# Price Discrimination in Production Networks

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# Motivation

**What is the price formation process of firms in production network structures?**

In inefficient economies, firms are usually modeled as choosing a single price with one distortionary markup, often considered a wedge, that can cumulate downstream production networks and generate production factors missallocation.

But if firms can discriminate prices, firm-specific or product-specific markups are not necessarily distortionary.

A possible starting point for analyzing firm-specific price discrimination distortionary effects is to (try to) understand why firms can discriminate prices.

# This paper (1)

Assuming that firms are multiproduct objects that discriminate prices within production networks:

**Questions:**

1. Why do firms can endogenously discriminate prices in production networks?
2. What are the aggregate implications of price discrimination in supply chains on (i) Production efficiency and (ii) Welfare?

# This paper (2)

**What this paper PLANS to do:**

(a) Present evidence of price discrimination in Chile.

(b) Develop a theoretical framework to endogenize product pricing decisions by firms facing heterogeneous demand elasticities downstream.

(c) Estimate firm-level elasticities of substitution and buyer-product level demand elasticities.

(d) Aggregate price discrimination effects on:

1. Heterogeneous Producers and Consumers Welfare.
2. TFP in supply chains with firm-product pairs markups.

(e) Run counterfactuals: What are the aggregate gains/losses of eliminating/reducing price discrimination heterogeneity?

# Related Literature

Price discrimination and missallocation
Bornstein and Peter (AER R&R 2023), Burstein, Cravino & Rojas (WP, 2024)

Endogenous multi-product market power
Edmond, Midrigan & Xu (JPE, 2023)

Aggregating in presence of distortions
Liu (QJE 2019), Baqaee & Farhi (QJE 2020), Davila & Schaab (WP, 2022)

Firm level elasticities of substitution
Fujiy, Ghose, Khanna (STEG WP, 2023)

1. Price discrimination evidence from Chile

2. Theoretical framework
   - Simplified model
   - Quantitative exploration simplified model

3. Application

# Data: Chilean IRS Electronic Invoices

Transaction-based data for the universe of formal Chilean firms from 2018.

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| 10232 | Transporte - Providencia | 1 | 15.529,41 | 15.529 |

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# Price variance decomposition

$\ln p_{ijg}$ is log price charged by firm $i$ to $j$ for product $g$ and $G$ is the mean of $\ln p_{ijg}$ across all $ijg_s$ triples. $\psi_{ig}$ is a seller-product fixed effect, $\theta_j$ is a buyer fixed effect, $\gamma_q$ is a quantity fixed effect, and $\omega_{ijg}$ is the residual and accounts for the match-specific characteristics.

$$\ln p_{ijg} = \ln G + \ln \psi_{ig} + \ln \theta_j + \ln \gamma_q + \ln \omega_{ijg}$$

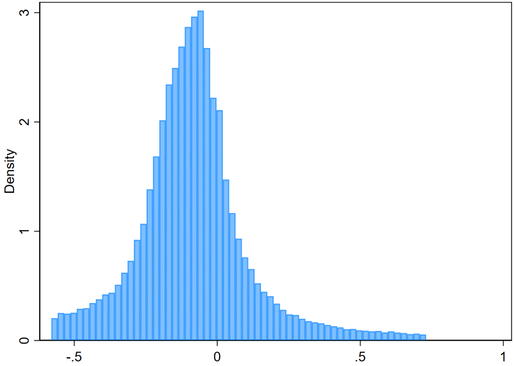
There are 4.5 Million seller-product fixed effects, but the focus is on buyers ($\theta_j$) and quantities ($\gamma_q$) variance decomposition: $\text{var}(\theta_j + \gamma_q)$.

| $\frac{\text{var}(\theta_j)}{\text{var}(\theta_j+\gamma_q)}$ | $\frac{\text{var}(\gamma_q)}{\text{var}(\theta_j+\gamma_q)}$ | $\frac{2\text{cov}(\theta_j,\gamma_q)}{\text{var}(\theta_j+\gamma_q)}$ | N obs | R2 | Adj R2 |
|---|---|---|---|---|---|
| 0.64 | 0.50 | -0.14 | 91,815,975 | 0.94 | 0.93 |

- Results suggest evidence of second and third-degree price discrimination.

second-degree data third-degree data

# Buyers fixed effect ($\theta_j$) distribution




- Buyers fixed effect (which could capture bargaining power, market power, centrality) varies.
- Which might suggest upstream competition forces driving the price formation process.

**Upstream competition will motivate my modeling strategy.**

1. Price discrimination evidence from Chile

2. Theoretical framework
   - Simplified model
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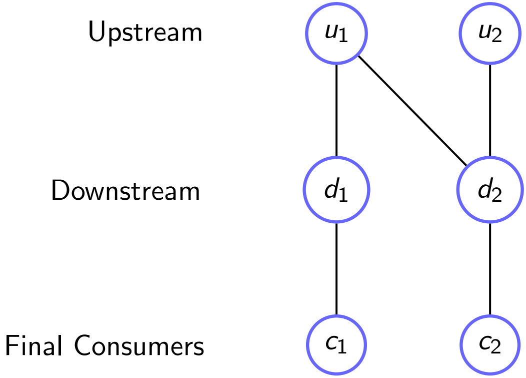
# Simplified Model




- Firm $u_1$ sells quantity $m_{1,d1}$ and $m_{1,d2}$ at prices $w_{1,d1}$ and $w_{1,d2}$ to $d_1$ and $d_2$ respectively. While Firm $u_2$ sells quantity $m_2$ at prices $w_2$ to $d_2$.
- Firms $d_1$ and $d_2$ produce $q_1$ and $q_2$ that sells to $c_1$ and $c_2$ respectively.

# Final consumers

Each final consumer consumes only one good and has the following symmetric demand:

$$q_c = p_c^{-\eta} \quad \text{with } c \in \{1, 2\}$$

# Downstream firms: $d_1$

Firm $d_1$ production function is $q_{d1} = m_{1,d1}$ and a faces marginal cost that equals the price that pays to upstream firm 1 $w_{1,d1} = mc_{d1}$.

Assuming the firm competes Bertrand, it will charge a constant markup over marginal cost to c1 as a function of its elasticity and produce according to the consumer's demand:

$$p_1 = \frac{\eta}{\eta - 1} w_{1,d1}$$

$$q_1 = \left( \frac{\eta}{\eta - 1} w_{1,d1} \right)^{-\eta}$$

# Downstream firms: $d_2$ (1)

Firm $d_2$ buys producion inputs form both upstream firms, $m_{1,d2}, m_{2,d2}$ at prices $w_{1,d2}, w_{2,d2}$, following a CES production function with elasticity of substitution $\sigma$:

$$q_2(m_{1,d2}, m_{2,d2}) = A\left(\alpha_1 m_{1,d2}^{\frac{\sigma-1}{\sigma}} + \alpha_2 m_{2,d2}^{\frac{\sigma-1}{\sigma}}\right)^{\frac{\sigma}{\sigma-1}}$$

The profit maximization problem will yield prices and quantities:

$$q_2 = \left(\frac{\eta}{\eta-1}\underbrace{\frac{1}{A}\left(\alpha_1^{\sigma} w_{1,d2}^{1-\sigma} + \alpha_2^{\sigma} w_{2,d2}^{1-\sigma}\right)^{\frac{1}{1-\sigma}}}_{mc_{d2}}\right)^{-\eta}$$

$$p_2 = \frac{\eta}{\eta-1} mc_{d2}$$

Downstream firm $d_2$ will charge a constant markup to consumer $c_2$ as a function of its demand elasticity.

# Downstream firms: $d_2$ (2)

$d_2$ conditional (on output and input prices) demands for each input are:

$$m^*_{1,d2}(w_{1,d2}, w_{2,d2}, q_2) = \frac{q_2}{A}\left(\frac{\alpha_1}{w_{1,d2}}\right)^{\sigma}\left(\alpha_1^{\sigma} w_{1,d2}^{1-\sigma} + \alpha_2^{\sigma} w_{2,d2}^{1-\sigma}\right)^{\frac{\sigma}{1-\sigma}}$$

$$m^*_{2,d2}(w_{1,d2}, w_{2,d2}, q_2) = \frac{q_2}{A}\left(\frac{\alpha_2}{w_{2,d2}}\right)^{\sigma}\left(\alpha_1^{\sigma} w_{1,d2}^{1-\sigma} + \alpha_2^{\sigma} w_{2,d2}^{1-\sigma}\right)^{\frac{\sigma}{1-\sigma}}$$

# Upstream firms: $u_1$ (1)

If $u_1$ **can** discriminate prices, it maximizes profits by choosing prices for downstream firms by observing its factor demands:

$$\max_{\{w_{1,d1},\ w_{1,d2}\}} \pi_{u1} = m_{1,d1}(w_{1,d1} - mc_u) + m_{1,d2}(w_{1,d2} - mc_u)$$

While if $u_1$ **cannot** price discriminate, it will choose only one price for both downstream firms:

$$\max_{\{w_1\}} \pi_{u1} = (m_{1,d1} + m_{1,d2})(w_1 - mc_u)$$

Both upstream firms face a constant marginal cost $mc_u$.

# Upstream firms: $u_1$ (2)

Downstream firm 1 only uses input from upstream 1 in production, hence when $u_1$ can price discriminate, applying the Bertrand pricing rule ($p = \frac{e}{e-1} mc$):

$$
\begin{aligned}
m_{1,d1} &= q_{d1} \\
m_{1,d1} &= \left( \frac{\eta}{\eta - 1} w_{1,d1} \right)^{-\eta} \\
\log(m_{1,d1}) &= -\eta \log \left( \frac{\eta}{\eta - 1} \right) - \eta \log(w_{1,d1}) \\
-e_{m_{1,d1}, w_{1,d1}} &= -\frac{\partial \log m_{1,d1}}{\partial \log w_{1,d1}} = \eta
\end{aligned}
$$

Hence:

$$
\begin{aligned}
q_{u1,d_1} &= m_{1,d1} = q_{d1} \\
w_{1,d1} &= \frac{\eta}{\eta - 1} mc_u
\end{aligned}
$$

# Upstream firms: $u_1$ (3)

$u_1$ decisions with respect to $d_2$ are different, because $d_2$ uses two production inputs under a CES technology. The conditional factor demand of $d_2$ for $u_1$ is $m_{1,d2}$, hence solving for $w_{1,d2}$

$$m_{1,d2} = \left(\frac{1}{A}\right)^{1-\eta} \left(\frac{\eta}{\eta-1}\right)^{-\eta} \left(\alpha_1^\sigma w_{1,d2}^{1-\sigma} + \alpha_2^\sigma w_{2,d2}^{1-\sigma}\right)^{\frac{\sigma-\eta}{1-\sigma}} \left(\frac{\alpha_1}{w_{1,d2}}\right)^\sigma$$

$$-\frac{\partial \log m_{1,d2}}{\partial \log w_{1,d2}} = (\eta - \sigma) \underbrace{\frac{\alpha_1^\sigma w_{1,d2}^{1-\sigma}}{\alpha_1^\sigma w_{1,d2}^{1-\sigma} + \alpha_2^\sigma w_{2,d2}^{1-\sigma}}}_{s_1} + \sigma$$

$$-e_{m_{1,d2},w_{1,d2}} = \eta s_1 + \sigma(1 - s_1)$$

where $s_1$ is the share of $u_1$ good on $d_2$ total costs. (Nested CES with inner and outer elasticity similar to Atkeson & Burstein, AER 2008)

# Upstream firms: $u_1$ (4)

Applying the same logic when $u_1$ cannot discriminate:

$$-e_{m_1,w_1} = \eta\ (sh_{m1} + sh_{m2}s_1) + \sigma\ sh_{m2}(1 - s_1)$$

Where $sh_{m1} = \frac{m_{1,d1}}{m1}$ is the share of u1 production that d1 purchases.

In sum:

$$e_{m_1,w_1} = \begin{cases} \eta s_1 + \sigma(1 - s_1) & \text{Price discrimination} \\ \eta\ (sh_{m1} + sh_{m2}s_1) + \sigma\ sh_{m2}(1 - s_1) & \text{NO price discrimination} \end{cases}$$

# Upstream firms $u_2$

Upstream 2 sells only to downstream 2, then:

$$
\begin{aligned}
m_{2,d2} &= \left(\frac{1}{A}\right)^{1-\eta}\left(\frac{\eta}{\eta-1}\right)^{-\eta}\left(\alpha_1^\sigma w_{1,d2}^{1-\sigma}+\alpha_2^\sigma w_{2,d2}^{1-\sigma}\right)^{\frac{\sigma-\eta}{1-\sigma}}\left(\frac{\alpha_1}{w_{2,d2}}\right)^{\sigma} \\
-e_{2,d2} &= \eta s_2 + \sigma(1-s_2) \\
w_{2,d2} &= \frac{\eta s_2+\sigma(1-s_2)}{\eta s_2+\sigma(1-s_2)-1} mc_u
\end{aligned}
$$

## Discussion: The $\eta - \sigma$ relation will govern markups

Upstream firm's demand elasticity is determined by how easy it is to substitute production inputs by downstream firms ($\sigma$) and the demand elasticity downstream firms face ($\eta$).

$$e_{i,di} = \eta s_i + \sigma(1 - s_i)$$

Large $\eta$ and $\sigma$ will prevent upstream firms from charging high markups. Hence, upstream firms can charge high markups:

- If the upstream firm good represents a small share of the total cost (small $s_i$), then upstream can charge a high markup (small $e_{i,di}$) as long as the downstream firm cannot substitute upstream firm good relatively easy (small $\sigma$).
- If the upstream firm good represents a large share of the total cost (large $s_i$), the upstream firm can charge a high markup as long as the demand elasticity downstream is low (small $\eta$)

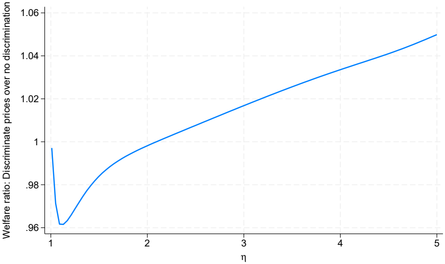
# Quantitative exploration: Welfare

Welfare is defined as the sum of consumer surplus and firm profits.

$$
\begin{aligned}
W &= CS_{c1} + CS_{c2} + \pi_{d1} + \pi_{d2} + \pi_{u1} + \pi_{u2} \\
W &= \int_0^{q_1^*} q^{-\frac{1}{\eta}} dq - p_1^* q_1^* + \int_0^{q_2^*} q^{-\frac{1}{\eta}} dq - p_2^* q_2^* \\
&\quad + \pi_{d1} + \pi_{d2} + \pi_{u1} + \pi_{u2}
\end{aligned}
$$

# Quantitative exploration: Variant $\eta$ Welfare

Assume $mc_u = 0.5$, $\alpha_1 = 0.6$, $\alpha_2 = 0.4$, $\sigma = 2$



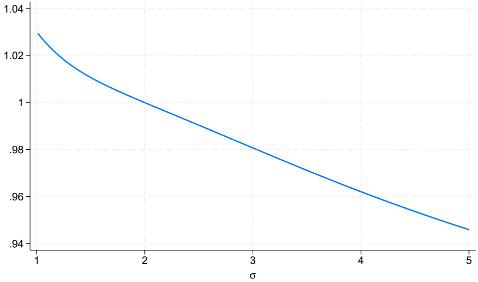

(a) Welfare ratio: Price disc./ no disc.

- With $\sigma > \eta$, final good has a relatively inelastic demand: u1 charges a high markup to d1 (not to d2) distorting d1 input and output and hence c1 consumer surplus.
- With $\eta > \sigma$, price discrimination is welfare enhancing as u1 can extract part of downstream firms' profits by tailoring specific prices.

Factor Prices Welfare components

# Quantitative exploration: Variant $\sigma$ Welfare

Assume $\eta = 2$




(b) Welfare ratio: Price disc./ no disc.

Price discrimination is welfare enhancing only with $\eta > \sigma$.

Factor Prices  Welfare components

# Quantitative exploration: Aggregate TFP with shock to $\mu$

Using Baqaee & Farhi, QJE 2020, growth accounting in the presence of distortions formula:

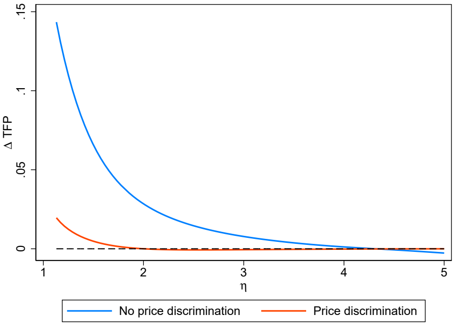
$$d \log TFP = \underbrace{\sum_i \tilde{\lambda}_i d \log A_i}_{\text{Technology}} \underbrace{- \sum_i \tilde{\lambda}_i d \log \mu_i - \sum_f \tilde{\Lambda}_{(f)} d \log \Lambda_f}_{\text{Allocative efficiency}}$$

Where $\tilde{\lambda}_i$ and $\tilde{\Lambda}_{(f)}$ are cost-based Domar weights for firms and factors respectively.

Assume a shock to markups given a 25% reduction of upstream marginal cost, $d \log A_i = d \log \Lambda_f = 0$, then:

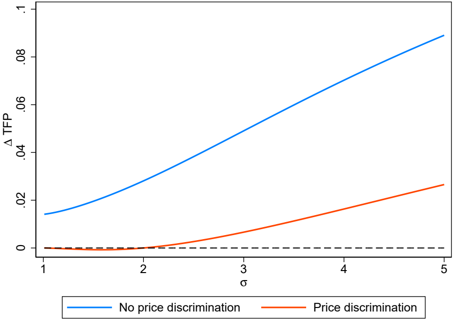
$$d \log TFP = -\sum_i \tilde{\lambda}_i d \log \mu_i$$

# Quantitative exploration: Aggregate TFP $\eta$ variant




- A reduction of marginal cost where firms cannot price discriminate (or face a unique demand downstream) will increase TFP if $\eta$ is not too large.
- While if firms can discriminate prices (or face heterogeneous demands downstream), TFP will increase when $\sigma > \eta$.
- With $\eta > \sigma$, TFP changes tend to disappear as high demand elasticity erases markups.

# Quantitative exploration: Aggregate TFP $\sigma$ variant




(c) TFP change

- With no price discrimination, TFP changes increase with a higher elasticity of substitution, and most of the mc reduction will be passed downstream.
- While with price discrimination, TFP increases only when $\sigma > \eta$.

1. Price discrimination evidence from Chile
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# First data test

(a) Take one month of transactions to get monthly weighted average prices and quantities for every seller-buyer-product.

(b) Keep only buyers that purchase at most two intermediate inputs.

(c) Keep only sellers that sell only one product.

# Identification Strategy (1)

$$w_{1,d2} = \frac{\eta s_1 + \sigma(1 - s_1)}{\eta s_1 + \sigma(1 - s_1) - 1} mc_u \tag{1}$$

$$w_{2,d2} = \frac{\eta s_2 + \sigma(1 - s_2)}{\eta s_2 + \sigma(1 - s_2) - 1} mc_u \tag{2}$$

Observed: $s_1, s_2, w_{1,d2}, w_{2,d2}$

If the firm exhibits CRS, then average variable cost (which is observed) equals marginal costs. Therefore, $\eta$ and $\sigma$ are identified.

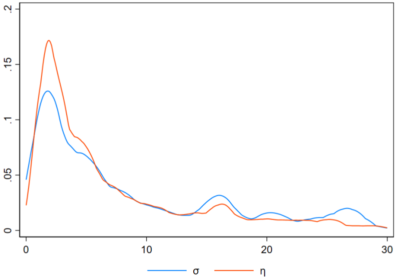
Define the learner index to be: $L = \frac{w - mc}{w}$

$$\sigma = \frac{s_1 L_1 - s_2 L_2}{(s_1 - s2) L_1 L_2}$$

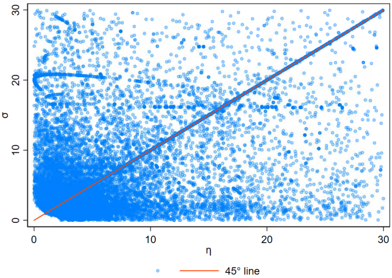
$$\eta = \frac{1 + L_1 \sigma (s_1 - 1)}{s_1 L_1}$$

# Preliminary Results: elasticities

Distribution



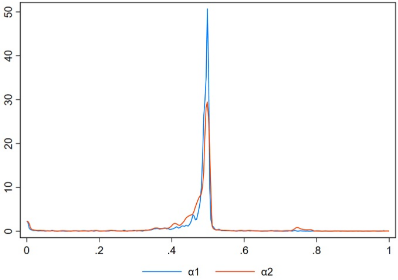

Scatter plot



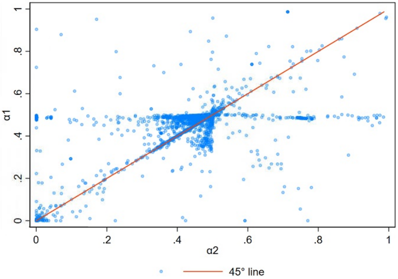

Estimations above and below 95% percentiles are trimmed.

# Preliminary Results: Alphas

Distribution




Scatter plot




$$s_1 = \frac{\alpha_1^{\sigma} w_{1,d2}^{1-\sigma}}{\alpha_1^{\sigma} w_{1,d2}^{1-\sigma} + \alpha_2^{\sigma} w_{2,d2}^{1-\sigma}}$$

$$s_2 = \frac{\alpha_2^{\sigma} w_{2,d2}^{1-\sigma}}{\alpha_1^{\sigma} w_{1,d2}^{1-\sigma} + \alpha_2^{\sigma} w_{2,d2}^{1-\sigma}}$$

# Next steps: Research plan

(a) Extend model to $n$ inputs and $g$ products.

(b) Evaluate more flexible production functions like CRESH, or at least include product nests inside the CES production function.

(c) Deal with the over-identification problem. Build GMM estimators for $\sigma_i$ and $\eta_{jg}$ to profit panel data.

(d) Run counterfactuals: What are the aggregate gains/losses of eliminating/reducing price discrimination heterogeneity?

# Price discrimination evidence: Second degree

Go back

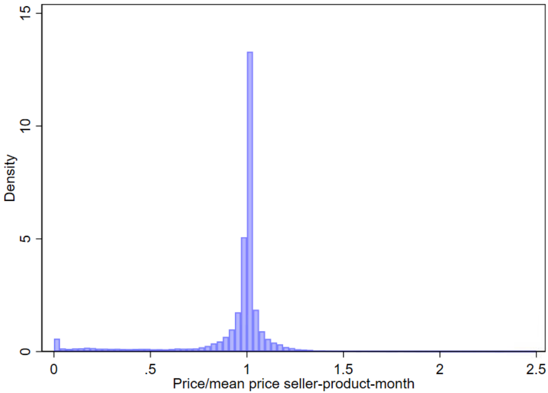
$$\log p_{ijt} = \beta_0 + \beta_1 \log q_{ijt}$$

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| Log q | -0.1048 | -0.0579 | -0.1621 | -0.1037 |
| (SE) | 0.00008 | 0.00006 | 0.00009 | 0.00007 |
| Seller FE | Yes | Yes | Yes | Yes |
| Product FE | Yes | Yes | Yes | Yes |
| Buyer FE | No | No | Yes | Yes |
| Q $>$1 | No | Yes | No | Yes |
| R2 | 0.9112 | 0.9489 | 0.9246 | 0.9655 |
| N obs | 72,178,033 | 44,656,779 | 71,809,764 | 44,496,689 |

# Price discrimination evidence: Third degree

Go back

Price variation by seller-product-month



# Bertrand pricing rule

$$\max_{\{p\}} \pi = q(p) \cdot p - q(p) \cdot mc$$

$$\frac{\partial q(p)}{\partial p} \cdot p + q(p) - \frac{\partial q(p)}{\partial p} \cdot mc = 0$$

$$\frac{\partial q(p)}{\partial p}(p - mc) + q(p) = 0$$

Multiplying by $\frac{p}{q(p)}$

$$\underbrace{\frac{\partial q(p)}{\partial p}\frac{p}{q(p)}}_{-\eta}(p - mc) + q(p)\frac{p}{q(p)} = 0$$

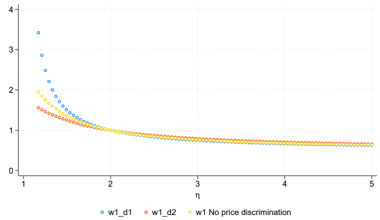
$$-\eta(p - mc) + p = 0$$

$$p(1 - \eta) = -\eta \cdot mc$$

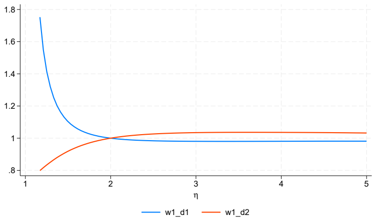
$$p = \frac{-\eta}{1 - \eta} \cdot mc$$

$$p = \frac{\eta}{\eta - 1} \cdot mc$$

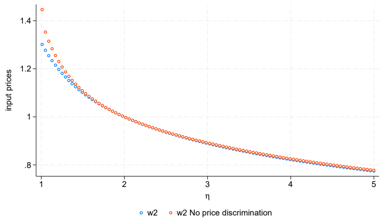
# Variant $\eta$ prices ▸ Go back



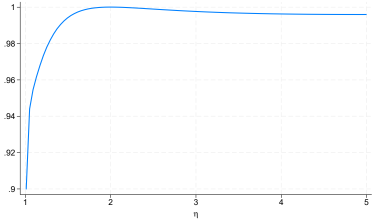

(d) $w1$ level




(e) $w1$ ratio: Price disc./ no disc.



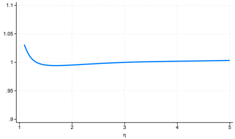

(f) $w2$ level



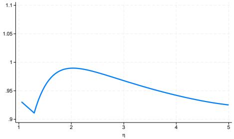

(g) $w2$ ratio: Price disc./ no disc.

# Variant $\eta$ welfare components ratio: Price disc./ no disc.

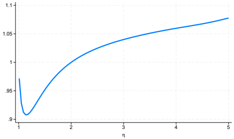
Go back



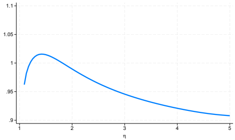

(h) $\pi$ Upstream 1



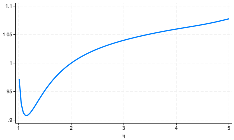

(i) $\pi$ Upstream 2



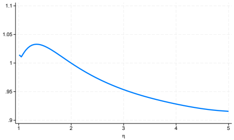

(j) $\pi$ Downstream 1




(k) $\pi$ Downstream 2




(l) Consumer 1 surplus




(m) Consumer 2 surplus

# Variant $\sigma$ prices

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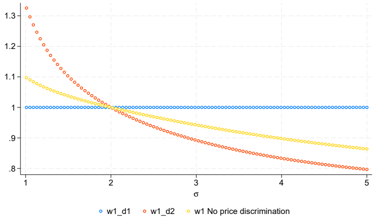
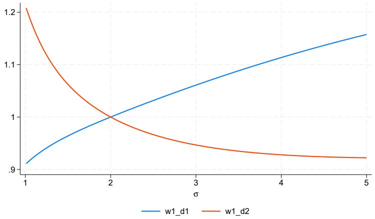
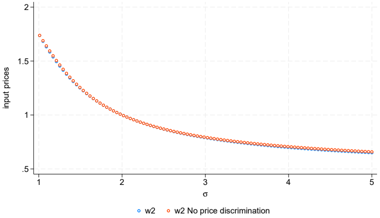


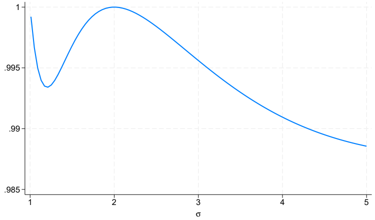

(n) $w1$ level




(o) $w1$ ratio: Price disc./ no disc.



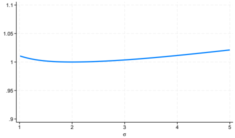

(p) $w2$ level



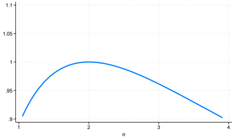

(q) $w2$ ratio: Price disc./ no disc.

# Variant $\sigma$ welfare components ratio: Price disc./ no disc.

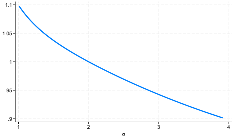
▸ Go back



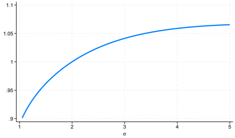

(r) $\pi$ Upstream 1



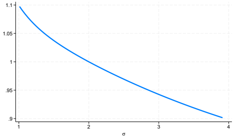

(s) $\pi$ Upstream 2



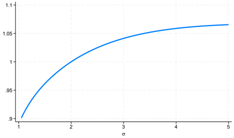

(t) $\pi$ Downstream 1




(u) $\pi$ Downstream 2




(v) Consumer 1 surplus




(w) Consumer 2 surplus