \in \Theta} \widehat{Q}(\vartheta), \qquad\qquad \widehat{Q}(\vartheta) = \sum_{j=1}^{81} w_j \left[\min\{\widehat{m}_j(\vartheta), 0\}\right]^2, \tag{61}$$

where $\widehat{m}_j(\vartheta)$ is the sample analog of the jth moment restriction, written so that its population counterpart is nonnegative, and $w_j > 0$ is a fixed normalization weight. Thus, satisfied inequalities contribute zero to the objective, while violations receive a quadratic penalty.

Model fit and results

After estimating the intensive- and extensive-margin model parameters, we assess the model's fit using municipal prices, markdowns, farmer adoption, and slaughterhouses' sourcing and entry deci-

sions, and defer additional assessments to the appendix.

Starting with the intensive margin parameters, Table 6 compares average prices, markdowns, and farmer adoption shares across markets implied by the data and the model. The table focuses on municipalities where we observe sourcing by at least one slaughterhouse serving China in 2017. None of these moments are directly targeted in estimation. The model tracks price variation across municipalities, with correlations of around 0.75 in both segments, but underpredicts average traditional and modern prices by 29 and 20 percent, respectively. It also overstates the modern-price premium: 0.92 BRL per kilogram in the model versus 0.20 in the data. Farmer adoption is also higher in the model: 11.16 percent versus 8.38 percent in the data, a difference of 2.78 percentage points. The correlation in adoption shares across markets is around 0.51.

By contrast, the model does a poor job matching traditional markdowns, severely underpredicting them and yielding a low, albeit positive, correlation of 0.2 across markets. One possible source of this difference is how we define the competitive fringe and its prices. Because we do not observe domestic beef prices at the intermediary level, we impute fringe prices from local wholesale prices in Brazil. We have not isolated the contribution of this imputation to the poor fit. This particular imputation is unnecessary in the modern segment, where we rely fully on customs data.

We now assess the assumption that intermediary productivity is proportional across segments, $z_M(i) = \chi_z z_T(i)$. Here, we recover unrestricted modern productivity directly from the modern sourcing FOC for each observed slaughterhouse–municipality pair, without imposing proportionality across segments. We obtain restricted modern productivity by multiplying recovered traditional productivity by the common estimated factor $\widehat{\chi}_z$. Figure 3 compares these two values. In panel (a), regressing log restricted productivity on log unrestricted productivity yields an R^2 of around 0.64 and a slope of 0.95. Panel (b) shows the size of the deviations: around 79 percent of restricted productivity values are within 25 percent of their unrestricted counterparts, and the standard deviation of the log ratio is 0.23. Thus, the restriction captures much of the variation among observed entrants.

Lastly, figure 4 assesses how broadly slaughterhouses source young cattle across their candidate municipalities. For each potential entrant i, we calculate the share of these municipalities from which it sources young cattle while exporting beef to China. We then compare the observed fraction of slaughterhouses reaching each sourcing share with the bounds implied by the model. Panel (a) includes all potential entrants. In contrast, panels (b) and (c) distinguish slaughterhouses without and

with exports to China in 2015 or 2016, so the figure shows how prior export experience relates to the share of municipalities from which they source young cattle while exporting to China. These statistics were not directly targeted in the estimation.

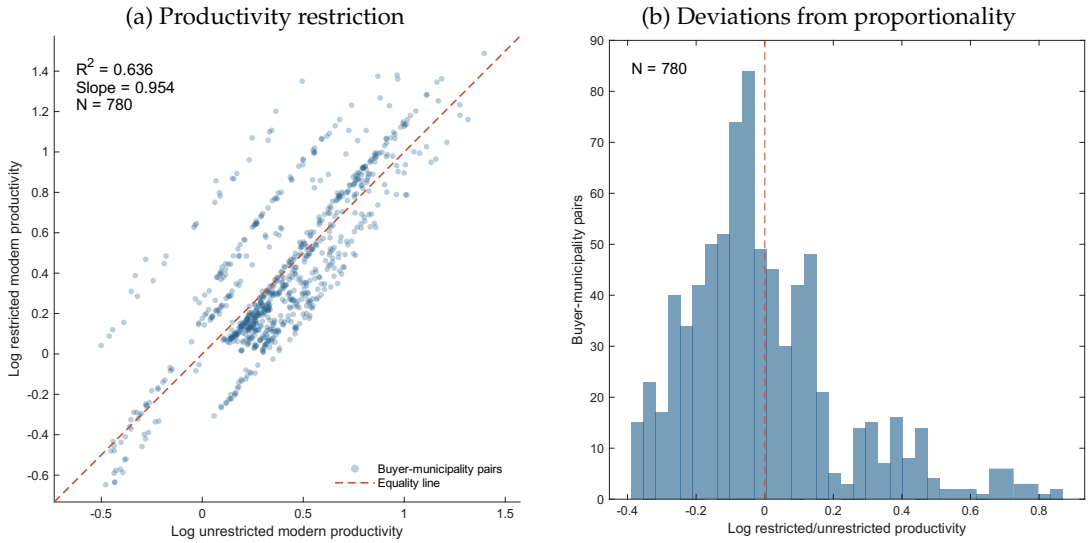
Panel (c) shows that prior China exporters participate broadly during the estimation period: nearly 95 percent source modern cattle from at least one-quarter of their candidate municipalities, and about 90 percent do so from at least three-quarters. These fractions fall within the model-implied bounds. Panel (b) shows much lower participation among slaughterhouses without prior China exports: only 13 percent enter anywhere. This is below the model-implied bounds of 19-30 percent. Conversely, the 12 percent reaching at least three-quarters of their candidate municipalities exceeds the upper bound of around 9 percent. Thus, the model replicates the broad participation difference by prior export experience, but fits the concentration of participation within slaughterhouses' sourcing networks less well.

Table 6: Intensive-margin equilibrium fit, 2017

	Mean		Correlation
Outcome	Data	Model	across markets
Traditional price, p_T	8.19	5.80	0.746
Modern price, p_M	8.39	6.72	0.751
Traditional markdown, μ_T (%)	76.41	41.08	0.200
Modern markdown (%), μ_M	56.37	52.86	0.497
Farmer adoption share (%)	8.38	11.16	0.506
Municipalities			607

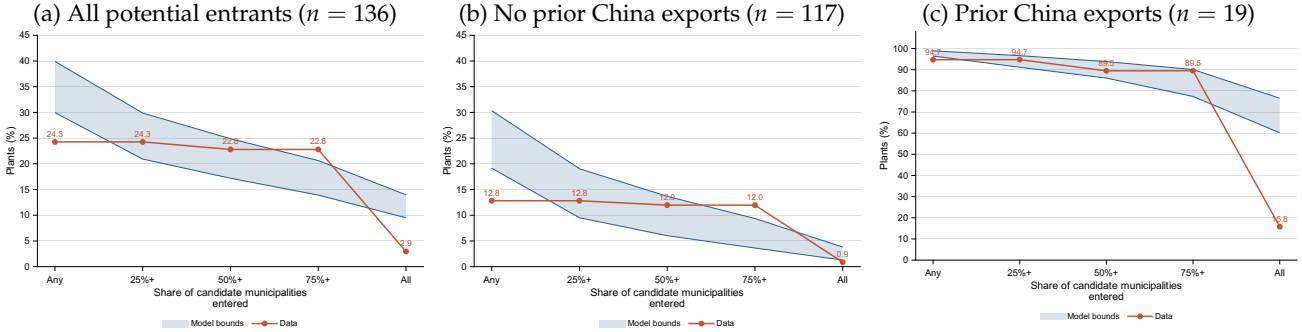
Notes: All rows use the same 607 markets with observed exposure to a China-eligible buyer and observed positive prices in both segments. Prices are measured in 2017 BRL per carcass-equivalent kilogram. Data-implied markdowns are computed using observed allocations plugged into markdown formulas implied by the model. Model values solve the intensive margin equilibrium under estimated parameters.

Figure 3: Estimated slaughterhouse productivity and fit implied by proportionality assumption



Notes: Panel (a) compares log modern-segment productivity recovered from the modern sourcing first-order condition (unrestricted) with log productivity implied by the cross-segment proportionality restriction, $\widehat{z}_{M,im} = \widehat{\chi}_z z_{T,im}$ (restricted). The sample includes slaughterhouse–municipality pairs observed in both segments. Panel (b) shows the distribution of log restricted-to-unrestricted productivity ratios, with zero indicating exact agreement.

Figure 4: Share of candidate municipalities served by modern sourcing, by prior China export experience



Notes: Orange lines show the observed fraction of slaughterhouses sourcing young cattle in at least the indicated share of their full set of candidate municipalities. Blue bands show model-implied lower and upper probabilities at the estimated parameters. *Any* denotes participation in at least one candidate municipality and *All* denotes participation in every candidate municipality. The sample includes all 136 potential entrant slaughterhouses and 5,902 slaughterhouse-municipality links across 1,915 municipalities. Panels split slaughterhouses by whether they exported to China in 2015 or 2016. These statistics were not directly targeted in estimation. Sampling uncertainty is not shown.

5 Counterfactuals

We use the estimated model to perform two quantitative exercises. First, quantify the role of cannibalization and multiproduct slaughterhouses in explaining markdowns and entry patterns in the data.

Second, we examine two policies to encourage slaughterhouse entry and therefore combat market power: subsidizing the fixed costs of entry into the modern segment and subsidizing entry by the competitive fringe in the traditional segment. Before doing so, however, we explain how we draw fixed costs for potential entrants under the estimated distribution and how we solve the entry games in each local market.

Implementation

Fixed costs draws We need to be careful when drawing fixed-cost shocks, as they must be consistent with the observed baseline equilibrium. To ensure consistency, we follow Fan and Yang (2025) again and draw cost observations that ensure the observed entrants have no incentive to unilaterally deviate from their entry decision in the baseline equilibrium. We defer a more thorough explanation to the appendix.

Figure 5 plots the fixed costs drawn following the procedure outlined above. Panel (a) shows the empirical CDF for the draws of both observed entrants and non-entrants. We see a large discrepancy in entry costs between the groups. Panel (b) plots the equilibrium opportunity cost of entering into MP production: $\pi_T^{SP}(i) - \pi_T^{MP}(i) = \tilde{f}_M(i) - f_M(i)$. These costs are an order of magnitude smaller than the exogenous component of panel (a). Finally, panel (c) shows the correlation between the two components. We see that non-entrants tend to have higher values for both components and that they are positively correlated, regardless of observed entry behavior. Together, these patterns suggest that policies lowering exogenous barriers to entry may have limited effects because slaughterhouses facing higher fixed costs also tend to face higher endogenous barriers—the loss of traditional profits caused by entering the modern segment.

Equilibrium computation in counterfactuals Unlike the estimation step, we must take a stance on equilibrium selection when running counterfactuals. We outline the solution algorithm below.

First, hold the national Home price index fixed and keep entry decisions at their observed levels. Within each local upstream market, consider slaughterhouses in descending order of modern productivity. For each one, compare profits from participating in modern sourcing with profits from staying out. In each comparison, we let the intensive-margin equilibrium adjust in response to the entry decision.

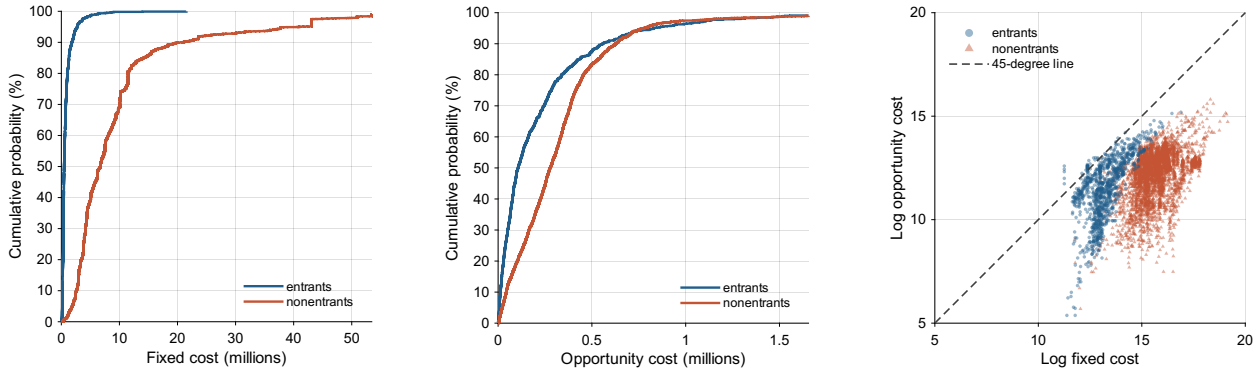
A slaughterhouse enters or exits if switching raises its profits. Because each switch also changes

Figure 5: Estimated fixed costs for entrants and non-entrants

(a) Fixed cost draws $f_M(i)$

(b) Equilibrium endogenous opportunity costs $\tilde{f}_M(i) - f_M(i)$

(c) Correlation between fixed cost draws f_i and opportunity costs of entry $\tilde{f}_M(i) - f_M(i)$



Notes: Panel (a) Shows realized exogenous fixed costs drawn from the estimate distribution. Panel (b) shows the distribution of endogenous opportunity entry costs $\tilde{f} - f$: traditional operating profits without modern sourcing minus those with modern sourcing, allowing upstream equilibrium outcomes to adjust while competitors' participation is held fixed (c) plots the logs of the two components for both entrants and non-entrants

competitors' incentives, we revisit those that decided before and let them reoptimize. We continue until no slaughterhouse can gain from deviating from its current choice. While we cannot guarantee uniqueness or rule out cycles in general, we do not encounter them when running counterfactuals.

After solving the entry game for each upstream market, we update the national Home price index to reflect the updated equilibrium in each upstream market. As the price index adjusts, we repeat the steps above and iterate until the price index converges.

Note that descending productivity determines who gets considered first when considering unilateral deviations, but does not guarantee that only the most productive slaughterhouses enter. This contrasts with the approach in Berry (1992), where equilibrium selection imposes that the most productive firms are those deciding to enter. We cannot adopt the much simpler approach in that paper for two reasons: i) with heterogeneity in fixed costs and productivity, there is no "scalar profitability index" providing a natural ordering, and ii) even if fixed costs were homogeneous, as in the model described in the theory section, productivity also shifts the endogenous fixed cost component, so we cannot prove that the marginal net benefit of entering the modern segment increases in productivity.

Removing cannibalization

Having established through the empirical evidence, the theoretical model, and the fixed cost estimation results that the presence of *MP*s influences the measurement of markdowns, entry decisions, and responses of producers to demand shocks, we use the estimated model to shed light on how important cannibalization forces are in determining market access, adoption, and markdowns.

We do so through a battery of exercises where we force all intermediaries to act as if they were single-product. We consider three successive comparisons:

1. *Mechanical markdown accounting*: we check how much the overlap component contributes to each segment markdown. We do not allow intermediaries to reoptimize, so this is purely an accounting exercise.

2. *Intensive margin equilibrium without MPs*: we remove the cross-segment terms from slaughterhouses' first-order conditions and solve for a new equilibrium, holding entry behavior fixed at the baseline.

3. *Extensive margin equilibrium without MPs*: we remove the cross-segment terms from slaughterhouses' first-order conditions, solve for a new equilibrium, and allow slaughterhouses to reoptimize their entry behavior.

Table 7 presents the accounting decomposition results. Cannibalization accounts for 28.6% of the markdown in the modern segment, and only 7.4% in the traditional one. The result is intuitive. As the traditional segment is much larger than the modern one, sourcing in the latter will be restricted to protect rents of *MP*s in the former. The reverse effect is weaker because the modern segment is relatively smaller. These estimates average over all municipalities with at least one active exporter, regardless of whether it is actually *MP* and accesses China. As a result, the numbers in 7 are a lower bound.

Turning to Table 8, we can compare the results for the second exercise, where we resolve the intensive margin, and for the third, which further allows changes in entry decisions.

Focusing on panel *B* first, we see that removing the multiproduct component sharply expands modern output. Keeping the extensive margin fixed, it expands by 16.1%. After allowing for entry to adjust, we see 77 new links between an entrant slaughterhouse and a municipality. This movement

compounds to an even stronger expansion of the modern segment, growing by 32%. Entry responds a lot because, as we saw, intermediaries' entry incentives were distorted by the opportunity cost of forgoing the extra profits associated with being SP in the traditional segment. This counterfactual shuts down that force, reinforcing the intensive margin results.

Panel C shows the underlying movements in markdowns. We see that μ_T^{MP} and μ^{MP} considerably fall as intermediaries that were multiproduct in the baseline start behaving as if they were single-product. As a result, these slaughterhouses expand their sourcing behavior, taking up part of the market shares of the competitive fringe and of the previous single-product buyers in the traditional segment. This reallocation effect slightly increases the traditional markdown.

Finally, in panel D we see that surplus for farmers, landowners, and intermediaries slightly increases, but more so for intermediaries, which manage to expand their sales.

Table 7: Mechanical contribution of multiproduct internalization

Segment	MP share of the markdown (%)
Traditional ($\mu_T - 1$)	7.4
Modern ($\mu_M - 1$)	28.6

Notes: Results aggregate across municipalities with at least one granular slaughterhouse.Prices, quantities, sourcing shares, participation, and supply elasticities remain at baseline values.

Fixed-cost subsidies

The following counterfactuals study policies that aim to increase competition and slaughterhouse entry into the modern segment while keeping the cannibalization forces active. We study two entry subsidies separately. First, we consider a government subsidy to entry into the modern segment. This subsidy should, in theory, incentivize intermediaries to enter that segment, increasing competition, lowering markdowns, and raising adoption and production. Second, we consider a subsidy to the fringe entry cost, which should increase competition in the traditional segment and, in turn, affect entry incentives into the modern segment. To make the two policies comparable, we adjust subsidies so that, in equilibrium, government spending is the same in both cases.

Subsidy to modern entry. The first policy pays a common subsidy to all slaughterhouses that decide to enter the modern segment. In the real world, the government might help meatpackers navigate red tape, licensing, audits, and certification with Chinese authorities. Importantly, we operationalize this

Table 8: Removing multiproduct internalization

		Change from baseline	
	Baseline	Fixed modern participation	Endogenous modern participation
Panel A. Participation			
Modern sourcing links	1,093.0	0.0	+77.0
Average modern buyers per municipality	1.7	0.0	0.0
Municipalities with modern access	637.0	0.0	+53.0
Panel B. Production and adoption			
Modern output	323.4	+16.1%	+32.0%
Traditional output	3,720.4	-1.0%	-1.9%
Farmer adoption rate (%)	2.2	+0.3 pp	+0.6 pp
Panel C. Buyer behavior			
Traditional markdown: all buyers (%)	18.8	+0.1 pp	+0.2 pp
Traditional markdown: baseline MP buyers (%)	43.7	-16.7 pp	-16.9 pp
Traditional markdown: baseline SP buyers (%)	46.6	-0.7 pp	-1.1 pp
Modern markdown (%)	34.9	-6.9 pp	-5.2 pp
Traditional share of baseline MP buyers (%)	3.7	+2.6 pp	+2.7 pp
Traditional share of competitive fringe (%)	68.7	-2.7 pp	-3.1 pp
Panel D. Income			
Farmer surplus (R$ billion)	2.6	+0.5%	+0.9%
Landowner surplus (R$ billion)	18.1	+0.6%	+1.0%
Intermediary profits (R$ billion)	7.4	+4.5%	+5.0%

Notes: Results aggregate across municipalities with at least one potential modern entrant in the baseline. Average modern buyers is the unweighted mean conditional on at least one active modern buyer in each equilibrium ($N_M > 0$). Changes in this average are absolute and may round to zero. The first column reports baseline levels, the remaining columns report changes from that baseline. Both counterfactuals remove cannibalization in sourcing. The last column also allows modern entry and exit based on stand-alone modern profits. Regional markdowns are then averaged using each equilibrium's total-cattle sourcing weights, conditional on the relevant group being active.

policy by giving subsidies to *all* entrants, irrespective of whether they have already entered in the baseline equilibrium.

We calibrate the subsidy to be the median baseline traditional-profit opportunity cost among MP slaughterhouses. We choose this amount to mimic alignment between the perceived fixed costs $\tilde{f}_M(i)$ of slaughterhouses in the decentralized equilibrium and the fixed cost $f_M(i)$ perceived by i under perfect competition.

The calibrated amount is approximately $s = R\$106,360$ per entrant (in 2017 reais), corresponding to around 22% of the median fixed cost $f_M(i)$ observed in the baseline equilibrium. Importantly, for baseline nonentrants, it is only 1.6% of their median exogenous fixed cost.

Subsidy to traditional fringe participation. An alternative policy is to address the domestic distortion directly and incentivize competition by subsidizing fringe entry in the domestic segment. In the real world, we can think of such a subsidy as an alternative policy lever for the Brazilian government if the Chinese government fully controls licensing for exporting slaughterhouses to China.

The second policy pays a common annual subsidy s_T per unit of operating fringe mass in eligible municipalities. Targeted municipalities must have at least one granular slaughterhouse, and entry into the modern segment must not already have been exhausted by all potential entrants.

We choose s_T so that equilibrium government spending equals realized spending under the modern subsidy of the other counterfactual:

$$s_T \sum_r M_r(s_T) = s_M \sum_{i,r} d_{ir}^{\text{modern subsidy}}, \tag{62}$$

where $M_m(s_T)$ is the equilibrium fringe mass under the fringe policy, the subsidy implies a payment of approximately R$11,080 per unit of the fringe mass, corresponding to 2.5% of the fringe entry cost f_T.

Theoretically, this policy can affect modern entry through two main channels: i) raising farmers' returns from traditional production, which increases demand for land in it, leading to lower slaughterhouse entry into the modern segment, and ii) lowering slaughterhouses' traditional profit opportunity cost of modern entry through an escape from competition effect.

Table 9 presents the results. Compared with the simulation with cannibalization turned off, these policies are less effective at correcting market power distortions.

Table 9: Subsidies to modern entry and traditional fringe participation

		Change from baseline	
Outcome	Baseline	Modern subsidy	Fringe subsidy
Panel A. Participation and access			
Modern sourcing links	1,093.0	+91.0	-79.0
Average modern buyers per municipality	1.7	0.0	-0.1
Municipalities with modern access	637.0	+40.0	-21.0
Competitive fringe mass	11,009.9	-0.3%	+3.9%
Panel B. Production and adoption			
Modern quantity	323.4	+6.8%	-3.8%
Traditional quantity	3,720.4	-0.4%	+0.3%
Farmer adoption rate (%)	2.2	+0.1 pp	-0.1 pp
Panel C. Buyer behavior			
Traditional markdown: all buyers (%)	18.8	0.0 pp	-0.4 pp
Traditional markdown: baseline MP buyers (%)	43.7	-0.2 pp	-1.0 pp
Traditional markdown: baseline SP buyers (%)	46.6	+0.1 pp	-0.5 pp
Modern markdown (%)	34.9	0.0 pp	-0.2 pp
Traditional share of baseline MP buyers (%)	3.7	0.0 pp	0.0 pp
Traditional share of competitive fringe (%)	68.7	0.0 pp	+0.5 pp
Panel D. Income, resource costs, and spending			
Farmer surplus (R$ million)	2,619.9	+0.1%	+0.4%
Landowner surplus (R$ million)	18,144.4	+0.2%	+0.4%
Intermediary profits, incl. transfers (R$ million)	7,443.8	+1.7%	-1.5%
Real intermediary entry costs (R$ million)	5,760.2	+1.5%	+2.0%
Government spending (R$ million)	0.0	+125.9 R$m	+125.9 R$m
Net industry surplus (R$ million)	28,208.1	+0.1%	-0.6%

Notes: Results aggregate across municipalities with at least one potential modern entrant in the baseline. Average modern buyers is the unweighted mean conditional on at least one active modern buyer in each equilibrium ($N_M > 0$). Changes in this average are absolute and may round to zero. The first column reports baseline levels; the remaining columns report changes. % and pp denote percent and percentage-point changes. Modern-link and access changes are counts; spending changes are in R$ million. Regional markdowns use each equilibrium's total-cattle sourcing weights, conditional on the relevant group being active. Intermediary profits include subsidy receipts and deduct fixed costs. Net industry surplus equals farmer and landowner surplus plus intermediary profits, less government spending; it excludes consumer surplus.

Focusing first on the modern subsidy, modern output increases by 6.8%, and the increase in the number of buyers is negligible. As a result, markdowns in either segment barely change. Intermediaries are the main beneficiaries of the policy, as expected, but they spend much of the surplus on entry costs. Accounting for the fiscal cost of the intervention, the overall net surplus is effectively unchanged. Overall, the policy is a transfer from the government to slaughterhouses.

Turning to the second counterfactual, the fringe subsidy leads to *lower* slaughterhouse entry and production in the modern segment, a small expansion of traditional production, and a small reduction in its markdown. Land competition across the two technologies raises farmers' returns from producing the traditional good. As a result, farmers would require a higher p_M to produce the modern good, reducing potential entrants' incentive to enter $g = M$. Furthermore, the escape-from-competition mechanism is not strong enough to induce entry. In the end, farmers still gain surplus, but the increase in fixed-cost expenditure makes the policy a net loss when government spending is considered.

Discussion

The counterfactuals show that multiproduct sourcing restrains both production in the modern segment and entry into it. Slaughterhouses account for the traditional profits they give up when entering or expanding in the modern segment, creating an endogenous barrier in addition to the exogenous fixed cost. Removing this incentive substantially expands modern production even when participation is held fixed. Allowing entry to adjust reinforces that expansion, showing that the mechanism operates through both existing slaughterhouses' sourcing decisions and producers' access to new modern buyers.

As for the subsidy counterfactuals, the modern entry subsidy increases modern activity modestly, while the fringe subsidy contracts it. The modern-entry subsidy mainly supports participation that already occurs without government assistance. According to the estimates, nonentrants in the baseline equilibrium face much higher exogenous fixed costs and therefore barely respond to the policy.

The comparison also highlights a trade-off between strengthening traditional-market competition and promoting modernization through access to the foreign supply chain. At the same level of government spending, the fringe subsidy produces larger gains for farmers and landowners than the modern-entry subsidy, but reduces modern entry, adoption, and output. Raising farmers' returns in traditional production can discourage upgrading even as their surplus increases. In this experiment, the reduction in slaughterhouses' traditional-profit opportunity cost is insufficient to offset the forces

discouraging modern participation.

Escape-from-competition incentives are therefore present but dominated by the other equilibrium responses. They could be stronger in a model where granular slaughterhouses choose which segment to enter and production in the two segments does not compete for shared inputs. In that setting, subsidizing the traditional fringe could make modern entry relatively more attractive by reducing traditional profits, without also raising modern production costs through competition for land.

Finally, we measure welfare as industry surplus. We abstract away from consumer surplus and distortionary taxation to finance the policies. Our results therefore describe only how producers and intermediaries share the surplus they produce. Therefore, results do not incorporate possible consumer benefits or losses and should not be read as a complete welfare ranking of the policies.

6 Conclusion

This paper studies how domestic buyer competition shapes producer upgrading and access to foreign markets in the Brazilian beef supply chain and its exports to China. Our evidence shows that large intermediaries operate in both the standard segment of the market and the segment associated with modern technology, and this matters quantitatively. Our model explains how multiproduct slaughterhouses' incentives to protect traditional profits can restrain modern sourcing and create an endogenous barrier to entry. Quantitatively, this mechanism limits modernization through both existing buyers' purchases and their willingness to provide market access.

The policy counterfactuals show that strengthening domestic competition and supporting modern entry can deliver different outcomes. The modern-entry subsidy mainly supports inframarginal participation, generating modest expansion and little additional industry surplus after accounting for government spending. At the same fiscal cost, subsidizing traditional fringe participation generates larger gains for farmers and landowners but reduces modern entry, adoption, and output, while lowering net industry surplus.

More broadly, the gains from foreign opportunities depend on the domestic business intermediaries have at stake and on producers' alternatives to upgrading. Stronger traditional competition can improve farmers' incomes even as it discourages participation in the foreign-oriented supply chain. Policies addressing domestic market power therefore need not expand foreign-market access or promote technology adoption. Assessing these policies requires considering both intermediaries'

willingness to provide access and farmers' incentives to use it.

References

Assunção, Juliano, and Arthur Bragança. 2019. "Productivity for Cattle Ranching in Brazil: Pasture-land Declines Might Show a New Pathway." Climate Policy Initiative.

Assunção, Juliano, Clarissa Gandour, and Rudi Rocha. 2015. "Deforestation slowdown in the Brazilian Amazon: prices or policies?" *Environment and Development Economics*, 20(6): 697–722.

Assunção, Juliano, Clarissa Gandour, Romero Rocha, and Rudi Rocha. 2020. "The effect of rural credit on deforestation: evidence from the Brazilian Amazon." *The Economic Journal*, 130(626): 290–330.

Atkin, David, Amit K Khandelwal, and Adam Osman. 2017. "Exporting and firm performance: Evidence from a randomized experiment." *The quarterly journal of economics*, 132(2): 551–615.

Atkin, David, and Dave Donaldson. 2015. *Who's Getting Globalized?: The Size and Implications of Intra-national Trade Costs.* National Bureau of Economic Research Cambridge, MA.

Bai, Jie, Lauren Falcao Bergquist, Ameet Morjaria, Russell Morton, and Yulu Tang. 2026. "Quality Incentives and Upgrading along Supply Chains: Experimental Evidence from Uganda." Preliminary and incomplete manuscript, July 2026.

Bai, Yan, Keyu Jin, and Dan Lu. 2024. "Misallocation under trade liberalization." *American Economic Review*, 114(7): 1949–1985.

Barrozo, Marcos. 2025. "Where is the beef? Supply chains and carbon emissions in the Amazon." Working paper, DePaul University.

Bergquist, Lauren Falcao, and Michael Dinerstein. 2020. "Competition and entry in agricultural markets: Experimental evidence from Kenya." *American Economic Review*, 110(12): 3705–3747.

Berry, Steven T. 1992. "Estimation of a Model of Entry in the Airline Industry." *Econometrica: Journal of the Econometric Society*, 889–917.

Bustos, Paula. 2011. "Trade Liberalization, Exports, and Technology Upgrading: Evidence on the Impact of MERCOSUR on Argentinian Firms." *American Economic Review*, 101(1): 304–340.

Chatterjee, Shoumitro. 2023. "Market Power and Spatial Competition in Rural India." *The Quarterly Journal of Economics*, 138(3): 1649–1711.

Coşar, A. Kerem, Nezih Guner, and James Tybout. 2016. "Firm Dynamics, Job Turnover, and Wage Distributions in an Open Economy." *American Economic Review*, 106(3): 625–663.

Dhingra, Swati, and Silvana Tenreyro. 2026. "The Rise of Agribusinesses and Its Distributional Consequences." *Journal of Political Economy Macroeconomics*. Forthcoming; April 2026 manuscript.

Dix-Carneiro, Rafael, Pinelopi Goldberg, Costas Meghir, and Gabriel Ulyssea. 2026. "Trade and Domestic Distortions: The Case of Informality." *Econometrica*, 94(2): 573–618.

Domínguez-Iino, Tomás. 2026. "Efficiency and Redistribution in Environmental Policy: An Equilibrium Analysis of Agricultural Supply Chains." *Journal of Political Economy*, 134(4): 1075–1109.

Edmond, Chris, Virgiliu Midrigan, and Daniel Yi Xu. 2015. "Competition, Markups, and the Gains from International Trade." *American Economic Review*, 105(10): 3183–3221.

Edmond, Chris, Virgiliu Midrigan, and Daniel Yi Xu. 2023. "How costly are markups?" *Journal of Political Economy*, 131(7): 1619–1675.

Einav, Liran, Mariana D Guido, and Peter J Klenow. 2026. "Customer Overlap and Diversion Ratios." National Bureau of Economic Research.

Fan, Ying, and Chenyu Yang. 2025. "Estimating discrete games with many firms and many decisions: An application to merger and product variety." *Journal of Political Economy*, 133(6): 1886–1931.

Farrokhi, Farid, Ahmad Lashkaripour, and Heitor S Pellegrina. 2024. "Trade and technology adoption in distorted economies." *Journal of International Economics*, 150: 103922.

Farrokhi, Farid, and Heitor S Pellegrina. 2023. "Trade, technology, and agricultural productivity." *Journal of Political Economy*, 131(9): 2509–2555.

Fieler, Ana Cecília, Marcela Eslava, and Daniel Yi Xu. 2018. "Trade, Quality Upgrading, and Input Linkages: Theory and Evidence from Colombia." *American Economic Review*, 108(1): 109–146.

Hsieh, Chang-Tai, and Peter J Klenow. 2009. "Misallocation and manufacturing TFP in China and India." *The Quarterly journal of economics*, 124(4): 1403–1448.

Krishna, Kala, and Yelena Sheveleva. 2017. "Wheat or strawberries? Intermediated trade with limited contracting." *American Economic Journal: Microeconomics*, 9(3): 28–62.

Macchiavello, Rocco, Josepa Miquel-Florensa, Nicolás de Roux, Eric Verhoogen, Mario Bernasconi, and Patrick Farrell. 2025. "Quality Upgrading in Global Supply Chains: Evidence from Colombian Coffee." IZA Institute of Labor Economics 18335. December 17, 2025 version; combines and supersedes Macchiavello and Miquel-Florensa (2019) and de Roux et al. (2022).

Pellegrina, Heitor S. 2022. "Trade, productivity, and the spatial organization of agriculture: Evidence from Brazil." *Journal of Development Economics*, 156: 102816.

Souza, Jr., Carlos M, Julia Z. Shimbo, Marcos R Rosa, Leandro L Parente, Ane A. Alencar, Bernardo FT Rudorff, Heinrich Hasenack, Marcelo Matsumoto, Laerte G. Ferreira, Pedro WM Souza-Filho, et al. 2020. "Reconstructing three decades of land use and land cover changes in brazilian biomes with landsat archive and earth engine." *Remote sensing*, 12(17): 2735.

Verhoogen, Eric. 2023. "Firm-level upgrading in developing countries." *Journal of Economic Literature*, 61(4): 1410–1464.

Verhoogen, Eric A. 2008. "Trade, quality upgrading, and wage inequality in the Mexican manufacturing sector." *The quarterly journal of economics*, 123(2): 489–530.

Zavala, Lucas. 2024. "Unfair Trade? Monopsony Power in Agricultural Value Chains." Working paper, September 3, 2024 revision of the job market paper.

zu Ermgassen, Erasmus K. H. J., Javier Godar, Michael J. Lathuillière, Pernilla Löfgren, Toby Gardner, André Vasconcelos, and Patrick Meyfroidt. 2020. "The origin, supply chain, and deforestation risk of Brazil's beef exports." *Proceedings of the National Academy of Sciences*, 117(50): 31770–31779.

A Supply and intermediation: derivations

This appendix derives the supply curves, supply elasticities, and intermediary sourcing conditions used in Section 3. We first fix farmer participation and then introduce endogenous adoption for quantification.

A.1 Producers

Farmers take upstream output prices (p_T, p_M), the common land rent r, and the material price p_x as given. The production functions are $Q_T = A_T L_T^{\eta}$ and $Q_M = A_M(L_M^{\alpha} X^{1-\alpha})^{\eta}$, with $0 < \alpha, \eta < 1$. Land supply is

$$L_T + L_M = \bar{L}(r/\kappa)^{\varphi}, \qquad \varphi > 0. \tag{A.1}$$

Here $\bar{L}$ is a scale normalization; the main text absorbs $\bar{L}^{-1/\varphi}$ into κ.

A.1.1 Producer problem

The representative farmer chooses traditional land, modern land, and materials jointly:

$$\max_{L_T, L_M, X \geq 0} \quad p_T A_T L_T^{\eta} + p_M A_M (L_M^{\alpha} X^{1-\alpha})^{\eta} - r(L_T + L_M) - p_x X. \tag{A.2}$$

At given prices and rent, the objective is separable across the two technologies. The traditional first-order condition and the resulting supply and land demand are

$$p_T = \frac{r}{\eta A_T L_T^{\eta-1}}, \tag{A.3}$$

$$\begin{aligned} L_T(p_T, r) &= \left(\frac{\eta A_T p_T}{r}\right)^{1/(1-\eta)}, \\ Q_T(p_T, r) &= A_T \left(\frac{\eta A_T p_T}{r}\right)^{\eta/(1-\eta)}, \quad r L_T = \eta p_T Q_T. \end{aligned} \tag{A.4}$$

For the modern farmer, the first-order conditions are

$$p_M \alpha \eta \frac{Q_M}{L_M} = r, \quad p_M (1-\alpha) \eta \frac{Q_M}{X} = p_x. \tag{A.5}$$

Solving gives output and land demands

$$\begin{aligned} Q_M(A_M, p_M, r) &= K A_M^{1/(1-\eta)} p_M^{\eta/(1-\eta)} r^{-\alpha\eta/(1-\eta)}, \\ L_M(A_M, p_M, r) &= B A_M^{1/(1-\eta)} p_M^{1/(1-\eta)} r^{-[1-\eta(1-\alpha)]/(1-\eta)}. \end{aligned} \tag{A.6}$$

Here K and B collect terms independent of (A_M, p_M, r), with

$$K = \left[\eta \alpha^{\alpha} (1-\alpha)^{1-\alpha}\right]^{\eta/(1-\eta)} p_x^{-(1-\alpha)\eta/(1-\eta)}, \quad B = \eta\alpha K. \tag{A.7}$$

Factor FOCs give

$$r L_M = \alpha\eta p_M Q_M, \quad p_x X = (1-\alpha)\eta p_M Q_M. \tag{A.8}$$

Hence we can write modern supply as

$$Q_M = Q_M(p_M, r) \equiv C_M p_M^{\eta/(1-\eta)} r^{-\alpha\eta/(1-\eta)}, \quad C_M \equiv K A_M^{1/(1-\eta)}. \tag{A.9}$$

Both traditional and modern output respond through the representative farmers' intensive input choices. Traditional operating profit is $(1-\eta) p_T Q_T$, while modern operating profit is $(1-\eta) p_M Q_M$.

A.1.2 Conditional input demands

Traditional land demand is $L_T = (Q_T / A_T)^{1/\eta}$. Modern factor demands satisfy

$$L_M = \frac{\alpha\eta p_M Q_M}{r}, \quad X = \frac{(1-\alpha)\eta p_M Q_M}{p_x}. \tag{A.10}$$

Equilibrium land allocations and the common rent jointly solve these demands and (A.1). A shock to either output raises the rent paid by both uses.

A.1.3 Inverse supply curves

The inverse output supply curves are

$$\begin{aligned} p_T(Q_T, Q_M) &= \frac{r(Q_T, Q_M)}{\eta A_T^{1/\eta}} Q_T^{(1-\eta)/\eta}, \\ p_M(Q_T, Q_M) &= \left(\frac{Q_M}{C_M}\right)^{(1-\eta)/\eta} r(Q_T, Q_M)^{\alpha}. \end{aligned} \tag{A.11}$$

The common rent $r(Q_T, Q_M)$ is determined by land market clearing.

Conditional on output, modern input demands solve

$$\mathcal{C}_M(Q_M; r) = \min_{L_M, X \geq 0} \left\{ rL_M + p_x X : A_M (L_M^{\alpha} X^{1-\alpha})^{\eta} \geq Q_M \right\}. \tag{A.12}$$

The factor ratio and minimized variable cost are

$$\begin{aligned} \frac{X}{L_M} &= \frac{(1-\alpha) r}{\alpha p_x}, \\ \mathcal{C}_M(Q_M; r) &= \frac{r^{\alpha} p_x^{1-\alpha}}{\alpha^{\alpha} (1-\alpha)^{1-\alpha}} \left(\frac{Q_M}{A_M} \right)^{1/\eta}. \end{aligned} \tag{A.13}$$

Differentiating this cost with respect to Q_M gives the modern inverse supply curve above. Its conditional land demand is

$$L_M(Q_M, r) = \left(\frac{Q_M}{A_M} \right)^{1/\eta} \left(\frac{\alpha p_x}{(1-\alpha) r} \right)^{1-\alpha}. \tag{A.14}$$

Consequently, the common rent is the solution to

$$\bar{L} \left(\frac{r}{\kappa} \right)^{\varphi} = \left(\frac{Q_T}{A_T} \right)^{1/\eta} + \left(\frac{Q_M}{A_M} \right)^{1/\eta} \left(\frac{\alpha p_x}{(1-\alpha) r} \right)^{1-\alpha}. \tag{A.15}$$

The left side increases in r and the right side weakly decreases, giving a unique positive rent at positive output. The normalization in the main text absorbs $\bar{L}^{-1/\varphi}$ into the land-supply shifter.

For completeness, the resource cost of land is

$$\begin{aligned} C_L(L_T, L_M) &= \int_0^{L_T + L_M} \kappa (s/\bar{L})^{1/\varphi} ds \\ &= \frac{\kappa \varphi \bar{L}}{1+\varphi} \left(\frac{L_T + L_M}{\bar{L}} \right)^{1+1/\varphi}. \end{aligned} \tag{A.16}$$

Its marginal cost is the same rent in either use.

A.1.4 Supply elasticities

We now compute the relevant supply elasticities. Define $\ell_T \equiv \frac{L_T}{L_T + L_M}$, the share of the traditional sector in total land.

At fixed material price, conditional input demands imply

$$\begin{aligned} d \ln L_T &= \frac{1}{\eta} d \ln Q_T, \\ d \ln L_M &= \frac{1}{\eta} d \ln Q_M - (1-\alpha) d \ln r. \end{aligned} \tag{A.17}$$

Land-market clearing gives $\varphi d\ln r = \ell_T d\ln L_T + (1-\ell_T) d\ln L_M$. Substituting these two input responses and collecting rent terms yields

$$[\varphi + (1-\alpha)(1-\ell_T)] d\ln r = \frac{1}{\eta}[\ell_T d\ln Q_T + (1-\ell_T) d\ln Q_M]. \tag{A.18}$$

Finally, log-differentiating the inverse supply curves gives

$$\begin{aligned} d\ln p_T &= \frac{1-\eta}{\eta} d\ln Q_T + d\ln r, \\ d\ln p_M &= \frac{1-\eta}{\eta} d\ln Q_M + \alpha d\ln r. \end{aligned} \tag{A.19}$$

In every case, ε_{p_g,Q_h} denotes $\partial \ln p_g / \partial \ln Q_h$, holding the other output fixed.

$$\begin{aligned} d\ln r &= \Gamma(\ell_T)\left[\ell_T d\ln Q_T + (1-\ell_T) d\ln Q_M\right]. \\ \Gamma(\ell_T) &\equiv \frac{1}{\eta[\varphi + (1-\alpha)(1-\ell_T)]} > 0. \end{aligned} \tag{A.20}$$

Thus $\Gamma(\ell_T)$ is the land-price elasticity with respect to a common proportional expansion of both outputs. Its denominator accounts for additional land supply, φ, and modern input substitution weighted by modern's land share, $(1-\alpha)(1-\ell_T)$.

Modern producers' ability to substitute materials for land dampens the rent response to a common proportional expansion of both outputs. This mechanism is stronger when modern production accounts for a larger share of land. As $\ell_T \to 0$, the rent elasticity approaches $1/[\eta(\varphi + 1 - \alpha)]$; as $\ell_T \to 1$, it approaches $1/(\eta\varphi)$. Thus modern input substitution reduces the rent response relative to the traditional-production benchmark.

We can multiply $\Gamma(\ell_T)$ by the respective land shares to obtain the elasticity of the land price with respect to output in each segment:

$$\varepsilon_{r,Q_T} = \ell_T \Gamma(\ell_T), \quad \varepsilon_{r,Q_M} = (1-\ell_T)\Gamma(\ell_T). \tag{A.21}$$

Using these, the four inverse output-supply elasticities are

$$\begin{aligned} \varepsilon_{p_T,Q_T} &= \frac{1-\eta}{\eta} + \ell_T \Gamma(\ell_T), \quad & \varepsilon_{p_T,Q_M} &= (1-\ell_T)\Gamma(\ell_T), \\ \varepsilon_{p_M,Q_T} &= \alpha \ell_T \Gamma(\ell_T), & \varepsilon_{p_M,Q_M} &= \frac{1-\eta}{\eta} + \alpha(1-\ell_T)\Gamma(\ell_T). \end{aligned} \tag{A.22}$$

Equivalently, with rows indexing producer prices and columns indexing quantities,

$$\boldsymbol{\varepsilon}(\ell_T) = \frac{1-\eta}{\eta} \cdot I + \Gamma(\ell_T) \begin{pmatrix} \ell_T & 1-\ell_T \\ \alpha\ell_T & \alpha(1-\ell_T) \end{pmatrix}. \tag{A.23}$$

With both segments active, $0 < \alpha, \eta < 1$, and $\varphi > 0$, all four elasticities are positive. Each technology has a direct own-output price response from decreasing returns, equal to $(1-\eta)/\eta$ holding the land rent and the materials price fixed.

The remaining effects operate through the common land market. Holding η, α, and φ fixed,

$$\frac{\partial \boldsymbol{\varepsilon}(\ell_T)}{\partial \ell_T} = \eta\, \Gamma(\ell_T)^2 \begin{pmatrix} \varphi + 1 - \alpha & -\varphi \\ \alpha(\varphi + 1 - \alpha) & -\alpha\varphi \end{pmatrix} \tag{A.24}$$

The signs follow directly: a higher traditional land share strengthens both prices' responses to traditional output and weakens their responses to modern output.

A.2 Intermediary sourcing

We now use the supply system specified above to characterize intermediaries' profit maximization. As in the main text, downstream sales satisfy $q_g^b(i) = z_g(i) q_g(i) = B_g [p_g^b(i)]^{-\sigma}$. Intermediaries take B_g and competitors' sourcing quantities as given.

Single-product intermediaries. An SP intermediary in segment $g = T$ solves

$$\max_{q_g(i) \geq 0} \quad B_g^{1/\sigma} [z_g(i) q_g(i)]^{(\sigma-1)/\sigma} - p_g(Q_T, Q_M) q_g(i), \tag{A.25}$$

where $Q_g = Q_{g,-i} + q_g(i)$.

The first-order condition is

$$\frac{\sigma - 1}{\sigma} z_g(i) p_g^b(i) = p_g + \frac{\partial p_g}{\partial Q_g} q_g(i). \tag{A.26}$$

Define the firm's upstream market share in market g as $s_g(i) \equiv \frac{q_g(i)}{Q_g}$. Then we write the FOC as

$$p_g^b(i) = \frac{\sigma}{\sigma - 1} \frac{p_g}{z_g(i)} \left[1 + s_g(i) \varepsilon_{p_g, Q_g} \right]. \tag{A.27}$$

Defining the markdown as the ratio of marginal revenue product to the upstream price, we arrive at

$$\begin{aligned}\mu_g^{SP}(i) &\equiv \frac{\sigma-1}{\sigma}\frac{z_g(i)p_g^b(i)}{p_g} \\ &= 1 + s_g(i)\varepsilon_{p_g,Q_g}.\end{aligned} \tag{A.28}$$

Multiproduct intermediaries. An MP intermediary chooses both sourcing quantities to solve

$$\max_{q_T(i),q_M(i)\geq 0} \quad \sum_{g\in\{T,M\}} \left\{ B_g^{1/\sigma}[z_g(i)q_g(i)]^{(\sigma-1)/\sigma} - p_g(Q_T,Q_M)q_g(i) \right\}, \tag{A.29}$$

where $Q_g = Q_{g,-i} + q_g(i)$ in both segments. Its first-order condition in segment g is

$$\frac{\sigma-1}{\sigma} z_g(i)p_g^b(i) = p_g + \frac{\partial p_g}{\partial Q_g}q_g(i) + \frac{\partial p_{-g}}{\partial Q_g}q_{-g}(i). \tag{A.30}$$

Defining i's markdown in market g analogously, we get

$$\begin{aligned}\mu_g^{MP}(i) &\equiv \frac{\sigma-1}{\sigma}\frac{z_g(i)p_g^b(i)}{p_g} \\ &= 1 + s_g(i)\varepsilon_{p_g,Q_g} + s_{-g}(i)\frac{p_{-g}Q_{-g}}{p_gQ_g}\varepsilon_{p_{-g},Q_g}.\end{aligned} \tag{A.31}$$

We can simplify the expression above by noting that, from producer cost minimization, $\varepsilon_{p_T,Q_M} = \frac{p_MQ_M}{p_TQ_T}\varepsilon_{p_M,Q_T}$, implying

$$\mu_g^{MP}(i) = 1 + s_g(i)\varepsilon_{p_g,Q_g} + s_{-g}(i)\varepsilon_{p_g,Q_{-g}}. \tag{A.32}$$

Fringe intermediaries. A fringe intermediary takes both B_T and p_T as given and solves

$$\max_{\bar{q}_T\geq 0} \quad B_T^{1/\sigma}(\bar{z}_T\bar{q}_T)^{(\sigma-1)/\sigma} - p_T\bar{q}_T. \tag{A.33}$$

Its first-order condition is

$$\bar{p}_T^b = \frac{\sigma}{\sigma-1}\frac{p_T}{\bar{z}_T}, \qquad \mu_T^F = \frac{\sigma-1}{\sigma}\frac{\bar{z}_T\bar{p}_T^b}{p_T} = 1. \tag{A.34}$$

All sourcing decisions are made for given participation profiles. In particular, granular intermediaries take the prevailing fringe mass as given and do not internalize $\partial M/\partial q_g(i)$.

A.3 Fringe entry

For any candidate multiproduct set, fringe entry adjusts until operating profits equal f_T, provided the fringe mass is positive. With CES demand and the pricing condition above, revenue per fringe intermediary satisfies

$$\begin{aligned} \bar{R}_T &= B_T(\bar{p}_T^b)^{1-\sigma} = \sigma f_T, \\ \bar{p}_T^b &= \left(\frac{B_T}{\sigma f_T}\right)^{1/(\sigma-1)}, \qquad p_T = \frac{\sigma-1}{\sigma}\bar{z}_T\bar{p}_T^b, \\ \bar{q}_T &= \frac{(\sigma-1)f_T}{p_T}, \qquad M = \frac{Q_T - \sum_{i\in\mathcal{I}_T} q_T(i)}{\bar{q}_T}. \end{aligned} \tag{A.35}$$

Thus, conditional on B_T, free entry fixes the operating scale of each fringe intermediary and the traditional producer price. The fringe absorbs the remaining traditional output. The granular participation conditions in Section 3 compare continuation profits after fringe entry and sourcing have adjusted, holding other granular intermediaries' participation fixed.

A.4 Equilibrium

We separate sourcing and production for given intermediary participation from intermediary entry. The set $\mathcal{I}_T$ of granular traditional buyers is exogenous. Let $\mathcal{I}_M \subseteq \mathcal{I}_T$ denote the multiproduct set, M the traditional fringe mass, and $\mathbf{B} = (B_T, B_M)$ the downstream demand shifters.

A.4.1 Intensive margin

Definition (Intensive-margin equilibrium). Conditional on $(\mathcal{I}_M, M, \mathbf{B})$, an intensive-margin equilibrium consists of producer prices (p_T, p_M), rent r, inputs (L_T, L_M, X), outputs (Q_T, Q_M), and intermediary sourcing quantities and downstream prices such that:

1. The representative farmer solves the joint maximization problem (A.2), taking producer prices, rent, and the material price as given.

2. Each granular intermediary maximizes operating profits, taking competitors' sourcing and $\mathbf{B}$ as given. Buyers in $\mathcal{I}_M$ choose both sourcing quantities jointly; buyers in $\mathcal{I}_T \setminus \mathcal{I}_M$ source only the traditional good. Fringe intermediaries take p_T as given. In these sourcing problems, the participation profile, including M, is held fixed.

3. Upstream goods and land markets clear:

$$\begin{aligned} Q_T &= \sum_{i \in \mathcal{I}_T} q_T(i) + M\bar{q}_T, \\ Q_M &= \sum_{i \in \mathcal{I}_M} q_M(i), \\ L_T + L_M &= \bar{L}(r/\kappa)^{\varphi}. \end{aligned} \tag{A.36}$$

4. Downstream sales satisfy technology and CES demand:

$$q_g^b(i) = z_g(i) q_g(i) = B_g [p_g^b(i)]^{-\sigma}, \tag{A.37}$$

with the analogous condition for each traditional fringe variety.

Farmer participation is fixed in this version. Free entry is not imposed when solving the sourcing problems at a given M.

A.4.2 Extensive margin

For a candidate multiproduct set $\mathcal{A} \subseteq \mathcal{I}_T$, let $M(\mathcal{A}; \mathbf{B})$ be the fringe mass after free entry and the intensive-margin equilibrium have adjusted. Entry costs are held fixed throughout. Define $\widehat{\Pi}^{MP}(i; \mathcal{A}, \mathbf{B})$ and $\widehat{\Pi}_T^{SP}(i; \mathcal{A}, \mathbf{B})$ as operating profits in that continuation equilibrium, gross of the modern entry cost f_M.

Definition (Extensive-margin equilibrium). Conditional on $\mathbf{B}$, an extensive-margin equilibrium consists of a multiproduct set $\mathcal{I}_M^*$, a fringe mass $M^* = M(\mathcal{I}_M^*; \mathbf{B})$, and an associated intensive-margin equilibrium satisfying:

1. Every active multiproduct intermediary weakly prefers remaining active in modern sourcing to withdrawing:

$$\widehat{\Pi}^{MP}(i; \mathcal{I}_M^*, \mathbf{B}) - f_M \geq \widehat{\Pi}_T^{SP}(i; \mathcal{I}_M^* \setminus \{i\}, \mathbf{B}). \tag{A.38}$$

2. No single-product granular intermediary gains from modern entry:

$$\widehat{\Pi}_T^{SP}(i; \mathcal{I}_M^*, \mathbf{B}) \geq \widehat{\Pi}^{MP}(i; \mathcal{I}_M^* \cup \{i\}, \mathbf{B}) - f_M. \tag{A.39}$$

3. Fringe entry satisfies

$$M^* \geq 0, \qquad \Pi_T^F \leq f_T, \qquad M^*(f_T - \Pi_T^F) = 0. \tag{A.40}$$

In the positive-fringe case maintained in the main text, $\Pi_T^F = f_T$.

In each granular deviation, other granular intermediaries' participation is held fixed, while sourcing, producer prices, land allocations, and fringe entry adjust. Demand shifters remain fixed. This is a pure-strategy Nash equilibrium of modern participation decisions, with continuation profits incorporating traditional operations. Granular intermediaries do not pay the fringe entry cost. The conditions may admit more than one participation profile.

A.4.3 Downstream consistency

A full equilibrium also requires the demand shifters to be consistent with the active varieties. In the single-region version,

$$\begin{aligned} P_T^{1-\sigma} &= \sum_{i \in \mathcal{I}_T} [p_T^b(i)]^{1-\sigma} + M(\bar{p}_T^b)^{1-\sigma}, \\ P_M^{1-\sigma} &= \sum_{i \in \mathcal{I}_M} [p_M^b(i)]^{1-\sigma}, \\ P_H^{1-\sigma} &= P_T^{1-\sigma} + P_M^{1-\sigma}, \qquad P_C = P_M, \\ B_T &= \frac{E_H}{P_H^{1-\sigma}}, \qquad B_M = \frac{E_H}{P_H^{1-\sigma}} + \frac{E_C}{P_M^{1-\sigma}}. \end{aligned} \tag{A.41}$$

B A planner problem

Throughout this appendix, let $\rho = (\sigma - 1)/\sigma$. The planner comparison uses the representative-farmer model with fixed farmer participation.

The planner maximizes *industry surplus*, defined as downstream revenues net of upstream production costs, taking the aggregate demand coefficients $\mathbf{B} = (B_T, B_M)$ as given. We abstract from consumer surplus. Conditional on $\mathbf{B}$, the planner chooses intensive-margin allocations, the mass of fringe intermediaries M, and the mass of granular intermediaries that become MP, N_M.We allow N_M to be continuous in the following so that we can take derivatives.

Given the final demand system, inverse demand for variety $i \in \mathcal{I}_g$ is

$$p_g^b(i) = B_g^{1/\sigma} \left(q_g^b(i) \right)^{-\frac{1}{\sigma}}. \tag{B.42}$$

There is an exogenous mass N_T of granular intermediaries, all of which are active in segment $g = T$. To make the MP entry decision continuous, index granular intermediaries by

$$i \in [0, N_T]$$

and order them so that modern productivity $z_M(i)$ is weakly decreasing in i. With a common MP entry cost f_M, the planner assigns MP status to the most productive modern intermediaries. Intermediary costs are transfers within industry surplus, so cannibalization forces do not affect this ranking. Hence, if the planner chooses a mass $N_M \in [0, N_T]$ of MP intermediaries, the set of MP intermediaries is $[0, N_M]$.

The planner solves

$$\begin{aligned} \max_{\substack{N_M, M, \\ \{q_T(i)\}_{i\in[0,N_T]}, \{q_M(i)\}_{i\in[0,N_M]}, \bar{q}_T, \\ Q_T, Q_M, L_T, L_M, X}} \quad & \int_0^{N_T} B_T^{1/\sigma} \left[z_T(i) q_T(i) \right]^\rho \, di + M B_T^{1/\sigma} \left[\bar{z}_T \, \bar{q}_T \right]^\rho \\ & + \int_0^{N_M} B_M^{1/\sigma} \left[z_M(i) q_M(i) \right]^\rho \, di \\ & - f_T M - f_M N_M - p_x X - C_L(L_T, L_M) \end{aligned} \tag{B.43}$$

subject to

$$Q_T = \int_0^{N_T} q_T(i)\, di + M\bar{q}_T, \tag{B.44}$$

$$Q_T = A_T L_T^{\eta}, \tag{B.45}$$

$$Q_M = \int_0^{N_M} q_M(i)\, di, \tag{B.46}$$

$$Q_M = A_M \left(L_M^{\alpha} X^{1-\alpha} \right)^{\eta}, \tag{B.47}$$

$$0 \leq N_M \leq N_T, \tag{B.48}$$

$$L_T, L_M \geq 0, \tag{B.49}$$

B.1 Intermediary allocation

We first solve the planner's allocation of a given amount of upstream output across active intermediaries, conditional on the entry margins (N_M, M) and aggregate upstream quantities (Q_T, Q_M).

At fixed (B_T, B_M), the downstream revenue functions are separable across segments, so the allocation problem can be solved independently for each g.

For the traditional segment, the planner solves

$$R_T(Q_T; M) \equiv \max_{\{q_T(i)\}_{i\in[0,N_T]}, \bar{q}_T} \int_0^{N_T} B_T^{1/\sigma} \left[z_T(i) q_T(i) \right]^{\frac{\sigma-1}{\sigma}} di + M B_T^{1/\sigma} \left[\bar{z}_T\, \bar{q}_T \right]^{\frac{\sigma-1}{\sigma}} \tag{B.50}$$

$$\text{s.t.} \quad \int_0^{N_T} q_T(i)\, di + M\bar{q}_T = Q_T. \tag{B.51}$$

Let λ_T denote the multiplier on (B.51). For every granular intermediary, the first-order condition is

$$\frac{\sigma-1}{\sigma} B_T^{1/\sigma} z_T(i)^{\frac{\sigma-1}{\sigma}} q_T(i)^{-\frac{1}{\sigma}} = \lambda_T, \tag{B.52}$$

while for a fringe intermediary,

$$\frac{\sigma-1}{\sigma} B_T^{1/\sigma} \bar{z}_T^{\frac{\sigma-1}{\sigma}} \bar{q}_T^{-\frac{1}{\sigma}} = \lambda_T. \tag{B.53}$$

Hence, denoting the solution with $*$

$$q_T^*(i) = \left(\frac{\sigma-1}{\sigma}\frac{B_T^{1/\sigma}}{\lambda_T}\right)^{\sigma} z_T(i)^{\sigma-1}, \tag{B.54}$$

$$\bar{q}_T^* = \left(\frac{\sigma-1}{\sigma}\frac{B_T^{1/\sigma}}{\lambda_T}\right)^{\sigma} \bar{z}_T^{\sigma-1}. \tag{B.55}$$

Define planner productivity in the traditional segment as

$$Z_T^*(M) \equiv \left[\int_0^{N_T} z_T(i)^{\sigma-1}\, di + M\bar{z}_T^{\sigma-1}\right]^{\frac{1}{\sigma-1}}. \tag{B.56}$$

Using market clearing,

$$Q_T = \left(\frac{\sigma-1}{\sigma}\frac{B_T^{1/\sigma}}{\lambda_T}\right)^{\sigma} \left[Z_T^*(M)\right]^{\sigma-1}, \tag{B.57}$$

so that the efficient allocation can be written as

$$q_T^*(i) = Q_T \frac{z_T(i)^{\sigma-1}}{\left[Z_T^*(M)\right]^{\sigma-1}}, \tag{B.58}$$

$$\bar{q}_T^* = Q_T \frac{\bar{z}_T^{\sigma-1}}{\left[Z_T^*(M)\right]^{\sigma-1}}. \tag{B.59}$$

Substituting the optimal allocation into the objective gives

$$R_T(Q_T; M) = B_T^{1/\sigma}\left[Z_T^*(M) Q_T\right]^{\frac{\sigma-1}{\sigma}}. \tag{B.60}$$

The shadow value of one additional unit of traditional upstream output is therefore

$$\lambda_T \equiv \frac{\partial R_T(Q_T; M)}{\partial Q_T} = \frac{\sigma-1}{\sigma} B_T^{1/\sigma}\left[Z_T^*(M)\right]^{\frac{\sigma-1}{\sigma}} Q_T^{-\frac{1}{\sigma}}. \tag{B.61}$$

For the modern segment, the result is analogous:

$$R_M(Q_M; N_M) = B_M^{1/\sigma}\left[Z_M^*(N_M) Q_M\right]^{\frac{\sigma-1}{\sigma}} \tag{B.62}$$

$$\lambda_M \equiv \frac{\partial R_M(Q_M; N_M)}{\partial Q_M} = \frac{\sigma-1}{\sigma} B_M^{1/\sigma}\left[Z_M^*(N_M)\right]^{\frac{\sigma-1}{\sigma}} Q_M^{-\frac{1}{\sigma}}. \tag{B.63}$$

Thus, conditional on (Q_T, Q_M, M, N_M), the planner allocates upstream output across intermediaries according to

$$q_g^*(i) \propto z_g(i)^{\sigma-1}. \tag{B.64}$$

It is convenient to use the envelope theorem and derive the marginal value of a fringe or MP entrant, which will be used later on the derivation:

$$\frac{\sigma-1}{\sigma} z_g(i) p_g^b(i) = \lambda_g. \tag{B.65}$$

Since

$$\frac{\partial}{\partial M}\left[Z_T^*(M)\right]^{\sigma-1} = \bar{z}_T^{\sigma-1},$$

we obtain

$$\frac{\partial R_T(Q_T;M)}{\partial M} = \frac{\lambda_T \bar{q}_T^*}{\sigma-1}. \tag{B.66}$$

Similarly,

$$\frac{\partial}{\partial N_M}\left[Z_M^*(N_M)\right]^{\sigma-1} = z_M(N_M)^{\sigma-1},$$

so that

$$\frac{\partial R_M(Q_M;N_M)}{\partial N_M} = \frac{\lambda_M q_M^*(N_M)}{\sigma-1}. \tag{B.67}$$

B.2 Upstream production

Having solved the allocation of output across intermediaries, we now solve the upstream production problem conditional on the entry margins (M, N_M).

Using the intermediary allocation derived above, the planner chooses (L_T, L_M, X) to solve

$$\max_{L_T, L_M, X} \quad R_T(Q_T;M) + R_M(Q_M;N_M) - p_x X - C_L(L_T, L_M) \tag{B.68}$$

subject to

$$Q_T = A_T L_T^{\eta}, \tag{B.69}$$

$$Q_M = A_M \left(L_M^{\alpha} X^{1-\alpha}\right)^{\eta}. \tag{B.70}$$

Here $\lambda_g \equiv \partial R_g / \partial Q_g$ is the planner's marginal value of upstream output, while φ is the elasticity

of total cattle land supply. The marginal cost of land is the same in both uses:

$$r^* = \frac{\partial C_L(L_T^*, L_M^*)}{\partial L_g} = \kappa \left(\frac{L_T^* + L_M^*}{\bar{L}} \right)^{1/\varphi}, \qquad g \in \{T, M\}. \tag{B.71}$$

The first-order condition for traditional land is

$$\lambda_T \eta A_T L_T^{\eta-1} = r^*. \tag{B.72}$$

Equivalently,

$$\lambda_T = \frac{r^*}{\eta A_T L_T^{\eta-1}}. \tag{B.73}$$

The first-order condition for modern land is

$$\lambda_M \frac{\partial Q_M}{\partial L_M} = r^*, \tag{B.74}$$

which implies

$$r^* L_M = \alpha \eta \lambda_M Q_M. \tag{B.75}$$

Finally, the material-input condition is

$$\lambda_M \frac{\partial Q_M}{\partial X} = p_x, \tag{B.76}$$

or

$$p_x X = (1 - \alpha) \eta \lambda_M Q_M. \tag{B.77}$$

As expected, producer optimization is efficient in the decentralized equilibrium if the prices they receive are the same as the planner's shadow values. That is, there is no additional inefficiency coming from the producers' side.

B.3 Intermediary entry

The general entry problem is a choice of which heterogeneous granular intermediaries become multi-product, as well as the mass of fringe entrants. Let $\mathcal{A} \subseteq [0, N_T]$ be the set of granular intermediaries assigned to the modern segment, and let $|\mathcal{A}|$ denote its mass. All granular intermediaries remain active in the traditional segment regardless of their MP status. For an arbitrary modern active set,

define

$$S_M(\mathcal{A}) \equiv \int_{\mathcal{A}} z_M(i)^{\sigma-1}\, di, \qquad R_M(Q_M;\mathcal{A}) = B_M^{1/\sigma} Q_M^{(\sigma-1)/\sigma} S_M(\mathcal{A})^{1/\sigma}.$$

This is the optimized modern revenue obtained by allocating Q_M across $\mathcal{A}$. Let

$$\widetilde{\mathcal{V}}(M,\mathcal{A}) \equiv \max_{L_T, L_M, X \geq 0} \left\{ R_T(Q_T;M) + R_M(Q_M;\mathcal{A}) - p_x X - C_L(L_T, L_M) \right\},$$

subject to the constraints listed before. The planner therefore solves

$$\max_{M\geq 0,\ \mathcal{A}\subseteq[0,N_T]} \left\{ \widetilde{\mathcal{V}}(M,\mathcal{A}) - f_T M - f_M |\mathcal{A}| \right\}.$$

It is easy to see that the planner would always want to choose the intermediaries with highest productivities to enter the modern segment. Thus we may restrict attention to $\mathcal{A} = [0, N_M]$. Heterogeneity in $z_T(i)$ does not affect this ranking because MP entry does not remove an intermediary from the traditional segment and markdowns do not enter the planner's objective or constraints.

We can focus, therefore, in solving

$$\max_{M\geq 0,\ 0\leq N_M \leq N_T} \quad \mathcal{V}(M, N_M) - f_T M - f_M N_M. \tag{B.78}$$

Because all upstream quantities and input choices have already been optimized conditional on (M, N_M), the envelope theorem implies that the effect of entry on the planner's value is given by its direct effect on the relevant downstream revenue function.

B.3.1 Fringe entry

We characterize the planner's fringe choice conditional on demand **B**, displaying its dependence on f_T. Write $M^*(f_T)$ and $r^*(f_T)$ for the jointly optimal fringe mass and land rent, and use the same convention for other optimal quantities. By the envelope theorem and (B.66), the marginal benefit of an additional fringe intermediary is $\lambda_T^*(f_T)\bar{q}_T^*(f_T)/(\sigma-1)$. Assuming an interior allocation for the fringe, we get

$$M^*(f_T)\left(f_T - \frac{\lambda_T^*(f_T)\bar{q}_T^*(f_T)}{\sigma - 1} \right) = 0. \tag{B.79}$$

Let $\bar{R}_T^*(f_T) \equiv \bar{p}_T^{b,*}(f_T)\bar{z}_T\bar{q}_T^*(f_T)$ be sales revenue per fringe intermediary, where $\bar{p}_T^{b,*}(f_T)$ is its downstream price. Efficient sourcing implies $\lambda_T^*(f_T)\bar{q}_T^*(f_T) = (\sigma-1)\bar{R}_T^*(f_T)/\sigma$. The entry condition

therefore fixes revenue per fringe intermediary at σf_T. Using CES demand gives

$$\bar{R}_T^*(f_T) = \sigma f_T, \tag{B.80}$$

$$\bar{p}_T^{b,*}(f_T) = \left(\frac{B_T}{\sigma f_T}\right)^{1/(\sigma-1)}. \tag{B.81}$$

The planner's marginal value of traditional output and each fringe intermediary's upstream purchases are, therefore,

$$\begin{aligned}\lambda_T^*(f_T) &= \frac{\sigma-1}{\sigma}\bar{z}_T\,\bar{p}_T^{b,*}(f_T) \\ &= \frac{\sigma-1}{\sigma}\bar{z}_T\left(\frac{B_T}{\sigma f_T}\right)^{1/(\sigma-1)},\end{aligned} \tag{B.82}$$

$$\bar{q}_T^*(f_T) = \frac{(\sigma-1)f_T}{\lambda_T^*(f_T)}. \tag{B.83}$$

Thus, conditional on B_T, fringe entry fixes the operating scale of each active fringe intermediary and the planner's traditional shadow value.

We use this condition to determine the fringe's mass of entrants. Efficient allocation across traditional buyers implies

$$q_T^*(i; f_T) = \bar{q}_T^*(f_T)\left(\frac{z_T(i)}{\bar{z}_T}\right)^{\sigma-1}. \tag{B.84}$$

Substituting into traditional market clearing yields

$$M^*(f_T) = \frac{Q_T^*(f_T)}{\bar{q}_T^*(f_T)} - \int_0^{N_T}\left(\frac{z_T(i)}{\bar{z}_T}\right)^{\sigma-1} di. \tag{B.85}$$

The first term measures total traditional output in units of one fringe intermediary's purchases; the integral measures granular purchases in the same units. Fringe intermediaries absorb the remaining output.

Substituting the production function for the traditional good and the expressions for $\lambda_T^*(f_T)$ and $\bar{q}_T^*(f_T)$ above gives

$$\begin{aligned}M^*(f_T) = \mathcal{C}_T\, B_T^{\frac{1}{(\sigma-1)(1-\eta)}} f_T^{-\left[1+\frac{1}{(\sigma-1)(1-\eta)}\right]} (r^*(f_T))^{-\frac{\eta}{1-\eta}} \\ - \int_0^{N_T}\left(\frac{z_T(i)}{\bar{z}_T}\right)^{\sigma-1} di.\end{aligned} \tag{B.86}$$

where

$$\mathcal{C}_T \equiv \left[\frac{(A_T\bar{z}_T)^{\sigma-1}[\eta(\sigma-1)]^{\eta(\sigma-1)}}{\sigma^{\sigma}}\right]^{\frac{1}{(\sigma-1)(1-\eta)}},$$

Holding the other terms fixed, stronger downstream demand raises fringe entry, while higher entry costs or rent reduce it. Modern production and entry affect the fringe through the endogenous land rent.

B.3.2 Multi-product entry

Note that, for the modern segment,

$$[Z_M^*(N_M)]^{\sigma-1} = \int_0^{N_M} z_M(i)^{\sigma-1}\,di. \tag{B.87}$$

Intermediaries are ordered so that $z_M(i)$ is weakly decreasing in i, and the marginal MP intermediary has productivity $z_M(N_M)$.

The amount of modern output efficiently allocated to the marginal intermediary is

$$q_M^*(N_M) = Q_M \frac{z_M(N_M)^{\sigma-1}}{\left[Z_M^*(N_M)\right]^{\sigma-1}} \tag{B.88}$$

$$= \left(\frac{\sigma-1}{\sigma}\frac{B_M^{1/\sigma}}{\lambda_M}\right)^{\sigma} z_M(N_M)^{\sigma-1}. \tag{B.89}$$

Again using the envelope theorem,

$$\frac{\partial \mathcal{V}(M,N_M)}{\partial N_M} = \frac{\partial R_M(Q_M;N_M)}{\partial N_M} \tag{B.90}$$

$$= \frac{\lambda_M q_M^*(N_M)}{\sigma-1}. \tag{B.91}$$

Hence an interior choice $0 < N_M < N_T$ satisfies

$$\frac{\lambda_M q_M^*(N_M)}{\sigma-1} = f_M. \tag{B.92}$$

Substituting (B.89) into (B.92) yields

$$f_M = \frac{1}{\sigma-1}\left(\frac{\sigma-1}{\sigma}B_M^{1/\sigma}\right)^{\sigma} z_M(N_M)^{\sigma-1}\lambda_M^{1-\sigma}. \tag{B.93}$$

Therefore the planner's marginal value of modern output is proportional to the productivity of

the marginal MP intermediary:

$$\lambda_M^* = K_M z_M(N_M), \tag{B.94}$$

$$K_M \equiv \frac{\sigma-1}{\sigma} B_M^{1/\sigma} \left(\frac{B_M^{1/\sigma}}{\sigma f_M}\right)^{\frac{1}{\sigma-1}}. \tag{B.95}$$

Let $r^*(N_M; f_T)$ denote the rent when the fringe mass and upstream inputs are optimized conditional on N_M. Note that on the production side,

$$Q_M^* = Q_M(\lambda_M^*, r^*(N_M; f_T)). \tag{B.96}$$

While on the demand side,

$$Q_M^* = \left(\frac{\frac{\sigma-1}{\sigma} B_M^{1/\sigma}}{\lambda_M^*}\right)^{\sigma} [Z_M^*(N_M)]^{\sigma-1}. \tag{B.97}$$

Substituting $\lambda_M^* = K_M z_M(N_M)$ into supply and demand and expanding K_M gives, with $\rho \equiv (\sigma-1)/\sigma$ and $\Delta \equiv \sigma + \eta/(1-\eta)$,

$$\begin{aligned}\frac{z_M(N_M)^{\Delta}}{[Z_M^*(N_M)]^{\sigma-1}} = \frac{1}{C_M}[r^*(N_M; f_T)]^{\frac{\alpha\eta}{1-\eta}} \\ \times \left(\rho B_M^{1/\sigma}\right)^{-\frac{\eta}{1-\eta}} \left(\frac{\sigma f_M}{B_M^{1/\sigma}}\right)^{\frac{\Delta}{\sigma-1}}\end{aligned} \tag{B.98}$$

The right-hand side separates three components. Higher land rent raises modern production costs and reduces the output available to support entrants. Stronger downstream demand raises the marginal value of modern output and induces upstream production, captured by the second term. The final term captures the marginal variety's requirement to generate revenue σf_M, relative to the demand shifter $B_M^{1/\sigma}$.

The left-hand side strictly decreases as entry expands: the marginal entrant becomes weakly less productive, while aggregate modern productivity increases. To prove this, recall that $[Z_M^*(N_M)]^{\sigma-1} = \int_0^{N_M} z_M(i)^{\sigma-1}\, di$. For $N_M > 0$ and a weakly decreasing productivity schedule,

$$\frac{d}{dN_M} \ln\left(\frac{z_M(N_M)^{\Delta}}{[Z_M^*(N_M)]^{\sigma-1}}\right) = \Delta \frac{z_M'(N_M)}{z_M(N_M)} - \frac{z_M(N_M)^{\sigma-1}}{[Z_M^*(N_M)]^{\sigma-1}} < 0.$$

The first term is nonpositive because $\Delta > 0$ and $z_M'(N_M) \leq 0$; the second is strictly negative. Thus, holding rent fixed, stronger demand increases efficient entry and higher entry costs reduce it. The

common land market makes rent endogenous, so the full entry response must also account for land rents changing.

C Wedges: intensive and extensive margins

We now compare the decentralized equilibrium with the planner allocation characterized in Appendix B. We organize the comparison along the intensive and extensive margins. At the intensive margin, we hold intermediary participation fixed and study allocation across active intermediaries, land composition across technologies, and aggregate scale. At the extensive margin, we compare decentralized and planner intermediary entry.

This organization separates four conceptually distinct manifestations of buyer power. First, buyer-level markdown dispersion distorts the *intensive margin* of sourcing: conditional on total output in a segment, cattle are allocated inefficiently across downstream varieties. Second, differences in the resulting segment-level wedges distort the allocation of land across the traditional and modern technologies. Third, the common level of these wedges distorts the scale of production, including total land use and modern material use. Finally, buyer power can distort both the number and the identity of active intermediaries.

Because the planner maximizes downstream revenue net of real resource costs, rather than consumer surplus, the usual CES downstream markup is not itself a wedge relative to our planner. The wedges below arise from upstream buyer power and from the entry decisions that it induces.

C.1 Intensive margin: allocation across active intermediaries

We begin by fixing the participation profile $(\mathcal{I}_M, M)$ and aggregate upstream quantities (Q_T, Q_M). The planner then allocates each Q_g across active downstream varieties so as to equalize their marginal revenue products.

C.1.1 Allocation across active varieties

Using CES demand equilibrium sourcing by buyer i satisfies

$$q_g(i) \propto z_g(i)^{\sigma-1} \mu_g(i)^{-\sigma}. \tag{C.99}$$

By contrast, the planner allocation derived in Appendix B satisfies

$$q_g^*(i) \propto z_g(i)^{\sigma-1}. \tag{C.100}$$

Thus, conditional on Q_g, buyer power distorts the allocation of cattle across intermediaries whenever markdowns differ across active varieties. Relative to the planner, a buyer with a high markdown sources too little:

$$\frac{q_g(i)/q_g(m)}{q_g^*(i)/q_g^*(m)} = \left(\frac{\mu_g(m)}{\mu_g(i)}\right)^{\sigma}. \tag{C.101}$$

In segment M, where all active buyers are granular, a fixed Q_M is allocated efficiently if and only if

$$\mu_M^{MP}(i) = \mu_M^{MP}(m) \qquad \forall i, m \in \mathcal{I}_M. \tag{C.102}$$

The common markdown need not equal one: a common markdown changes the scale of the segment, but not the allocation of a fixed Q_M across varieties.

Segment T is different because the price-taking fringe is active. Since $\mu_T^F = 1$, efficient allocation of a fixed Q_T requires

$$\mu_T^{MP}(i) = \mu_T^{SP}(m) = 1 \qquad \forall i \in \mathcal{I}_M, \quad m \in \mathcal{I}_T \setminus \mathcal{I}_M. \tag{C.103}$$

Thus, even if all granular buyers have the same markdown, segment T remains misallocated whenever that markdown exceeds one: granular buyers source too little relative to the competitive fringe.

To summarize this intensive-margin distortion, define equilibrium segment productivity Z_g by

$$R_g(Q_g) = B_g^{1/\sigma} \left(Z_g Q_g\right)^{\rho}. \tag{C.104}$$

Using the equilibrium sourcing conditions,

$$Z_g = \left[\sum_{i \in \mathcal{I}_g} z_g(i)^{\sigma-1} \left(\frac{\mu_g}{\mu_g(i)}\right)^{\sigma-1}\right]^{\frac{1}{\sigma-1}}, \tag{C.105}$$

where in segment T the summation notation includes the mass M of fringe varieties, each with productivity $\bar{z}_T$ and markdown one.

The corresponding planner productivity is

$$[Z_T^*(M)]^{\sigma-1} = \sum_{i=1}^{N_T} z_T(i)^{\sigma-1} + M\bar{z}_T^{\sigma-1}, \tag{C.106}$$

$$[Z_M^*(\mathcal{I}_M)]^{\sigma-1} = \sum_{i=1}^{N_M} z_M(i)^{\sigma-1}. \tag{C.107}$$

Since the planner maximizes revenue conditional on Q_g and the participation profile,

$$Z_g \leq Z_g^*, \tag{C.108}$$

with equality if and only if the decentralized sourcing allocation is efficient.

Thus the first inefficiency generated by buyer power is *within-sector misallocation*: high-markdown intermediaries are too small relative to their downstream productivity.

We next hold the participation profile fixed and ask how the distorted intermediary allocation affects upstream production.

The distinction between Z_g and Z_g^* is important here. Buyer power affects upstream production through two channels. First, even conditional on the decentralized allocation of output across varieties, the segment-level markdown lowers the price transmitted to producers. Second, markdown dispersion lowers segment productivity itself, reducing the revenue generated by a given amount of upstream output.

C.1.2 Allocation across segments

At the decentralized allocation, let R_g denote total downstream revenue in segment g. Then

$$\mu_g = \rho \frac{R_g}{p_g Q_g}, \tag{C.109}$$

so the marginal revenue generated by proportionally expanding the decentralized allocation is

$$\begin{aligned} \lambda_g &\equiv \rho B_g^{1/\sigma} \left(Z_g\right)^{\rho} Q_g^{-1/\sigma} \\ &= \mu_g p_g. \end{aligned} \tag{C.110}$$

Now evaluate the planner's marginal value of upstream output at the same aggregate quantity Q_g, participation profile and demand coefficients (B_T, B_M), but allowing the planner to allocate that

output efficiently across active varieties:

$$\lambda_g^* \equiv \rho B_g^{1/\sigma} \left(Z_g^*\right)^{\rho} Q_g^{-1/\sigma}. \tag{C.111}$$

It follows that

$$\frac{\lambda_g^*}{p_g} = \underbrace{\mu_g}_{\text{buyer-power wedge}} \underbrace{\left(\frac{Z_g^*}{Z_g}\right)^{\rho}}_{\text{within-sector misallocation}}. \tag{C.112}$$

So at the segment-level, wedges are summarized by

$$\begin{aligned} \Omega_g &\equiv \frac{\lambda_g^*}{p_g} \\ &= \mu_g \mathcal{A}_g, \qquad \mathcal{A}_g \equiv \left(\frac{Z_g^*}{Z_g}\right)^{\rho} \geq 1. \end{aligned} \tag{C.113}$$

This decomposition is useful because it separates two conceptually distinct inefficiencies. The markdown μ_g captures how buyer power suppresses the value transmitted upstream for a given decentralized intermediary allocation. The term $\mathcal{A}_g$ captures the additional loss from allocating output to the wrong intermediaries.

C.2 Intensive margin: land composition across technologies

The common land market links the two segment wedges. At the decentralized allocation,

$$p_T \eta A_T L_T^{\eta-1} = r, \tag{C.114}$$

$$p_M \frac{\partial Q_M}{\partial L_M} = r. \tag{C.115}$$

Thus private returns to marginal land are equalized across technologies.

Hence the relevant *composition wedge* is

$$\frac{\Omega_M}{\Omega_T} = \frac{\mu_M}{\mu_T} \left[\frac{Z_M^*/Z_M}{Z_T^*/Z_T}\right]^{\rho}. \tag{C.116}$$

If $\Omega_M > \Omega_T$, the social return land is larger at the margin in the modern technology than in the traditional technology, and the planner would reallocate land toward segment M. If $\Omega_T > \Omega_M$, the reverse is true. We see, therefore, that $\frac{\Omega_M}{\Omega_T}$ captures misallocation *across segments*.

Even if $\mu_T = \mu_M$, land composition is inefficient whenever within-sector misallocation differs across segments.

C.3 Intensive margin: aggregate scale and input use

After showing that market power leads to misallocation due to within- and cross-segment markdown dispersion, we now consider how aggregate markdown acts as a uniform output tax, leading to insufficient production scale and factor use. Because the technologies in the two segments differ, aggregation is not direct, and it is hard to discuss aggregate productivity without additional assumptions. We focus instead on deriving an expression for the aggregate markdown and showing that it generates a *scale* distortion by leading to underuse of flexible factors of production: materials X and aggregate land use $L = L_T + L_M$.

We can write the production problem as one of choosing Q_T and Q_M directly given segment revenues and resource costs, subject to wedges μ_T and μ_M:

$$\max_{Q_T, Q_M \geq 0} \quad \frac{1}{\mu_T} R_T(Q_T) + \frac{1}{\mu_M} R_M(Q_M) - C(Q_T, Q_M), \tag{C.117}$$

Define the aggregate markdown as the revenue-weighted harmonic mean of the segment markdowns:

$$\mu \equiv \left(\sum_{g \in \{T,M\}} \frac{\omega_g}{\mu_g} \right)^{-1}, \qquad \omega_g \equiv \frac{R_g(Q_g)}{R_T(Q_T) + R_M(Q_M)}. \tag{C.118}$$

It follows that

$$\frac{R_T}{\mu_T} + \frac{R_M}{\mu_M} = \frac{1}{\mu}(R_T + R_M), \qquad \omega_g = \frac{\mu_g p_g Q_g}{\sum_h \mu_h p_h Q_h}, \tag{C.119}$$

$$\mu = \frac{\sum_g \mu_g p_g Q_g}{\sum_g p_g Q_g}. \tag{C.120}$$

total downstream revenue by $1/\mu$, corresponding to an output tax.

The aggregate wedge leads to a suboptimal scale of primary factors. To see this, set $\mu_T = \mu_M = \mu > 1$. The decentralized allocation can then be written as

$$\max_{L_T, L_M, X \geq 0} \quad \frac{1}{\mu} R_T(Q_T) + \frac{1}{\mu} R_M(Q_M) - C_L(L_T, L_M) - p_x X, \tag{C.121}$$

$$\text{s.t.} \quad Q_T = A_T L_T^{\eta}, \qquad Q_M = A_M (L_M^{\alpha} X^{1-\alpha})^{\eta}.$$

The first-order conditions are

$$\frac{1}{\mu}\frac{\partial R_T}{\partial Q_T}\eta\frac{Q_T}{L_T} = r(L), \tag{C.122}$$

$$\frac{1}{\mu}\frac{\partial R_M}{\partial Q_M}\alpha\eta\frac{Q_M}{L_M} = r(L), \tag{C.123}$$

$$\frac{1}{\mu}\frac{\partial R_M}{\partial Q_M}(1-\alpha)\eta\frac{Q_M}{X} = p_x. \tag{C.124}$$

We can show the effect on unconditional factor demands explicitly. Let $\beta \equiv \eta\rho \in (0,1)$ and $b \equiv 1-(1-\alpha)\beta$. The first-order conditions imply $X = [(1-\alpha)/\alpha][r(L)/p_x]L_M$. Substituting into the land conditions and adding the resulting demands gives

$$L(\mu) = \mu^{-\frac{1}{1-\beta}}\left[K_T r(L(\mu))^{-\frac{1}{1-\beta}} + K_M r(L(\mu))^{-\frac{b}{1-\beta}}\right], \tag{C.125}$$

where $K_T, K_M > 0$ collect fixed demand, productivity, and material-price terms.

Using $\mathrm{d}\ln L = \ell_T \mathrm{d}\ln L_T + (1-\ell_T)\mathrm{d}\ln L_M = \varphi\,\mathrm{d}\ln r$ and defining $D \equiv (1-\beta)\varphi + \ell_T + (1-\ell_T)b > 0$, log-differentiation gives

$$\frac{\mathrm{d}\ln L}{\mathrm{d}\ln \mu} = -\frac{\sigma\varphi}{(\varphi+1)[\sigma(1-\eta)+\eta] + \eta(\sigma-1)[\alpha+(1-\alpha)\ell_T]} < 0, \tag{C.126}$$

$$\tag{C.127}$$

Consequently, at a common markdown $\mu > 1$, total land use and material use are below their levels in the corresponding $\mu = 1$ problem. This force acts in conjunction with the land misallocation induced by dispersion in segment markdowns. The latter concerns relative marginal returns across technologies, while here we study *unconditional factor demands*, allowing outputs and total factor use to adjust.

C.4 Extensive margin: intermediary entry

We finally compare intermediary participation decisions. There are two distinct entry margins: free entry of the competitive fringe into segment T, and the decision of granular intermediaries to become multi-product and enter segment M.

C.4.1 Fringe entry

We continue to hold **B** fixed and display the dependence on the entry cost f_T, as we will vary it in counterfactuals. A fringe intermediary takes p_T as given and satisfies

$$\rho \bar{z}_T \, \bar{p}_T^b = p_T. \tag{C.128}$$

Its operating profit is therefore

$$\begin{aligned} \Pi_T^F &= \bar{p}_T^b \bar{z}_T \, \bar{q}_T - p_T \bar{q}_T \\ &= \frac{p_T \bar{q}_T}{\sigma - 1}. \end{aligned} \tag{C.129}$$

Free entry implies

$$\frac{p_T \bar{q}_T}{\sigma - 1} = f_T. \tag{C.130}$$

The planner, by contrast, chooses the fringe mass according to

$$\frac{\lambda_T^* \bar{q}_T^*}{\sigma - 1} = f_T. \tag{C.131}$$

Note that in either case, free entry implies

$$p_T(f_T) = \lambda_T^*(f_T) = p_T^*(f_T), \tag{C.132}$$

$$\bar{q}_T(f_T) = \bar{q}_T^*(f_T), \tag{C.133}$$

Hence, the upstream traditional price is not altered by markdowns, as it is pinned by the exogenous entry cost f_T. Nonetheless, aggregate supply in the traditional segment is dependent on markdown as the equilibrium land cost is not the same as the planner's

$$\frac{Q_T}{Q_T^*} = \left(\frac{r^*}{r} \right)^{\eta/(1-\eta)}. \tag{C.134}$$

Using market clearing, the fringe mass is given by:

$$M = \mathcal{C}_T \, B_T^{\frac{1}{(\sigma-1)(1-\eta)}} f_T^{-\left[1+\frac{1}{(\sigma-1)(1-\eta)}\right]} r^{-\frac{\eta}{1-\eta}} - \int_0^{N_T} \left(\frac{z_T(i)}{\bar{z}_T} \right)^{\sigma-1} [\mu_T(i)]^{-\sigma} \, di, \tag{C.135}$$

where $\mathcal{C}_T$ is the same constant as in (B.86). Thus the decentralized and planner expressions differ through the differences in the land price r and through the markdowns that reduce granular purchases

relative to a fringe intermediary.

C.4.2 Multi-product entry

To compare with the planner's MP-entry equation, suppose that N_M is continuous and granular intermediaries enter sequentially in decreasing order of modern productivity, so that $\mathcal{I}_M = [0, N_M]$ and the marginal entrant has productivity $z_M(N_M)$. This is a restriction on the entry process: with heterogeneous markdowns and opportunity costs, private entry returns need not follow the productivity ranking.

Let $\mu_M^c \equiv \mu_M^{MP}(N_M; f_T)$ denote the marginal buyer's modern markdown. Similarly, $\mu_T^k(N_M; f_T)$ denotes this buyer's traditional markdown under status k. These are buyer-level markdowns at the cutoff, distinct from the input-share-weighted segment markdowns μ_M and μ_T defined above.

Conditional on operating in segment M, CES demand and the sourcing condition imply

$$q_M(N_M; f_T) = \left(\frac{\rho B_M^{1/\sigma}}{\mu_M^c p_M} \right)^{\sigma} z_M(N_M)^{\sigma-1}.$$

Using the buyer's sourcing condition and $\rho = (\sigma - 1)/\sigma$, note that we can write

$$\begin{aligned} \pi_M^{MP}(N_M; f_T) &= \frac{1 + \sigma(\mu_M^c - 1)}{\sigma - 1} \, p_M q_M, \\ \pi_T^k(N_M; f_T) &= \frac{1 + \sigma[\mu_T^k(N_M; f_T) - 1]}{\sigma - 1} \, p_T^k q_T^k, \qquad k \in \{SP, MP\}. \end{aligned}$$

At the cutoff, the marginal buyer is indifferent between remaining single-product and becoming multi-product:

$$\pi_T^{MP}(N_M; f_T) + \pi_M^{MP}(N_M; f_T) - f_M = \pi_T^{SP}(N_M; f_T).$$

Rearranging gives the entry condition in equilibrium,

$$\pi_M^{MP}(N_M; f_T) = f_M + \pi_T^{SP}(N_M; f_T) - \pi_T^{MP}(N_M; f_T) \equiv \widetilde{f}_M(N_M; f_T). \tag{C.136}$$

Thus, profits associated with becoming MP must cover f_M plus any traditional profit forgone by changing status - this opportunity cost is endogenous and responds in particular to market conditions in the traditional segment.

To save on notation, define the function below

$$\mathcal{H}(m) \equiv \frac{\sigma m - (\sigma - 1)}{m^{\sigma}}. \tag{C.137}$$

which summarizes how the markdown affects profits.

Using the free-entry condition in the traditional segment, we have that for either status $k \in \{SP, MP\}$, variable profits are

$$\pi_T^k(N_M; f_T) = f_T \left(\frac{z_T(N_M)}{\bar{z}_T} \right)^{\sigma-1} \mathcal{H}\left(\mu_T^k(N_M; f_T)\right). \tag{C.138}$$

Consequently, the effective modern entry cost can be written explicitly as

$$\begin{aligned} \widetilde{f}_M(N_M; f_T) = f_M + f_T \left(\frac{z_T(N_M)}{\bar{z}_T} \right)^{\sigma-1} \\ \times \left[\mathcal{H}\left(\mu_T^{SP}(N_M; f_T)\right) - \mathcal{H}\left(\mu_T^{MP}(N_M; f_T)\right) \right]. \end{aligned} \tag{C.139}$$

At fixed N_M, f_T scales the traditional opportunity cost directly and changes both markdowns through the induced market structure and land allocation. Its total effect on $\widetilde{f}_M$ therefore also includes those endogenous responses.

Note that $\mathcal{H}'(m) = -\sigma(\sigma-1)(m-1)m^{-\sigma-1} \leq 0$ for $m \geq 1$, with strict inequality for $m > 1$. Thus, when the cutoff buyer has $\mu_T^{MP} > \mu_T^{SP}$, $\widetilde{f}_M(N_M; f_T) > f_M$: entry into the modern sector is relatively *more* costly once we take into account that intermediaries maximize profits jointly across segments.

To make the opportunity-cost channel explicit, let $\bar{\mu}_T > 1$ be a common reference markdown in the traditional segment. A first-order expansion of (C.139) around $\mu_T^{SP} = \mu_T^{MP} = \bar{\mu}_T$ gives

$$\widetilde{f}_M \approx f_M + \sigma(\sigma-1) f_T \left(\frac{z_T(N_M)}{\bar{z}_T} \right)^{\sigma-1} \frac{\bar{\mu}_T - 1}{\bar{\mu}_T^{\sigma+1}} \left(\mu_T^{MP} - \mu_T^{SP} \right). \tag{C.140}$$

Holding N_M and $\bar{\mu}_T$ fixed, a higher fringe entry cost f_T directly raises the traditional profit forgone upon becoming multiproduct when $\mu_T^{MP} > \mu_T^{SP}$. Changes in f_T may affect the gap between $\mu_T^{MP} - \mu_T^{SP}$, so the overall effect is ambiguous:

$$\frac{\partial \widetilde{f}_M}{\partial f_T} \approx \sigma(\sigma-1) \left(\frac{z_T(N_M)}{\bar{z}_T} \right)^{\sigma-1} \frac{\bar{\mu}_T - 1}{\bar{\mu}_T^{\sigma+1}} \left[\mu_T^{MP} - \mu_T^{SP} + f_T \left(\frac{\partial \mu_T^{MP}}{\partial f_T} - \frac{\partial \mu_T^{SP}}{\partial f_T} \right) \right]. \tag{C.141}$$

In the competitive limit, though, $\tilde{f}_M = f_M$.

Having computed the opportunity cost of becoming MP, we now use the entry condition to solve

for the marginal entrant. Recalling that we defined μ_M^c as the marginal entrant's markdown, we can write its profits obtained in the modern segment as

$$\pi_M^{MP}(\mu_M^c) = \frac{B_M}{\sigma}\left(\frac{\rho z_M(N_M)}{p_M}\right)^{\sigma-1}\mathcal{H}(\mu_M^c). \tag{C.142}$$

Imposing that these profits are equal to $\tilde{f}(N_M)$ and solving for the modern price:

$$p_M = \rho\left(\frac{B_M}{\sigma}\right)^{\frac{1}{\sigma-1}} z_M^c\left[\widetilde{f}_M(N_M; f_T)\right]^{-\frac{1}{\sigma-1}}\left[\mathcal{H}(\mu_M^c)\right]^{\frac{1}{\sigma-1}}. \tag{C.143}$$

Relative to the planner's price condition, the effective entry cost replaces f_M and the last bracket captures the effect of the marginal entrant's markdown on its profit.

We can plug this in the expression for modern supply, equate it with downstream demand and rearrange to arrive at the indifference condition below. The equilibrium number of entrants N_M is such that the marginal entrant has productivity z_M^c and is the one with N_M-th highest productivity, where N_M is such that the following holds:

$$\begin{aligned}\frac{(z_M^c)^{\Delta}}{Z_M^{\sigma-1}} = C_M^{-1} r^{\frac{\alpha\eta}{1-\eta}}\left(\rho B_M^{1/\sigma}\right)^{-\frac{\eta}{1-\eta}}\left(\frac{\sigma\widetilde{f}_M}{B_M^{1/\sigma}}\right)^{\frac{\Delta}{\sigma-1}} \\ \times\left[\mathcal{H}(\mu_M^c)\right]^{-\frac{\Delta}{\sigma-1}}\mu_M^{-\sigma}.\end{aligned} \tag{C.144}$$

To express the first-order approximation directly in terms of entry, hold B_M and technology parameters fixed and move sourcing misallocation to the right-hand side. Using $z_M^c = z_M(N_M)$ and $[Z_M^*(N_M)]^{\sigma-1} = \int_0^{N_M} z_M(i)^{\sigma-1}\,di$, taking logs and differentiating (C.144) gives

$$\begin{aligned}\left[\frac{(z_M^c)^{\sigma-1}}{[Z_M^*(N_M)]^{\sigma-1}} - \Delta\frac{z_M'(N_M)}{z_M(N_M)}\right]\mathrm{d}N_M = \sigma\,\mathrm{d}\ln\mu_M - \frac{\alpha\eta}{1-\eta}\,\mathrm{d}\ln r - \frac{\Delta}{\sigma-1}\,\mathrm{d}\ln\widetilde{f}_M \\ - \frac{\sigma\Delta(\mu_M^c-1)}{1+\sigma(\mu_M^c-1)}\,\mathrm{d}\ln\mu_M^c + (\sigma-1)\,\mathrm{d}\ln\frac{Z_M^*(N_M)}{Z_M}.\end{aligned} \tag{C.145}$$

Here $\Delta \equiv \sigma + \eta/(1-\eta)$. The coefficient multiplying $\mathrm{d}N_M$ is strictly positive because entry is ordered by decreasing productivity. The last term isolates changes in sourcing misallocation, while $\widetilde{f}_M$ retains the endogenous opportunity cost separately.

This yields the following partial effects, holding the remaining terms on the right-hand side fixed:

1. A higher $\widetilde{f}_M$ reduces entry. Since $\widetilde{f}_M > f_M$, the endogenous opportunity cost of entry discourages entry.

2. A higher segment-level modern markdown μ_M raises entry as it reduces producer prices in the modern segment.

3. A higher marginal entrant's markdown μ_M^c reduces entry as, for a given segment-level markdown, it implies reduced sourcing.

4. If all modern buyers have the same markdown, sourcing is efficient and $\mu_M^c = \mu_M$. The two markdown terms then combine into

$$\sigma \, \mathrm{d} \ln \mu_M - \frac{\sigma \Delta (\mu_M - 1)}{1 + \sigma(\mu_M - 1)} \, \mathrm{d} \ln \mu_M = \frac{\sigma(1 - \eta \mu_M)}{(1 - \eta)[1 + \sigma(\mu_M - 1)]} \, \mathrm{d} \ln \mu_M.$$

   Holding rent and effective entry costs fixed, entry rises with the common markdown for $1 \leq \mu_M < 1/\eta$ and falls for $\mu_M > 1/\eta$, an inverted-U relationship.

D Measurement and estimation

This appendix documents the construction of measured inputs and supporting estimation results used in Section 4.

D.1 Regional productivity shifters

We construct municipal productivity shifters for traditional and modern production, S_{Tr} and S_{Mr}, using FAO-GAEZ potential grass yields. These shifters capture geographic variation in productivity in the decomposition $A_{gr} = K_g S_{gr}$, where $g \in \{T, M\}$. The national scales K_T and K_M are estimated separately from cattle production data.

D.1.1 Construction

Following the approach of Domínguez-Iino (2026), we relate potential grass yields to observed cattle stocking rates. We use FAO-GAEZ v4 grass yields under low- and high-input management, holding historical climate, rainfed water supply, and local soil water-storage capacity fixed across scenarios. The yields are measured in tonnes of dry matter per hectare.

FAO-GAEZ's generic low-input scenario assumes traditional plant varieties, labor-intensive production, no nutrient applications or chemical pest and disease control, and minimal conservation measures. Its high-input scenario assumes improved or high-yielding plant varieties, mechanization where feasible, and adequate nutrient applications and chemical pest, disease, and weed control. In our application, these plant varieties refer to pasture grasses. We associate these scenarios with traditional and modern production in the model. [5]

Let G_{Tr} and G_{Mr} denote municipal potential grass yields under these two scenarios. We construct the observed stocking rate h_r by dividing total cattle stock from the 2017 Agricultural Census by physical pasture hectares from MapBiomas in the same year. We estimate

$$h_r = a + bG_{Tr} + u_r, \tag{D.1}$$

weighting municipalities by pasture area.

[5] See FAO-GAEZ v4 model documentation, Chapter 4, Land Utilization Types.

We apply the same estimated conversion to both scenarios:

$$S_{gr} = \frac{\widehat{a} + \widehat{b} G_{gr}}{c_S}, \qquad g \in \{T, M\}, \tag{D.2}$$

where c_S is the geometric mean of all positive low-input predictions.

This construction produces dimensionless shifters and preserves the high–low grass-yield difference up to the common factor $\widehat{b}/c_S$. Applying the low-input conversion to high-input yields assumes that the same relationship between grass yield and cattle stocking capacity holds under both management scenarios. The national scales subsequently connect these geographic shifters to annual cattle output, measured in carcass kilograms.

D.1.2 Stocking-rate conversion

Table 10 reports the relationship between observed stocking rates and low-input grass yields, adding potential maize and soybean yields separately and jointly. The four specifications use a common sample of municipalities with positive potential yields for both crops. All regressions include an intercept, use pasture-area weights, and report heteroskedasticity-robust standard errors.

The coefficient on grass yield ranges from 0.166 to 0.184 across specifications. Thus, the estimated relationship changes little when we include crop suitability. We construct the shifters using the specification without crop controls.

Table 10: GAEZ potential yields and observed cattle stocking rates

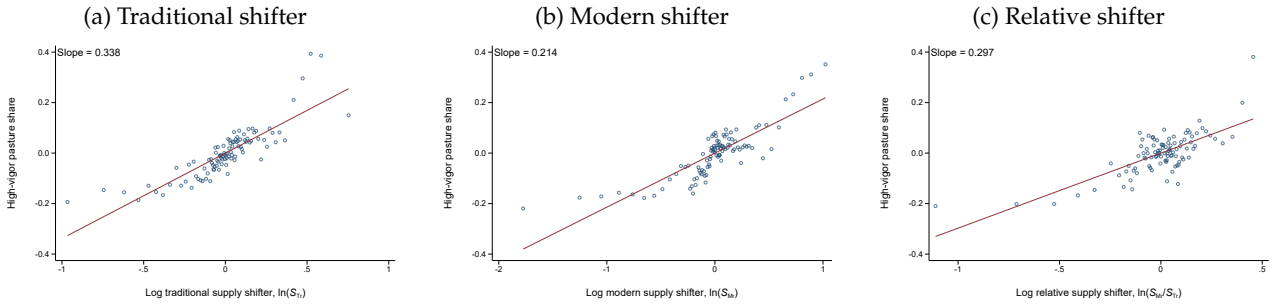
	Stocking rate (heads/ha)			
	(1)	(2)	(3)	(4)
Grass yield (t/ha)	0.166***	0.180***	0.184***	0.179***
	(0.005)	(0.006)	(0.006)	(0.006)
Maize yield (t/ha)		0.081***		-0.239***
		(0.018)		(0.049)
Soybean yield (t/ha)			0.370***	1.118***
			(0.059)	(0.161)
Municipalities	4,408	4,408	4,408	4,408
R-squared	0.246	0.254	0.261	0.268

Standard errors in parentheses
2017 Census cattle stock / physical pasture hectares.
Regressions weighted by pasture area. Heteroskedasticity-robust standard errors.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Reassuringly, our estimated supply shifters are positively correlated with other independent mea-

sures of pasture productivity. Specifically, our measures correlate positively with the share of high-vigor pasture in a municipality, as measured by satellite data from Map Biomas before our main sample period. Figure 6 shows results from binscatter regressions, displaying a positive association between the share of high-vigor pasture and measures of a region's absolute advantage in using modern technology, the traditional one, or its comparative advantage in using the modern one.

Figure 6: Regional productivity shifters and pasture condition



Notes: The outcome is the 2010–2014 mean share of physical pasture classified as high vigor by MapBiomas Collection 10, measured on its original 0–1 scale. High vigor is the highest vegetative-vigor class, based on regionally normalized satellite Enhanced Vegetation Index data. The horizontal variables are $\log S_{Tr}$, $\log S_{Mr}$, and $\log(S_{Mr}/S_{Tr})$. The common sample retains municipalities with all three logged shifters between their respective 1st and 99th percentiles. Both axes are residualized on state effects.