Price, Productivity and Wage Dispersion in German Manufacturing (Firm Dynamics with Frictional Product and Labor Markets)

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Motivation

- Firm heterogeneity matters for the labor market and for the macroeconomy (e.g. hires, separations, wages, productivity).
- Macro literature considers shocks to *revenue* productivity to account for firm dynamics
- But supply and demand affect firms differently.
- Foster, Haltiwanger and Syverson (2008, 2016):
  - Demand is important for firm growth and firm survival.
  - Price dispersion: younger firms are more demand constrained and charge lower prices.

Research question

Examine the respective roles of demand and productivity for

1. Firm-level dynamics of prices, output, employment and wages
2. Aggregate dynamics

Contribution

- 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 productivity shocks
- Quantitative evaluation using firm-level data on prices, output, employment and wages for German manufacturing (1995–2014).

Literature

Firm dynamics and the labor market

Hopenhayn & Rogerson 1993, Smith 1999, Cooper, Haltiwanger & Willis 2007, Veracierto 2007, Elsby & Michaels 2013, Fujita & Nakajima 2013, Acemoglu & Hawkins 2014, Kaas & Kircher 2015

Search in product markets

Gourio & Rudanko 2014, Kaplan & Menzio 2014, Den Haan 2013, Michaillat & Saez 2015, Petrosky-Nadeau & Wasmer 2015, Huo & Rios-Rull 2015

Price and productivity dispersion

Abbott 1992, Foster, Haltiwanger & Syverson 2008, 2012, Smeets & Warzynski 2013, Kugler & Verhoogen 2012, Carlson & Skans 2012, Carlson, Messina & Skans 2014

Data

- Administrative Firm Data (AFiD), Panel *Industriebetriebe* and Module *Produkte*.
- All establishments in manufacturing (& mining, quarrying) with $\geq$ 20 employees.
- Restriction to one-establishment firms.
- 1995–2014 (annual).
- Sales value and quantity for nine-digit products.
- Employment, working hours, wages.
- $\approx 400,000$ firm-years.

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

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

- Further consider log growth rates of employment E, hours H and hourly wage w.

Firm dynamics

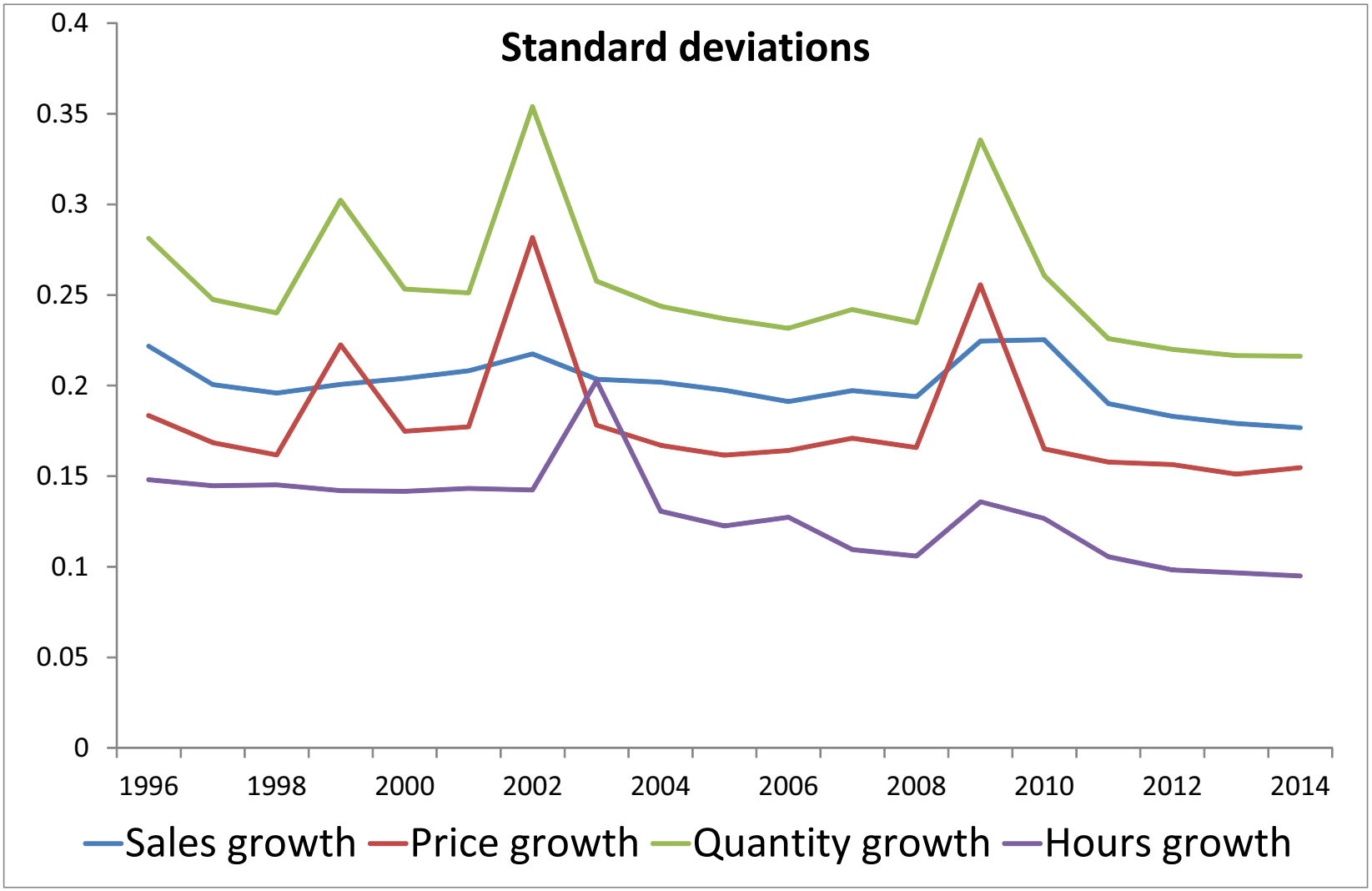
	Std. dev.
$\hat{S}$	0.20
$\hat{P}$	0.18
$\hat{Q}$	0.26
$\hat{E}$	0.10
$\hat{H}$	0.14
$\widehat{w}$	0.10

	Correlation
$(\hat{P}, \hat{Q})$	-0.54
$(\hat{Q}, \hat{E})$	0.25
$(\hat{Q}, \hat{H})$	0.29

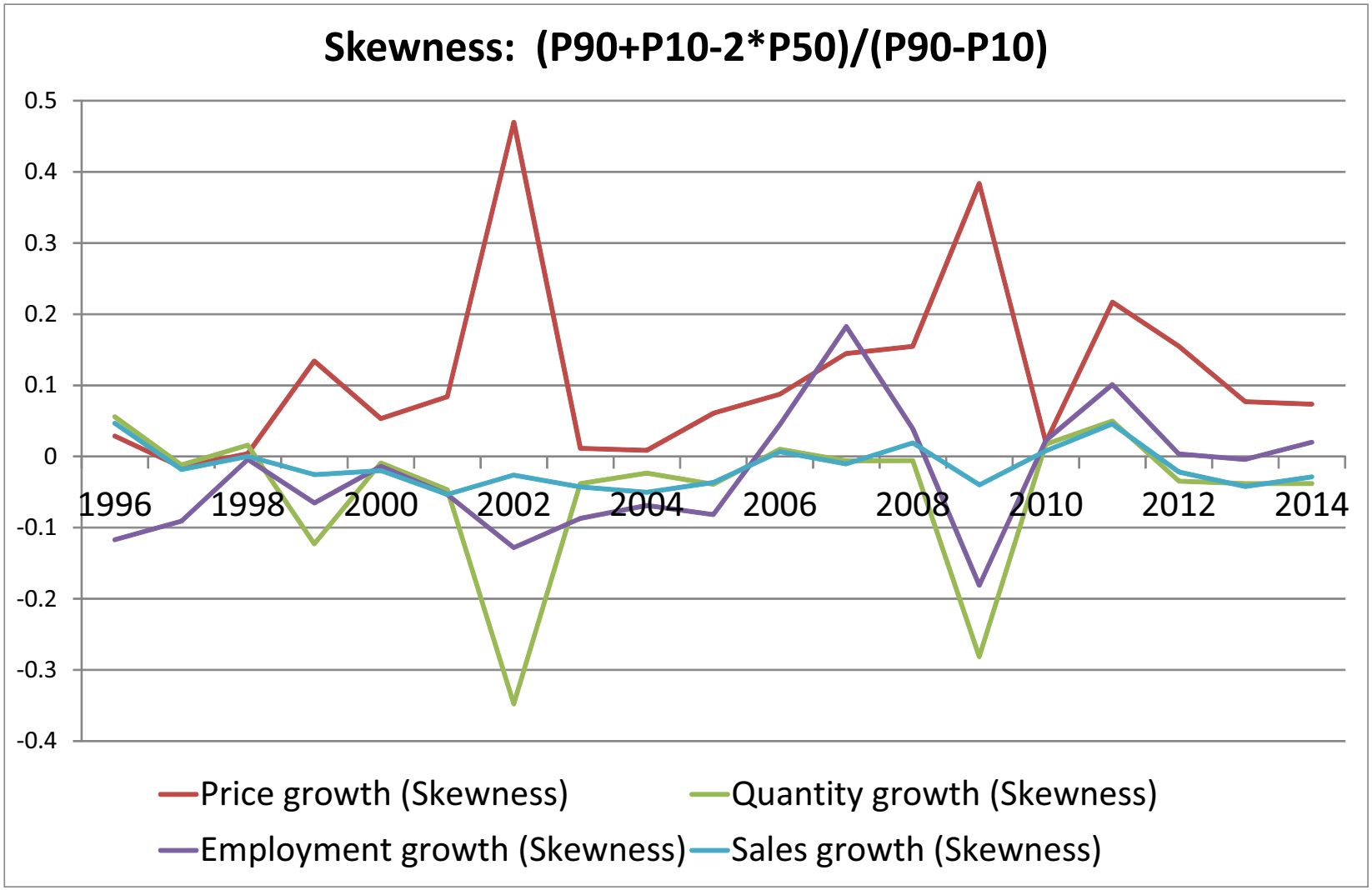
	Fraction $[-2\%, +2\%]$
$\hat{P}$	0.35
$\hat{Q}$	0.11
$\hat{E}$	0.25

Data statistics are averages of yearly residuals after controlling for industry and region.

Dispersion of firm growth (1996–2014)



Skewness (1996–2014)



Price and productivity dispersion

- Consider subsample of *homogeneous* goods (measured in length, area, volume, or weight). ▸ Examples
- $\overline{P}_j$ quantity-weighted mean price of good j (in a given year).
- Firm i's relative price index:

$$\widetilde{P}_i = \frac{\sum_j P_{ji} Q_{ji}}{\sum_j \overline{P}_j Q_{ji}}$$

- Revenue and quantity labor productivity (per hour):

$$RLP_i = \frac{\sum_j Q_{ji} P_{ji}}{H_i} \ , \ QLP_i = \frac{\sum_j Q_{ji} \overline{P}_j}{H_i} \ , \ RLP_i = \widetilde{P}_i \cdot QLP_i \ .$$

Wage dispersion

- Matched employer-employee data for subsample ($\approx 15\%$) of establishments in 2001, 2006, 2010 and 2014.
- Regress hourly wages on worker observables and job characteristics: $\log w_{ki} = \beta X_{ki} + \varepsilon_{ki}$.
- Firm i's relative wage index:

$$\widetilde{W}_i = \frac{\sum_k w_{ki} h_{ki}}{\sum_k e^{\beta X_{ki}} h_{ki}}$$

▸ Wage decomposition

Price, productivity and wage dispersion

	Std. dev.
$\log(RLP)$	0.639
$\log(QLP)$	1.032
$\log(\tilde{P})$	0.727
$\log(\tilde{W})$	0.210

	Correlation
$\log(QLP), \log(\tilde{P})$	-0.769
$\log(QLP), \log(\tilde{W})$	0.282
$\log(RLP), \log(\tilde{W})$	0.422

Data statistics are averages of yearly residuals after controlling for industry and region.

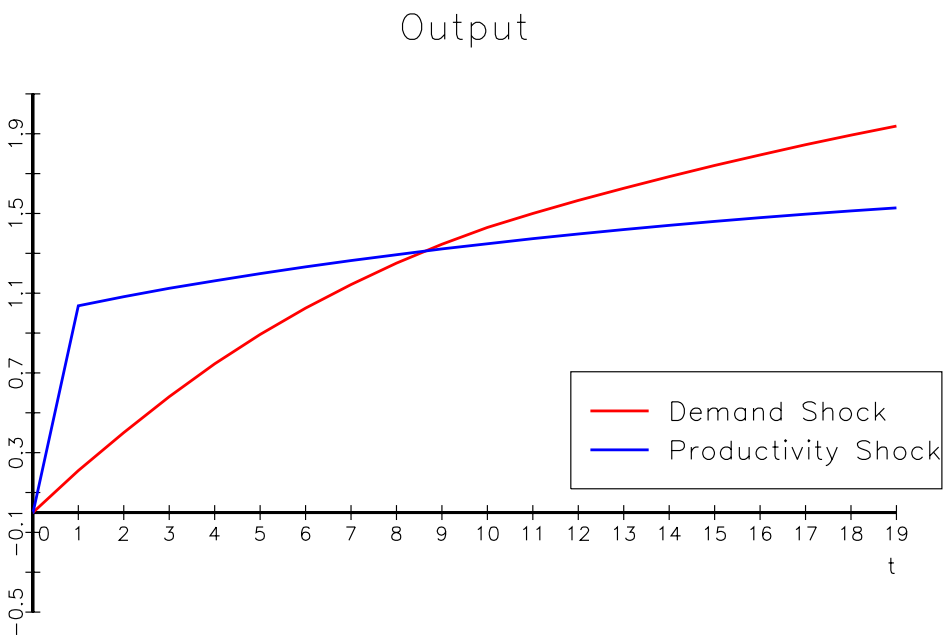
Negative relation between QLP and $\tilde{P} \Rightarrow \sigma(RLP) < \sigma(QLP)$.

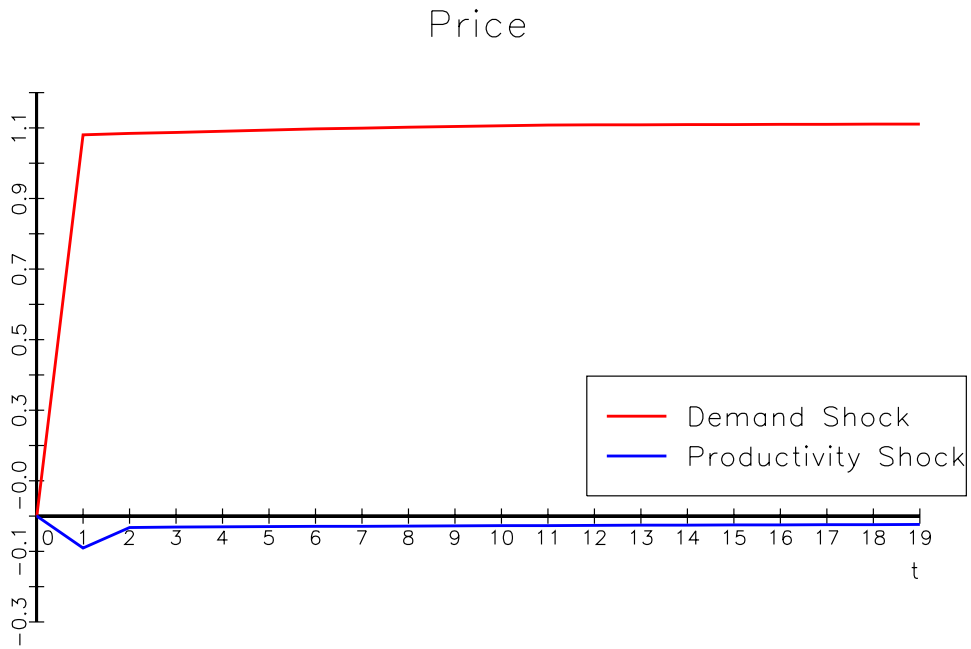
The model

- General equilibrium model of firm dynamics with search frictions in product and labor markets.
- Firms build customer base B and workforce L via costly sales and recruitment activities.
- Firms react to idiosyncratic productivity (cost) shocks x and demand shocks y.
- Dispersion of wages and prices, reflecting differences in x, y (and firm age).

▸ Model details

Response to firm-level shocks





Quantitative analysis

- Calibrate the model to evaluate the respective roles of productivity and demand for firm dynamics.
- Patterns of price, wage and productivity dispersion.
- Business-cycle analysis (impulse responses)

▸ More

Productivity and demand shocks

- Idiosyncratic productivity and demand shocks

$$\begin{aligned} \log(x_{t+1}) &= \rho_x \log(x_t) + \sigma_x \varepsilon^x_{t+1} \ , \\ \log(y_{t+1}) &= \rho_y \log(y_t) + \sigma_y \varepsilon^y_{t+1} \ . \end{aligned}$$

- Set $\sigma_x = 0.125$, $\sigma_y = 0.130$, $\rho_x = -0.34$, $\rho_y = 0.78$ to match volatility and persistence of firm-level price and output dynamics.

Firm dynamics

Productivity and demand shocks calibrated to match

	Data	Model	Only x shocks	Only y shocks
$\sigma(\hat{P})$	0.18	0.18	0.03	0.17
$\sigma(\hat{Q})$	0.26	0.27	0.24	0.10
$\hat{P} \in [-2\%, +2\%]$	0.35	0.36	0.47	0.72
$\hat{Q} \in [-2\%, +2\%]$	0.11	0.14	0.31	0.32

Data statistics are averages of yearly residuals after controlling for industry and region.

Demand shocks are important for dispersion of price growth.

Employment, hours and wages

	Data	Model	Only x shocks	Only y shocks
$\sigma(\hat{E})$	0.10	0.15	0.02	0.15
$\sigma(\hat{H})$	0.136	–	–	–
$\hat{E} \in [-2\%, +2\%]$	0.25	0.31	0.870	0.24
$\sigma(\widehat{W/E})$	0.09	0.08	0.01	0.07
$\sigma(\widehat{W/H})$	0.10	–	–	–

Data statistics are averages of yearly residuals after controlling for industry and region.

Price, productivity and wage dispersion

	Data	Model	Only x shocks	Only y shocks
$\sigma(RLP)$	0.639	0.220	0.132	0.178
$\sigma(QLP)$	1.032	0.312	0.147	0.115
$\sigma(\tilde{P})$	0.727	0.259	0.018	0.257
$\sigma(\tilde{W})$	0.210	0.077	0.015	0.073
$\rho(QLP, \tilde{P})$	-0.769	-0.550	-0.859	-0.803
$\rho(QLP, \tilde{W})$	0.282	-0.023	0.332	-0.315
$\rho(RLP, \tilde{W})$	0.422	0.820	0.336	0.893

Data statistics are averages of yearly residuals after controlling for industry and region.

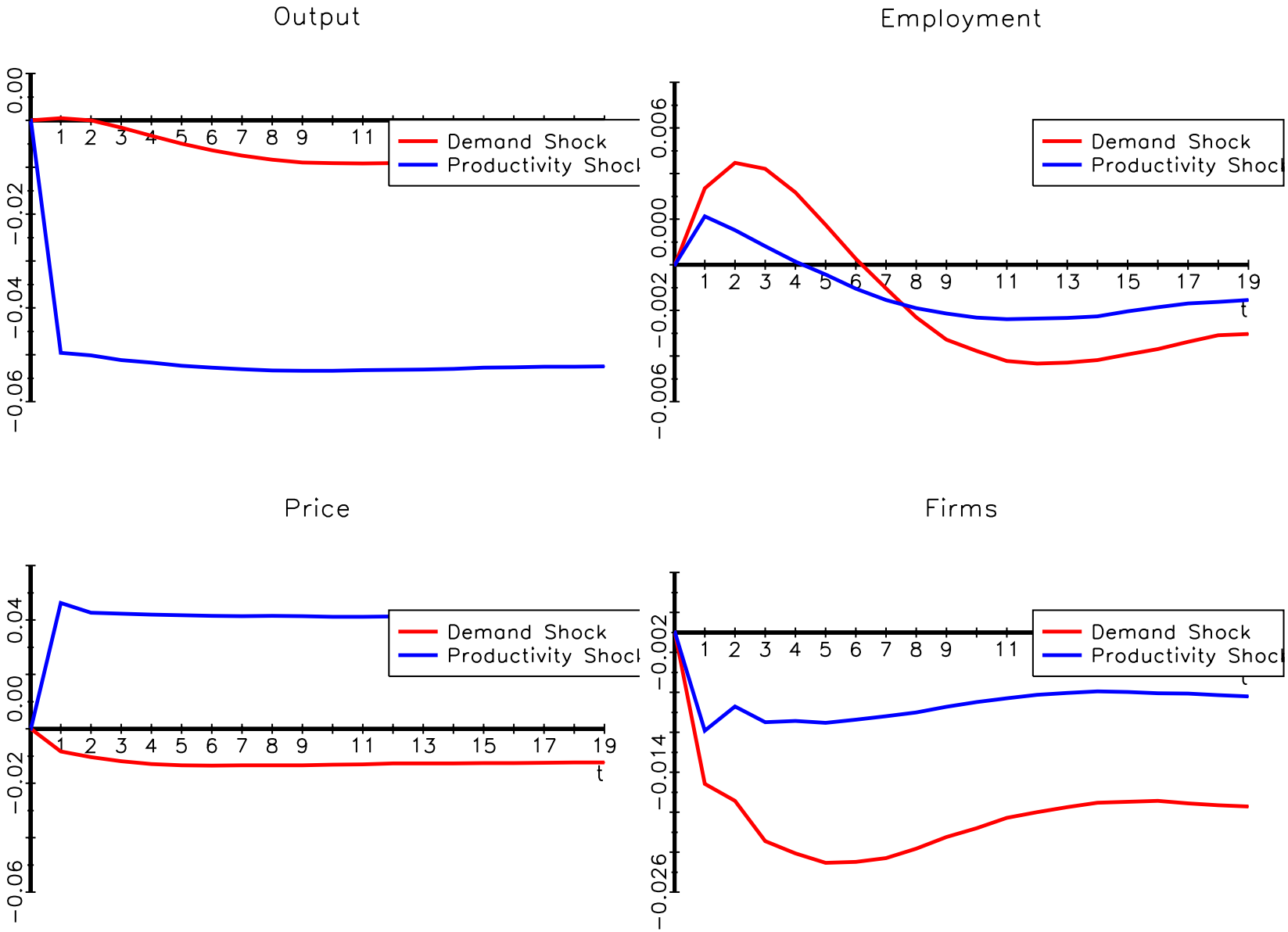
Model accounts for $\sim 1/3$ of price, productivity and wage dispersion.

Model impulse responses

Aggregate shocks:

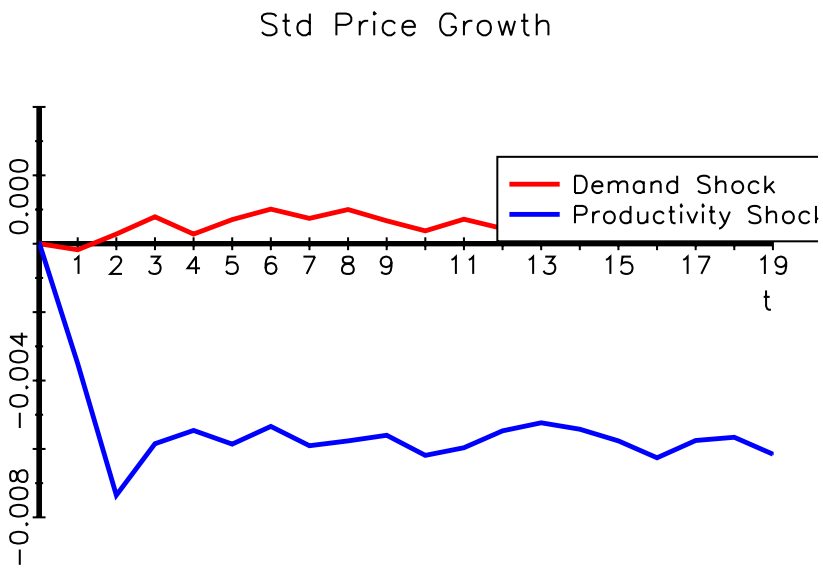
1. Mean productivity (decrease of x by 5%).
2. Mean demand (decrease of y by 5%).
3. Productivity uncertainty (increase of σ_x by 20%).
4. Demand uncertainty (increase of σ_y by 20%).

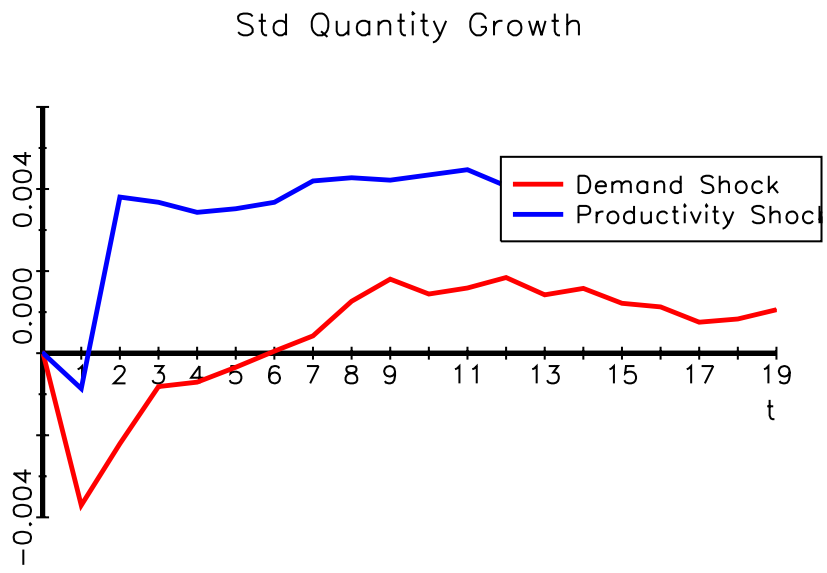
Impulse response to lower mean productivity/demand

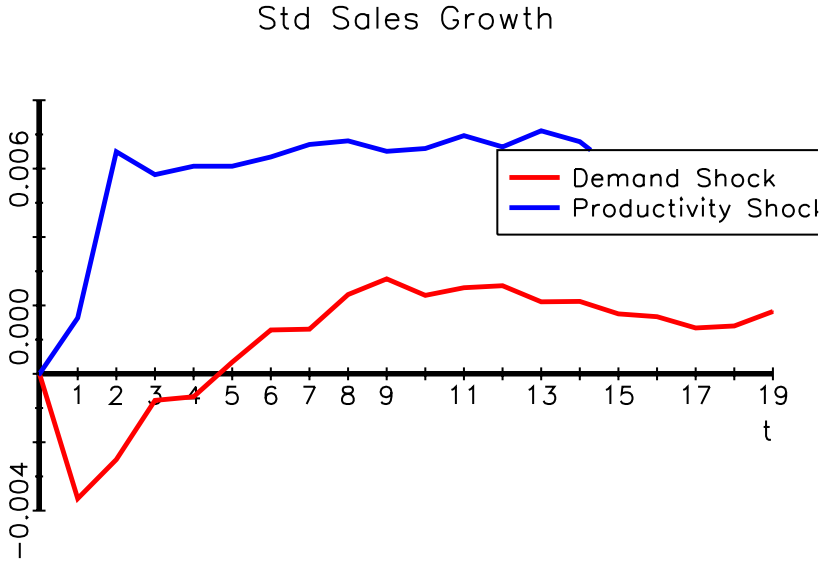


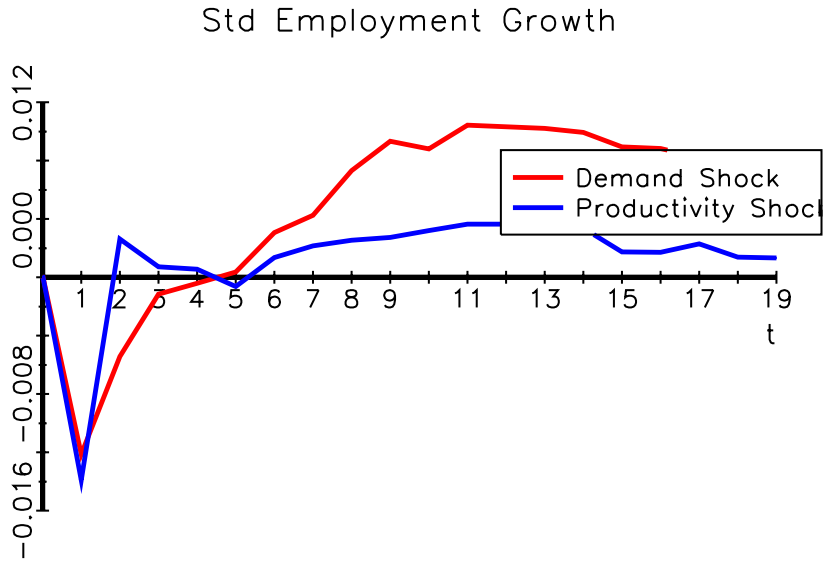
▸ More

Impulse response to lower mean productivity/demand

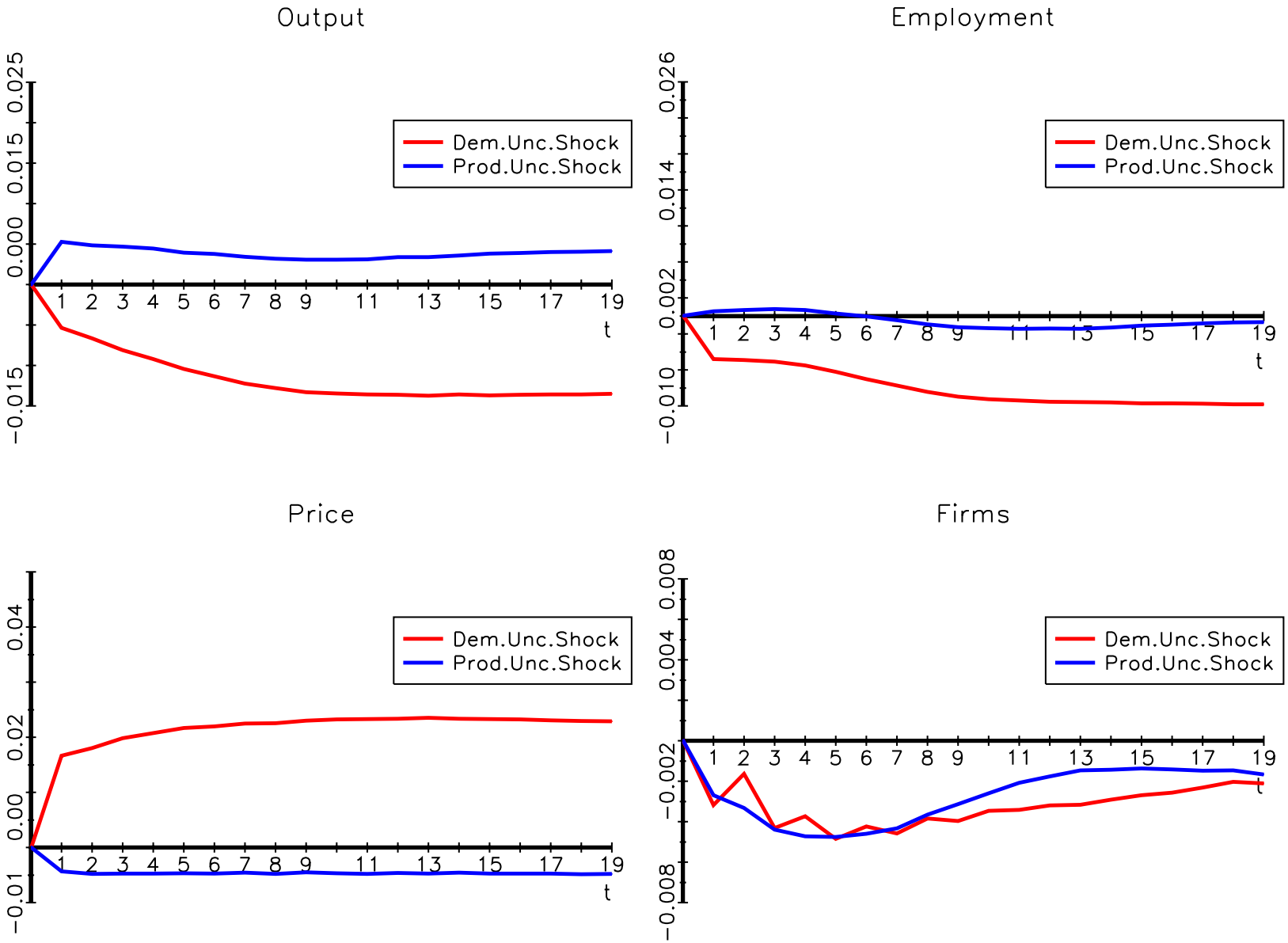








Impulse response to uncertainty shocks



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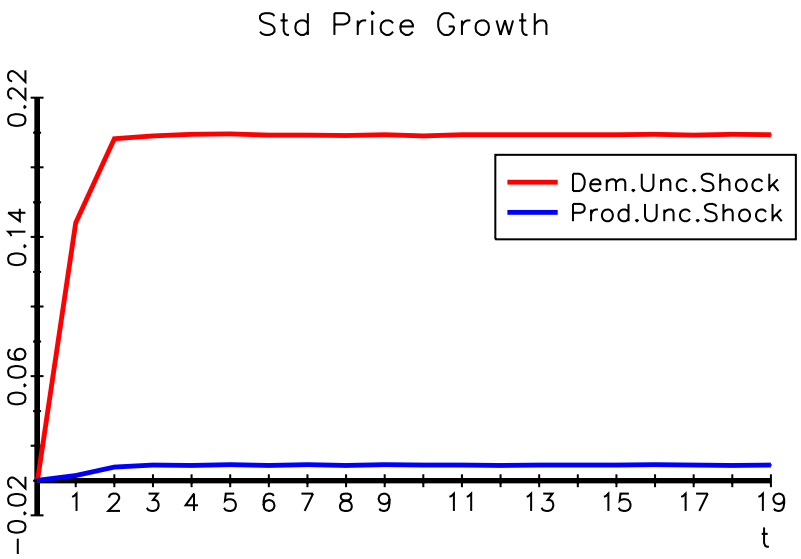
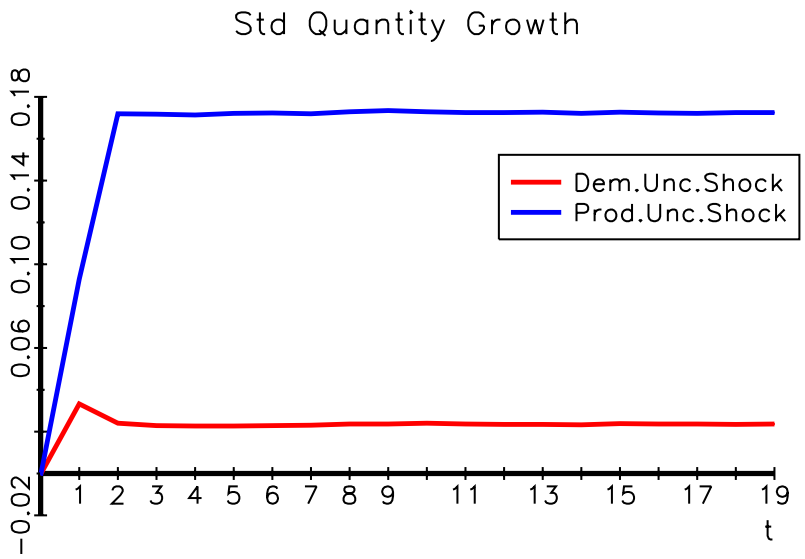
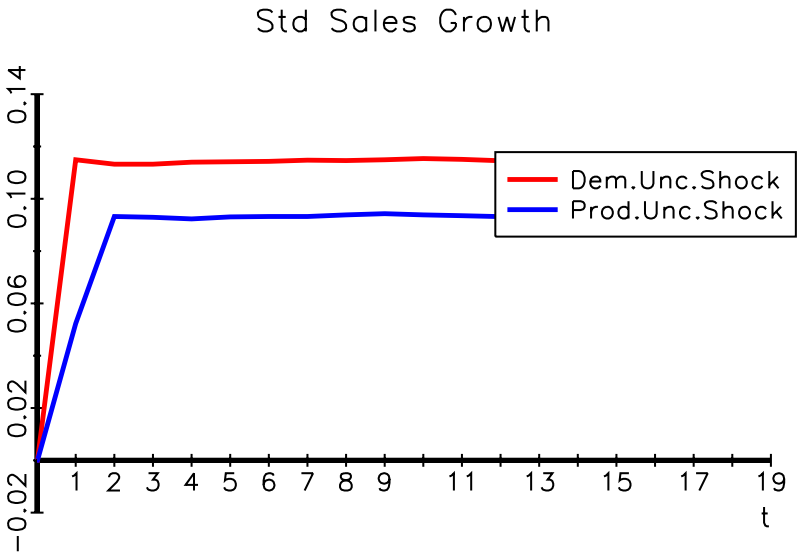
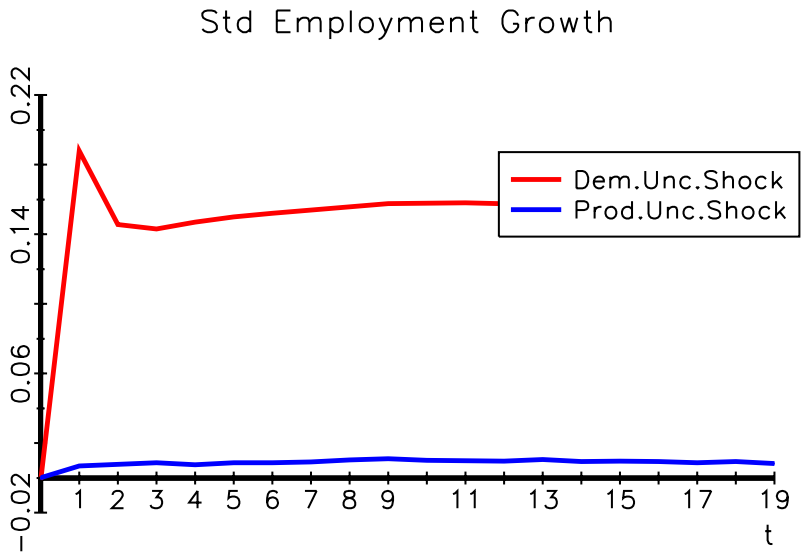
Impulse response to uncertainty shocks









Conclusions

- Firm dynamics with product and labor market frictions: separate roles for demand & productivity.
- Quantitative analysis: calibrate productivity and demand shocks to capture price and output dynamics.
- Implications for wage and price dispersion
- Mean productivity/demand shocks cannot account for counter-cyclical firm dispersion.
- Demand uncertainty shocks generate sizeable reactions of output and employment.

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
  - 1740 24 300 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").

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Wage dispersion

- Firm i's relative wage index:

$$\widetilde{W}_i = \frac{\sum_k w_{ki} h_{ki}}{\sum_k e^{\beta x_{ki}} h_{ki}}$$

- Decomposition of log hourly wage:

$$\log(w_i) = \log(\widetilde{W}_i) + \log\Bigg(\underbrace{\frac{\sum_k e^{\beta x_{ki}} h_{ki}}{\sum_k h_{ki}}}_{=\overline{w}_i \text{ (Predicted wage)}} \Bigg) .$$

- Variance decomposition:

$$\underbrace{8.6\%}_{var(\log(w))} = \underbrace{3.2\%}_{var(\log(\overline{w}))} + \underbrace{4.4\%}_{var(\log(\tilde{W}))} + \underbrace{1.0\%}_{2 \cdot covar(\log(\overline{w}),\log(\tilde{W}))} .$$

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The Model

- Canonical model of firm dynamics with trading frictions in product and labor markets.
- Representative household with
  - $\overline{L}$ worker members, each supplying one unit of labor per period.
  - Endogenous measure of shopper members (cost c), each buying up to one unit of a good per period.
- Preferences

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

e_t consumption of a numeraire good,
$y_t(f)$ firm-specific demand state ,
$C_t(f)$ consumption of firm f's output,
$\mu_t(.)$ measure of active firms in period t.

Firms

- Consider a firm with L workers and B customers.
- Output $xF(L)$ with $F' > 0$, $F'' < 0$. x is firm-specific productivity.
- The firm sells $\min(B, xF(L))$ units of output.
- $z = (x, y)$ follows a Markov process.
- Recruitment and sales costs $r(R, L)$ and $s(S, L)$.
- Costs are increasing & convex in effort R, S and possibly declining in size L (scale effects).

Search and matching

- Firms offer long-term wage contracts to new hires and price discounts to new customers.
- Directed search: Matching rates vary across firms.
- Firm hires $m(\lambda)R$ where λ are unemployed workers per unit of recruitment effort ($m' > 0$, $m'' < 0$).
- Firm attracts $q(\varphi)S$ new customers where φ are unmatched shoppers per unit of sales effort ($q' > 0$, $q'' < 0$).
- 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_0, y_0), $(L_0, B_0) = (0, 0)$.
- Firms exit with probability δ.
- Exogenous quit rates $\bar{\delta}_w$ and $\bar{\delta}_b$.
- Firms choose customer and worker separation rates $\delta_b \geq \bar{\delta}_b$, $\delta_w \geq \bar{\delta}_w$.

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, aggregate consumption C, and workers' search value 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) Free entry:

$$K = \sum_{z_0} \pi^0(z_0) J(0, z_0)$$

(e) Aggregate resource feasibility:

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

Social optimality

Recursive planning problem: Maximize the social firm value

$$G(L_-, B_-, x, y) = \max \Big\{ u'(C) y B - bL - r(R, L_-(1-\delta_w)) - s(S, L_-(1-\delta_w))$$

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

subject to

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

Firm policies

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

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

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

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

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

Prices and revenue

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

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

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Calibration

- Functional forms:

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

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

- Parameters

$$\alpha = 0.7, \ \nu = \sigma = 2, \ \mu = \gamma = 0.5 \ ,$$

$$\bar{\delta}_w = 0.02 \ , \ \bar{\delta}_b = 0.43 \ , \ \delta = 0.02 \ , \ \beta = 0.96 \ .$$

- m_0, q_0 such that matching rates for workers (shoppers) are 0.45 (0.5).
- Expenditures for recruitment (sales) are 1% (2%) of output.

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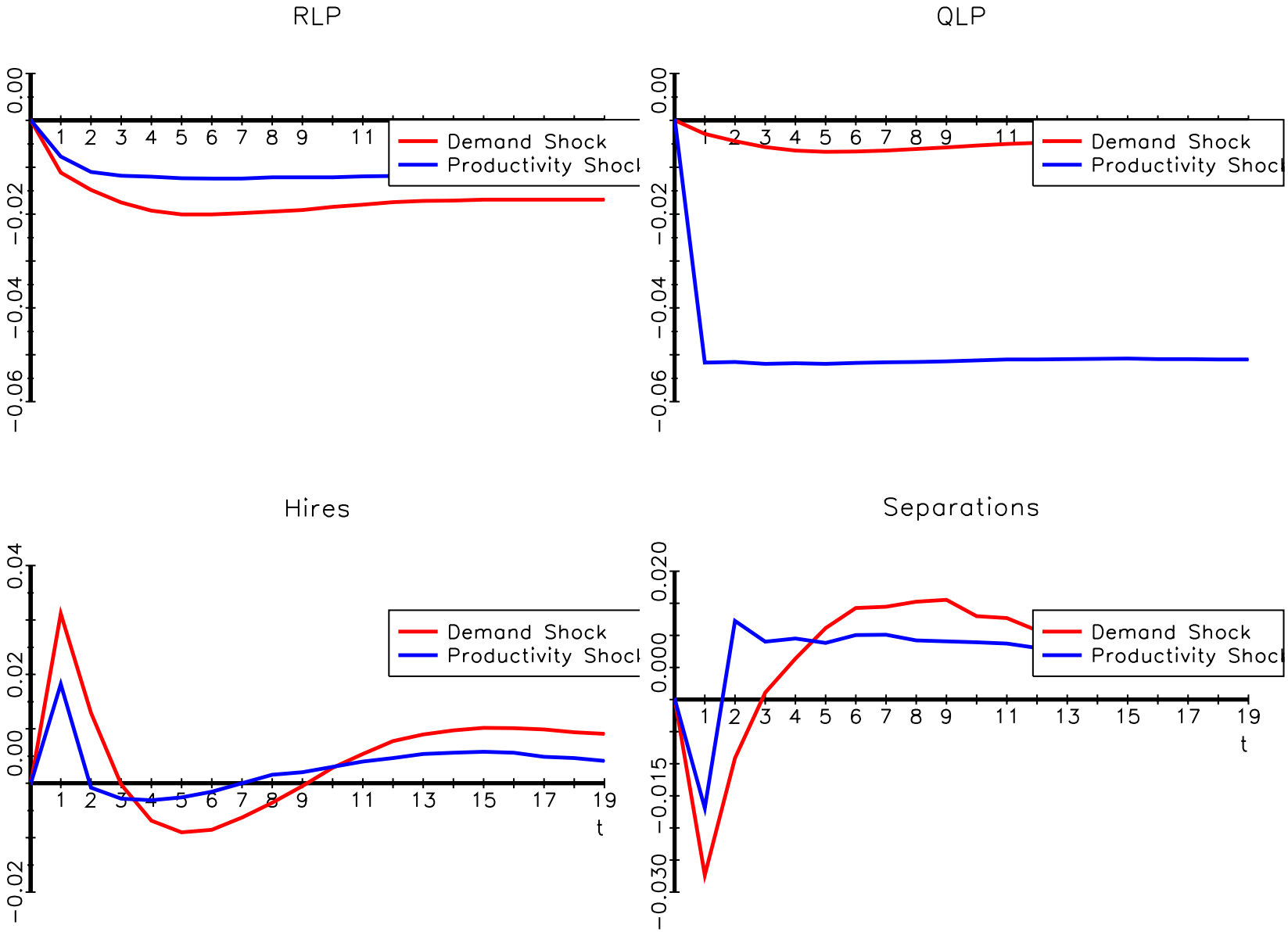
Impulse response to lower mean productivity/demand



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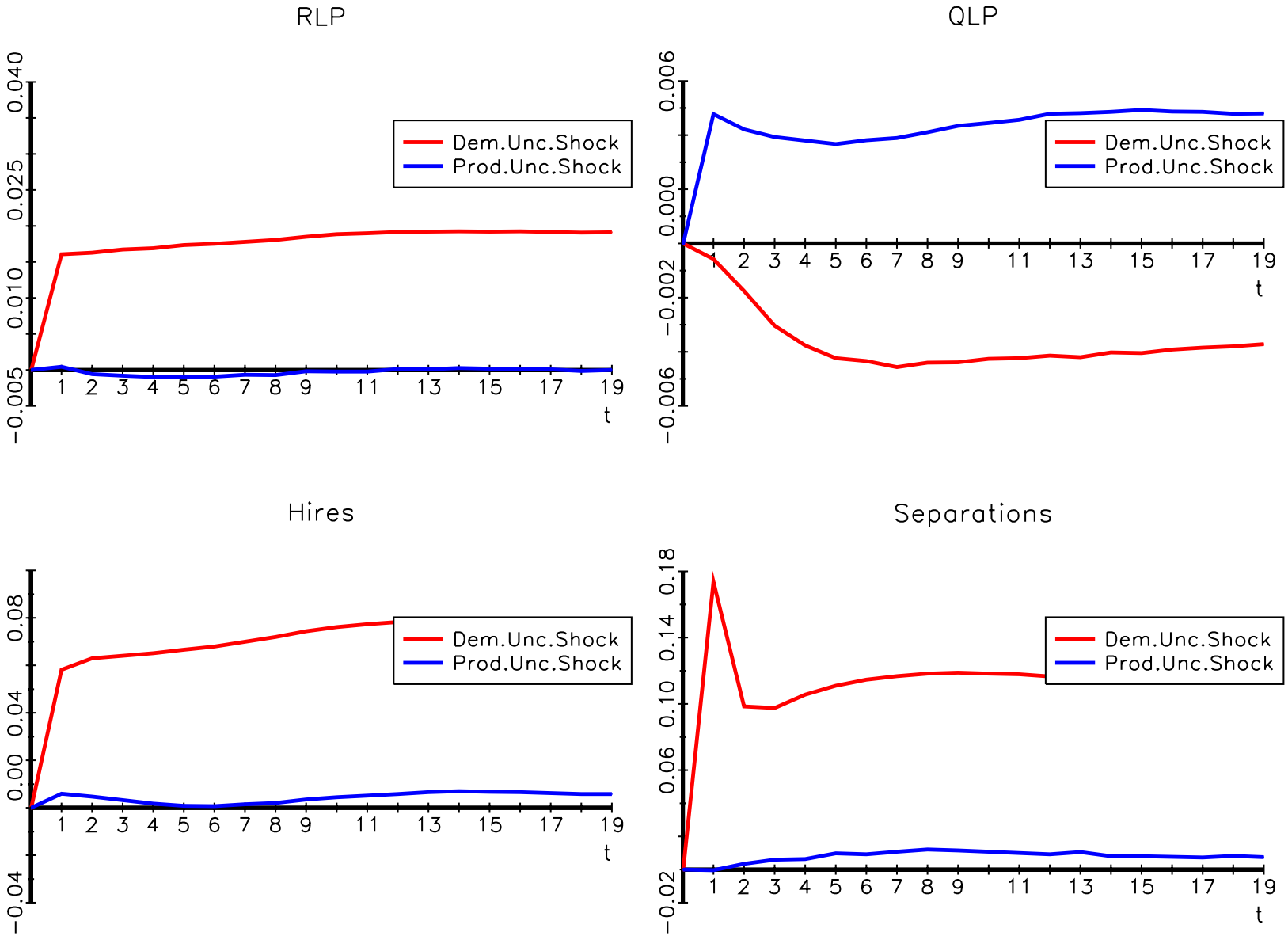
Impulse response to uncertainty shocks



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