# Pricing Inequality

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## Firms and Household Heterogeneity

Firms are large because...

- they sell to more customers (Argente et al. (2021); Einav et al. (2021); Afrouzi et al. (2023)),
- are higher quality (Hottman et al. (2016); Eslava et al. (2024)).

Customer bases vary in systematic ways. High income households...

- buy higher price varieties ( Bils and Klenow (2001), Handbury (2021), Jaimovich et al. (2019)),
- are less price sensitive than low income households (Auer et al. (2022)),
- buy from larger firms (Faber and Fally (2022)).

Our paper: a dynamic, GE model of household inequality and product market power that

1. rationalizes the facts above, and we use it to...
2. show that household heterogeneity is important to account for markup variation,
3. show how a fiscal transfer to households leads to increases in markups.

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How we do it:

1. Incomplete markets (Bewley, Aiyagari, Hugget) + extensive margin demand (multinomial logit + oligopoly). Key is how marginal utility of wealth shapes hh-level elasticities and sorting.
2. Decompose markup variation into two sources: hh-heterogeneity (58%) and market power (42%).
3. Fiscal transfers increase markups: 1% transfer of GDP $\Rightarrow$ 0.3 pp increase in ag. markup.

## Outline

**1.** Model

- Setup and illustrate how things work.

**2.** Calibration

- How we discipline things and markup decomposition.

**3.** Policy experiment

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## Goods and Firms

**Differentiated goods**:

Markets $m \in \mathcal{M}$, each contain $J$ firms $j \in \{1, \ldots, J\}$. Firm $jm$ produces the variety $jm$ with technology

$$Y_{jmt} = Z_{jm}\left(N_{jmt}\right)^{\alpha} \quad , \quad \left(\psi_{jm}, z_{jm}\right) \sim \Gamma_{\psi,z}(\psi, z).$$

- $Z_{jm}$ is firm productivity.
- $N_{jmt}$ are efficiency units of labor supplied by households.
- $\alpha$ controls extent of DRS (or IRS) for the firm.
- $\psi_{jm}$ is quality (next slide), $\Gamma_{\psi,z}$ is the joint distribution of quality and productivity.

**Homogeneous good**:

Continuum of identical firms, competitive

$$Y_{ct} = \overline{Z}_c N_{ct}.$$

used for government spending, may be valued by household, and is the numeraire.

# Households

Continuum of households with names $i \in [0,1]$

**Household preferences:**

$$\mathbb{E}_0 \left[ \sum_{t=0}^{\infty} \beta^t \sum_{m \in \mathcal{M}} \sum_{j=1}^{J} \widetilde{u}^i_{jmt} \right] \quad , \quad \widetilde{u}^i_{jmt} = \begin{cases} u\left(c^i_t, x^i_{jmt}\right) + \psi_{jm} + \zeta^i_{jmt} & \text{, if consume } jm \\ 0 & \text{, otherwise} \end{cases} \quad , \quad \underbrace{\zeta^i_t \sim \Gamma_\zeta\Big(\zeta\Big).}_{\text{iid each period}}$$

**Each period a household chooses:**

- a single good from a market $m$ and producer $j$, and quantity $x^i_{jmt}$,
- consumption of the homogeneous good,
- save $a^i_t$ in government debt with gross interest rate $R$, subject to borrowing constraint $\underline{a}$,
- earning $We^i_t$ with $e^i_t$ being stochastic productivity evolving according to a Markov chain,
- pays income taxes $\tau We^i_t$, receives transfers $T$, and profits $\Pi$.

## Households

Continuum of households with names $i \in [0,1]$

**Household preferences:**

$$\mathbb{E}_0\left[\sum_{t=0}^{\infty}\beta^t \sum_{m\in\mathcal{M}}\sum_{j=1}^{J}\tilde{u}^i_{jmt}\right] \quad , \quad \tilde{u}^i_{jmt} = \begin{cases} u\left(c^i_t, x^i_{jmt}\right) + \psi_{jm} + \zeta^i_{jmt} & \text{, if consume } jm \\ 0 & \text{, otherwise} \end{cases} \quad , \quad \underbrace{\zeta^i_t \sim \Gamma_\zeta\left(\zeta\right).}_{\text{iid each period}}$$

Taste shocks are distributed GEV:

$$\Gamma_\zeta\left(\zeta\right) = \prod_{m\in\mathcal{M}} \exp\left\{-\left(\sum_{j\in J} e^{-\eta\zeta^i_{jm}}\right)^{\theta/\eta}\right\}.$$

- $\eta$ controls dispersion across $j$s within market $m$. $\theta$ controls dispersion across markets $\mathcal{M}$.
- Why? With $\theta \leq \eta$ allows us to think about an Atkeson and Burstein (2008) like setting; with $\theta = \eta$ collapses to monopolistic competition.

## Households

Continuum of households with names $i \in [0,1]$

**Household preferences:**

$$\mathbb{E}_0\left[\sum_{t=0}^{\infty}\beta^t\sum_{m\in\mathcal{M}}\sum_{j=1}^{J}\widetilde{u}^i_{jmt}\right] \quad , \quad \widetilde{u}^i_{jmt} = \begin{cases} u\left(c^i_t, x^i_{jmt}\right) + \psi_{jm} + \zeta^i_{jmt} & \text{, if consume } jm \\ 0 & \text{, otherwise} \end{cases} \quad , \quad \underbrace{\zeta^i_t \sim \Gamma_\zeta\left(\zeta\right)}_{\text{iid each period}}.$$

For now, we keep $u$ general and summarize everything in terms of the hh's multiplier on its budget constraint.

## Questions...

What about units / balanced growth?

- This is in the dispersion parameters and scaling them appropriately takes care of this.

What about multiple goods at the same time?

- We have variations with (i) continuous time or (ii) two stage budgeting with many goods, discrete varieties of a good. **Does not** change the elasticity and sorting results.

What about the additivity of the shock?

- Tractable, especially with dynamics. **Does not** hardwire in non-homotheticity. Key issue is $u$.

In general, why?

- Settings like this are appealed to as micro-foundations of aggregators (e.g. CES).
- Evidence emphasizing extensive margin of demand as determinant of firm sales; discreetness as a key feature of household behavior in scanner data.

# What Households Do I

Focus on a stationary setting. A hh's state are its asset holdings $a$ and shock $e$. Work backwards...

**2.** Conditional on choosing firm $jm$, and given $W$, $R$, $\Pi$, $P_{jm}$, their problem is

$$v(a, e, jm) = \max_{a', c, x} u\big(c, x\big) + \beta \int \overline{V}(a', e')\, d\Gamma_e\big(e'|e\big),$$

$$\text{subject to:} \quad c + P_{jm}x_{jm} + a' = \Big(1 - \tau\Big)We + Ra + \Pi + T \quad \text{and} \quad a' \geq \underline{a}.$$

An **important** object: $\lambda(a, e, jm) =$ multiplier on the budget constraint.

**1.** Given preference shocks $\zeta_{jm}$, choose a market $m$ and producer $j$

$$v(a, e, \zeta) = \max_{jm} \Big\{ \ v(a, e, jm) + \psi_{jm} + \zeta_{jm} \ \Big\}.$$

## What Households Do II

Equations characterizing the commodity choice, consumption, and savings. . .

**1.** The choice probability is:

$$\rho_{jm}(a,e) = \underbrace{\left(\frac{\exp\left\{v(a,e,jm)+\psi_{jm}\right\}}{\exp\left\{\widetilde{v}(a,e,m)\right\}}\right)^{\eta}}_{\rho_{jm|m}(a,e)} \underbrace{\left(\frac{\exp\left\{\widetilde{v}(a,e,m)\right\}}{\exp\left\{\overline{V}(a,e)\right\}}\right)^{\theta}}_{\rho_{m}(a,e)}$$

**2.** Consumption choices must respect:

$$u_x(c, x_{jm}) = \lambda(a,e,jm)P_{jm}.$$

**3.** Away from the constraint, asset choices must respect:

$$\lambda(a,e,jm) = \mathbb{E}_{e'}\left[\sum_{m\in M}\sum_{jm'\in J_m}\Big\langle \beta R\ \rho_{jm}(a',e')\Big\rangle \lambda(a',e',jm')\right].$$

## What Firms Do

Given competitors' prices $\mathbf{P}_m$ and aggregates $\mathbf{S}$, choose price $P_{jm}$ to maximize profits.

Let $i = (a, e)$. A firm's perceived demand curve is

$$X_{jm} = \int \rho^i_{jm} x^i_{jm} \, di.$$

which depends on the number of customers $\rho_{jm}$ and sales per customer $x_{jm}$.

Optimality leads to a standard markup condition under Bertrand

$$P^*_{jm} = \underbrace{\frac{\varepsilon_{jm}}{\varepsilon_{jm} - 1}}_{\text{Markup}} \times \text{ marginal cost}_{jm},$$

$$\text{where} \quad \varepsilon_{jm} = - \frac{\partial \log X_{jm}}{\partial \log P_{jm}} \bigg|_{\mathbf{P}^*_{-jm}} = \int \underbrace{\left( \frac{\rho^i_{jm} x^i_{jm}}{X_{jm}} \right)}_{\text{weights}} \underbrace{\left( \varepsilon^{\rho,i}_{jm} + \varepsilon^{x,i}_{jm} \right)}_{\text{individual elasticities}} \, di,$$

so a firm's elasticity of demand is a weighted average of **individuals** elasticities of demand on the **extensive** and **intensive** margin.

# The Extensive Margin Elasticity

The household-level extensive margin elasticity takes this form

$$\varepsilon_{jm}^{\rho,i} = \underbrace{\left[\boldsymbol{\eta}\left(1 - \rho_{j|m}^{i}\right) + \boldsymbol{\theta}\rho_{j|m}^{i}\right]}_{\text{oligopoly}} \times \underbrace{\left[\lambda_{jm}^{i}\ P_{jm}\ x_{jm}^{i}\right]}_{\text{wealth}}$$

Extensive margin depends on two factors:

1. How important firm *jm* is in the market of type *i* consumers — where the oligopoly part matters.
2. How rich or poor those consumers as summarized by $\lambda_{jm}^{i}$ — where heterogeneity matters.

How does the wealth component vary with wealth? It's a race between the marginal utility wealth and expenditure.

## The Extensive Margin Elasticity

The household-level extensive margin elasticity takes this form

$$\varepsilon^{\rho,i}_{jm} = \underbrace{\left[\boldsymbol{\eta}\left(1 - \rho^{i}_{j|m}\right) + \boldsymbol{\theta}\rho^{i}_{j|m}\right]}_{\text{oligopoly}} \times \underbrace{\left[x^{i}_{jm}\right]^{1-\sigma}}_{\text{wealth}}$$

Special case —separable between $c$ and $x$, with CRRA over each.

How does the wealth component vary with wealth?

When $\sigma > 1$, than the poor are **more elastic** on the extensive margin.

# The Intensive Margin Elasticity

Intensive margin is harder to characterize, but with only differentiated goods and CRRA its

$$\varepsilon_{jm}^{x,i} = \frac{1}{\sigma}\left(\frac{\partial \lambda_{jm}^{i}/\lambda_{jm}^{i}}{\partial P_{jm}/P_{jm}} + 1\right).$$

and we can bound this...

- very wealth: $\lambda$ does not vary with $P_{jm}$ and thus its $\frac{1}{\sigma}$,
- poor, hand-to-mouth: it's one $\Rightarrow$ the poor are **more elastic** on the intensive margin.
- In our quantitative setting, this is small relative to extensive margin.

# Sorting

What about the weights? This determines the type of customers a firm is facing, e.g. rich (inelastic) or poor (elastic). This depends upon how the rich and poor **sort** across varieties.

Sorting is given by a log supermodularity condition:

$$\eta \int_{\log P_{jm}}^{\log P_{jm'}} \left[ \lambda_k^p P_k x_k^p - \lambda_k^r P_k x_k^r \right] d \log P_k ,$$

and the sign determines the propensity for the rich to choose a high price versus the low price, all relative to the poor.

The wealth component of the extensive margin elasticities determines the sign $\Rightarrow$ if the rich are less price sensitive, **rich hhs are more likely to purchase from high price firms.**

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## Functional Forms and Predetermined Parameters

**Time:** A time period is one quarter.

**Household:**

- No outside good, CRRA for $u(x)$.
- Earnings process as in Krueger et al. (2016).
- No Borrowing, $\bar{a} = 0$.

**Firms:**

- All markets $\mathcal{M}$ are symmetric.
- Firm quality $\psi_j$ is distributed Pareto, $Z_j$ is common.

**Government** (Kaplan and Violante (2022), Kaplan et al. (2020)):

- Labor income taxes are 15% of GDP, transfers are 5% of GDP.
- Fix annual interest rate of 2%.
- Government debt of 56% of GDP, we find $\beta$ so the Gov asset supply matches hh asset demand.

# Calibration

**Internally Calibrated Parameters**

| Parameter | | Value | Moment | Data | Model |
|---|---|---|---|---|---|
| **A. Households** | | | | | |
| Taste dispersion — within markets | $\eta$ | 8.9 | Average markup | 1.25 | 1.25 |
| Taste dispersion — across markets | $\theta$ | 0.0 | Edmond et al. (2023) reg. coefficient | 0.03 | 0.03 |
| Coefficient of relative risk aversion | $\sigma$ | 2.57 | Auer et al. (2022) reg. coefficient | 2.20 | 2.20 |
| Discount rate | $\beta$ | 0.99 | Mean liquid assets / Mean income | 0.56 | 0.56 |
| **B. Firms** | | | | | |
| Firms per market | $J$ | 25 | Amiti and Heise (2022) sales HHI | 525 | 525 |
| Tail parameter of Pareto | $\xi$ | 10.9 | Amiti and Heise (2022) top 4 share | 30.5 | 30.5 |
| Decreasing returns | $\alpha$ | 0.63 | Jaimovich et al. (2019) reg. coefficient | 0.14 | 0.14 |
| **C. Government** | | | | | |
| Income tax rate | $\tau$ | 0.27 | Total labor income taxes to GDP | 0.15 | 0.15 |
| Transfers per capita | $T$ | 0.05 | Total transfers to GDP | 0.05 | 0.05 |

## Non-Targeted Moments

The extensive margin of demand.

- Afrouzi et al. (2023) — 86.1% of the variance in firm sales is attributable to number of customers. Using the same approach, it's 60% in our model.

Quality determines firm size.

- Hottman et al. (2016): large firms are large because of quality, have higher marginal costs and markups. Our model: Same thing!

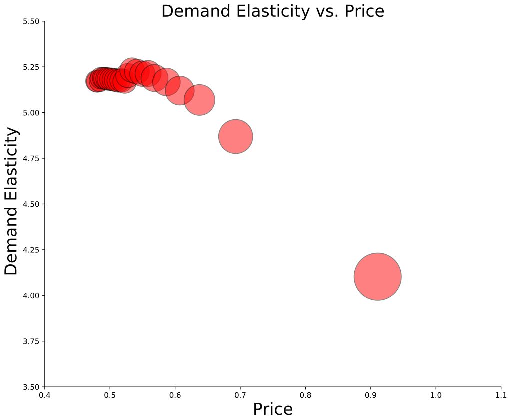
Firm size and household expenditure.

- Faber and Fally (2022) — purchases of households in the top decile of expenditure are from firms that are 27% larger than from the bottom decile. Our model: 29%.

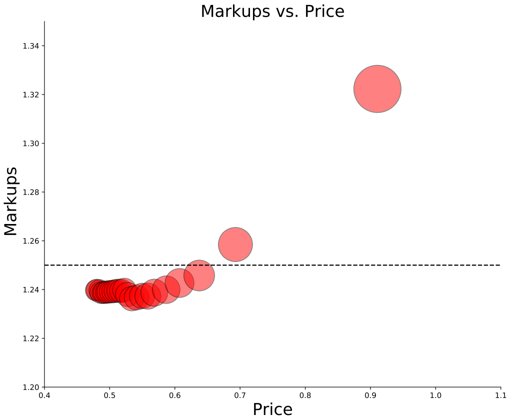
Wealth shocks and markups.

- Stroebel and Vavra (2019) — regions with relatively large changes in wealth (due to houseling prices) had relative increases in markups.
- We replicate their research design in our model: SV estimate: 0.10 to 0.23, our model: 0.11.

# Calibration: Demand Elasticities and Markups




**Demand Elasticities**




**Markups**

## What Accounts for Elasticity / Markup Variation?

Differences across firms in elasticities / markups came from **two** sources:

- Market power,
- Household heterogeneity.

Which force is more important?

**Elasticity Decomposition**

| | Market Power | Household Heterogeneity |
|---|---|---|
| Top − Bottom Quintile Firms | 42 | 58 |
| Middle − Bottom Quintile Firms | 48 | 52 |

**Note:** Quintile are formed on the basis of sales.

**Alternative Calibrations and Elasticity Decomposition**

| | Baseline | Log model | Monp. Comp. |
|---|---|---|---|
| **A. Households** | | | |
| Taste dispersion — within markets | 8.9 | 2.12 | 11.7 |
| Taste dispersion — across markets | 0.0 | 0.0 | — |
| Coefficient of relative risk aversion | 2.6 | — | 3.4 |
| **B. Firm parameters** | | | |
| Tail parameter of Pareto | 10.9 | 4.1 | 14.7 |
| Decreasing returns | 0.63 | 0.66 | 0.64 |
| **C. Moments** | | | |
| Average markup | 1.25 | 1.25 | 1.25 |
| Amiti and Heise (2022) top 4 share | 0.30 | 0.30 | 0.30 |
| Edmond et al. (2023) reg. coefficient | 0.03 | 0.03 | 0.03 |
| Auer et al. (2022) reg. coefficient | 2.20 | 0.0 | 2.62 |
| Jaimovich et al. (2019) reg. coefficient | 0.14 | 0.0 | 0.17 |
| **D. Elasticity Decomposition** | | | |
| Household het. share of elasticity variation | 58 | 0 | 100 |

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## How Does the Economy Respond to a Fiscal Transfer?

What we do: Shock the economy with an unanticipated increase in government transfers $T$ by 1% of GDP in one quarter. Note: Covid-era transfers were 7.5% of GDP (SF Fed).

Answers the question: How much do markups and prices respond per 1% of GDP of transfers?

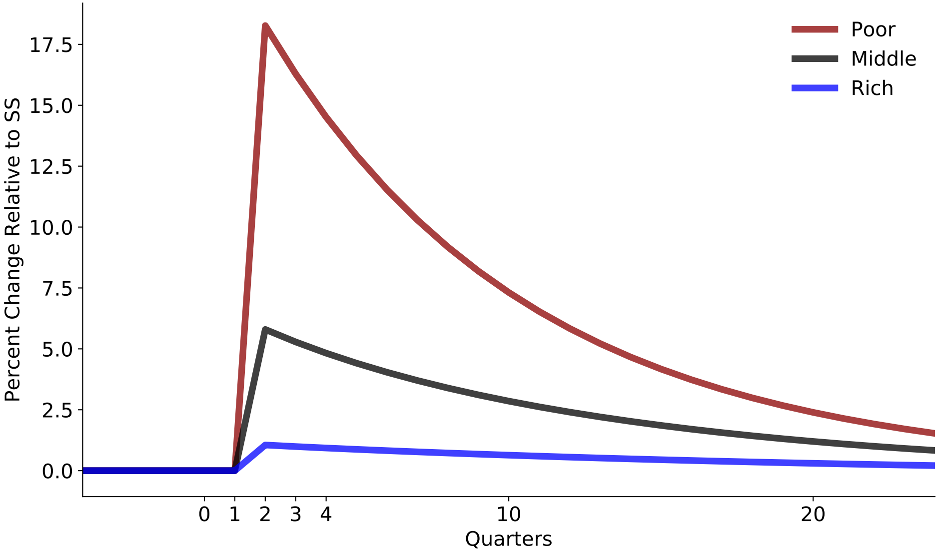
Important details:

- Government spending $G$ is fixed.
- $R$ is held fixed.
- Taxes are gradually adjusted to finance the increase in debt according to the function

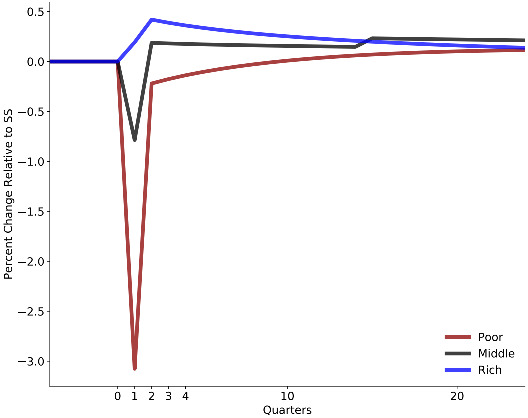
$$\tau_t = \tau \left( \frac{B_{t-1}}{B} \right)^{\varsigma}$$

and set $\varsigma$ for a half-life of debt of 10 years.

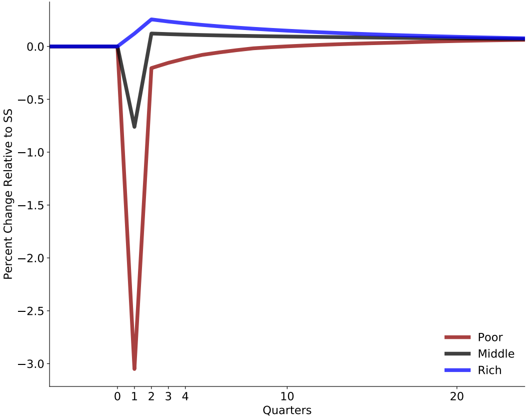
# Excess Savings



# Marginal Utility of Consumption and Demand Elasticities

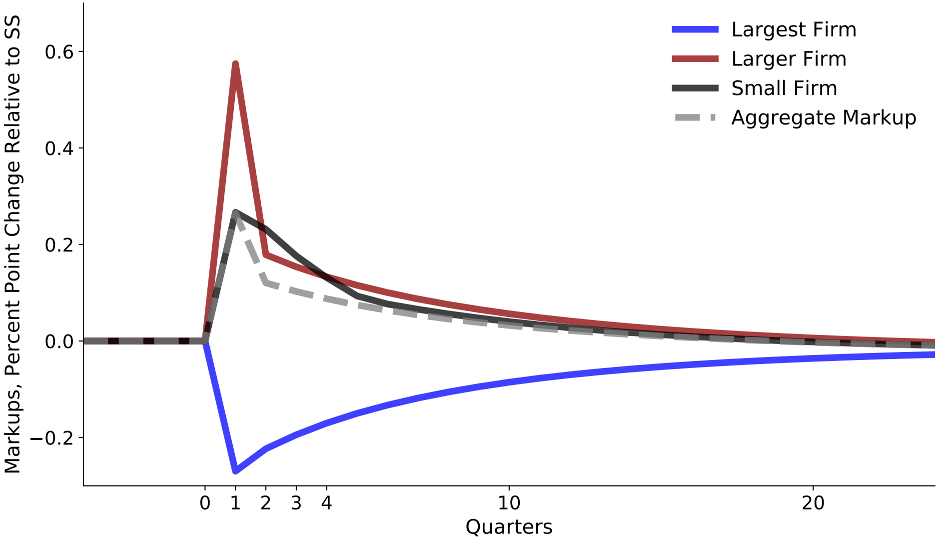



**Marginal Utility in Consumption**



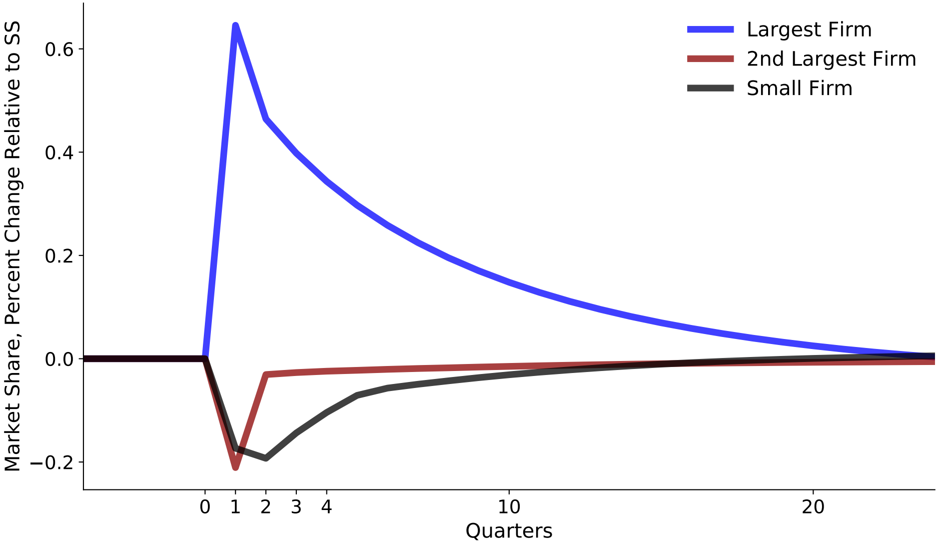

**Demand Elasticities**

# Markups

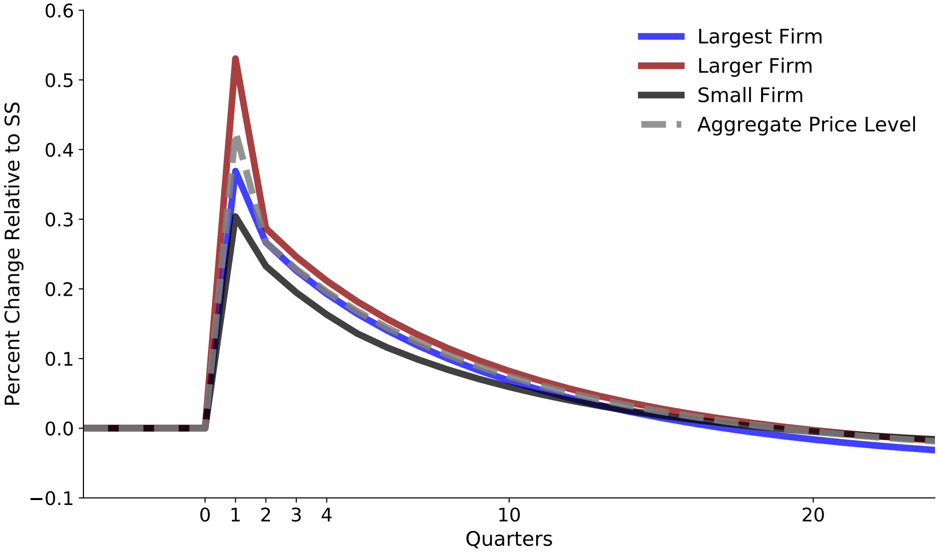


Largest Firm
Larger Firm
Small Firm
Aggregate Markup
Markups, Percent Point Change Relative to SS
0.6
0.4
0.2
0.0
−0.2
0
1
2
3
4
10
20
Quarters

# Market Share

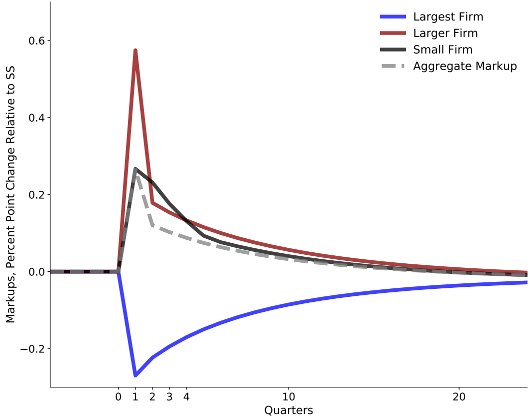


# Prices

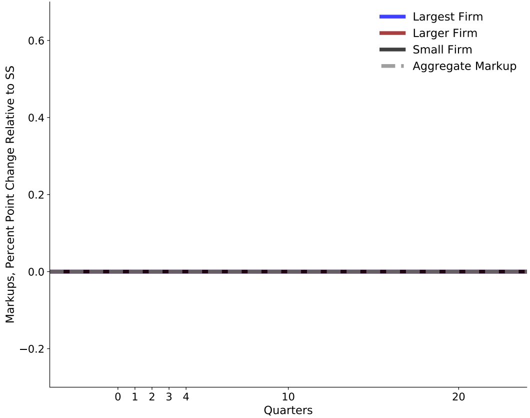


0.6
0.5
0.4
0.3
0.2
0.1
0.0
−0.1
Percent Change Relative to SS
0
1
2
3
4
10
20
Quarters
Largest Firm
Larger Firm
Small Firm
Aggregate Price Level

# The Role of Household Heterogeneity — Markups

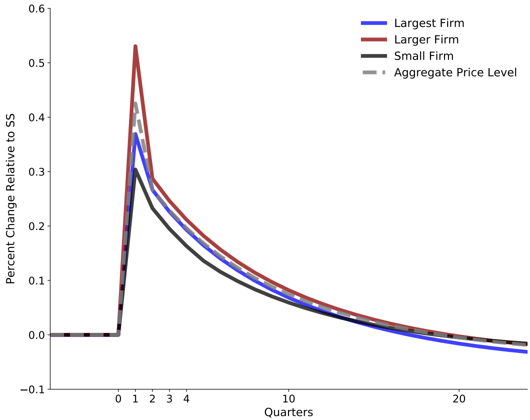



**Baseline Model**

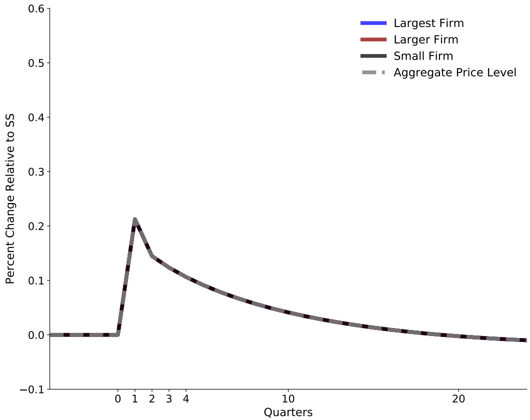



**Log Model**

# The Role of Household Heterogeneity — Prices




**Baseline Model — Prices**




**Log Model — Prices**

# Final Thoughts. . .

**1. Framework.** Flexible framework for disaggregated demand across heterogeneous households and how it matters for firm pricing.

- Leverages the standard economic logic of heterogeneous agent consumption / savings models.
- Applied in labor supply (Berger, Herkenhoff, Mongey, Oppenheimer 2024) and trade (Waugh 2024).

**2. Empirics.** Makes sense of a broad set of well known empirical regularities on firm size, firm pricing and household purchasing. More work to be done!

**3. Policy.** Has implications for fiscal transfers (this paper), monetary policy (maybe at some point), etc. and how these policies will affect markups and prices.

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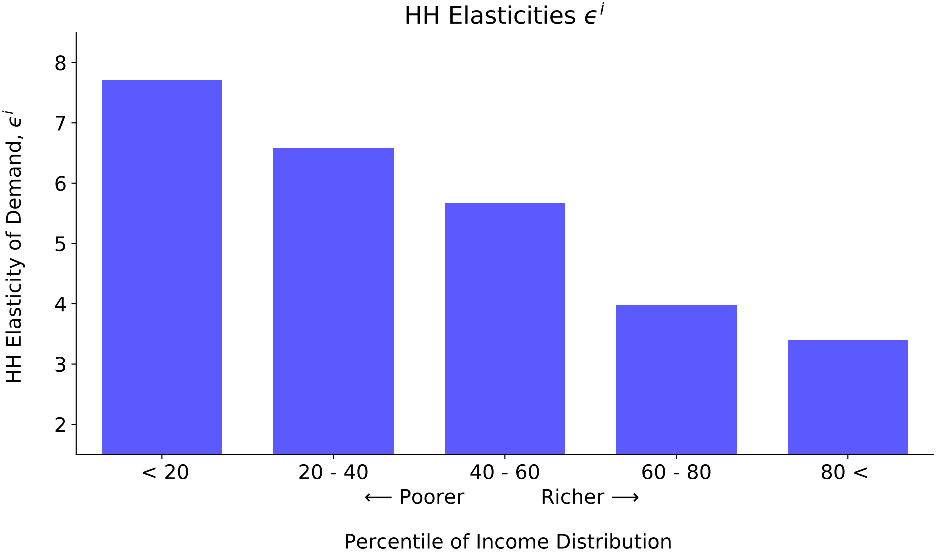
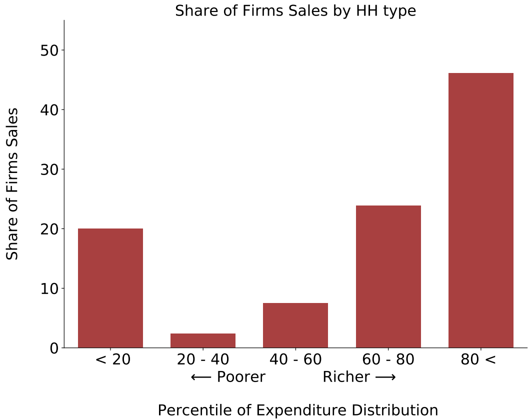
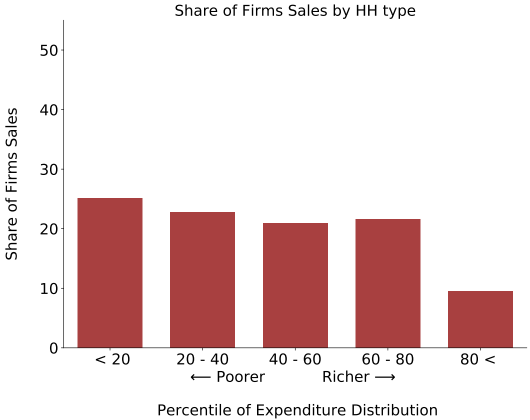
# Calibration: HH-Level Elasticities



# Calibration: Sorting




**High Quality, High Price Firm**




**Low Quality, Low Price Firm**

# Calibration — Disciplining $\sigma$

Auer, Burstein, Lein, and Vogel (2022) regression:

$$\log\left(\frac{b^i_{Mt}}{b^i_{Dt}}\right) = \boldsymbol{\beta}_0 - \boldsymbol{\beta}_1 \log\left(\frac{p_{Mt}}{p_{Dt}}\right) + \boldsymbol{\beta}_2 \log e^i \log\left(\frac{p_{Mt}}{p_{Dt}}\right) + \varepsilon_{it}$$

which is run on Swiss households during the Franc appreciation of 2015.

Idea is that French goods (imports) became cheaper relative to Swiss goods (domestic), so people buy more French stuff...the key finding /issue is that this is much less for richer households $\beta_2$ is positive.

The same thought experiment in our model. . . run the same type of regression in the model

$$\log\left(\frac{b^H_{j'}}{b^H_j}\right) - \log\left(\frac{b^L_{j'}}{b^L_j}\right) \approx \underbrace{\left\{\varepsilon^{\rho,L}_j\right\}\left\{\sigma\right\}\left\{\frac{\partial \log c^L_j}{\partial \log e^L}\right\}}_{\text{Coefficient estimated in Auer et al (2022)}} \underbrace{\log\left(\frac{e^H}{e^L}\right)\log\left(\frac{p_{j'}}{p_j}\right)}_{\text{Interaction term}},$$

Key implication: The Auer et al. (2022) results are highly informative about $\sigma$.

## Calibration — Quality variation and DRS

Quality and DRS $\Rightarrow$ big firms are high quality, high marginal cost, high price firms. Why do we find this? Consider a high quality firm versus low quality firm $\psi_h > \psi_l$

- Market power + DRS imply that $p_h > p_l$
- Sorting implies that the rich sort relatively more towards the high price, high quality firm.
- Data — consistent with empirical evidence that the rich pay higher prices for the same good ✓
- Data — consistent with empirical evidence that big firms have high markups ✓

Pure story of productivity heterogeneity has problems. . .

- Not enough sorting and / or the wrong direction.
- Size-markup correlation is wrong — big firms are low price, face elastic consumers, and low markup.

## Pass-Through

How do prices change given a change in marginal costs, aka pass-through:

$$\frac{\partial \log p_{jm}}{\partial \log mc_{jm}} = \frac{[\varepsilon_{jm} - 1]}{[\varepsilon_{jm} - 1] + \left\{ \frac{\partial \log \varepsilon_{jm}}{\partial \log p_{jm}} \right\}_{(+)}} \in (0,1),$$

where $\frac{\partial \log \varepsilon_{jm}}{\partial \log p_{jm}} := \mathcal{E}_{jm}$ is the "super-elasticity" which takes this form...

## The Super-Elasticity

The super-elasticity…

$$\mathcal{E}_{jm} = \int \overbrace{\underbrace{\left(\frac{\rho^i_{jm} x^i_{jm} \varepsilon^i_{jm}}{\int \rho^i_{jm} x^i_{jm} \varepsilon^i_{jm}}\right)}_{\text{weights}} \left(\frac{\partial \log \left[\rho^i_{jm} x^i_{jm} / x_{jm}\right]}{\partial \log p_{jm}}\right)}^{\text{composition}} di \quad + \quad \int \left(\frac{\rho^i_{jm} x^i_{jm} \varepsilon^i_{jm}}{\int \rho^i_{jm} x^i_{jm} \varepsilon^i_{jm}}\right) \underbrace{\mathcal{E}^i_{jm}}_{\text{i's super elasticity}} di.$$

The aggregate super-elasticity is a weighted average of

- how do expenditure weights change,
- how individual elasticities change.

# The Individual Super-Elasticity

Individual super elasticity is weighted average of extensive and intensive margin super elasticities... abstract from the intensive margin and we have:

$$\mathcal{E}^i_{jm} \approx \underbrace{\left[\frac{\eta(\eta-\theta)\rho^i_{j|m}(1-\rho^i_{j|m})}{\eta-(\eta-\theta)\rho^i_{j|m}}\right] \times \left[\lambda^i_{jm} p_{jm} x^i_{jm}\right]}_{\text{market power effect}} + \underbrace{\frac{\partial \log \lambda^i_{jm}}{\partial \log p_{jm}} + \varepsilon^{i,x}_{jm} + 1}_{\text{wealth effect}}.$$

As with the elasticities, very similar ideas here:

- market power,
- how the marginal utility of wealth changes.

# The Individual Super-Elasticity

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As with the elasticities, very similar ideas here:

- market power,
- how the marginal utility of wealth changes.

So what? The key issue is how markups and super-elasticities are (i) not "parameterized" and (ii) depend upon market power forces and the distribution of wealth.

## Elasticity Decomposition

- For each firm, extensive margin elasticity is:

$$\varepsilon_j^{\rho} = \int_i \omega^i \left(\eta - (\eta - \theta)\rho_j^i\right) \lambda_j^i p_j c_j^i \, di$$

- Approximately, this is

$$\widetilde{\varepsilon}_j^{\rho} = \underbrace{\left[\int_i \omega^i \left(\eta - (\eta - \theta)\rho_j^i\right) di\right]}_{\text{Market power: } \varepsilon_j^{MP}} \times \underbrace{\left[\int_i \omega^i \lambda_j^i p_j c_j^i \, di\right]}_{\text{Heterogeneity: } \varepsilon_j^{H}}$$

- Decompose difference in $\widetilde{\varepsilon}_j^{\rho}$ across $Q_1$ and $Q_5$ firms by price:

$$\log \widetilde{\varepsilon}_j^{\rho} = \log \varepsilon_j^{MP} + \log \varepsilon_j^{H}$$

$$Share^H = \frac{\mathbb{E}\left[\log \widetilde{\varepsilon}_j^{H} \middle| j \in Q_1\right] - \mathbb{E}\left[\log \widetilde{\varepsilon}_j^{H} \middle| j \in Q_5\right]}{\mathbb{E}\left[\log \widetilde{\varepsilon}_j^{\rho} \middle| j \in Q_1\right] - \mathbb{E}\left[\log \widetilde{\varepsilon}_j^{\rho} \middle| j \in Q_5\right]} = 72.1 \text{ percent}$$