Firm dynamics, demand amplification and endogenous price flexibility

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In a nutshell

Motivation

- Evidence shows frequency of price adjustment has risen recently...
- ...in the wake of several large adverse shocks (Covid-19, Ukraine war).

Our argument

- We relate increased price flexibility to rise in productivity uncertainty facing firms.
- In a regime of high uncertainty, more firms invest in price adjustment technology.

What we do

- We study Keynesian demand amplification of supply shocks through entry-exit...
- ...in a model with endogenous price flexibility.

Paper outline

Keynesian demand amplification through entry-exit

- With endogenous firm entry and exit, output effects of an adverse supply shock are amplified in sticky-price model relative to flexible-price model (Bilbiie and Melitz, 2020).

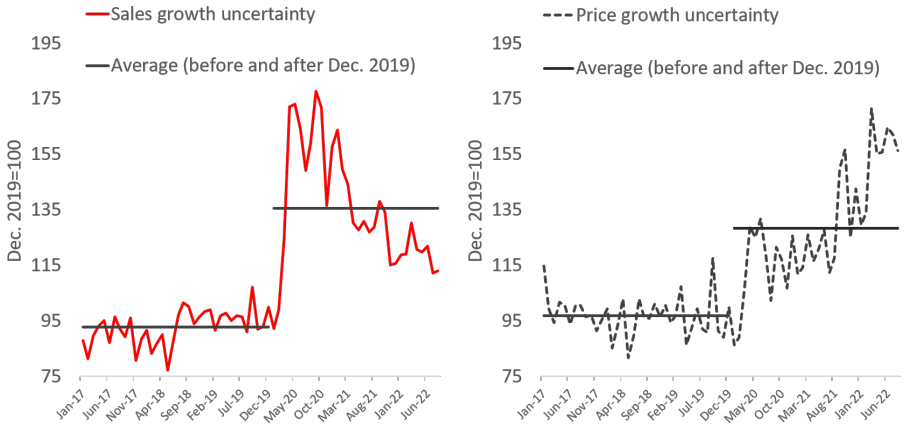
We consider investment in price adjustment technology

- Here, we endogenize degree of price flexibility following Devereux (2006)
- We re-evaluate demand amplification through entry-exit under endogenous price flexibility

Result

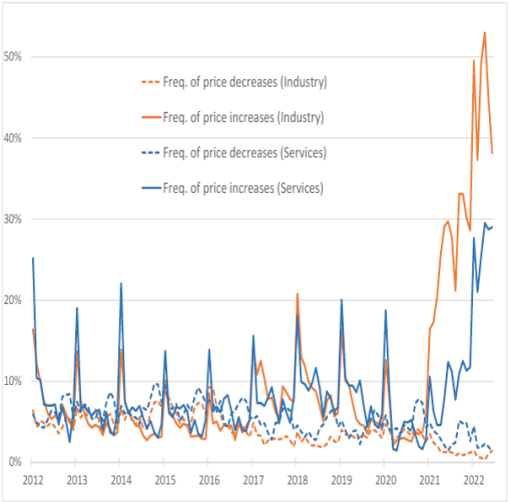
- Degree of price adjustment depends positively on supply shock volatility
- With endogenous price flexibility, demand amplification through entry-exit is dampened

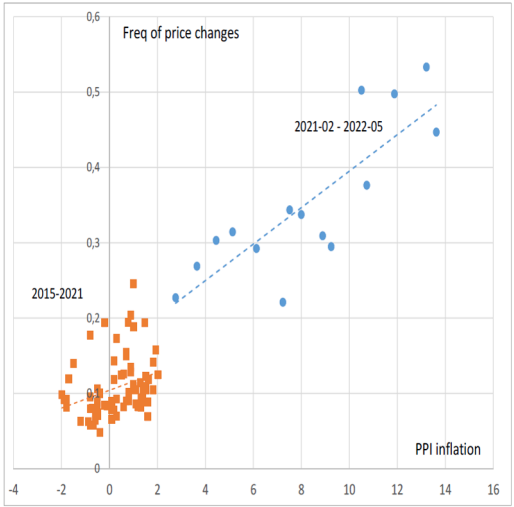
Firm-level uncertainty: evidence from UK survey data



Sources: Bank of England (Decision Maker Panel, DMP). Black solid line depicts pre- and post-December 2019 averages.

Frequency of price adjustment: evidence from France





Sources: Gautier et al. 2022, Banque de France monthly business survey.

Related literature - empirical

- Increased frequency of price adjustment in UK (Gautier et al. 2022), US (Montag and Villar 2022), Germany (Balleer et al. 2022)
- Relation between firm-level volatility and price flexibility: Vavra (2013), Bachmann et al. (2019)
- Relation between frequency of price adjustment and level of inflation: Gagnon (2009), Nakamura et al. (2018), Alvarez et al. (2018)
- 'Pricing capital': Dutta et al. (2002), Zbaracki et al. (2005)

Related literature - theoretical

- Keynesian demand amplification of supply shocks: Bilbiie and Melitz (2020), Guerrieri et al. (2022)
- Endogenous firm/product entry: Bilbiie et al. (2012), Bilbiie et al. (2019), Bilbiie et al. (2007), Bergin and Corsetti (2008)
- Endogenous price flexibility: Dotsey et al. (1999), Alvarez et al. (2011) state-dependent pricing models with 'ex-post price flexibility'; Devereux (2006) 'ex-ante price flexibility'

Model features

New Keynesian model with endogenous entry-exit

- Monopolistic competition, firms are indexed by $\omega \in (0, N)$
- Some firms set price flexibly, others set price one period in advance
- Zero-profit condition determines number of firms

As in Devereux (2006),

- Firms can invest in technology that allows them to change prices
- Costs of investing in price flexibility specified in labor units
- Firms differ in their cost of price flexibility $\Phi(\omega)$, where $\Phi'(\omega) > 0$

$\Rightarrow$ Degree of price flexibility is endogenous in the model

Production, demand, expected profits

Production function

$$Y(\omega) = Al(\omega) - D_\omega \Phi(\omega), \qquad \text{where } D_\omega \in \{0, 1\}$$

Demand

$$Y(\omega) = \left(\frac{P(\omega)}{P} \right)^{-\theta} Y$$

Expected profits

$$E\Gamma \left\{ P(\omega) Y(\omega) - \frac{W}{A} Y(\omega) - \frac{W}{A} D_\omega \Phi(\omega) \right\}$$

where Γ is Lagrange multiplier on budget constraint

Price setting and expected profits

Price setting, flex-price and sticky-price firms

$$\tilde{P} = \delta W/A$$

$$\bar{P} = \delta \frac{E\{\Gamma(W/A)\hat{Y}\}}{E\{\Gamma\hat{Y}\}}$$

Expected profits, flex-price and sticky-price firms

$$\tilde{V}(\Theta) = (\delta^{1-\theta} - \delta^{-\theta})E\{\Gamma(W/A)^{1-\theta}\hat{Y}\}$$

$$\bar{V}(\Theta) = (\delta^{1-\theta} - \delta^{-\theta})E\{\Gamma(W/A)\hat{Y}\}^{1-\theta}E\{\Gamma\hat{Y}\}^{\theta}$$

where $\delta = \theta/(\theta - 1)$, $\hat{Y} = P^{\theta}Y$ and $\Theta = \{\Gamma, W, \hat{Y}, A\}$

Investment in price flexibility

Firm chooses $D_\omega = 1$ if

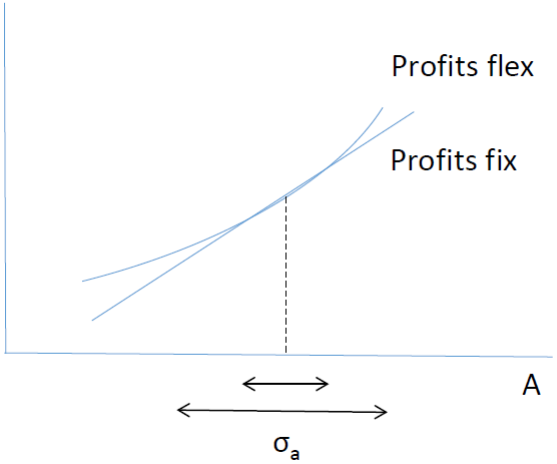
$$\tilde{V}(\Theta) - \bar{V}(\Theta) > E\left\{\Gamma \frac{W}{A}\Phi(\omega)\right\}$$

or rather if gains from price flexibility exceed costs

$$\Delta(\Theta) \equiv \frac{\tilde{V}(\Theta) - \bar{V}(\Theta)}{E\left\{\Gamma W/A\right\}} \geq \Phi(\omega)$$

We derive a second order approximation of gain function $\Delta(\Theta)$

Gains from price flexibility increase in volatility of productivity



Consistent with evidence in Gorodnichenko and Weber (2016) and Dutta et al. (2002)

more details

What is 'investment in price flexibility'?

Electronic shelf label system in supermarkets

- Electronic price displays allow for cheaper and more efficient price adjustment

'Price escalation clauses'

- These clauses allow firms to increase previously agreed-upon price in event of unexpected cost rises, e.g. due to higher prices of raw materials or energy
- Bundesbank's firm survey of August 2022 shows that proportion of firms using price escalation clauses has doubled since 2021, rising to 34%

Moving to online sales

- Gorodnichenko et al. (2018) and Rudolf and Seiler (2022) show that online prices change more frequently than offline prices

Determination of price flexibility in the aggregate

Cost of investing in price flexibility

- Firms ranked according to their unique fixed cost of flexibility $\Phi(\omega)$
- Let $zN \in (0, N)$ denote firm with highest cost still willing to invest in flexibility

Price flexibility z determined by

$$\Delta(\Theta) = \Phi(zN), \quad 0 \leq z \leq 1,$$

$$\Delta(\Theta) > \Phi(N), \quad z = 1.$$

Households

Choose consumption C, labor L and money holdings M to maximize

$$\ln C + \eta \ln \frac{M}{P} - \chi \frac{L^{1+\varphi}}{1+\varphi}$$

subject to budget constraint

$$\Pi + WL + M_0 + T \geq PC + M$$

First order conditions

$$\chi L^{\varphi} = \frac{1}{PC} W$$
$$M = \eta PC$$

final goods firm

Firm entry-exit, price index and aggregation

Price index with two firm types, flexible and sticky

$$P^{1-\theta} = N[z\tilde{P}^{1-\theta} + (1-z)\bar{P}^{1-\theta}]$$

Total operating profits of all firms

$$\Pi = \int_0^{zN} \tilde{P}(\omega)\tilde{Y}(\omega)d\omega + \int_{zN}^{N} \bar{P}(\omega)\bar{Y}(\omega)d\omega - WL$$

Labor market clearing

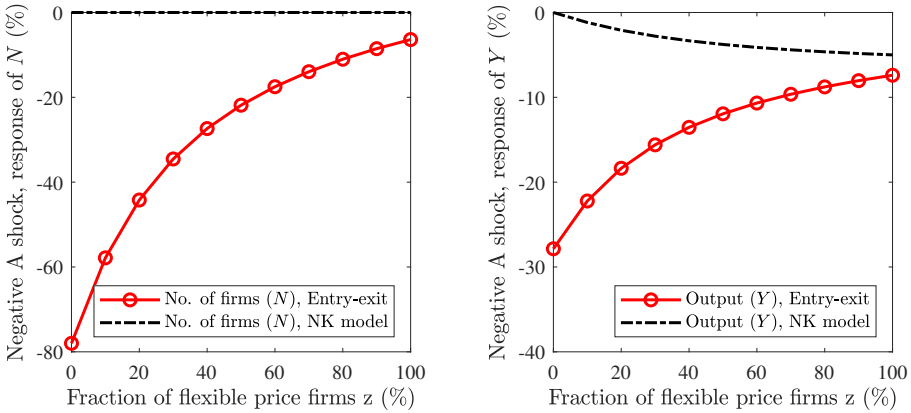
$$L = (N/A)\{z(\tilde{P}/P)^{-\theta}Y + (1-z)(\bar{P}/P)^{-\theta}Y\} + \int_0^{zN} \Phi(\omega)d\omega$$

Entry/exit (zero profit condition): $\Pi/(PN) = f$

model summary | calibration | model solution

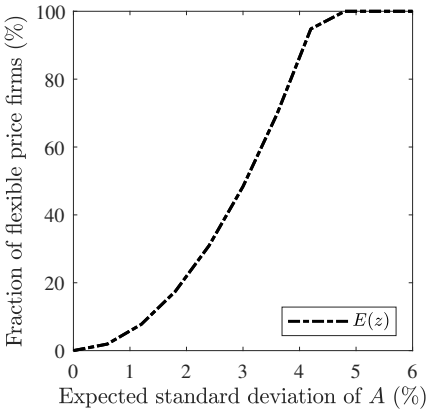
Entry-exit amplification under constant price flexibility

CPI response



Impact response to a negative supply shock, as a function of price flexibility z, standard New Keynesian model versus entry-exit model.

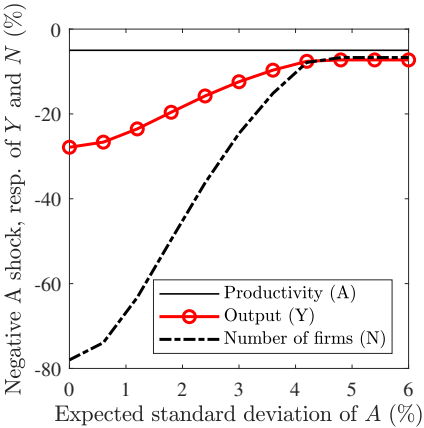
Endogenous price flexibility and shock volatility



Fraction of flexible price firms – in the model with endogenous price flexibility – for different volatilities of labor productivity A.

Entry-exit amplification under endogenous price flexibility

Price response



Impact response of the number of firms and of output to an adverse labor productivity shock – in the model with endogenous price flexibility – for different *ex ante* volatilities of labor productivity A.

Conclusion

Entry-exit amplification of supply shocks (Bilbiie and Melitz, 2020)

- When prices are sticky, firm entry/exit amplifies output response to supply shocks, especially to adverse supply shocks

We study entry-exit amplification under endogenous price flexibility (Devereux, 2006)

- Firm can invest in technology that allows it to change its price in response to shocks
- Standard deviation of shocks critical for equilibrium price flexibility

Result

- When productivity uncertainty increases, more firms are willing to invest in price flexibility $\Rightarrow$ This raises producer price inflation and reduces entry-exit amplification

further results

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Gains from price flexibility increase in volatility of labor productivity back

Second-order approximation of gain function

$$\Delta(\Theta) \approx \frac{\Omega}{2}(\theta-1)\theta\underbrace{\left[\sigma_w^2+\sigma_a^2-2\sigma_{wa}\right]}_{Var(\ln W-\ln A)}$$

where $\Omega \equiv V(\exp(E\ln\Theta))/\exp(E\ln\Gamma + E\ln W - E\ln A) > 0$ and $V(\exp(E\ln\Theta))$ are profits – of flex-price firms or sticky-price firms – evaluated at stochastic mean $E\ln\Theta$.

Gains to price flexibility depend

- positively on variance of the wage
- positively on variance of productivity
- negatively on their covariance

Final goods firm back

Aggregate output as in Dixit and Stiglitz (1977)

$$Y = \left(\int_0^N Y(\omega)^{\frac{\theta-1}{\theta}} d\omega \right)^{\frac{\theta}{\theta-1}}, \text{where } \theta > 1$$

Demand for good ω is solution to

$$\min_{Y(\omega)} \int_0^N P(\omega) Y(\omega) d\omega$$

Price index

$$P = \left(\int_0^N P(\omega)^{1-\theta} d\omega \right)^{\frac{1}{1-\theta}}$$

Model summary back

Price flexibility	$\Delta(\Theta) = \Phi(zN), 0 \leq z \leq 1$
	$\Delta(\Theta) > \Phi(N), \quad z = 1$
Flexible price	$\tilde{P} = \delta W/A$
Sticky price	$\bar{P} = \delta E\{\Gamma(W/A)\hat{Y}\}/E\{\Gamma\hat{Y}\}$
Price index	$P^{1-\theta} = N[z\tilde{P}^{1-\theta} + (1-z)\bar{P}^{1-\theta}]$
Labor market	$L = (N/A)\{z(\tilde{P}/P)^{-\theta}Y + (1-z)(\bar{P}/P)^{-\theta}Y\} + \Phi\frac{1}{2}(zN)^2$
Labor supply	$W = \chi L^{\varphi} YP$
Money market	$Y = M/(\eta P)$
Zero profit condition	$(1 - \chi L^{1+\varphi})Y = fN$

Baseline parameter values back

Parameter name	Value	Target / Reference
Substitution elasticity between goods	$\theta = 3.8$	Bergin and Corsetti (2008)
Labor supply elasticity	$\varphi = 2$	Keane and Rogerson (2012)
Returns to labor in production	$\alpha = 1$	Bilbiie and Melitz (2020)
Std. dev. of productivity shocks	$\sigma_A = 5\%$	approx. 25% output drop
Persistence of productivity shocks	$\rho_A = 0.5$	Bilbiie and Melitz (2020)
Costs of investing in price flexibility	$\Phi = 0.03$	3% of output for $z = 1$
Per-period entry cost	$f = 0.2604$	determined endogenously
Weight on labor in utility	$\chi = 0.6935$	determined endogenously

Model solution: two-step numerical approach back

Step 1: Firms' investment in price flexibility

- Evaluate fraction of flexible price setters at stochastic steady state (Meyer-Gohde, 2017)

Step 2: Given degree of price flexibility, solve dynamic general equilibrium model

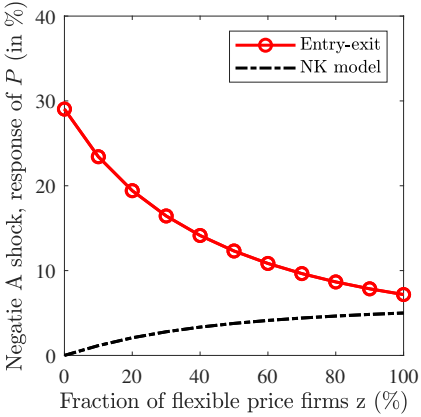
- Compute generalized impulse response functions

Further complication: occasionally binding constraint

- Number of firms cannot be negative
- Fraction of flexible-price firms has to be between zero and one

$\Rightarrow$ Use Holden (2016) toolbox to check robustness

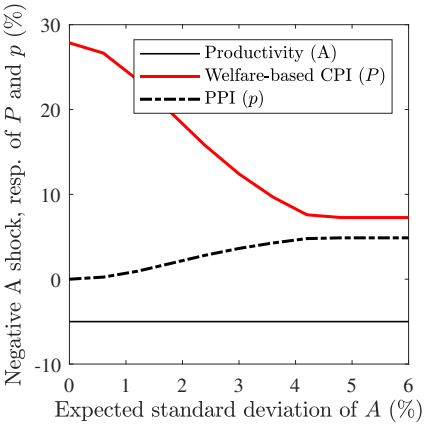
Consumer price response back



Impact response to an adverse supply shock, as a function of price flexibility z, standard New Keynesian model versus entry-exit model.

Price response for different volatilities of labor productivity

back



Impact response of labor productivity, the CPI and the PPI to an adverse labor productivity shock – in the model with endogenous price flexibility – for different *ex ante* volatilities of labor productivity A.

Further results and robustness back

Further results

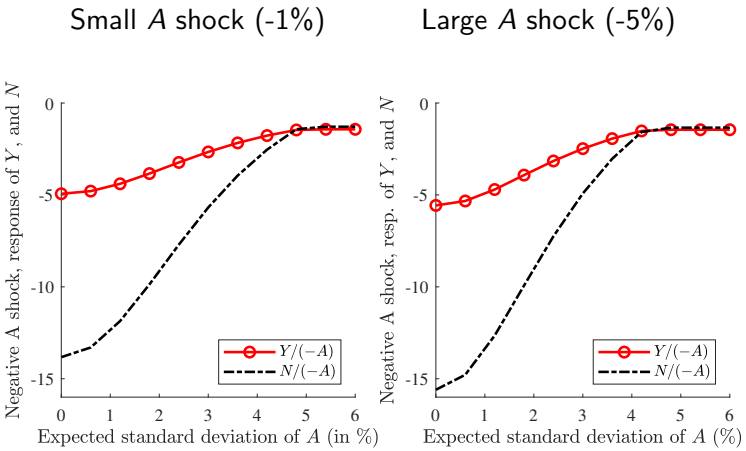
- Asymmetric effects of small versus large shocks as in Bilbiie and Melitz (2020) asymmetries
- Larger demand elasticity makes price flexibility curve steeper θ
- Larger inverse labor supply elasticity makes price flexibility curve steeper φ

Robustness

- Model assumes that aggregate zero-profit condition and labor market clearing – and given the ex ante initial condition of the number of flexible- and sticky-price firms – determine the *ex post* number of flexible- and sticky-price firms left in the market *after* an adverse shock happens.
- However, we abstract from the possibility that flexible-price firms can better cope with shocks and therefore do not exit the market before all sticky-price firms have exited.

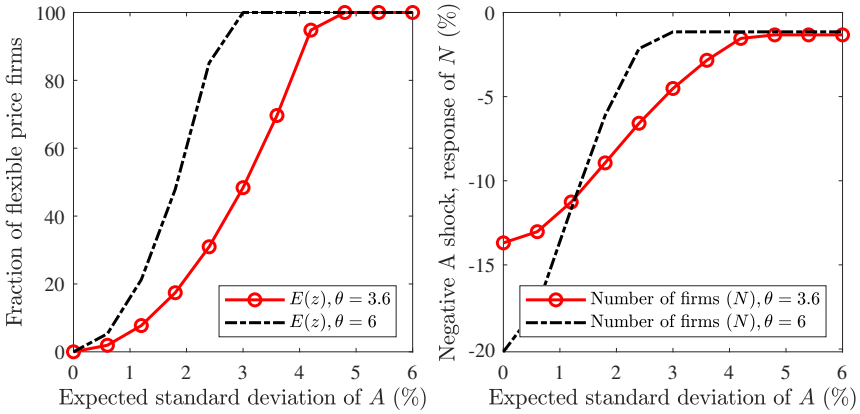
$\Rightarrow$ We formulate a modified model that takes into account this possibility and find quantitatively very similar results.

Entry-exit amplification for small and large shocks back



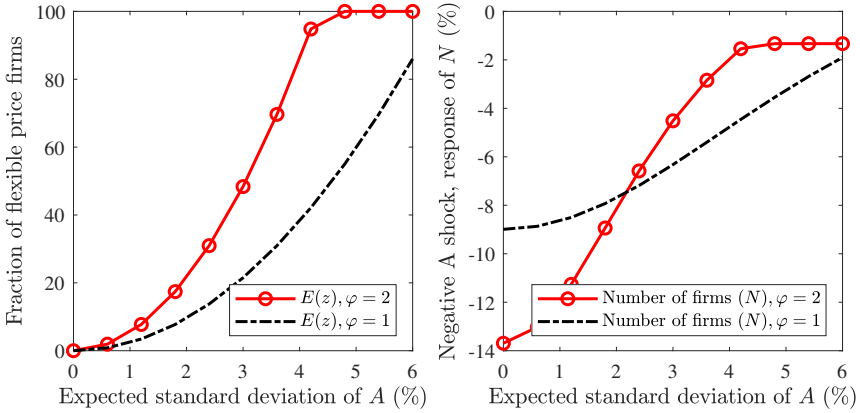
Left panel shows impact response to a small adverse supply shock (-1pp); right panel shows impact response to a large adverse supply shock (-5pp). Normalized by the (negative) impact of productivity.

Demand elasticity θ back



Left panel: Fraction of flexible price firms for high and low demand elasticity θ. Right panel: Simulation of productivity drop by 1 %; impact response of the number of firms to an adverse supply shock for a high and a low demand elasticity θ.

Inverse labor supply elasticity φ back



Left panel: Fraction of flexible price firms for high and low inverse Frisch elasticity of labor supply φ. Right panel: Simulation of productivity drop by 1 %; impact response of the number of firms to an adverse supply shock for a high and a low inverse Frisch elasticity φ.