Firm Dynamics with Frictional Product and Labor Markets

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Work in progress

Motivation

- Firm dynamics and heterogeneity is central for the labor market and for aggregate outcomes (hires, separations, wages, productivity, ...).
- Much of the theoretical and quantitative literature considers shocks to *revenue* productivity to account for firm dynamics (e.g. Hopenhayn & Rogerson 1993, Cooper, Haltiwanger & Willis 2007, Veracierto 2007, Elsby & Michaels 2013,...)

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- Firm dynamics and heterogeneity is central for the labor market and for aggregate outcomes (hires, separations, wages, productivity, ...).
- Much of the theoretical and quantitative literature considers shocks to *revenue* productivity to account for firm dynamics (e.g. Hopenhayn & Rogerson 1993, Cooper, Haltiwanger & Willis 2007, Veracierto 2007, Elsby & Michaels 2013,...)
- But supply and demand shocks affect firms differently.
- Foster, Haltiwanger and Syverson (2008, 2012):
  - Demand is important for firm growth (more than productivity)
  - Price dispersion: younger firms are more demand constrained and charge lower prices.

Research Question

What are the respective roles of demand and productivity for the firm-level dynamics of prices, output, employment and wages?

This paper

- Document the joint dynamics of prices, output, employment, working hours and wages for German manufacturing firms.
- Document patterns of price, labor productivity (and wage) dispersion.

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- Document patterns of price, labor productivity (and wage) dispersion.
- Develop an equilibrium model of firm dynamics with
  - product and labor market frictions
  - costly recruitment and sales, wage and price dispersion
  - separate roles for demand and supply shocks
- Quantitative evaluation, counterfactual experiments (in progress)

Literature

Price and productivity dispersion

Abbott 1992, Foster, Haltiwanger & Syverson 2008, 2012, Smeets & Warzynski 2013, Kugler & Verhoogen 2012

Firm-level price and employment dynamics

Carlson & Skans 2012, Carlson, Messina & Skans 2014

Firm dynamics with labor market frictions

Smith 1999, Veracierto 2007, Elsby & Michaels 2013, Acemoglu & Hawkins 2014, Kaas & Kircher 2015

Firm dynamics with product market frictions

Gourio & Rudanko 2014

Data (I)

- Administrative Firm Data (AFiD) of the German Federal Statistical Office.
- All establishments in manufacturing (& mining, quarrying) with $\geq$ 20 employees
- 1995–2014 (annual). (So far, we work with 2005–2007)
- Sales value and quantity for nine-digit product categories
- Employment, working hours, wages
- Detailed worker information (matched employer-employee) for subsample of establishments in 1996, 2001, 2006, 2010, 2014.

Data (II)

- Consider one-establishment firms.
- Two samples of goods: ▸ Examples
  - Full: All goods with quantity info ⇒ Firm dynamics
  - Homogeneous: Those measured in length, area, volume, or weight; drop goods produced by less than 6 firms ⇒ Price & productivity dispersion

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- Two samples of goods: Examples
  - Full: All goods with quantity info $\Rightarrow$ Firm dynamics
  - Homogeneous: Those measured in length, area, volume, or weight; drop goods produced by less than 6 firms $\Rightarrow$ Price & productivity dispersion
- Drop firm observations where sample sales value is less than 50 percent of total sales:
  - Full sample: 61,034 firm-years, 13,177 product-years
  - Homogeneous sample: 38,651 firm-years, 3,730 product-years

Price and productivity dispersion

- $\overline{P}_{jt}$ quantity-weighted mean price of good j in year t.
- Firm i's relative price:

$$\widetilde{P}_{it} = \frac{\sum_j P_{jit} Q_{jit}}{\sum_j \overline{P}_{jt} Q_{jit}}$$

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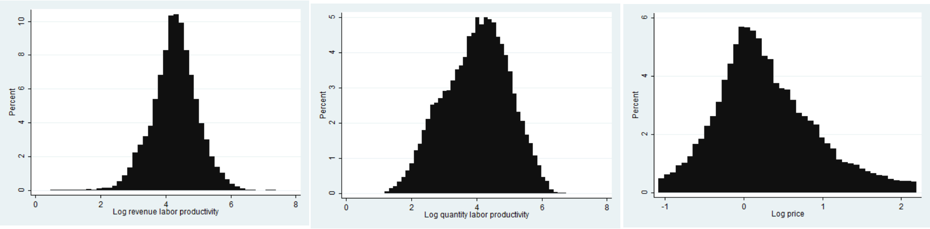
- Revenue and quantity labor productivity (per hour):

$$RLP_{it} = \frac{\sum_j Q_{jit} P_{jit}}{H_{it}} \quad , \quad QLP_{it} = \frac{\sum_j Q_{jit} \overline{P}_{jt}}{H_{it}} \; .$$

- $$RLP_{it} = \widetilde{P}_{it} \cdot QLP_{it} \; .$$

Revenue and quantity productivity, and prices



RLP QLP $\tilde{P}$

Correlations and standard deviations

Correlations	RLP	QLP	$\widetilde{P}$	Empl.	wage/hour
RLP	1				
QLP	0.775	1			
$\widetilde{P}$	-0.108	-0.712	1		
Empl	0.293	0.229	-0.035	1	
wage/h.	0.558	0.383	0.017	0.308	1
Std.dev.	0.697	0.986	0.629	0.871	0.374

All variables in logs. Weighted Residuals

Firm dynamics

- Measure firm i's output growth:

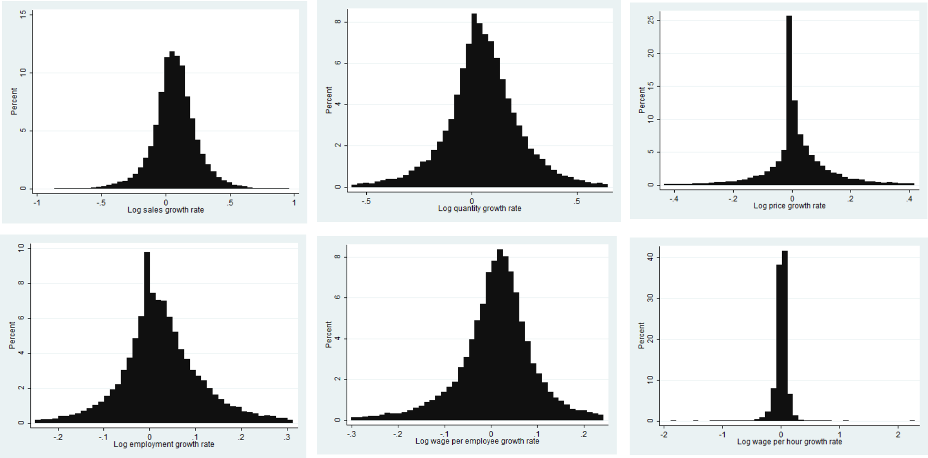
$$\frac{Q_{i,t+1}}{Q_{i,t}} = \frac{\sum_j P_{jit} Q_{ji,t+1}}{\sum_j P_{jit} Q_{jit}} \ .$$

- Log revenue growth is split into log output growth and log growth of the firm's Paasche price index:

$$\widehat{R}_{i,t} = \widehat{Q}_{i,t} + \widehat{P}_{i,t} \ .$$

- Further consider log growth rates of employment, hours, wages, revenue and quantity productivity.

Firm growth rates



Correlations and standard deviations

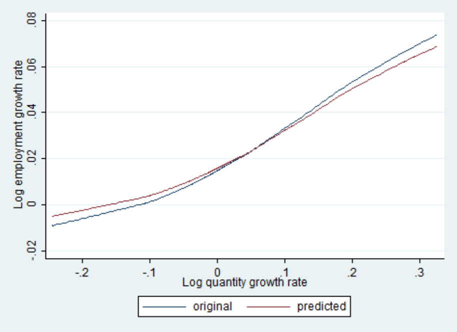
Correlations	$\widehat{PQ}$	$\widehat{Q}$	$\widehat{P}$	$\widehat{E}$	$\widehat{w/h}$
$\widehat{PQ}$	1				
$\widehat{Q}$	0.795	1			
$\widehat{P}$	0.284	-0.356	1		
$\widehat{E}$	0.307	0.276	0.035	1	
$\widehat{w/h}$	-0.009	-0.014	0.009	-0.013	1
Std.dev.	0.172	0.176	0.109	0.087	0.100

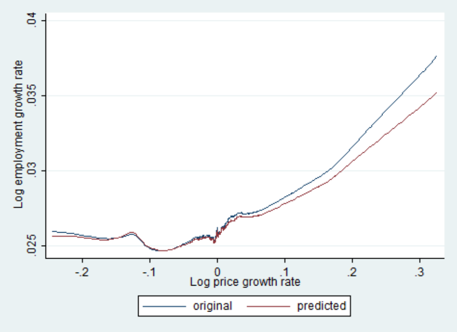
All variables are log growth rates.

Variance decomposition: $\widehat{P}$ accounts for 18% of revenue growth and 16% of the growth of hourly labor productivity.

▸ Weighted ▸ Residuals

Nonlinear relations between $\widehat{P}$, $\widehat{Q}$ and $\widehat{E}$





The model

- Canonical model of firm dynamics with trading frictions in product and labor markets.
- Risk-neutral representative household with $\overline{L}$ worker members and $\overline{B}$ shopper members.
- A worker member supplies one unit of labor per period.
- A shopper member can buy one unit of a good per period.
- Household's preferences are

$$\sum_{t \geq 0} \beta^t \left[e_t + \int y_t(f) c_t(f) d\mu_t(f) \right] .$$

e_t consumption of a numeraire good,
$y_t(f)$ firm-specific demand state (e.g. product quality),
$c_t(f)$ consumption of firm f's output.

Firms

- Consider a firm with L workers and B customers.
- Output $xF(L)$ with $F' > 0$, $F'' \leq 0$. x is firm-specific productivity.
- The firm sells $B \leq xF(L)$ units of output. (Waste if inequality is strict).
- $z = (x, y)$ follows a Markov process.
- Any firm's policy depends on the shock history z^a where a is firm age (stationary equilibrium).

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- $z = (x, y)$ follows a Markov process.
- Any firm's policy depends on the shock history z^a where a is firm age (stationary equilibrium).
- Recruitment and sales activities are costly. With recruitment effort R and sales effort S, costs are $r(R, L)$ and $s(S, L)$.
- Costs are increasing & convex in effort and possibly declining in size (scale effects).

Search and matching

- Firms offer long-term wage contracts to new hires and price discounts (initial period) to new customers.
- Search is directed: Unemployed workers and unmatched shoppers search in submarkets that differ by their matching rates and match values.

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- Firm hires $m(\lambda)R$ where λ are unemployed workers per unit of recruitment effort in the submarket ($m' > 0$, $m'' < 0$).
- Firm attracts $q(\varphi)S$ new custormers where φ are unmatched shoppers per unit of sales effort in the submarket ($q' > 0$, $q'' < 0$).

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- Matching rate for workers: $m(\lambda)/\lambda$.
- Matching rate for shoppers: $q(\varphi)/\varphi$.

Separations, entry and exit

- New firms enter at cost K, draw initial state (x, z), $(L_0, B_0) = (0, 0)$.

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- Firms exit with probability δ.
- Firms choose customer separation rates δ_b. Worker separation rates δ_w are pre-committed in long-term contracts.
- Separation rates are bounded below by exogenous quit rates $\bar{\delta}_w$ and $\bar{\delta}_b$.

Stationary competitive search equilibrium

Value functions for workers U, W, shoppers V, Q, firms J, firm policies λ, R, φ, S, δ_b, $\mathcal{C}^a = (w^a(.), \delta_w^a(.))$, $(L^\tau)_{\tau=0}^a$, L, B, p, p^R, entrant firms N_0, and search values c^* and ρ^* such that

(a) Workers search optimally.

(b) Shoppers search optimally.

(c) Firms' value functions J and policy functions solve the recursive firm problem. ▸ more

(d) Entry is optimal:

$$K = \sum_{z^0} \pi^0(z^0) J(0, z^0)$$

(e) Aggregate resource feasibility:

$$\bar{L} = \sum_{z^a} N(z^a) \Big\{ L(z^a) + [\lambda(z^a) - m(\lambda(z^a))] R(z^a) \Big\} \ ,$$

$$\bar{B} = \sum_{z^a} N(z^a) \Big\{ B(z^a) + [\varphi(z^a) - q(\varphi(z^a))] S(z^a) \Big\} \ .$$

Social optimality

The competitive search equilibrium is socially optimal.
Recursive planning problem: Maximize the social firm value

$$G(L_-, B_-, z) = \max \Big\{ yB - bL - r(R, L_-(1-\delta_w)) - s(S, L_-(1-\delta_w))$$

$$- \rho[L + (\lambda - m(\lambda))R] - c[B + (\varphi - q(\varphi))S] + \beta(1-\delta)\mathbb{E}_z G(L, B, z_+) \Big\} ,$$

subject to

$$L = L_-(1-\delta_w) + m(\lambda)R \ ,$$
$$B = B_-(1-\delta_b) + q(\varphi)S \ ,$$
$$B \leq xF(L) \ , \ \delta_w \geq \bar{\delta}_w \ , \ \delta_b \geq \bar{\delta}_b \ .$$

c and ρ are the social costs of shoppers and workers (multipliers on aggregate resource constraints).

Firm policies

- Recruitment expenditures and job matching rates are positively related. If $R > 0$,

$$r_1'(.) = \rho\left[\frac{m(\lambda)}{m'(\lambda)} - \lambda\right]$$

- Sales expenditures and customer matching rates are positively related. If $S > 0$,

$$s_1'(.) = c\left[\frac{q(\varphi)}{q'(\varphi)} - \varphi\right]$$

- Faster growing firms offer higher salaries to workers and greater discounts to customers.

Prices and revenue

- Discount price $p = y - \frac{c\varphi}{q(\varphi)}$ falls in φ (and S).
- Reservation price $p^R = y - c$.
- Younger firms charge lower prices to build a customer base.

Prices and revenue

- Discount price $p = y - \frac{c\varphi}{q(\varphi)}$ falls in φ (and S).
- Reservation price $p^R = y - c$.
- Younger firms charge lower prices to build a customer base.
- Revenue

$$p^R B_-(1 - \delta_b) + pq(\varphi)S$$

Calibrated example

- Functional forms:

$$F(L) = L^{\alpha}\ ,\ r(R, L_0) = \frac{r_0}{1+\nu}\left(\frac{R}{L_0}\right)^{\nu} R\ ,\ s(S, L_0) = \frac{s_0}{1+\sigma}\left(\frac{S}{L_0}\right)^{\sigma} S\ ,$$

$$m(\lambda) = m_0 \lambda^{0.5}\ ,\ q(\varphi) = q_0 \varphi^{0.5}\ .$$

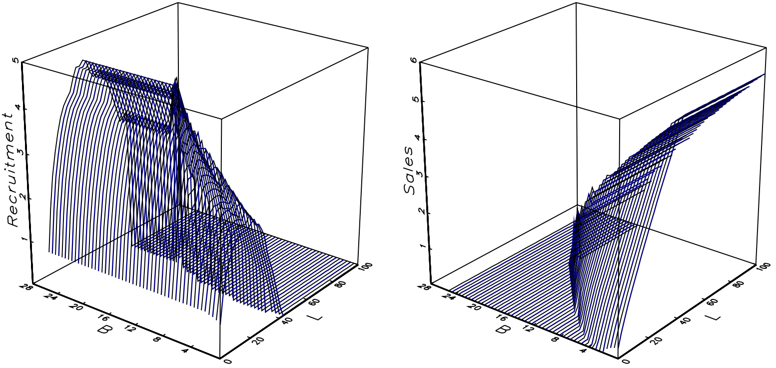
- Parameters

$$\alpha = 0.7,\ \nu = \sigma = 2,$$

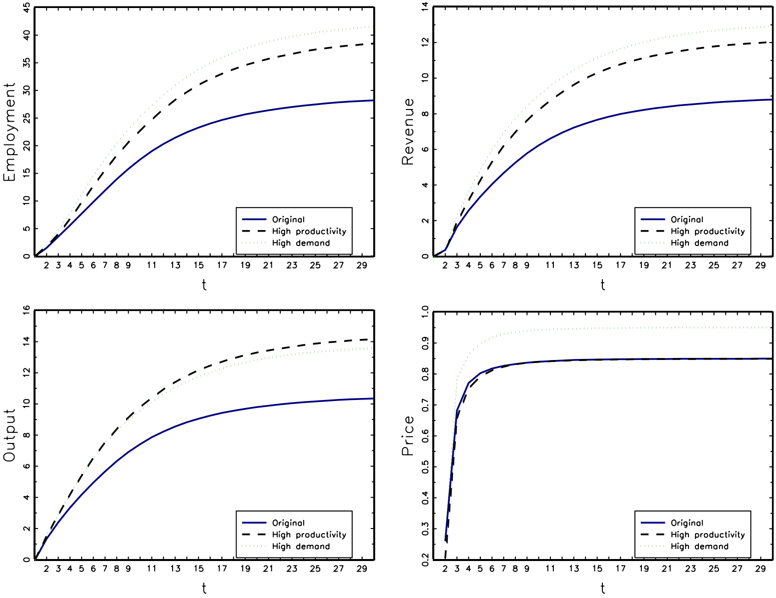
$$\bar{\delta}_w = 0.05\ ,\ \bar{\delta}_b = 0.15\ ,\ \delta = 0.05\ ,\ \beta = 0.96\ .$$

- Matching rates for workers (shoppers) are 0.49 (0.70).
- $x = y = 1$ (no heterogeneity).
- Expenditures for recruitment (sales) are 1%–2% of output.

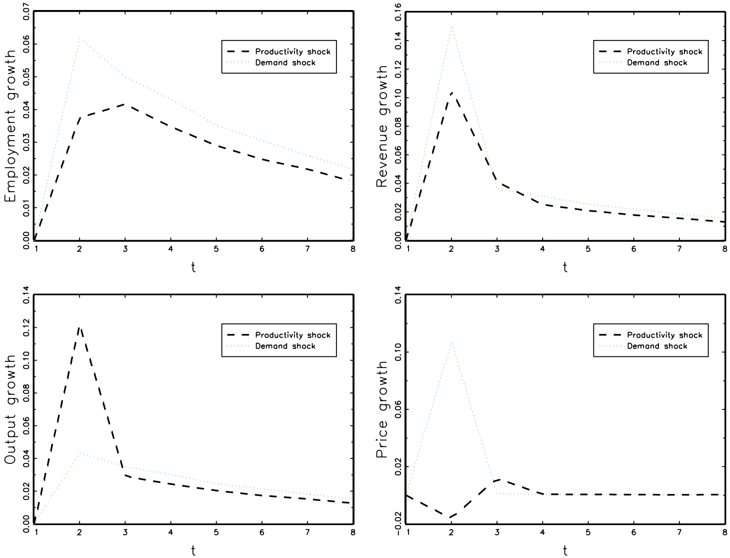
Firm policies



Firm growth


Employment
Revenue
Output
Price
t
Original
High productivity
High demand

Response to demand shock (dashed) and productivity shock (solid)



Conclusions and outlook

- Firm dynamics with product and labor market frictions: separate role of demand shocks.
- Quantitative application: calibrate productivity and demand shocks to capture price and output dynamics.
- Implications for wage and price dispersion?
- Experiments:
  - Impact of product market regulation on the labor market?
  - Implications of aggregate demand versus aggregate productivity shocks?

Examples of nine-digit products

- "Homogeneous" goods:
  - 1720 32 144 Fabric of synthetic fibers (with more than 85% synthetic) for curtains (measured in m^2).
  - 2112 30 200 Cigarette paper, not in the form of booklets, husks, or rolls less than 5 cm broad (measured in t).
  - 2125 14 130 Cigarette paper, in the form of booklets or husks (measured in kg).
- Other goods
  - 1720 32 144 Sleeping bags (measured in "items").
  - 2513 60 550 Gloves made of vulcanized rubber for housework usage (measured in "pairs").
  - 2971 21 130 Vacuum cleaner with voltage 110 V or more (measured in "items").

Back

Descriptive statistics

Correlations	RLP	QLP	$\widetilde{P}$	Empl.	wage/hour
RLP	1				
QLP	0.790	1			
$\widetilde{P}$	-0.142	-0.719	1		
Empl	0.387	0.315	-0.070	1	
wage/h.	0.543	0.381	0.000	0.439	1
Std.dev.	0.670	0.954	0.594	1.132	0.362

Statistics weighted by employment size. All variables in logs. Back

Descriptive statistics

Correlations	RLP	QLP	$\widetilde{P}$	Empl.	wage/hour
RLP	1				
QLP	0.623	1			
$\widetilde{P}$	0.083	-0.686	1		
Empl	-0.092	-0.053	-0.010	1	
wage/h.	0.330	0.205	0.027	-0.049	1
Std.dev.	0.115	0.166	0.139	0.089	0.063

All variables in logs. Residuals after controlling for year, 2-digit industry and German region. back

Correlations and standard deviations

Correlations	$\widehat{PQ}$	$\widehat{Q}$	$\widehat{P}$	$\widehat{E}$	$\widehat{w/h}$
$\widehat{PQ}$	1				
$\widehat{Q}$	0.782	1			
$\widehat{P}$	0.321	-0.339	1		
$\widehat{E}$	0.339	0.301	0.047	1	
$\widehat{w/h}$	-0.016	-0.024	0.012	-0.019	1
Std.dev.	0.159	0.160	0.105	0.076	0.090

Statistics weighted by employment size. All variables are log growth rates.

Variance decomposition: $\widehat{P}$ accounts for 21% of revenue growth and 19% of the growth of hourly labor productivity.

Back

Correlations and standard deviations

Correlations	$\widehat{PQ}$	$\widehat{Q}$	$\widehat{P}$	$\widehat{E}$	$\widehat{w/h}$
$\widehat{PQ}$	1				
$\widehat{Q}$	0.792	1			
$\widehat{P}$	0.281	-0.364	1		
$\widehat{E}$	0.247	0.227	0.021	1	
$\widehat{w/h}$	-0.016	-0.016	0.001	-0.033	1
Std.dev.	0.154	0.160	0.099	0.062	0.088

Residuals after controlling for year, 2-digit industry and German region. All variables are log growth rates.

Back

Firms' problem

Firm with shock history z^a has state vector $\sigma = [(L^\tau, \mathcal{C}^\tau)_{\tau=0}^{a-1}, B_-, z^a]$.

Recursive problem

$$J_a(\sigma) = \max_{(\lambda, R, \mathcal{C}^a), (\delta_b, \varphi, S, p, p^R)} \Big\{ p^R B_-(1-\delta_b) + pq(\varphi)S - W - r(R, L_0) - s(S, L_0) + \beta(1-\delta)\mathbb{E}J_{a+1}(\sigma_+) \Big\} \quad \text{s.t.}$$

$$L^{\tau+} = (1-\delta_w^\tau(z^a))L^\tau \ , \ \tau = 0, \dots, a-1 \ , \ L^{a+} = m(\lambda)R \ , \ L_0 = \sum_{\tau=0}^{a-1} L^{\tau+} \ ,$$

$$W = \sum_{\tau=0}^{a} w^\tau(z^a)L^{\tau+} \ ,$$

$$B = B_-(1-\delta_b) + q(\varphi)S \leq xF(L) \ , \ L = \sum_{\tau=0}^{a} L^{\tau+} \ ,$$

$$\rho^* = \frac{m(\lambda)}{\lambda}[W(\mathcal{C}^a, z^a) - b - \beta U] \ \text{if} \ \lambda > 0 \ ,$$

$$p = y_a - \frac{c^*\varphi}{q(\varphi)} \ \text{if} \ \varphi > 0 \ , \ p^R = y_a - c^* \ .$$

back