Pass-Through with Price Dispersion

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Market power = lack of contestability

- A firm has market power when it can sustain a high margin w/o losing (much) demand.
- Limited consideration ⇒ *captive* vs. *contested* demand.
- More captive demand–less exposure to rival prices ⇒ less contestable demand.

Market power here: insulation from direct price comparison.

Price dispersion and pass-through

- *Pass-through:* how cost shocks show up in prices paid by consumers.
- Standard theory typically posits (then differentiates) an *equilibrium price*.
- But w/ limited consideration the equilibrium object is a *price distribution*.
- E.g.,
  1. Gas stations. *Fuel taxes / wholesale shocks.*
  2. Online retail. *Marketplace fees.*
  3. Price-comparison sites. *Commissions / input costs.*
  4. Local services. *Sales taxes / wage shocks.*
- $\Rightarrow$ Pass-through: how a *price distribution* responds to cost shocks.

Question: how to compute *pass-through* when prices are dispersed?

Central result

$$\text{Pass-through} = \underbrace{\text{competition layer}}_{\text{Mkt structure} \mapsto \text{Eq dist. in NEM}} + \overbrace{\text{curvature layer}}^{\text{Margins} \mapsto_{\text{demand elasticity}} \text{Prices + pass-through}}$$

*N*ormalized *E*ffective *M*argins.

Main theorem: eq distribution(s) of margins depend(s) only on market (consideration) structure, not on demand curvature or cost levels.

Demand & costs translate from margins to prices.

Key implication: compute pass-through rates by differentiating the mapping from margins to prices (eq′m *margin* distribution is *invariant* to cost changes).

Literature

- *Pass-through:* Weyl & Fabinger (2013) and the incidence literature give sharp formulas when there is a *single price*.
- *Price dispersion:* Varian (1980), Burdett & Judd (1983), and especially *Armstrong & Vickers (2022)* on arbitrary consideration sets.
- *We build directly on Armstrong & Vickers (2022):* same consideration-set model, but now formalize the invariance to downward-sloping demand and use it for pass-through.
- Other recent papers: e.g., Garrod et al. (2024) & Montag et al. (2023).
  - Binary consumer types: captive vs. non-captive.

Plan (today)

1. Framework & main reformulation result.
2. Quantile pass-through: how each price in dist. responds to cost changes.
3. Transaction-weighted pass-through.
4. Bounds, comparative statics, and applications to gasoline / online retail / platform fees.

Model & Main Result

Framework

- n firms, $N := \{1, \ldots, n\}$.
- Demand side: unit mass of consumers partitioned by *consideration sets*.
- *Consideration structure*:
  - Probability distribution $\{\alpha_S\}_{S \subseteq N}$ ($\sum_{S \subseteq N} \alpha_S = 1$, possibly $\alpha_\emptyset > 0$ "no firms").
  - Mass $\alpha_S \geq 0$ is the mass of consumers who consider exactly the set S of firms.
  - "awareness," "availability rate," "choice set," "loyal customers."
- Consumer: observes only the prices in her consideration set and buys from the lowest-priced firm if the price is at most 1.
- Each buyer demands $x(p)$, where $x\colon [0,1] \to \mathbb{R}_+$ is continuous, weakly decreasing, and $x(1) > 0$.
- Firms have common marginal cost $c \in [0,1)$: *tax*, *input cost*, or *platform fee*...

Consideration structures

1. Random search.

- Consumer samples each firm independently w/ probability $\lambda \in (0,1)$: $\alpha_S = \lambda^{|S|}(1-\lambda)^{n-|S|}$.

2. Spatial / local markets

- Firms located on a circle.
- Consumers observe only their $k \in \{1, \ldots, n-1\}$ "nearest neighbors."
- $\alpha_S = 1/n$ if S is k consecutive firms, 0 otherwise.

- Platform rankings,
- Behavioral inattention,
- Local market segmentation.
- What matters: *who considers whom*.
- Why limited consideration?

Don't care!

Toward the theorem. Pricing game

Firm i's

$$\textit{reach } \sigma_i = \sum_{S \ni i} \alpha_S, \quad \textit{captive share } \alpha_{\{i\}} \quad \text{and} \quad \textit{captive-to-reach ratio } \rho_i = \frac{\alpha_{\{i\}}}{\sigma_i}.$$

- Break ties fairly w/in consideration sets.

$$q_i(p) = \sum_{S \ni i} \alpha_S \prod_{j \in S \setminus \{i\}} \big(1 - F_j(p)\big) \quad \text{(Demand)}$$

$$\Pi_i(p; c) = (p - c)x(p)q_i(p) \quad \text{(Profit)}$$

$(F_i)_{i \in N}$ on $[c, 1]$ is an equilibrium if $\forall\ i, \exists\ \pi_i(c)$:

1. *Indifference on support:* $\Pi_i(p; c) = \pi_i(c)\ \forall\ p \in \text{supp}(F_i)$.
2. *No profitable deviation:* $\Pi_i(p; c) \leq \pi_i(c)\ \forall\ p \notin \text{supp}(F_i)$.

Toward the theorem. Margins

Effective margin: firm gets $(p-c)x(p)$ from each customer it serves.

- Ass. $(p-c)x(p)$ strictly increasing on $[c,1]\ \forall\ p \in [c,1]$.
- *Viz.,* higher prices correspond to higher effective margins.
- Holds whenever $(p-c)x(p)$ maxed @ $p=1$ (and not interior), e.g., unit demand.

Normalized effective margin (NEM):

$$\mu(p;c) := \frac{\overbrace{(p-c)x(p)}^{\text{profit per served consumer}}}{\underbrace{(1-c)x(1)}_{\text{profit when pricing at the max price}}} \in [0,1].$$

- Key property: $\mu(p;c)$ is strictly increasing in p on eq′m support $\Rightarrow$ one-to-one correspondence between prices and normalized margins.

Toward the theorem. The margin game I

- Inverse map $\phi\colon [0,1] \to [c,1]$ ($\mu \mapsto_\phi p$), given implicitly by

$$(\phi(\mu,c) - c)x(\phi(\mu,c)) = \mu(1-c)x(1).$$

- $p \leftrightarrow \mu$ is 1-to-1 $\implies$ firms choose ~~prices~~ *competitive positions*.
- Firms (simultaneously) choose distributions over *margins* $\mu \in [0,1]$.
- If firm i posts μ, its payoff is $\Pi_i^\mu(\mu) = \mu q_i^\mu(\mu)$, w/ (ass. no atoms)

$$q_i^\mu(\mu) = \sum_{S \ni i} \alpha_S \prod_{j \in S \setminus \{i\}} \left[1 - F_j^\mu(\mu)\right].$$

- Same "lowest wins" logic as before–just rewritten in μ-space.

Toward the theorem. The margin game II

Original game: choose distributions over prices w/ objective

$$\Pi_i(p;c) = (p - c)x(p)q_i(p), \qquad \text{w/} \qquad q_i(p) = \sum_{S \ni i} \alpha_S \prod_{j \in S \setminus \{i\}} \left(1 - F_j(p)\right)$$

New game: choose distributions over margins w/ objective

$$\Pi_i^\mu(\mu) = \mu q_i^\mu(\mu), \qquad \text{w/} \qquad q_i^\mu(\mu) = \sum_{S \ni i} \alpha_S \prod_{j \in S \setminus \{i\}} \left[1 - F_j^\mu(\mu)\right].$$

Demand curvature & costs have *disappeared*.

Main theorem

Lemma The margin game admits an MSNE.

Theorem. Function $p \mapsto \mu(p;c)$ induces a bijection between equilibria of the pricing game and equilibria of the margin game. The equilibrium μ-distributions depend *only* on the consideration structure $\{\alpha_S\}$, not on demand $x(\cdot)$ or on cost c.

- *Competition layer:* solve for the equilibrium μ-distribution. Only consideration structure matters.
- *Curvature layer:* recover prices from $p = \phi(\mu, c)$.

Economics of the theorem

- NEM μ captures the fundamental trade-off in price-setting:
  - Higher $\mu \Rightarrow$ higher profit per customer but lower prob. of winning customers.
- $\mu \equiv$ the firm's "aggressiveness" in extracting surplus:
  - Aggressive: low μ, low margins, high market share.
  - Passive: high μ, high margins, low market share.
- Limited consideration creates captive & contested demand.
- The source of mkt power.
  1. Captive demand $\uparrow \Rightarrow \mu \uparrow$. Search $\uparrow \Rightarrow$ captives $\downarrow \Rightarrow \mu \downarrow$.
  2. Holding captive power fixed, more rivals in contested sets $\Rightarrow \mu \uparrow$.
- Demand curvature $x(\cdot)$ only affects the translation (via ϕ) between these strategic positions and actual prices, not the positions themselves.
- Separates platform-design/merger from demand assumptions.

Solve once in μ-space, then map back to prices.

Quantile Pass-through

Quantile pass-through

- How each price in the distribution responds to cost changes.
- B/c firms mix, different price quantiles can have *different pass-through rates*.
- Eq μ-quantile fnxn $\mu_i(u) := \inf\left\{\mu : \ F_i^{\mu}(\mu) \geq u\right\}$.
- *Pass-through rate at quantile u:* $\tau_i^Q(u;c) \equiv \frac{\partial p_i(u;c)}{\partial c}$, where $p_i(u;c) = \phi(\mu_i(u), c)$.

$$\tau_i^Q(u;c) = \phi_c(\mu_i(u), c) = \frac{\overbrace{x(p_i(u;c))(1-p_i(u;c))}^{x(p)(1-p)}}{\underbrace{(1-c)\left[x(p_i(u;c)) + (p_i(u;c)-c)x'(p_i(u;c))\right]}_{(1-c)[x(p)+(p-c)x'(p)]}}.$$

- D′ff′te b. sides of eq′m defining ϕ w.r.t. c (holding μ fixed), then algebra.

Quantile pass-through intuition

$$\tau_i^Q(u;c) = \phi_c(\mu_i(u), c) = \frac{\overbrace{x(p_i(u;c))(1-p_i(u;c))}^{x(p)(1-p)}}{\underbrace{(1-c)\left[x(p_i(u;c)) + (p_i(u;c)-c)x'(p_i(u;c))\right]}_{(1-c)[x(p)+(p-c)x'(p)]}}.$$

- $x(p)(1-p)$: direct effect of cost on profit:
  - Factor $x(p)$: firms selling more quantity face a larger cost p. customer served
  - Factor $(1-p)$: "headroom" for price increases.
  - Firms pricing closer to the reservation value have less room to raise prices.
- $(1-c)[x(p)+(p-c)x'(p)]$: slope of the effective margin function.
  - How responsive profit-per-customer is to price changes.
  - Highly elastic demand (large $|x'|$) dampens pass-through.
  - Inelastic demand facilitates pass-through.

Quantile pass-through intuition

$$\tau_i^Q(u;c) = \phi_c(\mu_i(u),c) = \frac{\overbrace{x(p_i(u;c))(1-p_i(u;c))}^{x(p)(1-p)}}{\underbrace{(1-c)\left[x(p_i(u;c)) + (p_i(u;c)-c)x'(p_i(u;c))\right]}_{(1-c)[x(p)+(p-c)x'(p)]}}.$$

Limiting cases as benchmarks:

- *Unit demand* ($x' = 0$): pass-through is $\tau = (1-p)/(1-c)$
- Firms pricing higher: lower pass-through b/c they're already extracting rents.
- *Perfect competition* ($p \to c$): pass-through $\to 1$.
- Firms w/ zero markups must fully pass through cost changes to break even.

Special class: independent consideration

- Whether a consumer considers firm i is stat. indep. of whether she considers firm j: each consumer considers firm j indep. w/ prob. $\lambda_j \in (0,1)$.
- Consideration structure: $\alpha_S = \prod_{j \in S} \lambda_j \prod_{k \notin S}(1-\lambda_k)$.
- Firm j's reach, $\sigma_j = \lambda_j$, and captive share, $\alpha_{\{j\}} = \lambda_j \prod_{k \neq j}(1-\lambda_k)$.
- Captive-to-reach ratio: $\rho_j = \frac{\alpha_{\{j\}}}{\sigma_j} = \prod_{k \neq j}(1-\lambda_k)$.
- Key property of indep.: firm j's demand in μ has separable form:

$$q_j^{\mu}(\mu) = \sum_{S \ni j} \alpha_S \prod_{i \in S \setminus \{j\}} (1 - F_i^{\mu}(\mu)) = \lambda_j \prod_{i \neq j} \left[1 - \lambda_i F_i^{\mu}(\mu)\right],$$

allowing closed-form solutions (paper).

Independent consideration and margin FOSD

- Higher-reach (higher λ) firms price higher at each quantile.
- Arrange $\lambda_1 > \lambda_2 > \lambda_3 \geq \cdots \geq \lambda_n$.

Corollary. Margin cdfs: $F_1^{\mu}(\mu) \leq F_2^{\mu}(\mu) \leq \cdots \leq F_n^{\mu}(\mu) \; \forall \; \mu$ in the common support.

Equivalently, $\mu_1(u) \geq \mu_2(u) \geq \cdots \geq \mu_n(u) \; \forall \; u \in [0, 1]$.

Higher reach $\Rightarrow$ higher captive-to-reach ratios $\Rightarrow$ relatively more captive power.

Quantile pass-through comparative statics

Proposition. Let $\mu^A(u)$ and $\mu^B(u)$ be two margin quantile functions. If $\mu^B(u) \geq \mu^A(u)$ for all $u \in [0, 1]$, then: **(a)** prices inherit the ordering, $p^B(u; c) \geq p^A(u; c)$ for all u; and **(b)** pass-through inherits the ordering if ϕ_c is increasing in μ, or the reverse ordering if ϕ_c is decreasing in μ.

Logic = EZ

- Mkts./firms w/ higher margin distributions $\Rightarrow$ higher prices at every quantile.
- If $\phi_c \downarrow$ in μ (unit or linear demand), lower pass-through at every quantile.
- If demand ($x(\cdot)$) is sufficiently convex, the pass-through ordering can reverse.

Transaction-weighted Pass-through

Why transaction-weighting matters

- Consumers do not buy uniformly from the posted-price distribution: low prices attract more transactions.
- On eq′m support, mass of transactions @ price p: $T_i(p; c) = x(p)q_i(p)$.
- Key identity:

$$T_i(p; c) = x(p)q_i(p) = \frac{\pi_i(c)}{p - c}.$$

- Lower markups must be compensated by higher volume.
- Posted-price dist. and price-paid dist. can move differently.

Easy formulas

Ass. price dist. has support bounded away from c (e.g., b/c captive-to-reach ratio $\rho_i > 0$).

- *Transaction-weighted cdf:*

$$F_i^{\text{trans}}(p;c) = \frac{\int_c^p x(s)q_i(s)dF_i(s;c)}{\int_c^1 x(s)q_i(s)dF_i(s;c)} \overset{\text{Eqm. Identity}}{=} \frac{\int_c^p \frac{1}{s-c}dF_i(s;c)}{\int_c^1 \frac{1}{s-c}dF_i(s;c)}.$$

- *Mean transaction-weighted price:*

$$\bar{p}_i^{\text{trans}}(c) = \int p\, dF_i^{\text{trans}}(p;c) = \frac{\int p \cdot \frac{1}{p-c}dF_i(p;c)}{\int \frac{1}{p-c}dF_i(p;c)}$$

- *Transaction-weighted pass-through rate:*

$$\tau_i^{\text{trans}}(c) = \frac{d\bar{p}_i^{\text{trans}}(c)}{dc} = 1 + \frac{\int_0^1 \frac{\phi_c(\mu_i(u),c)-1}{(\phi(\mu_i(u),c)-c)^2}du}{\left[\int_0^1 \frac{1}{\phi(\mu_i(u),c)-c}du\right]^2}$$

Unit-demand simplification

- Let $x(p) = 1$ & define $K_i := \int_0^1 \frac{1}{\mu_i(u)} du$.
- K_i: intensity of competition facing firm i, agg. across transaction dist.
- When the margin dist. concentrates on
  - Low μ (contested transactions): K_i is large and pass-through is high: firms facing stiff competition pass cost shocks to consumers.
  - High μ (captive transactions): K_i is small and pass-through is low: firms with market power absorb cost shocks.

$$\bar{p}_i^{\text{trans}}(c) = c + \frac{1-c}{K_i}, \qquad \Longrightarrow \qquad \tau_i^{\text{trans}} = 1 - \frac{1}{K_i}.$$

- Unit demand: incidence depends only on the eq′m margin dist.

Unit-demand transaction-weighted pass-through

$$\tau_i^{\text{trans}} = 1 - \frac{1}{K_i}.$$

- $1/K_i$: the harmonic mean of the firm's normalized margins.
- $\Rightarrow$ Low-margin transactions get a lot of weight.
- $\Rightarrow$ A lot of business at low μ, K_i large & pass-through is high.
- $\Rightarrow$ A lot of business at high μ (captives), K_i low & pass-through is low.
- $\mu_i(u) \leq 1 \Rightarrow \tau_i^{\text{trans}} \in [0, 1)$.

Two Markets W/ Price Dispersion

Gasoline markets

- Nearby stations often charge different prices for the same product.
- (Heterogeneous) search: drivers differ in how many stations they compare.
- Empirical lit. documents significant heterogeneity:
  - Marion and Muehlegger (2011): pass-through of state fuel taxes varies with supply conditions.
  - Stolper (2017): station level pass-through varies with local competition and spatial isolation.
  - Montag et al. (2023): heterogeneity at the *consumer* level. Informed ("shoppers") face higher pass-through than uninformed consumers.

Gas markets

- Consistent w/ our theory: differences in consideration patterns $\Rightarrow$ different eq′m margins $\Rightarrow$ different pass-through rates even with identical demand.
- Competitive locations $\Rightarrow$ lower margins (dominance of quantiles); and, under moderate curvature ($\phi_c \downarrow$ in μ), higher pass-through.
- Isolated / captive locations $\Rightarrow$ higher margins and more absorption of cost shocks.
- Mkts. w/ more price-comparing consumers (dominance of quantiles) have higher aggregate pass-through when demand ($x(\cdot)$) is not too convex.
  - E.g., unit demand: $\tau^{\text{trans}} = 1 - 1/K$.

Online retail & platforms

- Search rankings, recommendations, and sponsored listings determine who gets considered.
- Useful data: clicks/impressions/rankings are natural consideration proxies.
- A platform fee is just a cost shock in the model.
- A change in visibility (λ) moves the competition layer; a fee change moves the curvature layer.
- More exposure ($\lambda \uparrow$, showing more options) lowers margins and, when demand is not too convex, raises pass-through.
- More curation ($\lambda \downarrow$) creates captive segments, raising margins and lowering pass-through.

Online retail & platforms

- Heim (2021): links search behavior to pass-through.
- On price-comparison sites, pass-through of input costs falls with consumer search intensity.
- More search changes consideration $\Rightarrow$ changes the equilibrium margin distribution and where consumers transact within it.
- Curvature then determines the sign.
- Under unit or linear demand, lower-margin transactions have higher pass-through; w/ sufficiently convex demand, the sign can reverse, consistent with Heim.

Conclusion

Also in the paper

1. Robust bounds: (quantile) pass-through bounds for demand families.
2. More on quantile pass through.
3. More comparative statics.
4. Mergers: $\alpha \mapsto \alpha'$ shifts eq margin distribution; ϕ then maps that shift into post-merger prices and pass-through.
5. Endogenous consideration and general-equilibrium pass-through.

Takeaways

$$\text{Pass-through} = \underbrace{\text{competition layer}}_{\text{Mkt structure} \mapsto \text{Eq dist. in NEM}} + \overbrace{\text{curvature layer}}^{\text{Margins} \mapsto_{\text{demand elasticity}} \text{Prices + pass-through}}$$

- Eq object is a *distribution of margins*, not a single markup.
- Once that distribution is known, quantile formulas, transaction-weighted incidence, & much more fall out cleanly.
- Empirically, shifts attention from only estimating demand to also measuring *consideration structure*.

$$\tau_i^{\text{trans}} = 1 - 1/K_i.$$

Thank you!