Price Discrimination in Supply Chains*

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*The views expressed are those of the authors and do not necessarily represent the views of the Central Bank of Chile or its board members.

Markup welfare costs

In supply chains, heterogeneous **linear markups** affect welfare because:
(Edmond, Midrigan & Xu, 2023)

1. Act as a tax on production
2. Harm aggregate TFP through production factor misallocation
3. Distort firm entry

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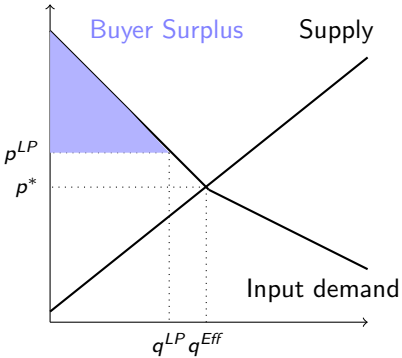
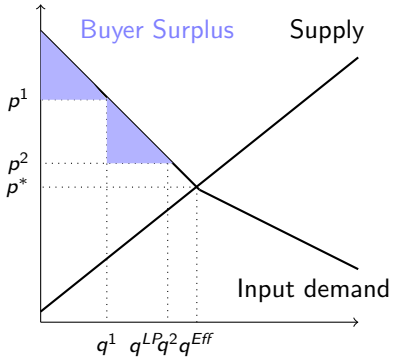
1. Act as a tax on production
2. Harm aggregate TFP through production factor misallocation
3. Distort firm entry

Based on firm-to-firm transactions for Chile, **price discrimination is prevalent**

- we cannot reject price discrimination in around 70% of transactions

Welfare: Linear markup vs. 2nd degree price-discrimination





2nd degree has ambiguous welfare effects relative to linear prices:

- Intensive margin ($+$): Resource allocations improve
- Extensive margin ($-$): With free entry, lower buyer surplus harms firm entry

Price discrimination implications

- Under price discrimination, the average price is not fully allocative
- Average markups are no longer a sufficient statistic to measure inefficiencies
- Need a different approach to study markups aggregate costs

This paper: What we do

Price discrimination descriptive evidence:

- Using firm-to-Firm transactions for Chile

Model

- Based on quantity discounts price discrimination literature + third-degree
- Supply chain with endogenous entry and CES demand system
- Firms can price-discriminate but also face price discrimination as buyers

Model quantification and counterfactuals

- Calibrate the model using Chilean data
- Compare welfare under planner vs linear vs price discrimination pricing

This paper: What we find

- Price discrimination is prevalent in the data
- Under Pareto distributed firm types, a two-part tariff fits the observed prices
- Accounting for observed price discrimination, markup welfare costs are around 80% of linear price setup costs
- Intensive margin explains around 70% of welfare changes

Main takeaway

Linear price setups overestimate markups' welfare costs

Literature

Firm-level distortions and macroeconomic outcomes

Hopenhayn (1992), Restuccia and Rogerson (2008), Hsieh and Klenow (2009, 2014), Bento and Restuccia (2017), De Loecker, Eeckhout, and Mongey (2022), Peter and Bornestein (2024)

Within supply chains

Baqaee and Farhi (2020), Bigio and La'O (2020), Baqaee and Farhi (2021), Edmond, Midrigan, and Xu (2023), Burstein, Cravino, and Rojas (2024), Boehm, Oberfield, South and Waseem (2024)

Price discrimination

Mussa & Rosen (1978), Borenstein (1985), Wilson (1993), Goldberg (1996), Stole (2007)

Agenda

1. Descriptive Evidence
2. Model
3. Counterfactual and Model Quantification
4. Conclusion

Data sources

Invoice example

Invoice transactions for the universe of Chilean formal firms for 2018

- Around 1.3 billion transactions
- More than 10 million different products. Assume seller-specific products
- Data on prices and quantities for every product transacted

Merged with firms' accounting balance sheet data

- Sales, materials, investment, 6-digit industry
- Employer-employee: Wages, headcount of employees
- Capital stock and investment

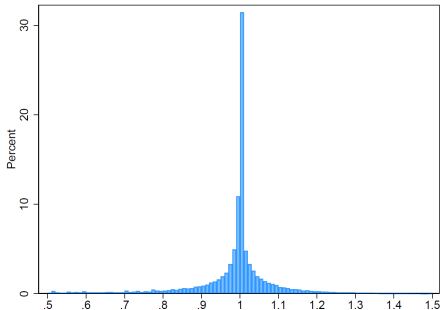
Data cleaning

Goal: Keep all plausible transactions

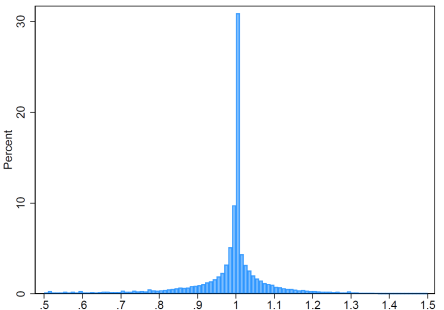
- Prices are net of discounts and recharges
- Drop if a transaction has missing or zero price or quantity
- Drop if product description is missing
- Drop prices above 10 times the mean price by seller-product-day
- Under this cleaning we keep around 99% of transactions

Price dispersion

Panel A. June 2018



Panel B. June 19th 2018



- $\theta_{ig} = \frac{p_{ijgt}}{\bar{p}_{ig}}$ (seller i, buyer j, product g, time t)
- Variance of $\log \theta_{ig} = 0.65$ (excluding products with one transaction)
- Price discrimination cannot be rejected in around 70% of transactions

Price variance determinants June 2018

Implicit assumption: We observe equilibrium objects and are agnostic about the data generation process

$$\ln p_{ijgt} = \beta_0 + \ln \psi_{ig} + \ln \epsilon_{ijgt} \quad (1)$$

$$\ln \epsilon_{ijgt} = \beta_1 + \ln \Psi + \ln \nu_{ijg} \quad (2)$$

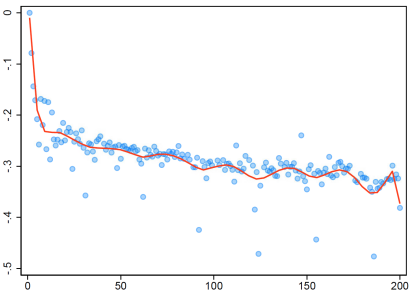
	(1)	(2a)	(2b)
Ψ: FE buyer		✓	
Ψ: FE buyer × quantity			✓
Observations (millions)	92	91	84
Adjusted R^2	0.927	0.067	0.203

- 92% of the variance is explained by seller×product fixed effects
- By fixing the contract, 7% residual variance is explained ($\approx$ 3rd)
- By fixing contract-quantity, 20% residual variance is explained ($\approx$ 2nd + 3rd)

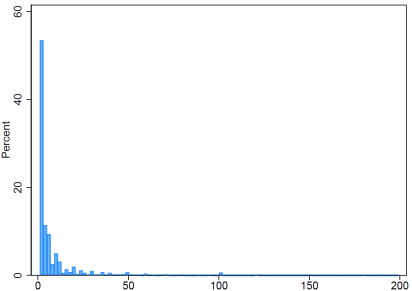
Quantity discounts within contracts (second degree)

$$\ln p_{ijg} = \beta_0 + \sum_{r=1}^{100} \beta_r \ln \mathrm{Q}\ \mathrm{bin}_r + \ln \psi_{ijg} + \ln \epsilon_{ijg}$$

Panel A. Quantity discounts fixed effects



Panel B. Quantity traded histogram

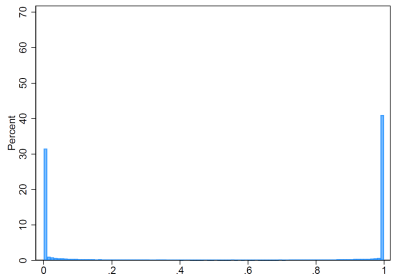


- Marginal discount diminishes with quantity Average effect | By industry | Price-quantity menus

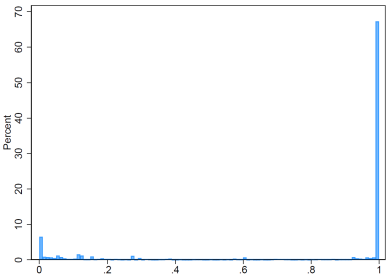
Sales partition

$$X_i = \begin{cases} 0 & \text{if all sales go to final consumers} \\ 1 & \text{if all sales go to other firms} \end{cases}$$

Panel A. Number of Firms



Panel B. Sales weighted



- More than 70% of firms sell only to final consumers or to other firms By sector

Recap of empirical evidence

1. Evidence of price dispersion on around 70% of transactions
2. Marginal discount decreases with quantity
3. Buyer-specific quantity-menus menus seem prevalent (2nd + 3rd degree price discrimination)
4. Firms sell predominantly to other firms or final consumers

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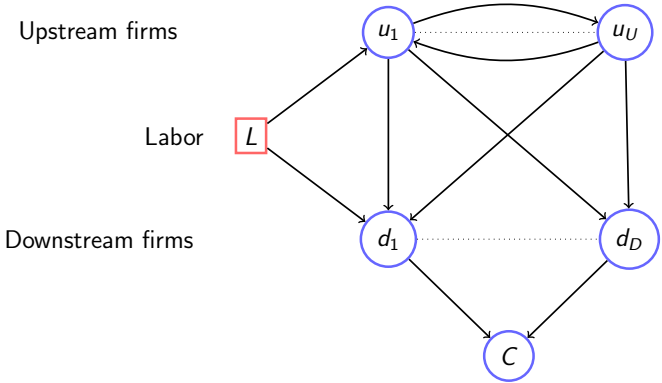
Supply Chain Structure



Setup: Representative Consumer

- CES aggregator on downstream varieties, z

$$Y = \left(\int_{z_0} q(z)^{\frac{\sigma-1}{\sigma}} M_z \mu(z) dz \right)^{\frac{\sigma}{\sigma-1}}$$

- M_z is the mass of downstream firms and $\mu(z)$ is the density of type z firms
- Offer labor and owns firms and receive their profits
- Budget constraint: $Y = wL^P + \Pi^U + \Pi^D$
- Exogenous aggregate labor supply; labor market clearing: $L = L^P + L^E$

Setup: Firms

- Firm partition on upstream (sells to other firms only) and downstream firms (sell to final consumers only)
- z is a downstream variety and ζ an upstream variety productivity, $\gamma \in \{z, \zeta\}$
- Production function:

$$q_\gamma = \gamma \left[\alpha \ l(\gamma)^{\frac{\eta-1}{\eta}} + (1-\alpha) m(\gamma)^{\frac{\eta-1}{\eta}} \right]^{\frac{\eta}{\eta-1}}, \quad \gamma \in \{z, \zeta\}$$

- m is a CES bundle of upstream varieties:

$$m(\gamma) = \left[\int_{\zeta_0} m(\gamma, \zeta)^{\frac{\sigma-1}{\sigma}} M_\zeta \mu(\zeta) d\zeta \right]^{\frac{\sigma}{\sigma-1}}$$

Setup: Entry

- Unbounded pool of prospective entrants that are ex-ante identical
- Pay a sunk cost c_e in units of labor
- Upon entry, firms draw a type from a common distribution $G(\gamma)$, $\gamma \in \{z, \zeta\}$
- Firms choose whether to enter upstream or downstream
- Free entry into both firms groups ($\mathbb{E}[\pi_\gamma] = c_e w$); M_z, M_ζ are endogenous

Setup: Seller's knowledge about their buyers

- Sellers know that they confront a distribution of heterogeneous buyers
- But sellers don't know their buyers type (productivity)
- Partially observe characteristics of its buyers
- Sellers will choose to set a pricing scheme based on the buyer's productivity distribution and observables

Assumptions

1. Upstream firms charge nonlinear prices (2nd degree)
2. Different prices menus to upstream and downstream (3rd degree)
3. Downstream firms charge linear prices to the representative consumer with normalized to 1 price
4. Firms' productivity follows a Pareto distribution with tail parameter κ
5. Firms are infinitesimal and take other firms' prices as given

Upstream profit maximization problem

Guess

- Upstream firm chooses a two-part tariff marginal cost

Mechanism design problem

- Chooses a transfer T and quantities m, separately for upstream and downstream firms

$$\max_{\substack{\{T(z,\zeta),m(z,\zeta)\},\\ \{T(\zeta',\zeta),m(\zeta',\zeta)\}}} \Pi_\zeta = \underbrace{\mathbb{E}_z\left[T(z,\zeta) - c_\zeta\, m(z,\zeta)\right] M_z}_{\text{Downstream firms}} + \underbrace{\mathbb{E}_{\zeta'}\left[T(\zeta',\zeta) - c_\zeta\, m(\zeta',\zeta)\right] M_{\zeta'}}_{\text{Other upstream firms}}$$

Subject to

- Individual Rationality (IR): Buyers receive non-negative surplus from buying
- Incentive Compatibility (IC): Buyers self-select into their tailored menu

Upstream price scheme

Proposition 1: A flat fee and a linear component describe the solution to the mechanism design problem of the seller: solution strategy

$$T(\gamma, \zeta) = F_\gamma(\zeta) + p(\zeta) m(\gamma, \zeta), \quad \gamma \in \{z, \zeta\}$$

Flat fee: Extract surplus of lower (upstream or downstream) type

Linear allocative markup: $p(\zeta) = \frac{\rho}{\rho - 1} c(\zeta), \quad \rho = \frac{\sigma\kappa}{\sigma - 1}, \quad \rho > \sigma$

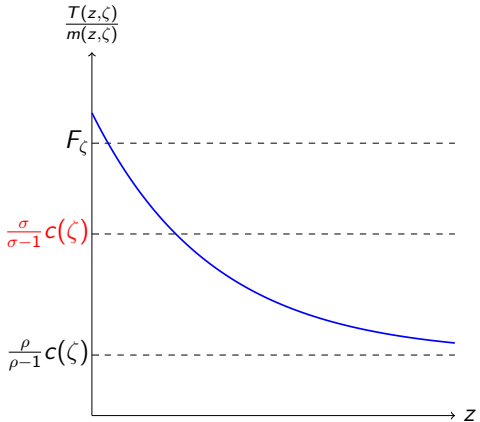
- Two different flat fees for upstream downstream firms: second-degree
- Allocative markup is smaller than linear price markup ($\rho > \sigma$)
- Complete market coverage: all types have positive virtual utility details

Upstream unit price scheme to downstream firms

Unit price paid by downstream firms:

$$\frac{T(z,\zeta)}{m(z,\zeta)} = \frac{F_z(\zeta)}{m(z,\zeta)} + p(\zeta)$$

- The flat fee unit price share is decreasing in firm productivity



Inefficiencies: Intensive margin

▸ Linear price BMK

Aggregate markup $\mathcal{M}$

- Acts as a uniform tax on production
- Distorts buyers quantities purchased and sellers quantities produced

$\Longrightarrow$ Not double, but N-marginalization problem

Markup heterogeneity upstream vs. downstream

- Factor marginal revenue products are different upstream vs. downstream

$\Longrightarrow$ Generate factor misallocation, which harms aggregate TFP

Inefficiencies: Extensive margin

Downstream

- Pay flat fees without receiving lower profits relative to upstream firms.

$\Longrightarrow$ Mass of upstream to downstream firms ratio is distorted

Upstream

- Allocative markup distorts profits distribution

$\Longrightarrow$ Entry upstream is distorted

Welfare: Price discrimination (PD) vs linear pricing (LP)

- Weighted mean output per firm: $\widehat{q}^r = \left[\int q(z)^\tau \cdot \mu(z) M_z^r(z) dz\right]^{\sigma/\sigma-1} / M_z^r$
- Welfare in price regime $r \in \{LP, PD\}$: $Y^r = \underbrace{(M_z^r)^{\sigma/\sigma-1}}_{\text{Extensive Margin}} \cdot \underbrace{\widehat{q}^r}_{\text{Intensive Margin}}$
- $\underbrace{\widehat{q}^r}_{\text{Intensive Margin}} = \underbrace{(z^r)^{\sigma/\sigma-1}}_{\text{Productivity selection}} \cdot \underbrace{(l/m^r)^{\alpha\sigma/\sigma-1}}_{\text{Input mix}} \cdot \underbrace{(m^r)^{\sigma/\sigma-1}}_{\text{Material usage}} \cdot \underbrace{\left(M_\zeta^r\right)^{1/\sigma}}_{\text{Input variety}}$

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- Higher output per firm in PD because of lower "output tax": $\widehat{q}^{PD} > \widehat{q}^{LP}$
- Firms substitute m with L; fewer L usage in entry: $M_z^{\text{PD}} < M_z^{\text{LP}}$
- Effects on welfare will depend on what margin dominates

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Two counterfactuals

Planer pricing (as in Baqaee and Farhi, 2021)

- Firms must charge markups to incentivize the optimal entry level
- But markup distorts input choices by acting as a uniform tax on production
- An output subsidy can restore undistorted marginal-cost, conditional on entry
- The subsidy is paid via a lump sum tax to the representative consumer

Linear prices (as in Edmond, Midrigan & Xu, 2023)

- Linear markup over marginal cost from monopolistic competition

Optimal policy to implement the efficient allocation

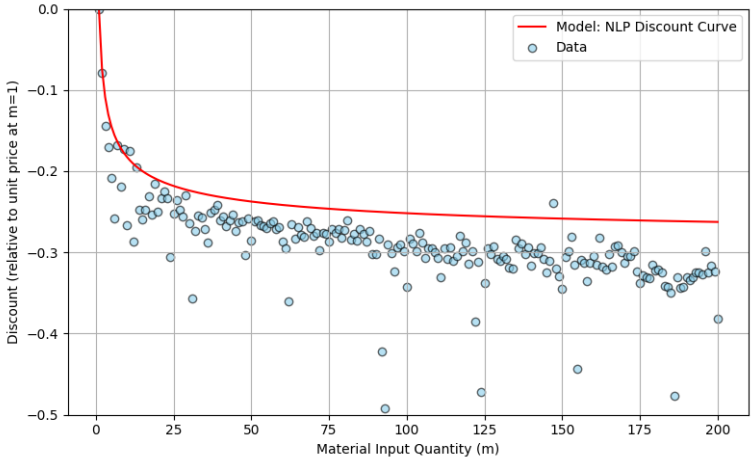
Assumptions and parametrization

- $\eta = 1$ to ensure equilibrium existence and uniqueness
- $\implies$ Cobb-Douglas production functions

Model Parameters

	Value	Source
Labor share in production (α)	0.38	Calibrated from data
Material bundle elasticity (σ)	3	Hsieh and Klenow (2009)
Firm exit rate ($1 - \delta$)	0.15	Calibrated from data
Entry cost (c_e)	0.16	Assumed
Pareto tail (κ)	2.4	Calibrated from data

Quantity discounts: Data vs model



- For the average upstream firm price schedule to the downstream firm, normalizing the continuous input quantity to be in the bounds of 1 to 200

Welfare Decomposition Relative to Efficiency

Define the welfare ratio: $\frac{Y^r}{Y^{\text{EFF}}} = \underbrace{\left(\frac{\widehat{q}^r}{\widehat{q}^{\text{EFF}}}\right)}_{\text{Intensive margin}} \cdot \underbrace{\left(\frac{M_z^r}{M_z^{\text{EFF}}}\right)^{\sigma/\sigma-1}}_{\text{Extensive margin}}$

	Linear Pricing (LP)	Price discrimination (PD)
Intensive Margin	0.15 (71%)	0.23 (69%)
Extensive Margin	2.73 (29%)	2.27 (31%)
Welfare	0.41	0.52

- Welfare losses under PD are 81% of of LP (48/59)
- In log differences intensive margin accounts for 70% of welfare changes

Intensive margin decomposition ratio

Weighted average firm output ratio:

$$\frac{\widehat{q}^r}{\widehat{q}^{EFF}} = \underbrace{\left(\frac{z^r}{z^{EFF}}\right)^{\sigma/\sigma-1}}_{\text{Productivity selection}} \cdot \underbrace{\left(\frac{l/m^r}{l/m^{EFF}}\right)^{\alpha\sigma/\sigma-1}}_{\text{Input mix}} \cdot \underbrace{\left(\frac{m^r}{m^{EFF}}\right)^{\sigma/\sigma-1}}_{\text{Material usage}} \cdot \underbrace{\left(\frac{M_\zeta^r}{M_\zeta^{EFF}}\right)^{1/\sigma}}_{\text{Input variety}}$$

	Linear Pricing	Price discrimination
Productivity selection	0%	0%
Input mix	42%	39%
Material usage	53%	49%
Input variety	5%	12%

- No selection as all firm types participate
- Input mix and material distortions explain the bulk of the intensive margin

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Conclusion: Markups are less costly with price discrimination

- Price discrimination is prevalent in the data
- Under Pareto distributed firm types, a two-part tariff fits the data
- Accounting for observed price discrimination, markup welfare costs are around 80% of linear price setups costs
- Intensive margin explains around 70% of welfare changes
- Failing to incorporate price discrimination overestimate markups welfare costs

Invoice Example

Go Back

KITCHEN CENTER

KITCHEN CENTER SPA

IMPORTACIÓN Y DISTRIBUCIÓN DE ELECTRODOMÉSTICOS

FDV SIMPLE COOK Cuisinart JUBLI Balumph smeg SUPERCOOK Ariete. LOFRA

Casa Matriz: Av. El Salto 3485, Recoleta, Santiago
Sucursales:
Casa Costanera: Av. Nueva Costanera 3900, Vitacura
Mall Parque Arauco: Av. Kennedy 5413 Local 572, Las Condes - Teléfono: (56-2) 24117777 - Fax: (56-2) 24117711
Mall Plaza Los Dominicos: Padre Hurtado Sur 875, Local A1080/1081, Las Condes - Teléfono: (+56 2) 24117738
Mall Sonnenstuna: San Ignacio 500 Local 12, Quilicura - Teléfono: (+56 2) 24117769
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Mall Marina Arauco: Av. Libertad 1348, Local PD-01/02, Viña del Mar - Teléfono: (56-2) 24117747/48
Outlet Park Viña: Camino Internacional 2440 Local 72, Viña del Mar
Mall Plaza Maule: Circunvalación 1050, Local 226/227, Talca - Teléfono: (56-2) 24117748
Concepción: Paicaví 2567, Local 2, Teléfono: (56-2) 2411 7716 / 17
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Mall Eastos Temuco: Rudencio Ortega 01780, Local L168-170, Temuco - Teléfono: (+56 2) 24117714
Servicio Técnico: Lautaro #280, Quilicura - Teléfono: 800411709 / 737 / 504
Centro de Distribución: Camino lo Boza #8887, Pudahuel, Santiago
Viña del Mar: E Nte. 514, Viña del Mar
Alto Las Condes: Av. Kennedy 9001 Local 1017, Las Condes.
Outlet El Salto: Av. El Salto 3400, Recoleta, Santiago.

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FECHA EMISIÓN : 01/08/2022

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FECHA EMISIÓN :
FECHA VENCIMIENTO : 03/08/2022
TIPO DESPACHO :

FORMA DE PAGO : Contado
COD. VENDEDOR :

Dirección Origen: Camino lo Boza 8887
Comuna : Pudahuel **Ciudad :** Santiago
Dirección Destino: Los Misioneros 1923
Comuna : Providencia **Ciudad :** Santiago

Orden de Venta: 793325
Número de OC:

CÓDIGO	DETALLE	CANTIDAD	PRECIO UNITARIO	PRECIO ÍTEM
13452	Lavaplatos FDV Small Acqua bajo cubierta	1	92.428,57	92.429
14761	Encimera FDV Design 4T GLTX 65 BUT 2.0	1	142.848,74	142.849
14265	Campana Kubli Neu Slider	1	100.831,93	100.832
19110	Horno FDV Design	1	201.672,27	201.672
13377	Lavavajillas FS FDV Element 14C	1	243.689,07	243.689
14917	Grifería FDV CONICA PLEX	1	84.025,21	84.025
10232	Transporte - Providencia	1	15.529,41	15.529

Sales partition: Sales shares (excluding exports) Go Back

Sector (sales)	All to final consumer	All to other firms
Firm population	0.08	0.67
Agriculture (2%)	0.04	0.60
Mining (1%)	0.27	0.08
Manufacturing (15%)	0.05	0.68
Utilities (3%)	0.20	0.51
Construction (8%)	0.02	0.89
Retail and Wholesale (32%)	0.09	0.68
Transport (10%)	0.16	0.68
Financial Services (18%)	0.18	0.67
Real Estate Services (1%)	0.24	0.37
Business Services (7%)	0.08	0.81
Personal Services (2%)	0.68	0.10

Quantity discounts regressions

Go Back

$$\ln p_{ijg} = \beta_0 + \beta_1 \ln q_{ijg} + \ln \psi + \ln \epsilon_{ijg}$$

	(1)	(2)	(3)	(4)	(5)
ln q	-0.083	-0.051	-0.045	-0.087	-0.071
	(0.00006)	(0.0001)	(0.001)	(0.0001)	(0.00007)
FE Seller×product	✓				
FE Seller×product× buyer		✓			
High price products (>p95)			✓		
Manufacturing				✓	
Retail and wholesale					✓
Observations (millions)	92	52	3.5	25	58
Adjusted R^2	0.928	0.956	0.756	0.911	0.945

Quantity discounts evidence by seller industry

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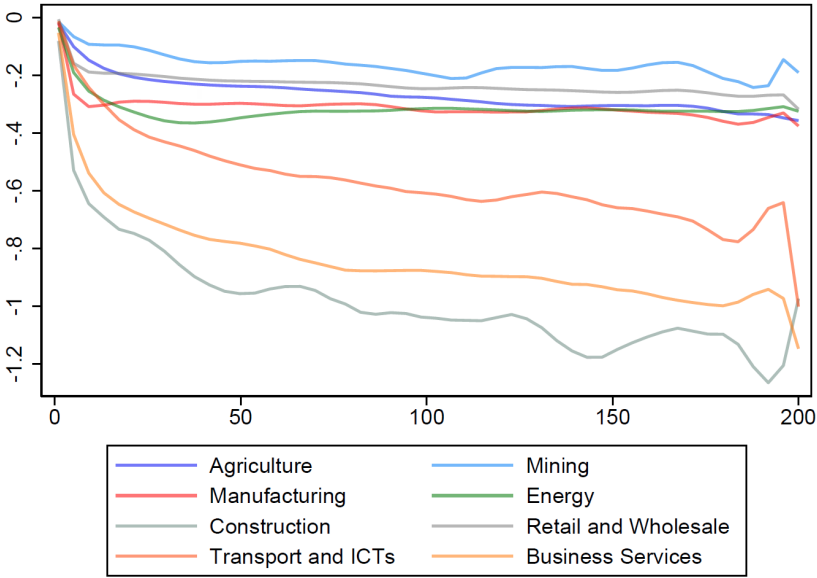

Price dispersion on price-quantity menus

Go Back

- Under pure second-degree: fix quantity, price variance should be zero
- Group X:{Seller-Product-Month + Quantity, Buyer}

$$C_X = \frac{\text{Standard deviation } p_X}{\text{median } p_X}; \quad X \in \{\text{Seller-Product + Quantity, Buyer}\}$$

	C_X Moments				
	p10	p25	Median	p75	p90
Seller - product	0.00	0.01	0.06	0.17	2.5
Seller - product - quantity	0.00	0.00	0.04	0.14	1.41
Seller - product - quantity - buyer	0.00	0.00	0.00	0.04	0.24

- Evidence of buyer-specific quantity-menus

Marginal cost

Go Back

$$c(\zeta) = \frac{1}{\zeta} c(w, p_m)$$

$$c(w, p_m) = \left[\alpha^{\eta} w^{1-\eta} + (1-\alpha)^{\eta} p_m^{1-\eta}\right]^{\frac{1}{1-\eta}}$$

where p_m is the CES index of the linear price in the two-part tariff:

$$p_m = \left(\int p(\zeta)^{1-\sigma} M_{\zeta} \mu(\zeta)\, d\zeta \right)^{\frac{1}{1-\sigma}}$$

Solution Strategy & Mechanism

Go Back

- Initial Conjectures:
  - Two-part tariff: $T(\gamma, \zeta) = p(\zeta)m(\gamma, \zeta) + F_\gamma(\zeta)$
  - Revenue functions: $R(z) = z^\theta y(l(z), m(z))^\theta A_z$
  - Buyer valuation: $\tau(\gamma) = \gamma^{(\sigma-1)/\sigma} p_m m(\gamma_0)^{1/\sigma}$
  - Distribution: τ follows Pareto with tail parameter $\rho = \frac{\kappa\sigma}{\sigma-1}$
- Verification Process:
  - Applied envelope theorem for IC constraints
  - Derived monotonicity conditions
  - Confirmed individual rationality via zero surpluses for the lowest type

Optimal Mechanism Characteristics

Go Back

- Pricing Structure:
  - Linear price: $p(\zeta) = \frac{\rho}{\rho-1} c(\zeta)$
  - Fixed fee: $F_\gamma(\zeta) = \text{Revenue}(\gamma_0) \frac{1}{\left(\frac{\alpha}{1-\alpha}\right)^\eta \left(\frac{pm}{w}\right)^{\eta-1}+1} \left(\frac{1}{\sigma}\right)$
- Properties:
  - Complete market coverage (all types served)
  - Markup lower than standard monopolistic competition pricing
  - Information rents decrease with type concentration (κ)
- Quantity Allocation:
  - $m(\tau, \zeta)$ optimally scales with buyer type
  - Allocation satisfies both IC and IR constraints

Virtual Utility

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Virtual Utility: Profits a seller gets when serving buyer firm type γ

- Positive term: Profits from serving firm type γ
- Negative term: Information rents given to higher types to prevent mimicking lower types
- If the virtual utility is positive, serving every firm type γ is optimal
- We can show that serving the upstream and downstream lowest type is optimal under a Pareto distribution
- Large density of lowest types makes optimal to serve them under Paretos

Optimal policy to implement the efficient allocation

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Intensive margin output subsidies

- Downstream: LP markup inverse, $\tau_z = \frac{\sigma-1}{\sigma}$
- Upstream : PD allocative markup inverse, $\tau_\zeta = \frac{\rho-1}{\rho}$

Both paid by a lump-sum taxed to the representative consumer

Extensive margin entry subsidy:

- Downstream: Flat fees from upstream firms, $F_z M_\zeta$
- Upstream: Profits from linear pricing minus allocative markup profits from PD to restore CES linear markups

The first financed by upstream firms and the second by a lump-sum tax on the representative consumer

Inefficiencies: Linear Price Benchmark

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Linear pricing (not in supply chains)

- One inefficiency: markup that distorts input choices
- Work as an output tax

Optimal Policy

- Subsidize output to restore marginal cost pricing, conditional on entry