Spillovers and Redistribution through Intra-Firm Networks: The Product Replacement Channel

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Econometric Society Winter Meeting, Poster Presentation (Full Version Slide)
December 31, 2020
Motivation

Q. How do regional shocks spill over across regions & reshape regional welfare?

- A long-standing question in macro/trade, relevant in within-county contexts
  e.g., A sudden differential collapse in local housing markets in Great Recession

⇒ regional conditions spill over through various networks and reshape regional inequality
This Paper

Q. How do regional shocks spill over across regions & reshape regional welfare?

- A long-standing question in macro/trade, relevant in within-county contexts
  e.g., A sudden differential collapse in local housing markets in Great Recession

This Paper

- **Intra-firm networks** of producers who sell in multiple counties/states
  ⇒ important firms, but ambiguous direction of spillovers

- **Empirics**: provide causal evidence of within-firm regional spillovers and identify a novel mechanism behind

- **Model**: formalize the mechanism & discuss aggregate implications
Summary: Empiric

By exploiting a detailed micro-data & sudden differential $\downarrow$ in local house prices in 07-09,
(1) Firm’s local sales decrease w.r.t. not only direct local demand shock but also firm’s average indirect local demand shock originating in its other markets.
(2) **Why?** Such *spillover* driven by *extensive margin response* from product replacement (while *direct local shock* $\Rightarrow$ *intensive margin* from continuing products)
Summary: Empiric

(2) **Why?** Product replacements typically *synchronized across many markets*

- Shocks hitting other mkts induce product replacement even in “not hit” mkt
- Firms *downgrade products* (organic→non-organic, expensive→cheap etc.)

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<thead>
<tr>
<th>Firm’s Sales from Region r’</th>
<th>Firm’s Sales from Region r”</th>
<th>Firm’s Sales from Region r′′′</th>
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<tbody>
<tr>
<td><strong>Negative Shock</strong></td>
<td>Firm’s Decision</td>
<td>Why?</td>
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<td>Continuing Products (Intensive)</td>
<td>△Sales Decomposition</td>
<td>Exit of High-valued Products &amp; Entry of Low-valued Products in Multiple Markets including Region r</td>
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<td>Replacement of Products (Extensive)</td>
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Delta Sales Decomposition
Summary: Empirical Results - Some Remarks

1. What are real world examples of synchronized product replacements?
   - Kraft Foods Inc. produces both organic and non-organic cheese

   (a) Organic Cheese
   (b) Non-organic Cheese

   - Organic: sold in 11 states in 2007, exited all the states in 2009
   - Non-organic: uniformly entered in the same states
   - Despite a large variation in regional shocks: -5% (PA) to -23% (MD)

2. We address potential endogeneity concerns in depth
**Summary: Theory**

**Empiric:** replacing high- to low- value products, which are synchronized across many markets

(2) **Mechanism**

A. producers facing negative demand shocks lower their product quality
   - because of the (i) scale effect and (ii) non-homotheticity

B. in doing so, they do it in multiple markets simultaneously
   - because of the local-firm-specific fixed cost of product replacement

(3) **Implication:** mitigates the regional consumption inequality

- many regions face the same quality goods: a novel redistribution mechanism
- \( \text{std(consumption growth)} \downarrow \) by 30% w/ our mechanism, \( \approx \$400 \) per HH
Related Literature

Networks, Spillovers, and Macroeconomy
- **Multi-Market**: Berman et al. 15, Ahn & Mcquoid 17, Almunia et al. 18, Erbahar 18
- **Multi-Establishment**: Carvino & Levchenko 17, Gilbert 18, Giroud & Mueller 19
- **Trade & Supply Chain**: di Giovanni & Levchenko 10, Acemoglu et al. 16, Stumpner 17, Caliendo et al. 18, Arkolakis et al. 18, Auerbach et al. 19, Boehm et al. 19
- **Banking Networks** (Acemoglu et al. 15, Gilje et al. 16, Mitchener & Richardson 19); **Migration** (House et al. 18); **Social Networks** (Bailey et al. 18)

Housing Market Collapse and the Great Recession
- Mian et al. 13, Mian & Sufi 14, Stroebel & Vavra 19, Kaplan et al. 16, Giroud & Mueller 17, Beraja et al. 19

Variety/Quality Changes & Distributional Implications
- Broda & Weinstein 10, Schmitt-Grohe and Uribe 12, Nakamura & Steinsson 12, Hottman et al. 16 Dingel 17, Jaimovich et al. 17, Argente et al. 18, Jaravel 18, Medina 20, Faber & Fally 20

Business Cycle Comovement
- Backus et al. 92, Frankel & Rose 98, Kose & Yi 06, Johnson 14, Liao & Santacreu 15, Cravino & Levchenko 17, di Giovanni et al. 18

Regional Risk-Sharing/Redistribution
- Asdrubali et al. 96, Lustig & Van Nieuwerburgh 10, Hurst et al. 16

Uniform Pricing in Retail Sector
- DellaVigna and Gentzkow 17, Cavallo 18, Hitsch et al. 19
Outline

1. Data and Regression Specification
2. Empirical Results: Regional Spillovers
3. Model and Implication: Regional Redistribution
4. Conclusion
Data

**Barcode-Region level Price and Quantity**: ACNielsen Retail Scanner
- covers \( \approx 2.6 \) million product prices and quantities,
  - (e.g. cherry-flavored 500ml diet coke in New York county)
- from \( \approx 35,000 \) participating stores

**Producer Information**: GS1, NETS
- producer name (e.g. Coca Cola), industry code, establishment location, credit rating

**Regional Housing Prices**: Zillow database
- county- and state-level median housing prices
Variables

Dependent Variables

- \( \tilde{\Delta}S_{rf} \equiv \left( \frac{\text{Sale}_{rf,09} - \text{Sale}_{rf,07}}{\text{Sale}_{rf}} \right) \): region-firm level sales growth in 2007-09

- **Sales Growth Exact Decomposition:**

  \[
  \tilde{\Delta}S_{rf} = \tilde{\Delta}S_{rf}^C + \tilde{\Delta}S_{rf}^R
  \]

  - intensive margin
  - extensive margin

Indirect Shock

- \( \tilde{\Delta}H_{Pr} \equiv \left( \frac{\text{HP}_{r,09} - \text{HP}_{r,07}}{\text{HP}_{r}} \right) \): regional house price growth in 2007-09

- **Indirect Shock:** firm’s average local demand shock from other regions

  \[
  \tilde{\Delta}H_{Pr} \text{ (other)} \equiv \sum_{r' \neq r} \omega_{r'f} \times \tilde{\Delta}H_{Pr'}
  \]

  where \( \omega_{r'f} \equiv \frac{\text{Sale}_{r'f,07}}{\sum_{r' \neq r} \text{Sale}_{r'f,07}} \) is the leave-out initial sales share weight

- **Also consider similarly constructed IVs**
Construction of Indirect Shock

Firm f’s “Indirect Shock” affecting Region A

Region A

\[ \tilde{\Delta}H_P_{A,f} \text{ (other)} = \frac{1}{3} \tilde{\Delta}H_P_B + \frac{2}{3} \tilde{\Delta}H_P_C \]

Region B

Sale_{B,f,07} = 100

\[ \tilde{\Delta}H_P_B \]

Region C

Sale_{C,f,07} = 200

\[ \tilde{\Delta}H_P_C \]
Empirical Specification

\[ \tilde{\Delta}S_{rf} = \beta_0 + \delta_s + \beta_1 \tilde{\Delta}HP_r + \beta_2 \tilde{\Delta}HP_{rf} \text{ (other)} + \text{Controls}_{rf} + \varepsilon_{rf} \]

where \( r \): region (county/state), \( f \): firm, \( \tilde{\Delta}X \): growth rate of \( X \) in 07-09
\( \delta_s \): primary sector FE

- \( \beta_2 \): the effect of regional shocks hitting other markets of firm \( f \)
  - conditional on direct local demand
  - A priori \( \beta_2 \leq 0 \) \( \Rightarrow \) We get \( \beta_2 > 0 \)

- \( \beta_1 \): the effect of direct regional shock in region \( r \)
  - Similar to Mian et al. (13), Kaplan et al. (16) \( \Rightarrow \) We expect \( \beta_1 > 0 \)
Empirical Specification

\[ \tilde{\Delta}S_{rf} = \beta_0 + \delta_{rs} + \beta_2 \tilde{\Delta}HP_{rf} \text{ (other)} + \text{Controls}_{rf} + \varepsilon_{rf} \]

where \( r \): region (county/state), \( f \): firm, \( \tilde{\Delta}X \): growth rate of \( X \) in 07-09
\( \delta_{rs} \): region \( \times \) sector FE

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- A priori \( \beta_2 \leq 0 \Rightarrow \) We get \( \beta_2 > 0 \)

- \( \beta_1 \): the effect of direct regional shock in region \( r \)
  - Similar to Mian et al. (13), Kaplan et al. (16) \( \Rightarrow \) We expect \( \beta_1 > 0 \)
  - Also consider region \( \times \) sector FE instead of including \( \tilde{\Delta}HP_r \)
Key Identifying Assumption

\[ \tilde{\Delta}S_{rf} = \beta_0 + \delta_s + \beta_1 \tilde{\Delta}HP_r + \beta_2 \tilde{\Delta}HP_{rf} \text{ (other)} + \text{Controls}_{rf} + \varepsilon_{rf} \]

Any confounding factor that affects firm’s local sales growth does not simultaneously affect its other market house price growth.
Key Identifying Assumption

\[ \Delta S_{rf} = \beta_0 + \delta_s + \beta_1 \Delta H P_r + \beta_2 \Delta H P_{rf} \text{ (other)} + \text{Controls}_{rf} + \epsilon_{rf} \]

Any confounding factor that affects firm’s local sales growth does not simultaneously affect its other market house price growth

Threats to identification

- Common or clustered regional shocks?

- Alternative channels?
Outline

1 Data and Regression Specification

2 Empirical Results: Regional Spillovers

3 Model and Implication: Regional Redistribution

4 Conclusion
Summary of Empirical Results

Overview of Empirical Results

Negative Shock

Firm’s Sales from Region r’
Firm’s Sales from Region r”
Firm’s Sales from Region r””

Firm’s Decision

Firm’s Sales from Region r
Visualization

\[ \tilde{\Delta} S_{rf} = \beta_0 + \delta_s + \beta_1 \tilde{\Delta} H P_r + \beta_2 \tilde{\Delta} H P_{rf} \text{(other)} + \text{Controls}_{rf} + \varepsilon_{rf} \]

Local sales respond to both direct and indirect shocks

Scatter plots (25 bins based on ventiles) depicting the relationship between (residualized) \( \tilde{\Delta} S_{rf} \) and either \( \tilde{\Delta} H P_r \) or \( \tilde{\Delta} H P_{rf} \) (other), where each point is the sales-weighted average across obs. within each bin. We use Frisch-Waugh theorem to tease out the effect.
Local sales respond to both direct and indirect shocks

$$\Delta S_{rf} = \beta_0 + \delta_s + \beta_1 \Delta H P_r + \beta_2 \Delta H P_{rf \ (other)} + \text{Controls}_{rf} + \varepsilon_{rf}$$

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<tr>
<td>Ordinary Least Square</td>
<td>$\Delta S_{rf}$, 2007-2009</td>
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<tr>
<td>$\Delta H P_r$</td>
<td>0.06** (0.03)</td>
<td>0.06** (0.03)</td>
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<tr>
<td>$\Delta H P_{rf \ (other)}$</td>
<td>0.35*** (0.11)</td>
<td>0.34*** (0.12)</td>
<td>0.40*** (0.10)</td>
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<td>0.61</td>
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<tr>
<td>$R^2$</td>
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<td>840,681</td>
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Local sales respond to both **direct** and **indirect** shocks

\[ \tilde{\Delta}S_{rf} = \beta_0 + \delta_S + \beta_1 \tilde{\Delta}HP_r + \beta_2 \tilde{\Delta}HP_{rf} \text{ (other)} + \text{Controls}_{rf} + \varepsilon_{rf} \]

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### Placebo Test

**Placebo Networks:** (1) Alternative weights; (2) Alternative regions

#### Placebo Tests

<table>
<thead>
<tr>
<th>Alternative measures of $\tilde{\Delta} HP_{rf}$ (other) using $\tilde{\Delta} S_{rf}$, 2007-2009</th>
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<td>equal</td>
<td>pop.</td>
<td>inc.</td>
<td>debt</td>
<td>entry</td>
<td>plant</td>
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<td>$\tilde{\Delta} HP_{rf}$ (other)</td>
<td>0.13</td>
<td>0.03</td>
<td>0.11</td>
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| Region-Firm Controls | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Sector x Region FE | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Observations | 840,681 | 840,681 | 840,681 | 835,778 | 833,290 | 704,809 | 840,681 |

*Note.  * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$; We consider seven alternative constructions of the indirect demand shock. We use different initial weights: the equal is equal weight, the pop. is population weight, the inc. is household median income weight, and the debt is the household debt-to-income weight. The entry is the weight that still uses 2007 sales but replaces to zero if the 2006 sales are non-zero, and the plant weight is based on the firms’ establishment network. In the random specification, we randomly allocate markets for each firm, measure the indirect demand shock, and estimate the coefficient; we repeat the procedure 1000 times and report the average estimates.*
## Placebo Test

### Placebo Networks: (1) Alternative weights; (2) Alternative regions

#### Placebo Tests

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<td>( \Delta HP_{rf} ) (other) using equal weights</td>
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Summary of Empirical Results

Overview of Empirical Results

Firm's Sales from Region $r'$
Firm's Sales from Region $r''$
Firm's Sales from Region $r'''$

Firm’s Decision

Why?

Continuing Products (Intensive)
Replacement of Products (Extensive)

Δ Sales Decomposition

Negative Shock

No Effect
Local sales respond to both direct and indirect shocks

\[
\tilde{\Delta}S_{rf} = \beta_0 + \delta_s + \beta_1 \tilde{\Delta}HP_r + \beta_2 \tilde{\Delta}HP_{rf} \text{ (other)} + \text{Controls}_{rf} + \varepsilon_{rf}
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<tr>
<td>(\tilde{\Delta}S_{rf})</td>
<td>(\beta_0)</td>
<td>(\delta_s)</td>
<td>(\beta_1)</td>
<td>(\beta_2)</td>
<td>(\varepsilon_{rf})</td>
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<tr>
<td>(\Delta HP_r)</td>
<td>0.059**</td>
<td>0.051**</td>
<td>0.009</td>
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<td>(0.028)</td>
<td>(0.024)</td>
<td>(0.014)</td>
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<tr>
<td>(\tilde{\Delta}HP_{rf} \text{ (other)})</td>
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<td>0.025</td>
<td>0.320***</td>
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<td>(0.110)</td>
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Direct effect works through the intensive margin

\[
\tilde{\Delta}S_{rf} = \beta_0 + \delta_s + \beta_1 \tilde{\Delta}HPr + \beta_2 \tilde{\Delta}HP_{rf} \text{ (other)} + \text{Controls}_{rf} + \varepsilon_{rf}
\]

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<tr>
<td>(\tilde{\Delta}HP_{rf} \text{ (other)})</td>
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Spillover effect works through the extensive margin

\[ \tilde{\Delta}S_{rf} = \beta_0 + \delta_s + \beta_1 \tilde{\Delta}HP_r + \beta_2 \tilde{\Delta}HP_{rf} \text{ (other)} + \text{Controls}_{rf} + \varepsilon_{rf} \]

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Spillover effect works through the extensive margin ⇒ robust to county x sector FE

\[ \tilde{\Delta}S_{rf} = \beta_0 + \delta_{rs} + \beta_2 \tilde{\Delta}H\!P_{rf} \text{ (other)} + \text{Controls}_{rf} + \varepsilon_{rf} \]

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<td>(\tilde{\Delta}S_{rf})</td>
<td>\text{0.398***}</td>
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Spillover effect works through the extensive margin through products replaced in multiple markets

\[ \tilde{\Delta} \Sigma_{rf} = \beta_0 + \delta_{rs} + \beta_2 \tilde{\Delta} HP_{rf} \text{ (other)} + \text{Controls}_{rf} + \varepsilon_{rf} \]

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<tr>
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<th>(1) (\tilde{\Delta} \Sigma_{rf})</th>
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Summary of Empirical Results

Overview of Empirical Results

Firm’s Sales from Region $r'$
Firm’s Sales from Region $r''$
Firm’s Sales from Region $r'''$

Firm’s Decision

Negative Shock

Continuing Products (Intensive)

Replacement of Products (Extensive)

ΔSales Decomposition

No Effect

Why?

Exit of High-valued Products & Entry of Low-valued Products in Multiple Markets including Region $r$
Spillover effect works through the extensive margin through products replaced in multiple markets from high- to low-valued products

\[ \tilde{\Delta}v_{rf} = \beta_0 + \delta_{rs} + \beta_2 \tilde{\Delta}HP_{rf} \text{ (other)} + \text{Controls}_{rf} + \epsilon_{rf} \]

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<td>[ \tilde{\Delta}v_{rf} \equiv \frac{v_{rf,09}^{\text{enter}} - v_{rf,07}^{\text{exit}}}{\bar{v}_{rf}} ]</td>
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where \( v_{rf} = \) sale per upc, price, price \(^{\text{group-adj.}}\), organic sale, \# of upc

\[ \tilde{\Delta}HP_{rf} \text{ (other)} \]

0.52**
(0.21)

0.92**
(0.44)

0.70**
(0.34)

43.78**
(17.88)

-0.06
(0.17)

region x sector FE: ✓ ✓ ✓ ✓ ✓
region-firm controls: ✓ ✓ ✓ ✓ ✓
R-squared: 0.40 0.41 0.42 0.38 0.40
Observations: 464,423 461,672 461,672 27,930 464,423

Note. For organic share, we use state as a unit of region.
Spillover effect works through the extensive margin through products replaced in multiple markets ⇒ not through simple reduction of variety

\[ \tilde{\Delta}v_{rf} = \beta_0 + \delta_{rs} + \beta_2 \tilde{\Delta}HP_{rf\,(\text{other})} + \text{Controls}_{rf} + \varepsilon_{rf} \]

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Note. For organic share, we use state as a unit of region.
Key Identifying Assumption: Further Robustness Check

\[ \tilde{S}_{rf} = \beta_0 + \delta_s + \beta_1 \tilde{HP}_r + \beta_2 \tilde{HP}_{rf} \text{ (other)} + \text{Controls}_{rf} + \varepsilon_{rf} \]

Any confounding factor that affects firm’s local sales growth does not simultaneously affect its other market house price growth.

Threats to identification

- Common or clustered regional shocks?
  - \( \tilde{HP}_{rf} \text{ (other)} \): exclude nearby counties
  - state-firm-level regression

- Alternative channels?
  - supply-side/collateral channel? \( \Rightarrow \tilde{HP}_{rf} \text{ (other)} \): exclude regions with plants
  - not driven by retailer
  - not driven by clientele effect
  - and many others ...

Further Results

- Heterogeneous treatment effect
Outline

1 Data and Regression Specification

2 Empirical Results: Regional Spillovers

3 Model and Implication: Regional Redistribution

4 Conclusion
Model Setup

**Purpose:** Formalize spillover mechanism & discuss aggregate implication

**Multi-region model with endogenous quality-adjustments by firms**

⇒ A parsimonious extension of Melitz 03 and Faber & Fally 20

D: Each region $r \in R$ has representative HH with exogenous income

S: Monopolistic competitive firms facing these HHs (multi-market) choose (i) price and (ii) product attribute or “quality”
Model Setup

Purpose: Formalize spillover mechanism & discuss aggregate implication

⇒ Two key mechanisms to match the empirical finding
(1) producers facing negative demand shocks lower their product quality
   - scale effect: Firms’ fixed cost increases with product quality
   - nonhomotheticity: HHs switch from high- to low-quality if income decreases
(2) firms choose uniform product quality across markets
   - can endogenize such assumption

⇒ Empirics

firms facing negative demand shocks decrease sales
by replacing high-valued products with low-valued products
in multiple markets simultaneously
Model Setup

**Purpose:** Formalize spillover mechanism & discuss aggregate implication

⇒ **Two key mechanisms** to match the empirical finding

(1) producers facing negative demand shocks lower their product quality
   - scale effect: Firms’ fixed cost increases with product quality
   - nonhomotheticity: HHs switch from high- to low-quality if income decreases

(2) firms choose uniform product quality across markets
   - can endogenize such assumption

⇒ **Further simplifying assumptions** to reduce “dimension” of the model

- Static model ⇒ compare static equilibrium with pre- vs. post-shock periods
- Each firm produces a single product (i.e. product bundle) ⇒ product attribute (intrinsic quality) change involves product replacement
Model Summary

(1) (Lower-tier) utility for CPG:

\[ U_r = \left[ \int_{f \in G_r} \left( q_{rf} \zeta_{rf} \right)^{\frac{\sigma-1}{\sigma}} \sigma \, df \right]^{\frac{\sigma}{\sigma-1}} \]

* \( \zeta_{rf} \equiv (\phi_f)^{\gamma_r} \): “perceived” product quality of firm \( f \) in region \( r \)

\( \phi_f \): uniform intrinsic product quality & \( \gamma_r \equiv \gamma(\text{Income}_r) \), \( \gamma'(\cdot) > 0 \): nonhomothetic

(2) Profit maximization problem under **uniform quality**:

\[
\max_{\phi_f, \{p_{rf}\}_r} \pi_f = \sum_r \left[ p_{rf} - mc(\phi_f; a_f) \right] Q_{rf} - \left[ f(\phi_f) + f_0 \right]
\]

\[
s.t. \; S_{rf} = \phi_f^{\gamma_r(\sigma-1)} (p_{rf} / P_r)^{1-\sigma} \; \text{Sales}_r
\]

* scale effect in fixed cost: \( f(\phi_f) \equiv b \beta \phi_f^{\frac{1}{\beta}} \); marginal cost \( mc(\phi_f; a_f) \equiv \frac{\phi_f^{\xi}}{a_f} \)

(c.f.) Profit maximization problem under **market-specific quality**:

\[
\max_{\{\phi_{rf}, p_{rf}\}_r} \pi_f^m = \sum_r \left[ [p_{rf} - mc(\phi_{rf}; a_f)] Q_{rf} - [f^m(\phi_{rf}) + f_{0r}^m] \right]
\]
Structural Equation: Intra-Firm Market Inter-Dependency

Region-Firm Sales Growth: Scale Effect and Non-homotheticity

\[ \Delta S_{rf} = \gamma_r \sum_{r'} \omega_{r'f} [\Delta S_{r'f} + \Delta (\gamma_{r'} - \xi)] + \text{other terms}_{rf} \]

where

\[ \gamma_r \approx \beta \times (\sigma - 1)(\gamma_r - \xi) \]

\( \gamma_r \): sales or preference in \( r' \) ⇒ quality of \( f \) \n\( \beta \): inverse elasticity of fixed cost w.r.t. quality, \( f(\phi_f) \equiv b \beta^{\frac{1}{\beta}} \phi_f \)
\( \sigma \): demand elasticity
\( \gamma_r \): how much households value the quality, \( \zeta_{rf} \equiv (\phi_f)^{\gamma_r} \)
\( \xi \): elasticity of marginal cost w.r.t. quality (pass-through to price), \( mc(\phi_f; a_f) = \frac{\phi_f^{\xi}}{a_f} \)
Real Consumption Growth

**Benchmark**: uniform quality across markets, \( \text{std}(\tilde{\Delta} U_r) = 4.0 \)

*Example*: Florida: real consumption growth = \(-14.8\%\), house price growth = \(-43.2\%\)
Oklahoma: real consumption growth = \(-0.4\%\), house price growth = \(+3.3\%\)
Real Consumption Growth

- **Counterfactual**: state-specific quality, std($\Delta U_r$) = 5.2
- From counterfactual to benchmark: std ↓ 30% ≈ $400 per HH redistribution

**e.g.** Florida: real consumption growth = **-17.2%** (-14.8% in baseline)

Oklahoma: real consumption growth = **+1.4%** (-0.4% in baseline)

More
Conclusion

New Empirical Findings: Regional Spillovers and behind Mechanism

- regional shocks spill over through the intra-firm networks created by multi-market firms
- by replacing high-valued products with low-valued products in multiple markets simultaneously

Model and Implication: Regional Redistribution (Risk-Sharing)

- quality downgrading through product replacement
- mitigates the regional consumption inequality
Thank you!