Consumer Surplus from Suppliers: How Big is it and Does it Matter for Growth?

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Importance of Consumer Surplus

- Widely believed: individual suppliers generate surplus for their consumers.
- i.e., there is positive area under the demand curve above the price.
- This surplus can motivate trade and can fuel growth.
- Paper seeks to quantify surplus for customers and its importance for aggregate growth.
- Make progress by focusing on firms as “consumers” buying inputs from suppliers.
- Advantage is that output observable but utility is not (arbitrary cardinalization).

What We Do

- **Micro**: How big is downstream firm's buyer surplus from suppliers?
  - Define statistic $\delta = \frac{\text{consumer surplus from supplier}}{\text{expenditures on supplier}}$.
    - Matters in models with an extensive margin (growth, trade, network formation).
    - Typically estimated by extrapolating & integrating functional form for demand curve.
  - Our approach: δ is elasticity of downstream firms' unit cost to entry & exit of suppliers.
  - Estimate δ using detailed Belgian firm panel data.

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  - Our approach: δ is elasticity of downstream firms' unit cost to entry & exit of suppliers.
  - Estimate δ using detailed Belgian firm panel data.
- **Finding:** supplier separations $\uparrow$ costs of production for downstr. firms, additions $\downarrow$ cost.

  1% variable cost share of suppliers exit (enter) $\implies$ unit cost rises (falls) by $\approx$ 0.3 p.p.

  Reject perfect competitive benchmark of $\delta = 0$ (Makowski-Ostroy 2001).

What We Do

- **Macro:** How much of *measured* productivity growth due to supplier churn?
  - Growth accounting with extensive margin for supplier additions & separations. (w/o fully specified model for counterfactuals).
  - Surplus propagates downstream to buyers, buyers' buyers, eventually final consumers.
  - Apply to broader firm-firm network, extrapolating micro estimates.
- **Finding:** About half of aggregate productivity growth in 2002-2018 (0.5 p.p. per year) can be accounted for by churn in supply chain — of this, $1/4$ from supplier birth, death.

Selected Literature

- **Expanding varieties and Schumpeterian models of entry and exit**
  Krugman (1979), Romer (1987), Aghion-Howitt (1991), Grossman-Helpman (1993), Melitz (2003), Bilbiie-Ghironi-Melitz (2005), Matsuyama-Ushchev (2020), Akcigit-Kerr (2018), Zhelobodko-Kokovin-Parenti-Thisse (2012), Baqaee-Farhi-Sangani (2020), Garcia-Hsieh-Klenow (2019), Dhingra-Morrow (2019), Baqaee-Farhi (2021), Grossman-Helpman-Lhullier (2023).

- **Production networks and extensive margin**
  Oberfield (2018), Baqaee (2018), Lim (2017), Miyauchi (2018), Acemoglu-Azar (2019), Huneeus (2020), Acemoglu-Tahbaz-Salehi (2020), Arkolakis-Huneeus-Miyauchi (2021), Bernard et. al. (2022).

- **Price indices with entry and exit, “unmeasured” growth, new goods**
  Feenstra (1994), Hausman (1996), Nevo (2003), Broda-Weinstein (2006), Hottman-Redding-Weinstein (2016), Feenstra-Weinstein (2017), Aghion-Bergeaud-Boppart-Klenow (2019), Foley (2022).

- **Input varieties & productivity**
  De Loecker et al. (2016), Amiti-Konings (2007), Gopinath-Neiman (2014), Halpern-Koren-Szeidl (2015), Blaum-Lelarge-Peters (2018).

Agenda

Microeconomic Analysis

Macroeconomic Analysis

Summary

Agenda

Microeconomic Analysis

Macroeconomic Analysis

Summary

Setup

- Downstream firm has constant-returns production function (after paying any overhead), with variable cost:

  $$C(\boldsymbol{p}, A, q) = mc(\boldsymbol{p}, A)q,$$

  where $\boldsymbol{p}$ is price of inputs, A is technology.

- If an input is unavailable, it's as-if the price is infinite.

- Continuum of inputs, grouped into types J.

- Cost function symmetric across inputs within each type.

Input Demand

- Demand for input of type J:

$$x_J(\boldsymbol{p}, A, q) = \frac{\partial C(\boldsymbol{p}, A, q)}{\partial p_J}.$$

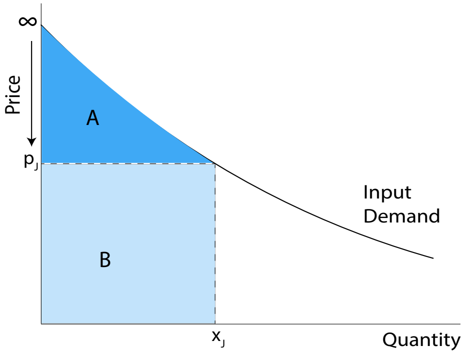
- "Consumer" surplus ratio is

$$\delta_J(p) = \frac{\int_p^\infty x_J(\xi)d\xi}{p x_J(p)} \geq 0.$$

  Area under input demand curve above price relative to spending.

- δ is not total surplus — it is surplus per unit of expenditures.

Consumer Surplus Ratio



- Graphically:

$$\delta_J = \frac{A}{B}.$$

Key Result

Perturb input prices $\Delta \boldsymbol{p}$, measure of available inputs $\Delta \boldsymbol{M}^{add}$ and $\Delta \boldsymbol{M}^{sep}$, technology ΔA.

$$\Delta \log mc \approx \underbrace{\sum_J \Omega_J M_J \Delta \log p_J}_{\text{marginal changes}} - \underbrace{\sum_J \delta_J \Omega_J \Delta M_J}_{\text{inframarginal changes}} + \underbrace{\frac{\partial \log \mathcal{C}}{\partial \log A} \Delta \log A}_{\text{own technology}}.$$

- $\Omega_J = \frac{p_J x_J}{\text{total variable cost}}$ is per-variety expenditure share of J.
- $\Delta M_J = \Delta M_J^{add} - \Delta M_J^{sep}$ is net change in mass of available inputs.
- $\Omega_J \Delta M_J$ is expenditure share on net additions of input J.

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- $\Omega_J = \frac{p_J x_J}{\text{total variable cost}}$ is per-variety expenditure share of J.
- $\Delta M_J = \Delta M_J^{add} - \Delta M_J^{sep}$ is net change in mass of available inputs.
- $\Omega_J \Delta M_J$ is expenditure share on net additions of input J.
- No first order effects from "smooth" additions and separations.
- Illustrate intuition using some examples.

Sketch of Proof (focus on separations)

- Define input price function for varieties of type J:

$$p_J(j) = \begin{cases} p_J^0 & j < M_J - M_J^{sep} \\ p_J^1 & j \in [M_J - M_J^{sep}, M_J] \\ \infty & j > M_J \end{cases}.$$

- Consider change in $mc(p_J^0, M_J, p_J^1, M_J^{sep})$ as p_J^1 rises from p_J^0 to ∞.

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- Consider change in $mc(p_J^0, M_J, p_J^1, M_J^{sep})$ as p_J^1 rises from p_J^0 to ∞.
- Shephard's lemma + Fundamental theorem of calculus + symmetry of cost function:

$$\log mc(p_J^0, M_J, \infty, M_J^{sep}) = \log mc(p_J^0, M_J, p_J^0, M_J^{sep}) + M_J^{sep} \int_{p_J^0}^{\infty} \Omega_J(p_J^0, M_J, \xi, M_J^{sep}) d \log \xi.$$

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- Differentiating with respect to M_J^{sep} around $M_J^{sep} = 0$:

$$d \log mc \approx dM_J^{sep} \int_{p_J^0}^{\infty} \Omega_J(p_J^0, M_J, \xi, 0) d \log \xi = dM_J^{sep} \int_{p_J^0}^{\infty} \frac{x_J(p_J^0, M_J, \xi, 0)}{\mathcal{C}(p_J^0, M_J, \xi, 0)} d\xi$$

$$= dM_J^{sep} \Omega_J \frac{\int_{p_J^0}^{\infty} x_J(p_J^0, M_J, \xi, 0) d\xi}{p_J^0 x_J(p_J^0, M_J, p_J^0, 0)} = dM_J^{sep} \Omega_J \delta_J .$$

Sketch of Proof (additions and marginal price changes)

- Define input price function for varieties of type J:

$$p_J(j) = \begin{cases} p_J^0 & j < M_J - M_J^{sep} \\ p_J^1 & j \in [M_J - M_J^{sep}, M_J + M_J^{add}] \\ \infty & j > M_J + M_J^{add} \end{cases}.$$

- For additions, consider change in marginal cost as p_J^1 goes from p_J^0 to ∞. Approximate this as M_J^{add} rises and evaluate at $M_J^{add} = M_J^{sep} = 0$.

- For smooth (marginal) consider change in marginal cost in response to changes in p_J^0 and evaluate at $M_J^{add} = M_J^{sep} = 0$.

- Proposition extends to $\boldsymbol{p}(\boldsymbol{x})$, where $\boldsymbol{p}(\boldsymbol{x})$ is homogeneous of degree zero in $\boldsymbol{x}$.
- Consumer-surplus ratio is

$$\delta_J = \frac{\int_1^\infty x_J(\xi p_J(\cdot))d\xi}{p_J x_J}.$$

Example I: CES with Expanding Varieties

- For CES, as long as $\sigma > 1$:

$$\delta_J = \frac{\int_{p_J}^{\infty} x_J(\xi) d\xi}{p_J x_J} = \frac{1}{\sigma - 1}, \quad \text{“love-of-variety.”}$$

- Expanding varieties:

$$\Delta \log mc \approx -\Omega_J \Delta M_J \delta_J = -\Omega_J \Delta M_J \frac{1}{\sigma - 1}.$$

- In general, δ_J is complicated reduced form (like price elasticity or pass-through).

Example II: Heterogenous but constant δ

- Suppose cost function is (Matsuyama & Uschev, 2022):

$$1 = \sum_J M_J \frac{\omega_J}{\sigma_J - 1} \left(\frac{p_J}{mc} \right)^{1-\sigma_J} .$$

- In this case,

$$\delta_J = \frac{\int_{p_J}^{\infty} x_J(\xi) d\xi}{p_J x_J} = \frac{1}{\sigma_J - 1} .$$

- Surplus heterogenous across types but constant for each type.

Example III: variable δ under Marshall's Second Law

Outside of CES, δ not simple function of σ. Price elasticity is

$$\sigma_J(\boldsymbol{p}) = -\frac{\partial \log x_J(\boldsymbol{p})}{\partial \log p_J} > 1.$$

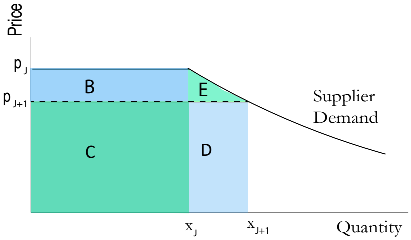
If Marshall's second law of demand holds ($\frac{\partial \sigma_J}{\partial p_J} \geq 0$), then

$$\delta_J(\boldsymbol{p}) < \frac{1}{\sigma_J(\boldsymbol{p}) - 1} = \delta^{CES}(\boldsymbol{p}).$$

CES maximizes δ under Marshall's second law (if you match price elasticity).

Example IV: Quality Ladder

- CES with continuum of varieties and two types per variety charging $p_{J+1} < p_J$.



- Consumer surplus for type $J+1$ is

$$\delta_{J+1} = \frac{\int_{p_{J+1}}^{\infty} x_{J+1}(\xi) d\xi}{p_{J+1} x_{J+1}} = \frac{B+E}{C+D}.$$

- Let M be mass of $J+1$ suppliers. Proposition implies:

$$\Delta \log mc \approx -\Delta M \Omega_{J+1} \delta_{J+1}$$

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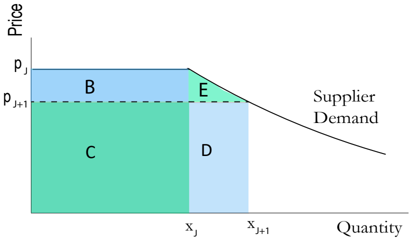

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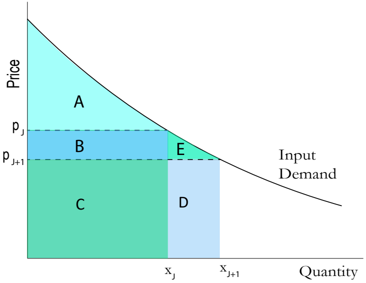
- Let M be mass of $J+1$ suppliers. Proposition implies:

$$\Delta \log mc \approx -\Delta M \Omega_{J+1}\delta_{J+1} = -\Delta M \Omega_{J+1}\left(1 - \left(\frac{p_J}{p_{J+1}}\right)^{1-\sigma}\right)\frac{1}{\sigma - 1}.$$

Quality Ladder as Expanding Variety

- To justify and interpret benchmark empirical specification under either class of models:
- We model movement along quality ladder as-if simultaneous addition and separation.



$$\Delta \log mc \approx -\Omega_{J+1} \frac{\int_{p_{J+1}}^{p_J} x(\xi)d\xi}{p_{J+1}x_{J+1}} \Delta M = -\Omega_{J+1} \underbrace{\frac{\int_{p_{J+1}}^{\infty} x(\xi)d\xi}{p_{J+1}x_{J+1}}}_{\delta_{J+1}^{EV}=\frac{A+B+E}{C+D}=\frac{1}{\sigma-1}} \Delta M + \Omega_J \underbrace{\frac{\int_{p_J}^{\infty} x(\xi)d\xi}{p_J x_J}}_{\delta_J^{EV}=\frac{A}{B+C}=\frac{1}{\sigma-1}} \Delta M.$$

Motivating Estimating Equation

- Rewrite proposition as:

$$\Delta \log mc_{it} \approx \bar{\delta}_{it}^{sep} \underbrace{\sum_J \Omega_{iJt} \Delta M_{iJt}^{sep}}_{\substack{\text{separation due} \\ \text{to price jump}}} - \bar{\delta}_{it}^{add} \underbrace{\sum_J \Omega_{iJt+1} \Delta M_{iJt}^{add}}_{\substack{\text{addition due} \\ \text{to price jump}}} + \underbrace{\sum_J \Omega_{iJt} M_{iJt} \Delta \log p_{Jt}}_{\text{continuing price changes}} + \underbrace{\mathcal{E}_{Ai,t} \Delta \log A_{it}}_{\text{technology}}.$$

- Average consumer surplus associated with separations and additions:

$$\bar{\delta}_{it}^{sep} = \sum_J \left(\frac{\Omega_{iJt} \Delta M_{iJt}^{sep}}{\sum_K \Omega_{iKt} \Delta M_{iKt}^{sep}} \delta_{iJt} \right), \qquad \bar{\delta}_{it}^{add} = \sum_J \left(\frac{\Omega_{iJt+1} \Delta M_{iJt}^{add}}{\sum_K \Omega_{iKt+1} \Delta M_{iKt}^{add}} \delta_{iJt} \right).$$

- Our goal is to identify $\mathbb{E}[\bar{\delta}_{it}^{sep}]$ and $\mathbb{E}[\bar{\delta}_{it}^{add}]$.

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- Our goal is to identify $\mathbb{E}[\bar{\delta}_{it}^{sep}]$ and $\mathbb{E}[\bar{\delta}_{it}^{add}]$.
- Consider regression:

$$\Delta \log mc_{it} = \hat{\delta}^{sep} \text{ separations share}_{it} - \hat{\delta}^{add} \text{ additions share}_{it} + \text{controls}_{it} + \varepsilon_{it}.$$

Measuring Marginal Cost (LHS)

- Survey of manufacturing firms with quantity & sales in Belgium (Prodcom), $\sim 3,000$ firms per year in our sample.
- $\Delta \log mc_{it} = \Delta \log$ total variable costs $- \Delta \log$ total quantity.
- total var costs = non-capital materials + 0.5 $\times$ (labor + capital).
  - non-capital materials = sales - value added reported by *i*.
  - estimated elasticity of labor + capital costs w.r.t materials, instrumented by demand ≈ 0.5
- $\Delta \log$ Prodcom quantity = Quantity Divisia by firm-PC8.
- $\Delta \log \text{total quantity} = \Delta \log \text{Prodcom quantity} + \Delta \log \frac{\text{total sales}}{\text{Prodcom sales}} + \varepsilon.$

Measuring Separation Share (RHS)

- Firm-to-firm input-output table from VAT returns (NBB B2B Transactions data).

- separation share$_{it}$ $= \frac{\text{purchases}_{it} \text{ from separating suppliers between t \& t+1}}{\text{variable costs}_{it}}$.

- addition share$_{it+1}$ $= \frac{\text{purchases}_{it+1} \text{ from added suppliers between t \& t+1}}{\text{variable costs}_{it+1}}$.

- RHS controls: $\Delta \log$ import price, $\Delta \log$ price of Prodcom suppliers, $\Delta \log$ price of i's non-Prodcom purchases using industry-level price indices, $\Delta \log$ wages, $\Delta \log$ user cost, 6-digit product $\times$ year fixed effects.

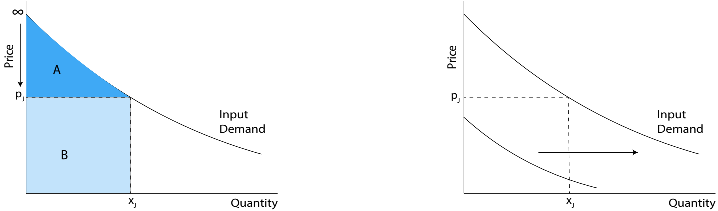
Omitted Variable Bias

- Recall theoretical equation:

$$\Delta \log mc_{it} = \bar{\delta}_{i,t}^{sep} \sum_J \Omega_{iJ,t} \Delta M_{iJ,t}^{sep} - \bar{\delta}_{i,t}^{add} \sum_J \Omega_{iJ,t+1} \Delta M_{iJ,t}^{add} + \sum_J \Omega_{iJ,t} M_{iJ,t} \Delta \log p_{J,t} + \mathcal{E}_{Ai,t} \Delta \log A_{it}.$$

- We don't observe everything on RHS, so OLS can suffer from omitted variable bias:
  - Unobserved continuing input price changes and technology shocks,
  - Separations and additions due to price jumps measured with error.

Not All Separations and Additions are Caused by Price Jumps



(a) Jump in the Price of the Input (b) Discontinuous Shift in Demand Curve

- Additions and separations due to shifts in input demand have no independent first order effect on marginal cost.
- Those due to discontinuous input demand shifts cause measurement error.

Instruments

- Instrument 1:

$$Z_{i,t}^{death} = \sum_j \Omega_{ij,t} 1(S_{j,t+1} = 0) 1 \left(p_{j,t} x_{ij,t} / S_{j,t} < \text{threshold} \right).$$

Share of i's suppliers that die between t and $t+1$ for whom i is a small customer.

- Instrument 2:

$$Z_{i,t}^{birth} = \sum_j \Omega_{ij,t+1} 1(S_{j,t} = 0) 1 \left(p_{j,t+1} x_{ij,t+1} / S_{j,t+1} < \text{threshold} \right).$$

Share of i's suppliers born between t and $t+1$ for whom i is a small customer.

Identification assumptions

- Assume that, conditional on controls (including continuing input prices, import prices, 6-digit product $\times$ year fixed effects), instruments (restricted exit/entry) mutually independent of error term in first and second stage, and $\bar{\delta}_{i,t}^{add}$ and $\bar{\delta}_{i,t}^{sep}$.

- Then estimators $\hat{\delta}^{add}$ and $\hat{\delta}^{sep}$ in regression

$$\Delta \log mc_{it} = \hat{\delta}^{sep} \text{ separations share}_{i,t} - \hat{\delta}^{add} \text{additions share}_{i,t} + \text{controls}_{it} + \varepsilon_{i,t},$$

consistently estimate $\mathbb{E}[\bar{\delta}_{i,t}^{add}]$ and $\mathbb{E}[\bar{\delta}_{i,t}^{sep}]$.

Summary Statistics Prodcom Sample of Firms

	(i)	(ii)	(iii)	(iv)	(v)	(vi)	(vii)	(viii)	(ix)	(x)	(xi)	(xii)
	Share in variable costs			Import	Service	Numb.	Share in variable costs					
	labor	capital	interm.	interm. share	interm. share	suppl.	separ-ations	addit-itions	deaths	births	deaths restricted	births restricted
mean	0.136	0.009	0.854	0.269	0.654	227	0.057	0.068	0.003	0.005	0.001	0.002
p25	0.071	0.003	0.805	0.000	0.522	112	0.022	0.026	0.000	0.000	0.000	0.000
p50	0.120	0.006	0.870	0.221	0.692	168	0.040	0.049	0.000	0.001	0.000	0.000
p75	0.184	0.012	0.922	0.469	0.815	257	0.073	0.087	0.002	0.003	0.001	0.001
count	41,980	41,980	41,980	41,980	41,980	41,980	41,980	41,980	41,980	41,980	41,980	41,980

- Share of additions and separations due to restricted birth/death are small.

Correlation of addition/separation with downstream size

	(i)	(ii)	(iii)	(iv)	(v)
	log number suppliers	separation share	addition share	restricted death share	restricted birth share
log employment	0.78	-0.23	-0.22	-0.04	-0.04
log sales	0.80	-0.30	-0.30	-0.07	-0.06

- Separation and addition shares weakly decreasing in firm size.
- Instruments uncorrelated with firm size.
- Treated downstream firms not necessarily small firms.

Estimates of δ

	(i)			
	$\Delta \log mc$	First stage	$\Delta \log mc$	$\Delta \log p$
Separation share	-0.013			
	(0.013)			
Addition share	0.016			
	(0.012)			
Restricted death share				
Restricted birth share				
Specification	OLS			
F-stat				
Controls	Y			
Industry $\times$ year FE	Y			
Observations	38,670			

Estimates of δ

	(i)				(v)	(vi)	
	$\Delta \log mc$		First stage		$\Delta \log mc$		$\Delta \log p$
Separation share	-0.013				0.279***	0.268***	
	(0.013)				(0.090)	(0.091)	
Addition share	0.016				-0.280***	-0.283***	
	(0.012)				(0.079)	(0.079)	
Restricted death share							
Restricted birth share							
Specification	OLS				IV	IV	
F-stat					115	111	
Controls	Y				N	Y	
Industry $\times$ year FE	Y				Y	Y	
Observations	38,670				38,670	38,670	

- Estimates consistent with $\delta \approx 0.28$. (e.g. CES elasticity ≈ 4.5).
- Reject perfectly competitive benchmark $\delta = 0$.

Estimates of δ

	(i)	(iii)	(iv)	(v)	(vi)	
	$\Delta \log mc$	First stage		$\Delta \log mc$		$\Delta \log p$
		Separat.	Addit.			
Separation share	-0.013			0.279***	0.268***	
	(0.013)			(0.090)	(0.091)	
Addition share	0.016			-0.280***	-0.283***	
	(0.012)			(0.079)	(0.079)	
Restricted death share		1.047***	0.290***			
		(0.052)	(0.061)			
Restricted birth share		0.377***	1.169***			
		(0.068)	(0.052)			
Specification	OLS	OLS	OLS	IV	IV	
F-stat		283	295	115	111	
Controls	Y	Y	Y	N	Y	
Industry $\times$ year FE	Y	Y	Y	Y	Y	
Observations	38,670	38,670	38,670	38,670	38,670	

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Estimates of δ

	(i)	(ii)	(iii)	(iv)	(v)	(vi)	
	$\Delta \log mc$		First stage		$\Delta \log mc$		$\Delta \log p$
			Separat.	Addit.			
Separation share	-0.013				0.279***	0.268***	
	(0.013)				(0.090)	(0.091)	
Addition share	0.016				-0.280***	-0.283***	
	(0.012)				(0.079)	(0.079)	
Restricted death share		0.199**	1.047***	0.290***			
		(0.083)	(0.052)	(0.061)			
Restricted birth share		-0.230***	0.377***	1.169***			
		(0.075)	(0.068)	(0.052)			
Specification	OLS	OLS	OLS	OLS	IV	IV	
F-stat			283	295	115	111	
Controls	Y	Y	Y	Y	N	Y	
Industry $\times$ year FE	Y	Y	Y	Y	Y	Y	
Observations	38,670	38,670	38,670	38,670	38,670	38,670	

- Estimates consistent with $\delta \approx 0.28$. (e.g. CES elasticity ≈ 4.5).
- Reject perfectly competitive benchmark $\delta = 0$.

Estimates of δ

	(i)	(ii)	(iii)	(iv)	(v)	(vi)	(vii)
	$\Delta \log mc$		First stage		$\Delta \log mc$		$\Delta \log p$
			Separat.	Addit.			
Separation share	-0.013				0.279***	0.268***	0.163***
	(0.013)				(0.090)	(0.091)	(0.076)
Addition share	0.016				-0.280***	-0.283***	-0.177***
	(0.012)				(0.079)	(0.079)	(0.063)
Restricted death share		0.199**	1.047***	0.290***			
		(0.083)	(0.052)	(0.061)			
Restricted birth share		-0.230***	0.377***	1.169***			
		(0.075)	(0.068)	(0.052)			
Specification	OLS	OLS	OLS	OLS	IV	IV	IV
F-stat			283	295	115	111	111
Controls	Y	Y	Y	Y	N	Y	Y
Industry $\times$ year FE	Y	Y	Y	Y	Y	Y	Y
Observations	38,670	38,670	38,670	38,670	38,670	38,670	38,670

- Pass-through rate to unit values $\approx$ 0.60.

Sensitivity of δ to Threshold for Small Customer

	(i)	(ii)	(iii)	(iv)	(v)	(vi)	(vii)	(viii)	(ix)	(x)	(xi)	(xii)
						$\Delta \log mc$						
Separation share	0.280***	0.282***	0.268***	0.275***	0.277***	0.265***	0.241***	0.205***	0.165**	0.070	0.077*	0.005
	(0.108)	(0.093)	(0.091)	(0.086)	(0.083)	(0.080)	(0.076)	(0.073)	(0.069)	(0.051)	(0.040)	(0.017)
Addition share	-0.221***	-0.230***	-0.283***	-0.269***	-0.258***	-0.241***	-0.229***	-0.209***	-0.190***	-0.037	0.039	-0.007
	(0.093)	(0.080)	(0.079)	(0.076)	(0.072)	(0.067)	(0.065)	(0.064)	(0.056)	(0.046)	(0.039)	(0.013)
Specification	IV	IV	IV	IV	IV	IV	IV	IV	IV	IV	IV	IV
F-stat	67	98	111	125	136	149	156	175	180	371	916	21,772
Controls	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Industry $\times$ year FE	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Cutoff	3	4	5	6	7	8	9	10	15	50	100	5
Suppliers	D&B	D&B	D&B	D&B	D&B	D&B	D&B	D&B	D&B	D&B	D&B	All

- Point estimates $\in [0.22, 0.29]$ as long as cut-off value not too high.

Pre-trends and Persistence

- Replace $\Delta \log(mc_{t+1}/mc_t)$ with $\Delta \log(mc_{t+s}/mc_t)$ for $s = \{-3, -2, -1, 1, 2, 3\}$.

	(i)	(ii)	(iii)	(iv)	(v)	(vi)
	$t-3$	$t-2$	$t-1$	$t+1$	$t+2$	$t+3$
Separation share	-0.049	-0.103	-0.007	0.268***	0.335***	0.375**
	(0.323)	(0.290)	(0.139)	(0.091)	(0.116)	(0.162)
Addition share	0.100	-0.104	-0.029	-0.283***	-0.313***	-0.447***
	(0.196)	(0.151)	(0.090)	(0.079)	(0.115)	(0.132)
Specification	IV	IV	IV	IV	IV	IV
F-stat	32	51	77	111	92	77
Controls	Y	Y	Y	Y	Y	Y
Industry $\times$ year FE	Y	Y	Y	Y	Y	Y
Observ.	21,931	26,410	31,999	38,670	32,052	26,502

- No pre-trends, and persistent effects from additions and separations.

Alternative Fixed-Effect Configurations

	(i)	(ii)	(iii)	(iv)	(v)
			$\Delta \log mc$		
Separation share	0.268***	0.303***	0.196**	0.220**	0.232***
	(0.091)	(0.106)	(0.080)	(0.092)	(0.083)
Addition share	-0.283***	-0.335***	-0.244***	-0.270***	-0.256***
	(0.079)	(0.090)	(0.071)	(0.082)	(0.068)
Specification	IV	IV	IV	IV	IV
F-stat	111	108	160	96	155
Controls	Y	Y	Y	Y	Y
6d industry $\times$ year FE	Y	Y	N	N	N
8d industry $\times$ year FE	N	N	N	Y	N
4d industry $\times$ year FE	N	N	N	N	Y
Year FE	N	N	Y	N	N
Firm FE	N	Y	N	N	N
Observ.	38,670	37,898	41.980	34,696	41,643

Heterogeneity of δ by supplier characteristics

- Estimate $\delta_{ijt}^{sep} = \delta_{ijt}^{add} = \bar{\delta}_0 + \bar{\delta}_1 Z_{ijt}$ for different choices of Z.

	(i)	(ii)
	Z_{ijt}	
	Zero slope	Relative sales of supplier
Intercept $\bar{\delta}_0$	0.278***	0.513***
	(0.074)	(0.117)
Slope $\bar{\delta}_1$	0	-0.118***
		(0.042)
Specification	IV	IV
F-stat	234	87
Controls	Y	Y
Industry $\times$ year FE	Y	Y
Observ.	38,670	38,670

- δ is lower for upstream suppliers that are relatively large in their industry .

Heterogeneity of δ by supplier characteristics

- Estimate $\delta_{ijt}^{sep} = \delta_{ijt}^{add} = \bar{\delta}_0 + \bar{\delta}_1 Z_{ijt}$ for different choices of Z.

	(i)	(ii)	(iii)	(iv)	(v)	(vi)	(vii)
				Z_{ijt}			
	Zero slope	Relative sales of supplier	Relative value added of supplier	Cost share	Material share	Distance btw. firms	Age of relationship
Intercept $\bar{\delta}_0$	0.278***	0.513***	0.324***	0.372***	0.363***	0.423*	0.293***
	(0.074)	(0.117)	(0.076)	(0.110)	(0.107)	(0.219)	(0.104)
Slope $\bar{\delta}_1$	0	-0.118***	-0.084*	-0.920	-0.700	-0.032	-0.003
		(0.042)	(0.047)	(0.620)	(0.474)	(0.056)	(0.015)
Specification	IV	IV	IV	IV	IV	IV	IV
F-stat	234	87	52	115	141	90	105
Controls	Y	Y	Y	Y	Y	Y	Y
Industry $\times$ year FE	Y	Y	Y	Y	Y	Y	Y
Observ.	38,670	38,670	38,670	38,670	38,670	33,233	38,670

- δ is lower for upstream suppliers that are relatively large in their industry .

Subset of Suppliers

	(i)	(ii)	(iii)	(iv)	(v)	(vi)	(vii)
				$\Delta \log mc$			
	Industry	Services	Exclude utilities	Exclude retail & wholesale	Incl. capital producers	Excl. finance	Excl. self-empl., finance, govt.
Separation share	0.102	0.388***	0.261***	0.228*	0.270***	0.264***	0.200**
	(0.119)	(0.121)	(0.092)	(0.123)	(0.089)	(0.090)	(0.090)
Addition share	-0.239	-0.328***	-0.276***	-0.300***	-0.271***	-0.280***	-0.235***
	(0.153)	(0.095)	(0.081)	(0.129)	(0.078)	(0.078)	(0.075)
Specification	IV	IV	IV	IV	IV	IV	IV
F-stat	100	90	107	71	108	123	120
Controls	Y	Y	Y	Y	Y	Y	Y
Industry $\times$ year FE	Y	Y	Y	Y	Y	Y	Y
Observ.	38,968	38,819	38,675	38,872	38,623	38,679	38,702

Alternative Measures of Marginal Cost

	(i)	(ii)	(iii)	(iv)	(v)	(vi)
	$\Delta \log mc$					
	Capital all overhead	60% overhead	40% overhead	0% overhead	Prod. fun. estimation	Decreasing returns
Separation share	0.271***	0.274***	0.313***	0.274**	0.310***	0.304***
	(0.091)	(0.090)	(0.103)	(0.108)	(0.113)	(0.105)
Addition share	-0.291***	-0.289***	-0.297***	-0.247***	-0.320***	-0.283***
	(0.079)	(0.078)	(0.082)	(0.084)	(0.098)	(0.088)
Specification	IV	IV	IV	IV	IV	IV
F-stat	113	112	110	107	111	111
Controls	Y	Y	Y	Y	Y	Y
Industry $\times$ year FE	Y	Y	Y	Y	Y	Y
Observ.	38,654	38,634	38,695	38,783	38,670	38,670

Subsample Analysis

	(i)	(ii)	(iii)	(iv)	(v)	(vi)	(vii)	(viii)	(ix)
	$\Delta \log mc$								
	Constant prod. mix	Single product	Two year cutoff	Three year cutoff	Employment weighted	Sep. & add. shares < 0.3	Sep. & add. shares < 1	Prodcom / total sales > 0.5	$\lvert\Delta \log mc\rvert < 1$
Separation share	0.258***	0.479***	0.262***	0.241**	0.387**	0.255**	0.316***	0.284***	0.263***
	(0.093)	(0.130)	(0.093)	(0.105)	(0.154)	(0.102)	(0.102)	(0.093)	(0.091)
Addition share	-0.297***	-0.355***	-0.293***	-0.276***	-0.239**	-0.296***	-0.289***	-0.286***	-0.282***
	(0.081)	(0.123)	(0.085)	(0.091)	(0.106)	(0.091)	(0.080)	(0.079)	(0.078)
Specification	IV	IV	IV	IV	IV	IV	IV	IV	IV
F-stat	105	54	96	73	86	156	75	106	111
Controls	Y	Y	Y	Y	Y	Y	Y	Y	Y
Industry $\times$ year FE	Y	Y	Y	Y	Y	Y	Y	Y	Y
Observ.	36,163	19,097	33,306	27,990	38,670	37,792	38,961	33,978	38,656

- Not shown: indicator for downstream firms $>$ median size (30 employ.), insignificant.

Estimates when separations and additions are regressed one at a time

	Separations		Additions	
Separation share	0.190**	0.182**		
	(0.077)	(0.079)		
Additions share			-0.181***	-0.192***
			(0.063)	(0.064)
Specification	IV	IV	IV	IV
Controls	N	Y	N	Y

- Recall: exog. births predict some separation & exog. deaths predict some addition.
- Evidence for some creative destruction.
- In pure quality ladder with CES, univariate regression identifies

$$\frac{\int_{p_J}^{p_{J+1}} x_J(\xi)d\xi}{p_J x_J} = \left| \frac{1}{\sigma - 1} \left(1 - (p_{J+1}/p_J)^{1-\sigma}\right) \right| < \frac{1}{\sigma - 1}.$$

- In $\sigma = 1$ limit, estimate identifies $|\log p_{J+1}/p_J| \approx 0.19$ (but this model is rejected).

Estimating $\delta = 1/(\sigma - 1)$ assuming CES

- Estimate $\Delta \log mc_{it} = \hat{\beta} \times \Delta \log \text{continuing share}_{it} + \text{controls}_{it} + \varepsilon_{it}$.

	(i)	(ii)	(iii)
	$\Delta \log mc$		
Δ log continuing share	0.265***	0.263**	0.266***
	(0.078)	(0.128)	(0.098)
Specification	IV	IV	IV
Instrument	Birth & death	Death	Birth
F-stat	48	27	82
Controls	Y	Y	Y
Industry $\times$ year FE	Y	Y	Y
Observ.	38,670	38,670	38,670

Estimating downstream price elasticity

- Estimate: $\Delta \log \text{quantity}_{it} = \hat{\beta} \times \Delta \log \text{price}_{it} + \text{controls}_{it} + \varepsilon_{it}$.

	(i)	(ii)	(iii)
		Δ log downstream quantity	
Time horizon	One year	Two years	Three years
Δ log downstream price	0.349	-1.403	-1.803**
	(0.970)	(1.000)	(0.798)
Specification	IV	IV	IV
Instrument	Death & birth	Death & birth	Death & Birth
F-stat	4	3	5
S-stat p-value	0.88	0.202	0.015
Controls	Y	Y	Y
Industry $\times$ year FE	Y	Y	Y
Observ.	38,670	32,052	26,502

- Changes in prices induced by instrument affect quantities, but takes time.

Agenda

Microeconomic Analysis

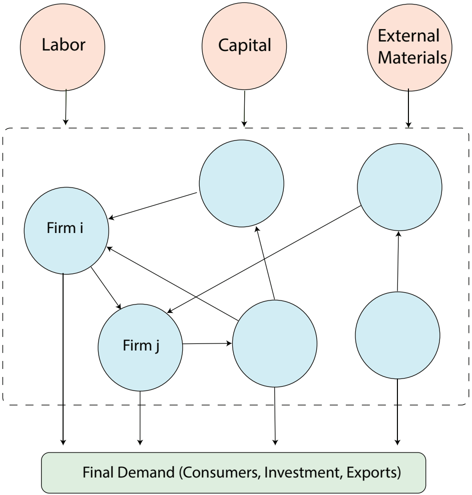
Macroeconomic Analysis

Summary

Aggregate Consequences

- How much of measured productivity growth attributable to firm-to-firm link formation?
- Changes in costs propagate along existing supply lines.
- Eventually hits final consumers & changes real aggregate output.
- Growth-accounting framework with churn in supply chain.

Circular Flow



Environment

- Producer $i \in N$ at time t has CRS technology

$$q_{i,t} = F_i\left(\{x_{ij,t}\}_{j\in N}, \{l_{if,t}\}_{f\in F}, A_{i,t}\right).$$

- C_t is the set of goods who are continuing at time t.
- Firm i's final output, $y_{i,t} = q_{i,t} - \sum_{j\in C_t} x_{ji,t}$.
- Change in final output of continuing firms:

$$\Delta \log Y_t = \Delta \log\left(\sum_{i\in C_t} p_{i,t} y_{i,t}\right) - \Delta \log P_t^Y,$$

  where

$$\Delta \log P_t^Y = \sum_{i\in C_t} b_{i,t} \Delta \log p_{i,t}.$$

- Total external inputs: $L_{f,t} = \sum_{i\in C_t} l_{if,t} + \sum_{i\in C_t} l_{if,t}^{\text{fixed}}$.

Towards aggregation

Micro proposition implies that

$$\Delta \log p_{i,t} = \underbrace{\Delta \log \mu_{i,t}/A_{i,t}}_{\substack{\text{markups \&} \\ \text{technology}}} + \sum_{f \in \mathcal{F}} \underbrace{\Omega^F_{if,t} \Delta \log w_{f,t}}_{\text{factor prices}} + \sum_{j \in \mathcal{J}} \underbrace{\Omega_{ij,t} \Delta \log p_{j,t}}_{\text{continuing input prices}} + \underbrace{\bar{\delta}^{\text{sep}}_{i,t} \Delta \mathcal{X}_{i,t}}_{\substack{\text{separations} \\ \text{due to jumps}}} - \underbrace{\bar{\delta}^{\text{add}}_{i,t} \Delta \mathcal{E}_{i,t}}_{\substack{\text{additions} \\ \text{due to jumps}}}.$$

where $\Delta \mathcal{X}_{i,t} = \sum_J \Omega_{iJ,t} \Delta M^{sep}_{iJ,t}$ and $\Delta \mathcal{E}_{i,t} = \sum_J \Omega_{iJ,t+1} \Delta M^{add}_{iJ,t}$.

- Solve linear system and deflate final output:

$$\Delta \log \text{real output}_t = \Delta \log \text{nominal output}_t - \sum_i b_{i,t} \Delta \log p_{i,t}.$$

- This results in the following proposition.

Growth Accounting with Supplier Churn

$$
\begin{aligned}
\Delta \log Y_t = {} & \underbrace{\sum_{i \in C_t} \lambda_{i,t} \Delta \log A_{i,t}}_{\text{technology residual}} + \underbrace{\sum_{f \in F} \Lambda_{f,t} \Delta \log L_{f,t}}_{\text{factor quantities}} \\
& - \underbrace{\sum_{i \in C_t} \lambda_{i,t} \Delta \log \mu_{i,t}}_{\text{markups}} - \underbrace{\sum_{f \in F} \Lambda_{f,t} \Delta \log \check{\Lambda}_{f,t}}_{\text{factor shares}} \\
& + \underbrace{\sum_{i \in C_t} \lambda_{i,t} \left(\bar{\delta}^{\text{add}}_{i,t} \Delta \mathcal{E}_{i,t} - \bar{\delta}^{\text{sep}}_{i,t} \Delta \mathcal{X}_{i,t} \right)}_{\substack{\text{supplier churn} \\ \text{due to price jumps}}} .
\end{aligned}
$$

- If $\Delta \mathcal{E}_{i,t} > \Delta \mathcal{X}_{i,t}$ and $\bar{\delta}^{\text{add}}_{i,t} \geq \bar{\delta}^{\text{sep}}_{i,t}$, then i's entering suppliers lower cost relative to exiting. Weigh i by its importance $\lambda_{i,t}$.
- Fixed costs need not be fully spelled out.

Mapping Growth Accounting to the Data

- Proposition is exact in continuous time, we use discrete-time approximation.
- For aggregation, assume all discontinuous additions and separations are due to price jumps. Add. and sep. caused by factors other than price jumps must be smooth
- Use VAT data on firm-to-firm transactions.
- Final output is non-financial private sector (less SGF and 0-employment firms) continuing firms' output.
- $100,000$ firms, 70% of VA & labor of non-F corporate sector (includes services).
- Factors: labor, capital, purchases from excluded & foreign firms.
- Experiment with δ^{add} and δ^{sep}.

Summary Statistics Growth Accounting Sample of Firms (sales weighted)

	(i)	(ii)	(iii)	(iv)	(v)	(vi)	(vii)	(viii)	(ix)	(x)
	Share in variable costs			Import	Services	Numb.	Share in domestic intermediate spending			
	labor	capital	interm.	interm. share	interm. share	suppl.	separations	additions	deaths	births
mean	0.074	0.009	0.917	0.315	0.725	675	0.096	0.110	0.005	0.009
p25	0.009	0.001	0.896	0.000	0.55	123	0.022	0.027	0.000	0.000
p50	0.037	0.002	0.958	0.148	0.846	330	0.053	0.065	0.000	0.001
p75	0.093	0.006	0.989	0.645	0.973	853	0.116	0.138	0.002	0.006
count	1,721,022	1,721,022	1,721,022	1,716,375	1,715,958	1,717,426	1,715,958	1,717,124	1,715,958	1,717,124

Growth Accounting — no consumer surplus

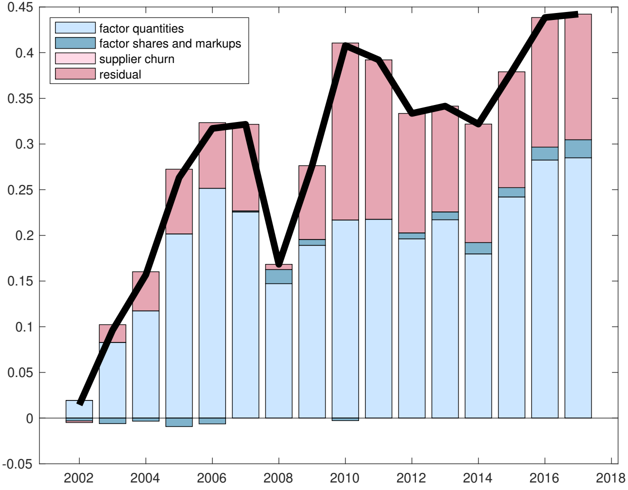
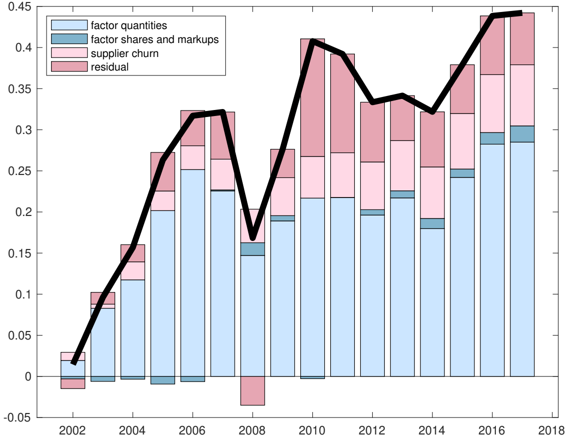


Figure: $\bar{\delta}^{\text{entry}} = \bar{\delta}^{\text{exit}} = 0$.

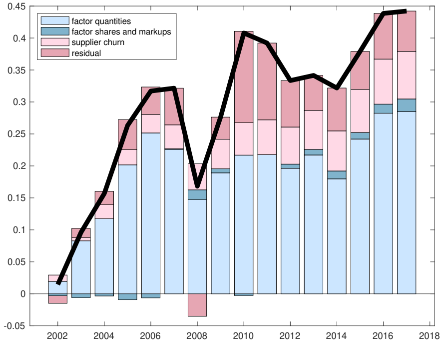
- "Unexplained" growth 14 log points — around 1% per year.

Growth Accounting — $\bar{\delta}^{\text{add}} = \bar{\delta}^{\text{sep}} = 0.28$

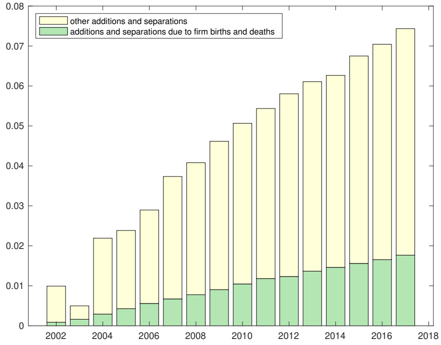


- Supplier churn accounts for 7.4 log points — continuing suppliers' share falls.
- Supplier churn less important for cycle.
- 3/4 from service-producing firms.

Growth Accounting — Role of supplier birth and death



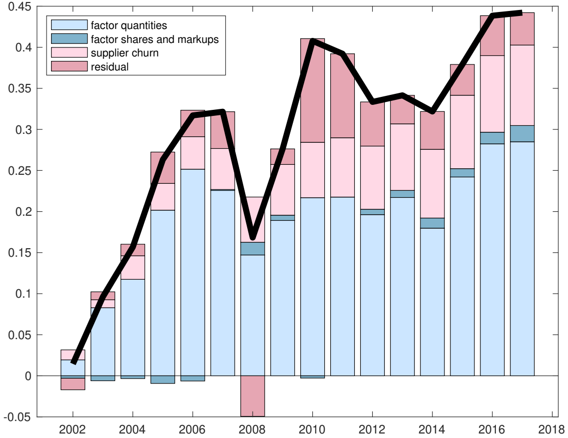
(a) Growth accounting



(b) Supplier churn decomposition

- Supplier churn accounts for 7.4 log points.
- Roughly 1/4 from birth/death.

Growth Accounting — $\bar{\delta}^{\text{add}} = 0.283$, $\bar{\delta}^{\text{sep}} = 0.268$



- Residual 2 p.p. smaller.

Growth Accounting — Sensitivity to δ^{add} and δ^{sep}

All separations and additions

		$\bar{\delta}^{sep}$				
		0.26	**0.27**	**0.28**	**0.29**	**0.30**
	0.26	0.069	0.054	0.039	0.023	0.008
	0.27	0.087	0.072	0.056	0.041	0.026
$\bar{\delta}^{add}$	**0.28**	0.105	0.090	0.074	0.059	0.044
	0.29	0.123	0.107	0.092	0.077	0.062
	0.30	0.141	0.125	0.110	0.095	0.080

Firm births and deaths

		$\bar{\delta}^{sep}$				
		0.26	**0.27**	**0.28**	**0.29**	**0.30**
	0.26	0.016	0.016	0.015	0.014	0.013
	0.27	0.018	0.017	0.016	0.016	0.015
$\bar{\delta}^{add}$	**0.28**	0.019	0.018	0.018	0.017	0.016
	0.29	0.021	0.020	0.019	0.018	0.018
	0.30	0.022	0.021	0.020	0.020	0.019

- Along diagonal, results fairly robust. Off-diagonal gaps matter for all additions & sep.

Growth Accounting — Sensitivity to δ^{add} and δ^{sep}

All separations and additions

		$\bar{\delta}^{sep}$				
		0.26	**0.27**	**0.28**	**0.29**	**0.30**
$\bar{\delta}^{add}$	**0.26**	0.069	0.054	0.039	0.023	0.008
	0.27	0.087	0.072	0.056	0.041	0.026
	0.28	0.105	0.090	0.074	0.059	0.044
	0.29	0.123	0.107	0.092	0.077	0.062
	0.30	0.141	0.125	0.110	0.095	0.080

Firm births and deaths

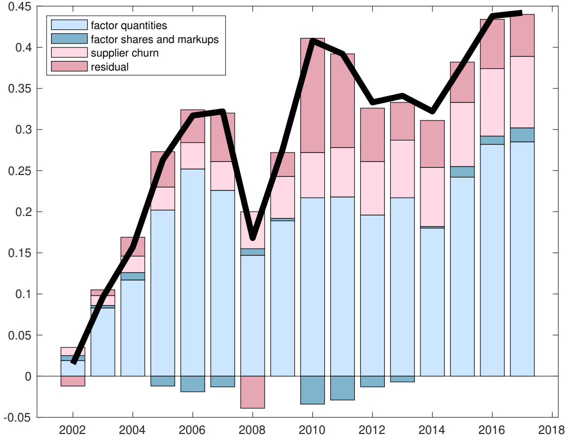
		$\bar{\delta}^{sep}$				
		0.26	**0.27**	**0.28**	**0.29**	**0.30**
$\bar{\delta}^{add}$	**0.26**	0.016	0.016	0.015	0.014	0.013
	0.27	0.018	0.017	0.016	0.016	0.015
	0.28	0.019	0.018	0.018	0.017	0.016
	0.29	0.021	0.020	0.019	0.018	0.018
	0.30	0.022	0.021	0.020	0.020	0.019

- Along diagonal, results fairly robust. Off-diagonal gaps matter for all additions & sep.
- To understand this, consider decomposition:

$$\bar{\delta}^{add}\Delta\mathcal{E} - \bar{\delta}^{sep}\Delta\mathcal{X} = \left[\frac{\bar{\delta}^{add}+\bar{\delta}^{sep}}{2}\right][\Delta\mathcal{E}-\Delta\mathcal{X}] + \left[\bar{\delta}^{add}-\bar{\delta}^{sep}\right]\left[\frac{\Delta\mathcal{E}+\Delta\mathcal{X}}{2}\right].$$

Growth Accounting —allowing δ to vary across suppliers

- Use estimates $\delta^{sep} = \delta^{add} = 0.513 - 0.118 \times$ log sales ratio of supplier.



- Results almost unchanged.

Agenda

Microeconomic Analysis

Macroeconomic Analysis

Summary

Conclusion

- Downstream firms' unit costs significantly affected by supplier entry and exits.
- "Direct" evidence on area under input demand curve.
- Reduced form statistic that shapes counterfactuals in models with extensive margin. (e.g. market size effects, gains from trade, optimal entry, innovation subsidies)
- Suggests supplier churn important channel for aggregate productivity growth.

Overhead Costs

Elasticity of labor and capital costs wrt. intermediate purchases

	(i)	(ii)	(iii)	(iv)	(v)	(vi)	(vii)
				Δ log (labor + capital)			
Δ log (interm. inputs)	0.268***	0.269***	0.576***	0.575***	0.668	0.481***	0.400***
	(0.006)	(0.006)	(0.169)	(0.175)	(0.458)	(0.157)	(0.054)
Specification	OLS	OLS	IV	IV	IV	IV	IV
F-stat			62	58	3	57	654
Sample of firms	Manufact.	Manufact.	Manufact.	Manufact.	Prodcom	Goods	All
Input prices control	N	Y	N	Y	Y	Y	Y
Bartik control	N	Y	N	Y	Y	Y	Y
Industry $\times$ year FE	Y	Y	Y	Y	Y	Y	Y
Obs.	305,158	304,421	219,992	219,892	39,149	295,916	3,105,547

Restricted deaths/births and other separations/additions

	(i)	(ii)	(iii)	(iv)
	Separation count share from continuing suppliers		Addition count share from continuing suppliers	
Restricted death count share	-0.355***	-0.356***	0.282***	0.284***
	(0.055)	(0.055)	(0.062)	(0.062)
Restricted birth count share	0.485***	0.484***	-0.005	-0.000
	(0.064)	(0.065)	(0.047)	(0.048)
Specification	OLS	OLS	OLS	OLS
Controls	N	Y	N	Y
Industry $\times$ year FE	Y	Y	Y	Y
Observations	38,670	38,670	38,670	38,670

- Restricted births do not predict additions of continuing suppliers.
- Evidence against reverse causality (e.g. positive prod. shock to downstream firm induces additions of both continuing and newly born suppliers).

Monte Carlo Simulations

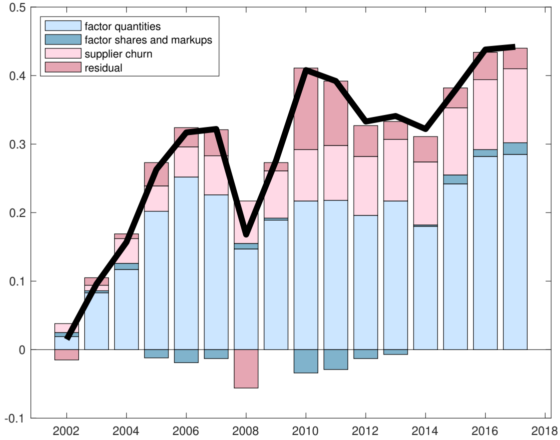
$$\sum_{j=1}^{M} \frac{\omega_{ij}}{\sigma_j - 1} \left(\frac{p_{ij}}{\tilde{mc}_i} \right)^{1-\sigma_{ij}} = \sum_{j=1}^{M} \frac{\omega_{ij}}{\sigma_{ij} - 1}.$$

	(i)	(ii)	(iii)	(iv)	(v)	(vi)	(vii)	(viii)	(ix)
Correlation δ, Ω		Zero			-0.5			$+0.5$	
Std. dev. A, p shocks	0	0.01	0.02	0	0.01	0.02	0	0.01	0.02
Addition share									
$\mathbb{E}[\bar{\delta}^{add}]$	0.283	0.283	0.283	0.283	0.283	0.283	0.283	0.283	0.283
Median estimate $\hat{\delta}^{add}$	0.285	0.285	0.281	0.274	0.275	0.269	0.297	0.299	0.298
5th percentile estimate	0.285	0.270	0.249	0.273	0.257	0.244	0.296	0.282	0.254
95th percentile estimate	0.286	0.299	0.313	0.274	0.292	0.304	0.298	0.316	0.330
Separation share									
$\mathbb{E}[\bar{\delta}^{sep}]$	0.268	0.268	0.268	0.268	0.268	0.268	0.268	0.268	0.268
Median estimate of $\hat{\delta}^{sep}$	0.271	0.270	0.270	0.260	0.261	0.263	0.280	0.279	0.283
5th percentile estimate	0.270	0.254	0.241	0.259	0.243	0.232	0.280	0.261	0.249
95th percentile estimate	0.271	0.288	0.294	0.260	0.282	0.299	0.281	0.294	0.310

Notes: Table reports Monte Carlo statistics from 100 simulations with a sample of $35,000$ firms in each simulation. The value of $\mathbb{E}[\bar{\delta}^{add}]$ and $\mathbb{E}[\bar{\delta}^{sep}]$ are unweighted averages of the true δ's for additions and separations.

Growth Accounting — Use log change continuing share assuming CES

- Supplier churn term measures contribution to aggregate productivity from changes in price of non-contininuing suppliers to continuing suppliers.
- Use point estimate $\delta = 0.265$.



- Supplier churn term slightly more important.

Consumer Surplus ratio δ increasing in quantity under MSL

If Marshall's second law of demand holds ($\frac{\partial \sigma_J}{\partial p_J} \geq 0$), then

$$\frac{\partial \delta_J}{\partial p_J} < 0.$$

If spending per added supplier is higher than spending per separating supplier, then

$$\delta^{addition} > \delta^{separation},$$

as long as Marshall's second law holds and suppliers are on the same input demand curve.