Measuring Price Selection in Micro Data: It's Not There

Peter Karadi Raphael Schoenle Jesse Wursten

February 2021

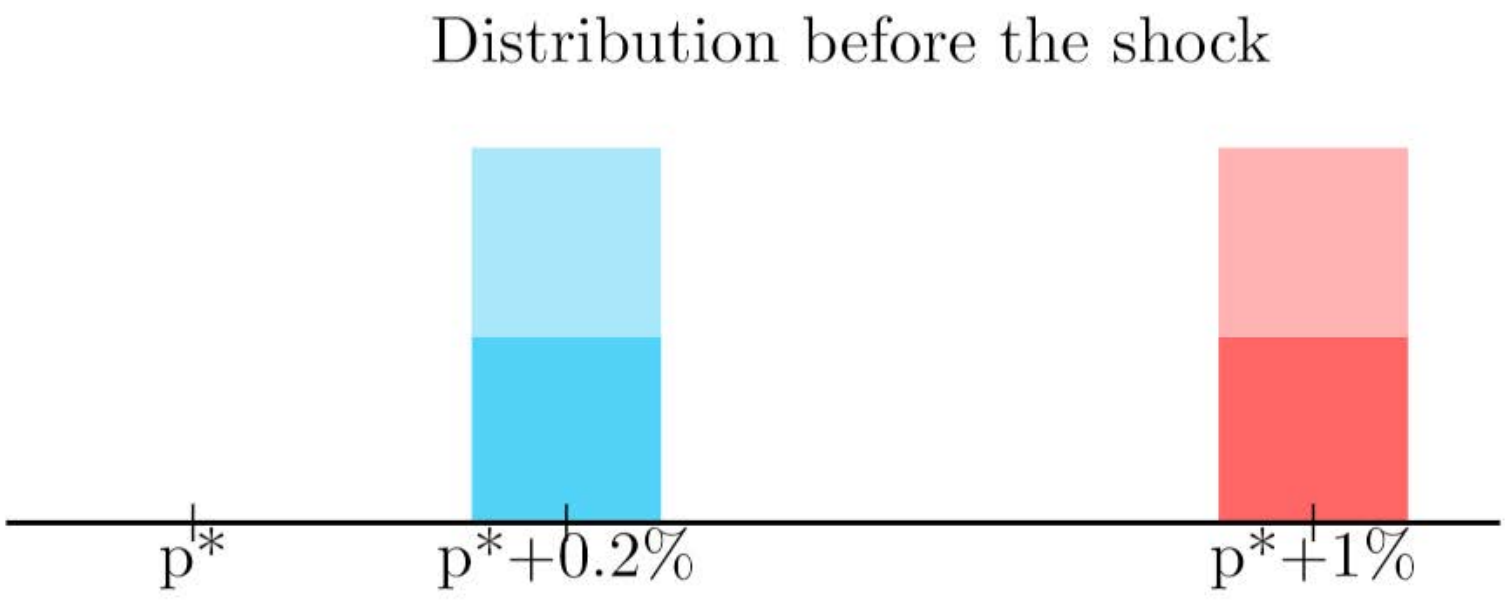
Motivation

- Rigidity of the price level influences
  - Real effects of monetary policy
  - Amplification through 'demand' channels
- Prices change infrequently (Bils and Klenow, 2004)
- In standard price-setting models (Calvo, 1983)
  - Low frequency implies rigid price level
- In micro-founded state-dependent models (Golosov and Lucas, 2007; Woodford, 2009)
  - Price level can stay flexible even if a small fraction adjusts
  - If *large* price changes are selected

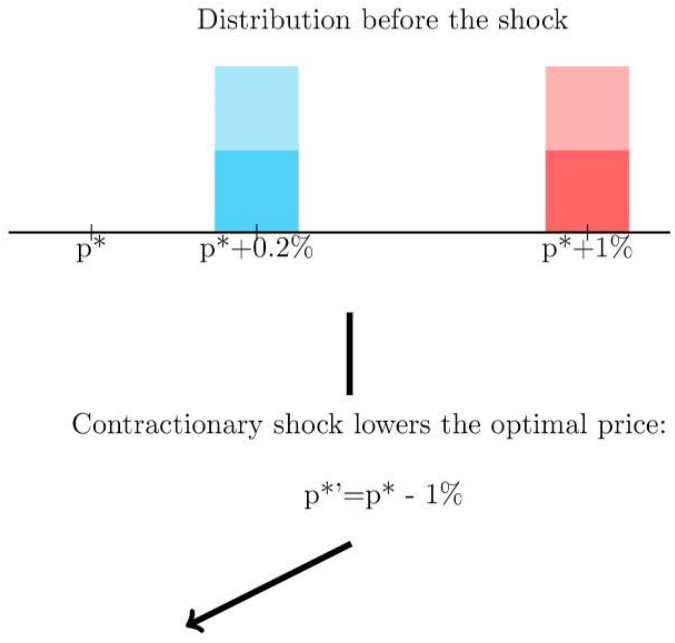
Selection of large price changes

- Why would large price changes be selected?
- Fixed costs of price adjustments (menu costs, or information-collection costs)
  - Optimal to concentrate on products with the largest mispricing
- When the aggregate shock hits
  - Adjusted prices are far from their optima,
  - When they change, they change by a large amount,
  - Raise the flexibility of the price level

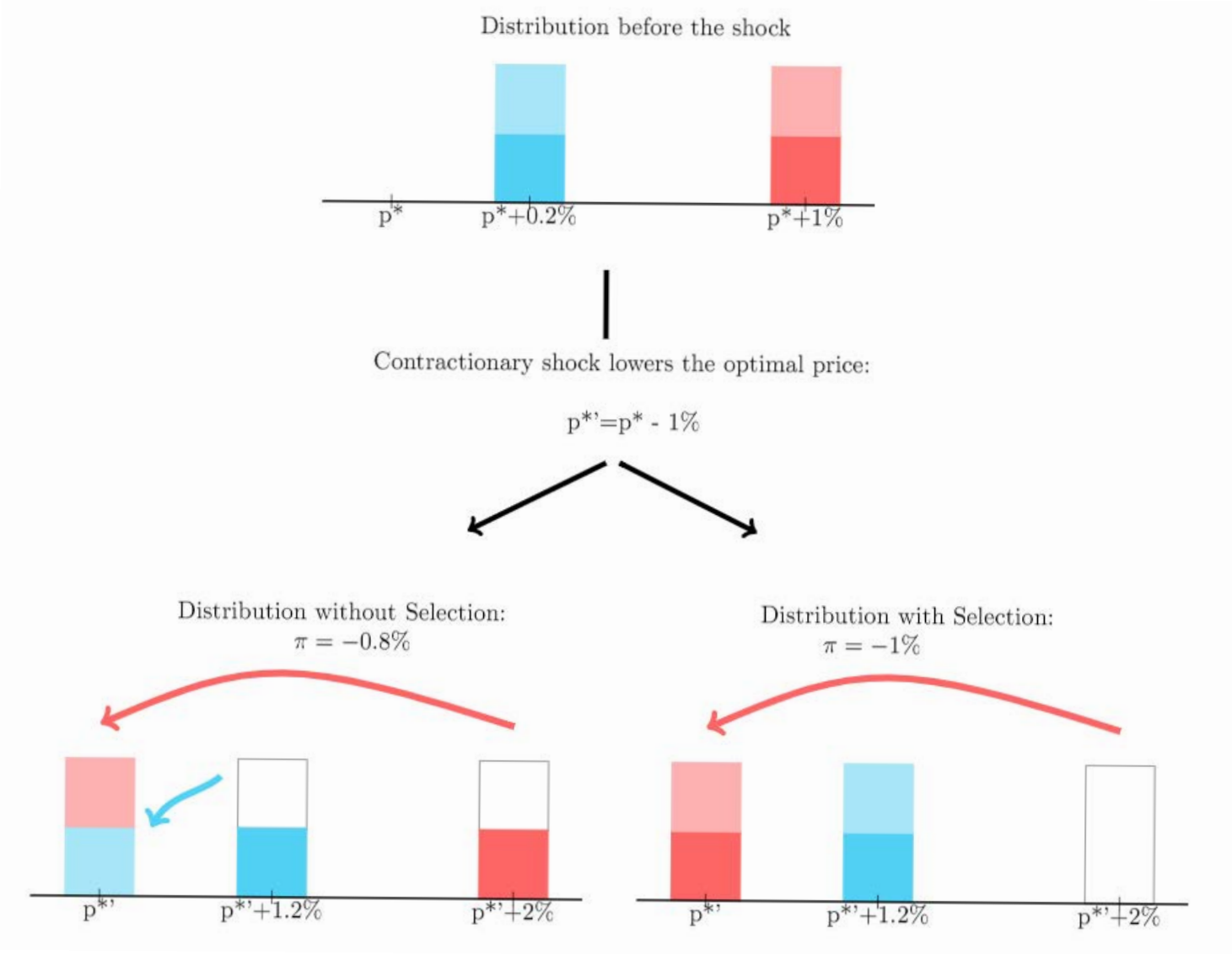
Price selection: toy example



Price selection: toy example, cont.



Price selection: toy example, cont.



What do we do? - Measure selection

- Generate product-store-level proxies for price gaps
- Identify aggregate shocks
- Selection: micro-macro interaction
  - A necessary condition: gap-shock interaction affects price-change probability
  - Then: conditional on the shock, prices with large gaps are changed with higher probability than those with small gaps

What do we find?

- State dependence: gap predicts change probability and size
- No selection: gap immaterial conditional on an aggregate shock
- Provides guidance for model choice and policy implications
- Consistent with mildly state-dependent models with sizable monetary non-neutrality (Dotsey et al., 1999; Woodford, 2009; Costain and Nakov, 2011; Luo and Villar, 2017; Alvarez et al., 2020)

Plan of talk

- Selected Literature
- US supermarket data (IRi) (robust to PPI)
- Price-gap proxy: competitor-gap (robust to reset-price gap)
- Aggregate credit shock: (robust to monetary policy shock)
- Selection
- Robustness (non-linear specification)

Selected literature

- State-dependent models: selection determines non-neutrality
- Classic menu cost: strong selection (Caplin and Spulber, 1987; Golosov and Lucas, 2007)
- Weak selection:
  - Fat tails Midrigan (2011), but Karadi and Reiff (2019)
  - Multiproduct Alvarez and Lippi (2014), but Bonomo et al. (2019)
  - Flat hazard: random menu cost (Dotsey et al., 1999; Luo and Villar, 2017; Alvarez et al., 2020) and rational inattention (Woodford, 2009)
- Us: Empirical question

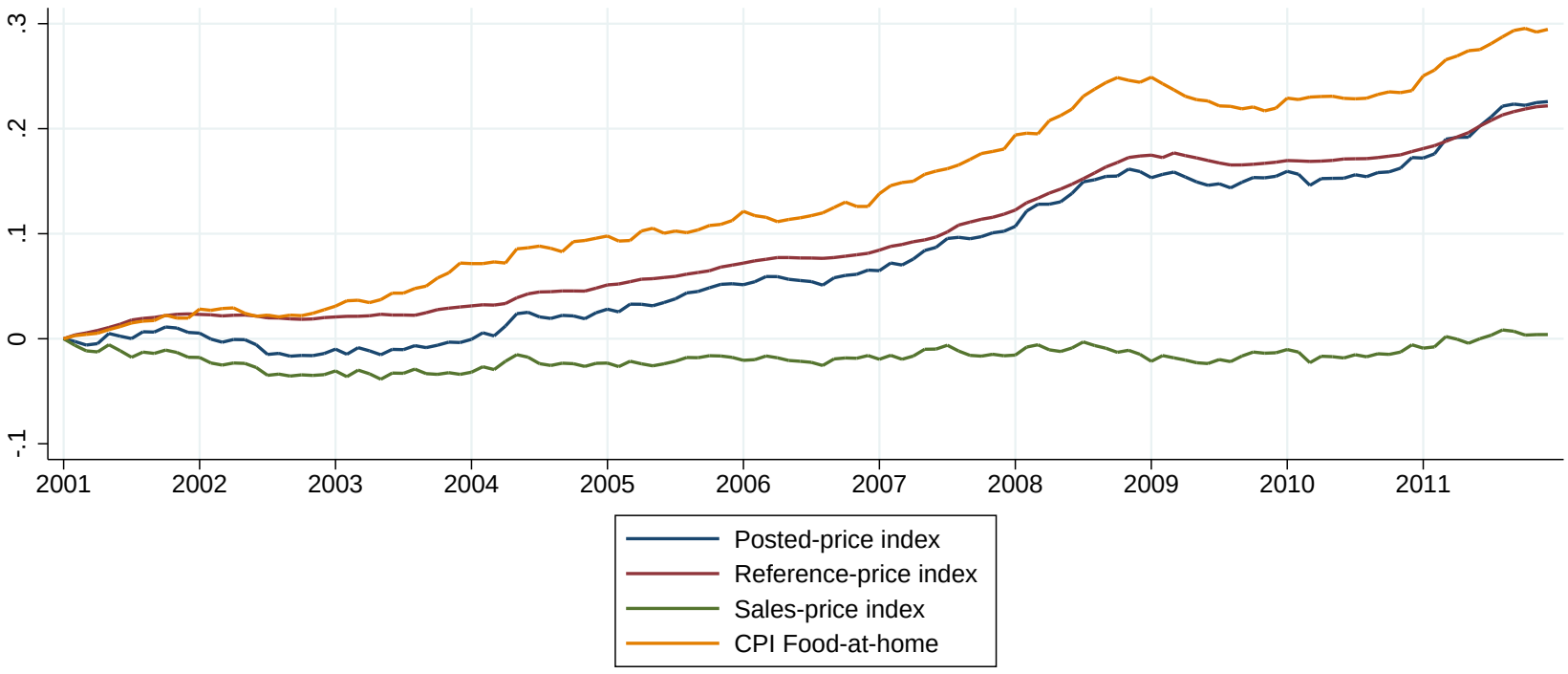
Selected literature, cont.

- Minimal structure
  - Implicit hazard-function approach (Caballero and Engel, 2007)
    - Estimate density and hazard function by matching moments
    - Sizable selection (Berger and Vavra, 2018; Petrella et al., 2019)
    - Weak selection (Luo and Villar, 2017, 2019)
  - Us: explicit hazard function (Gagnon et al., 2012)
- Construct informative moments that reveals selection
  - Carvalho and Kryvtsov (2018): preset-price-relative vs. inflation
  - Dedola et al. (2019): selection bias in Danish PPI
  - Us: shock-gap interaction on frequency

Data

- IRi supermarket scanner data ($\approx$ 15% of CPI)
  - Very granular: 170 000 products
  - Wide coverage: 50 markets across the US, over 3000 stores
  - 12 years of weekly data (2001-2012)
- Suitable dataset
  - Granularity: high-quality information about close substitutes
  - Long time series: can identify aggregate fluctuations
- Baseline data ▸ Data cleaning ▸ Expenditure weights
  - Reference prices: filter out temporary discounts ▸ Sales filtering
  - Time-aggregation: monthly mode

Posted, reference and sales-price indices



IRi supermarket index

- Similar business-cycle fluctuations as CPI food-at-home
- Trend inflation lower than CPI food-at-home
  - Main reason: new products
  - Higher-quality - higher-price than existing products
  - CPI takes this into account - we only use surviving products

Price gap

- Price gap
  - Theoretically: distance of the price from its optimum (w/o nominal frictions)
  - In many frameworks: relevant product-level state variable (Golosov and Lucas, 2007; Woodford, 2009)

- Empirically: a relevant component is observable
  1. Distance from the average price of close competitors,
  2. Controlling for store fixed effects (regional variation, amenities)
  3. Stores want no mispricing; higher: low demand; lower: low markup

Competitors' reference-price gap

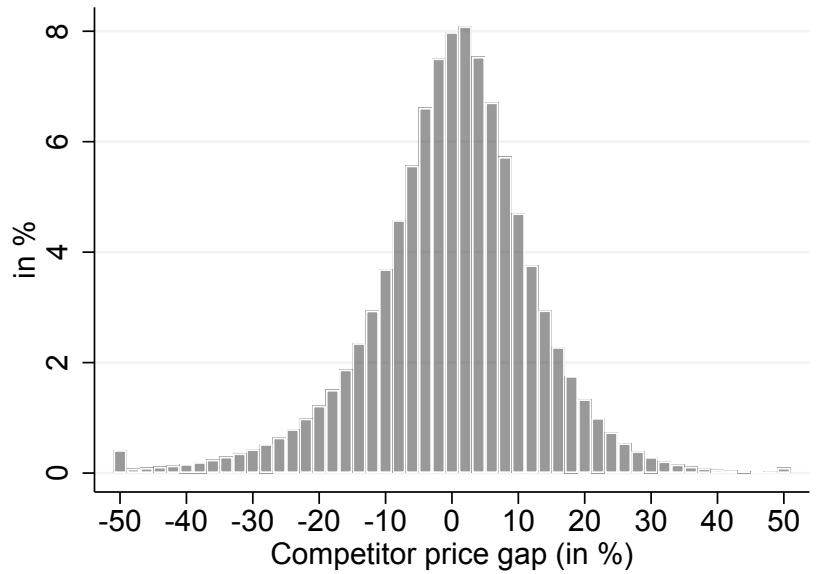
- Take sales-filtered reference prices p^f_{pst}
- Calculate gap

$$x_{pst} = p^f_{pst} - \bar{p}^{*f}_{pt} - \hat{\alpha}_s,$$

  where $\hat{\alpha}_s$ is the store-FE in $p^f_{pst} - \bar{p}^{*f}_{pt} = \alpha_s$.

- We use lagged gap x_{pst-1}
  - Predetermined; measure of 'initial' mispricing
  - We abstract from the impact of unobserved shocks (comp. Dedola et al., 2019)

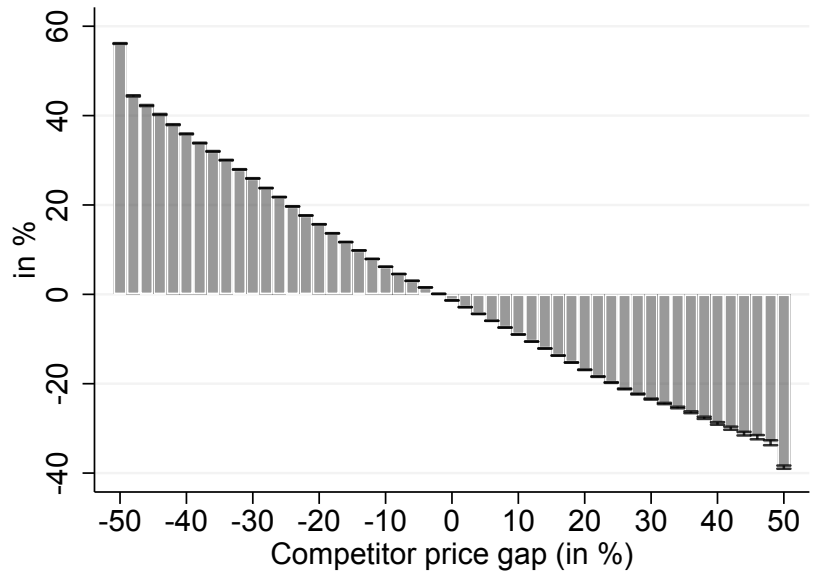
Competitors' price gap, density



- Density:
  - Sizable dispersion, fat tails
  - Despite sales-filtering and store-FE

Competitors' price gap, size

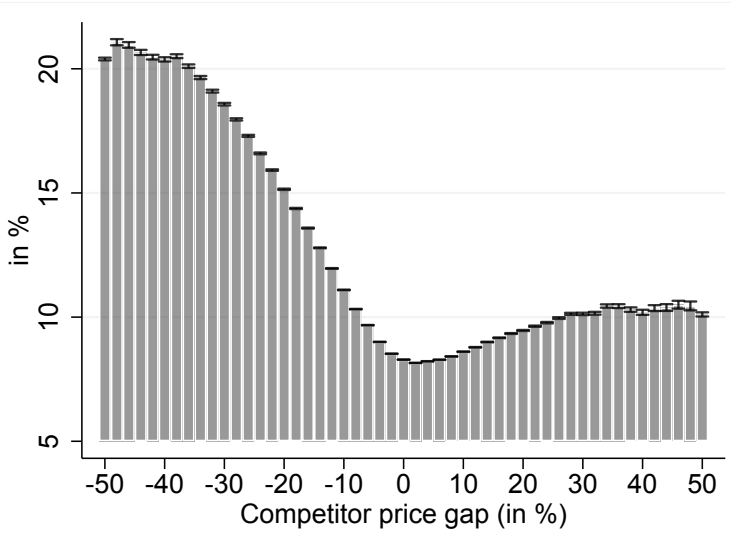
▸ Increases vs Decreases



- Size
  - Almost (inverse) one-on-one btw gap and size, on average
  - Relevant component of the gap

Competitors' price gap, frequency

▸ Increases vs Decreases



- Adjustment hazard in the data: (comp. Gagnon and López-Salido, 2014; Luo and Villar, 2019; Woodford, 2009)
  - Increases with distance from 0
  - Asymmetric, positive at 0
  - Close to (piecewise) linear in the relevant range (-20-20)

▸ Within item

Impulse response to a credit shock

- Sizable, exogenous tightening of credit conditions
- Identified with timing restrictions (Gilchrist and Zakrajšek, 2012)
  - Increase in the excess bond premium (default-free corporate spread)
  - No contemporaneous effect on activity, prices and interest rate

Local projections

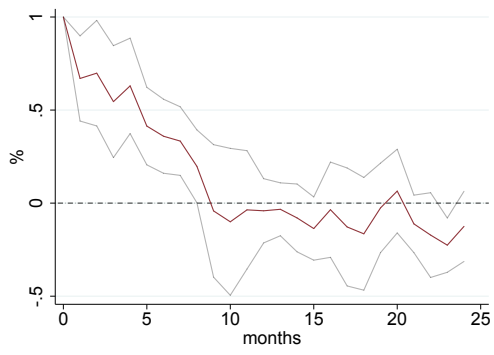
- Run a series of OLS regressions h (Jordà, 2005)

$$x_{t+h} - x_t = \alpha_h + \text{ebp}_t + \Gamma_h \Psi(L) X_t + u_{t,h},$$

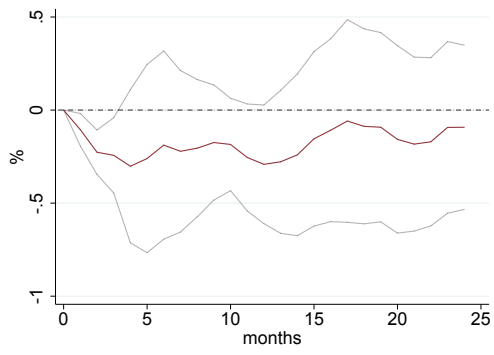
  - x: variable of interest, e.g. (log) price level
  - ebp_t: credit shock
  - $\Gamma_h \Psi(L) X_t$: set of controls: contemporaneous cpi, ip, 1y and 1-12m lags of cpi, ip, 1y, ebp
  - Monthly aggregates, seasonally adjusted
  - 95% confidence bands

Credit shock, 2001-2012

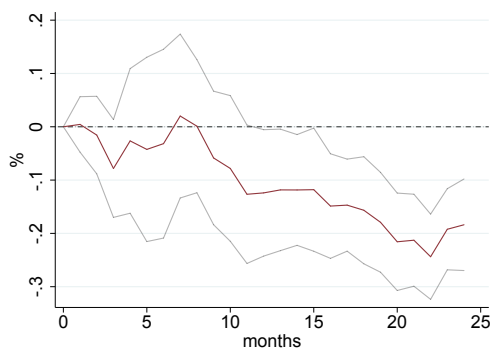
Excess bond premium



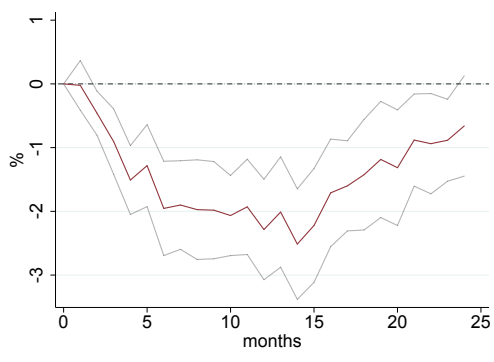
1-year Treasury



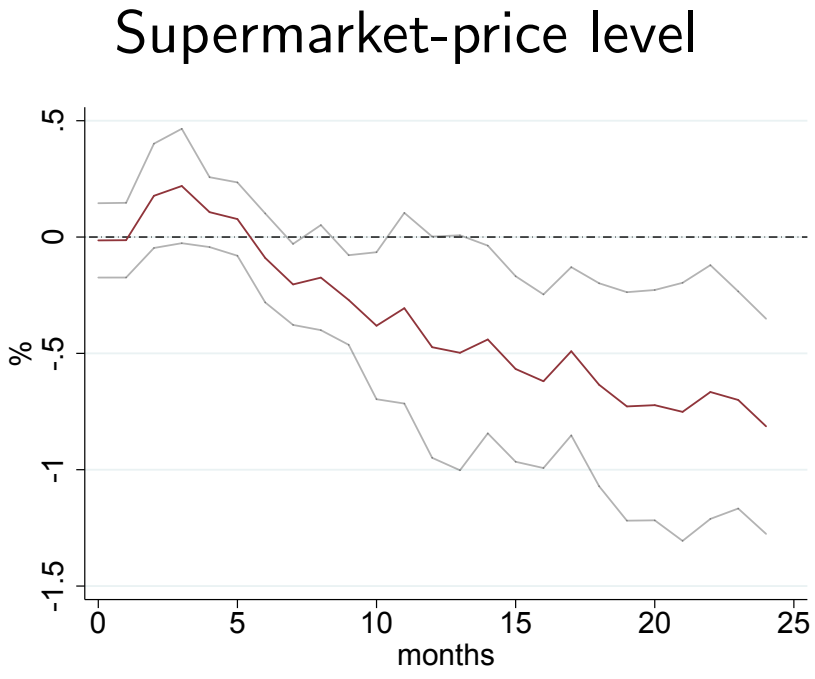
Core CPI



IP



Response of the supermarket-price index



- Gradual response, not unlike core CPI
- Peak effect not before 24 months

Selection

- With a product-level proxy and an aggregate shock: we can now assess selection.
- Do the new adjusters after a shock have large gaps?
- Approach: Selection is an interaction between
  - Aggregate shock and
  - Product-level proxy.
- Framework: Linear probability model of price adjustment
  - Does the interaction term influences adjustment probability?

Linear probability model

$$I^{\pm}_{pst,t+h} = \beta^{\pm}_{xih} x_{pst-1} \hat{\text{ebp}}_t + \beta^{\pm}_{xh} x_{pst-1} + \beta^{\pm}_{ih} \text{ebp}_t + \gamma^{\pm}_h T_{pst-1} + \Gamma^{\pm}_h \Phi(L) X_t + \alpha^{\pm}_{psh} + \alpha^{\pm}_{mh} + \varepsilon^{\pm}_{psth},$$

- $I^{\pm}_{pst,t+h}$ indicator of price increase (resp. decrease) of product p in store s between t and $t+h$
- x_{pst-1}: price gap (to control for its regular effect)
- ebp_t is the aggregate shock (to control for its average effect)
- $x_{pst-1}\text{ebp}_t$ gap-shock interaction (selection: focus of analysis)

Linear probability model, cont.

$$I^{\pm}_{pst,t+h} = \beta^{\pm}_{xih} x_{pst-1} \hat{\text{ebp}}_t + \beta^{\pm}_{xh} x_{pst-1} + \beta^{\pm}_{ih} \text{ebp}_t + \gamma^{\pm}_h T_{pst-1} + \Gamma^{\pm}_h \Phi(L) X_t + \alpha^{\pm}_{psh} + \alpha^{\pm}_{mh} + \varepsilon^{\pm}_{psth},$$

- T_{pst} (log) age of price (to control for time dependence)
- $\Gamma^{\pm}_h \Phi(L) X_t$ aggregate controls
- $\alpha\pm_{psh}$ product-store FE (to control for unexplained cross-sectional heterogeneity)
- $\alpha^{\pm}_{mh}$ are calendar-month FE (to control for seasonality)
- Standard errors are clustered across categories and time

Specification, cont.

- Focus: aggregate shock – price-gap interaction term
- Price increases I^{+}_{pst}: expected sign is positive
  - Driven by products with negative gap ($x_{pst-1} \leq 0$)
  - Credit tightening ($\hat{\text{ebp}}_t \geq 0$): less price increases
  - Credit easing ($\hat{\text{ebp}}_t < 0$): more price increases
- Price decreases I^{-}_{pst}: expected sign is positive
  - Driven by products with positive gap ($x_{pst-1} \geq 0$)
  - Credit tightening ($\hat{\text{ebp}}_t \geq 0$): more price decreases
  - Credit easing ($\hat{\text{ebp}}_t < 0$): less price decreases

Specification, cont.

- Additional interest
- Impact of the price gap β_{xh}: expected sign: negative for I^{+}_{pst} (positive for I^{-}_{pst})
  - More negative gap: more price increases
  - (More positive gap: more price decreases)
- Impact of aggregate shock β_{ih}: expected sign: negative for I^{+}_{pst} (positive for I^{-}_{pst})
  - Credit tightening ($\hat{\text{ebp}}_t > 0$) less increases, more decreases
  - Credit easing ($\hat{\text{ebp}}_t < 0$) more increases, less decreases

Results, competitors' price gap, h=24m

	(1)	(2)	(3)	(4)	(5)	(6)
	Price increase $\left(I^{+}_{pst,t+24}\right)$			Price decrease $\left(I^{-}_{pst,t+24}\right)$		
Gap (x_{pst-1})	-1.75^{***}			1.55^{***}		
Shock (ebp_t)	-0.03^{***}			0.03^{***}		
Selection ($x_{pst-1}\hat{\text{ebp}}_t$)	-0.00			0.01		
Age (T_{pst-1})	0.02^{***}			0.00^{**}		
Pos. gap (x^{+}_{pst-1})						
Neg. gap (x^{-}_{pst-1})						
Pos. sel. ($x^{+}_{pst-1}\hat{\text{ebp}}$)						
Neg. sel. ($x^{-}_{pst-1}\hat{\text{ebp}}$)						
Product x store FE	✓			✓		
Calendar-month FE	✓			✓		
Time FE	✗			✗		
N	$16.1M$			$16.1M$		
within R^2	18.5%			17.3%		

Specification, cont.

- 2 additional specifications for robustness
- Time-fixed effects (drop the direct impact of shock)
- Separate coefficients for positive and negative gaps

Results, competitors' price gap, credit shock, h=24m

	(1)	(2)	(3)	(4)	(5)	(6)
	Price increase $\left(I^{+}_{pst,t+24}\right)$			Price decrease $\left(I^{-}_{pst,t+24}\right)$		
Gap (x_{pst-1})	-1.75^{***}	-1.75^{***}		1.55^{***}	1.55^{***}	
Shock (ebp_t)	-0.03^{***}			0.03^{***}		
Selection ($x_{pst-1}\hat{\text{ebp}}_t$)	-0.00	-0.00		0.01	0.01	
Age (T_{pst-1})	0.02^{***}	0.02^{***}		0.00^{**}	0.01^{***}	
Pos. gap (x^{+}_{pst-1})						
Neg. gap (x^{-}_{pst-1})						
Pos. sel. ($x^{+}_{pst-1}\hat{\text{ebp}}$)						
Neg. sel. ($x^{-}_{pst-1}\hat{\text{ebp}}$)						
Product x store FE	✓	✓		✓	✓	
Calendar-month FE	✓	✗		✓	✗	
Time FE	✗	✓		✗	✓	
N	$16.1M$	$16.1M$		$16.1M$	$16.1M$	
within R^2	18.5%	16.6%		17.3%	16.4%	

Results, competitors' price gap, credit shock, h=24m

	(1)	(2)	(3)	(4)	(5)	(6)
	Price increase $\left(I^{+}_{pst,t+24}\right)$			Price decrease $\left(I^{-}_{pst,t+24}\right)$		
Gap (x_{pst-1})	-1.75^{***}	-1.75^{***}		1.55^{***}	1.55^{***}	
Shock (ebp_t)	-0.03^{***}		-0.04^{***}	0.03^{***}		0.03^{***}
Selection ($x_{pst-1}\hat{\text{ebp}}_t$)	-0.00	-0.00		0.01	0.01	
Age (T_{pst-1})	0.02^{***}	0.02^{***}	0.02^{***}	0.00^{**}	0.01^{***}	0.01^{***}
Pos. gap (x^{+}_{pst-1})			-2.26^{***}			2.29^{***}
Neg. gap (x^{-}_{pst-1})			-1.44^{***}			1.10^{***}
Pos. sel. ($x^{+}_{pst-1}\hat{\text{ebp}}$)			0.04			-0.04
Neg. sel. ($x^{-}_{pst-1}\hat{\text{ebp}}$)			-0.03			0.04
Product x store FE	✓	✓	✓	✓	✓	✓
Calendar-month FE	✓	✗	✓	✓	✗	✓
Time FE	✗	✓	✗	✗	✓	✗
N	$16.1M$	$16.1M$	$16.1M$	$16.1M$	$16.1M$	$16.1M$
within R^2	18.5%	16.6%	18.9%	17.3%	16.4%	18.2%

Implications

- State dependence: Gap significantly raises frequency
  - Probability of price increase 26 pp. lower btw 1st and 3rd quartile (decrease 23 pp higher)
- Adjustment on the (gross) extensive margin: aggregate shock shifts the probability of price increases vs price decreases
  - Probability of price increase 1pp lower after a 1sd credit tightening (30 bps)
  - Probability of price decrease 1pp higher after a similar tightening

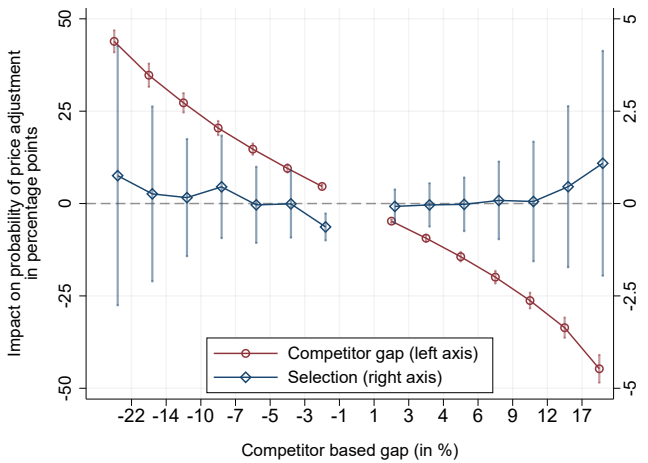
Implications, cont.

- No selection:
  - No evidence of significant interaction
  - Conditional on the shock, not adjusting the prices with larger gap
- Time dependence
  - Older prices are changed with higher probability

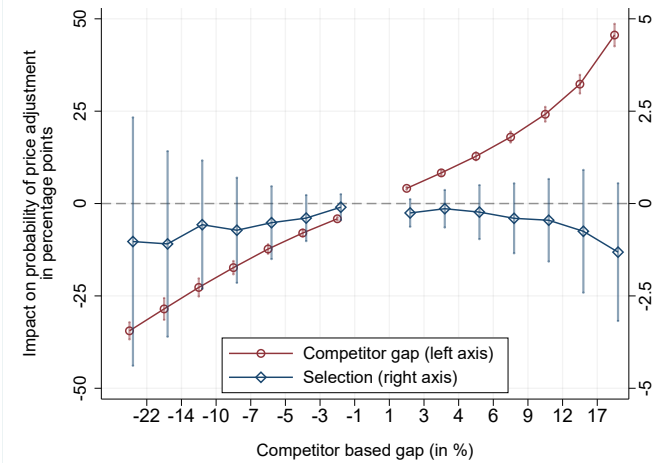
Robustness

- Relax linearity restriction
  - 15 gap groups, regressions with group dummies.

Price increases



Price decreases



- Robustness to non-linearity, alternative gap, shock, data

▸ Probit ▸ Heterogeneity across product categories ▸ Reset-price gap ▸ PPI dataset

▸ Monetary policy shock ▸ No FE ▸ Posted prices ▸ 2001-2007

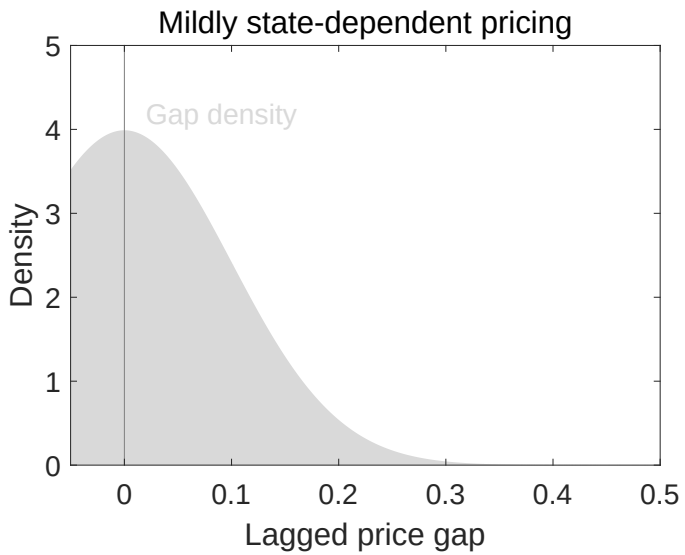
Conceptual framework (Caballero and Engel, 2007)

- Lumpy price adjustment
- Price gap $x_{it} = p_{it} - p^*_{it}$
  - p_{it} (log) price of product i: adjusts occasionally
  - p^*_{it} (log) optimal price: influenced continuously by both product-level and aggregate factors
- Price adjustment frictions: generalized hazard function $\Lambda(x)$
  - Time-dependent (Calvo, 1983): constant hazard
  - Classic (S,s) framework: step function
  - Continuum of intermediate cases (random menu cost, rational inattention).

Decomposing inflation: An accounting identity

$$\pi_t = \pi_t^+ + \pi_t^- = \int_{x<0} -x\Lambda(x)f_t(x)dx + \int_{x\geq 0} -x\Lambda(x)f_t(x)dx$$

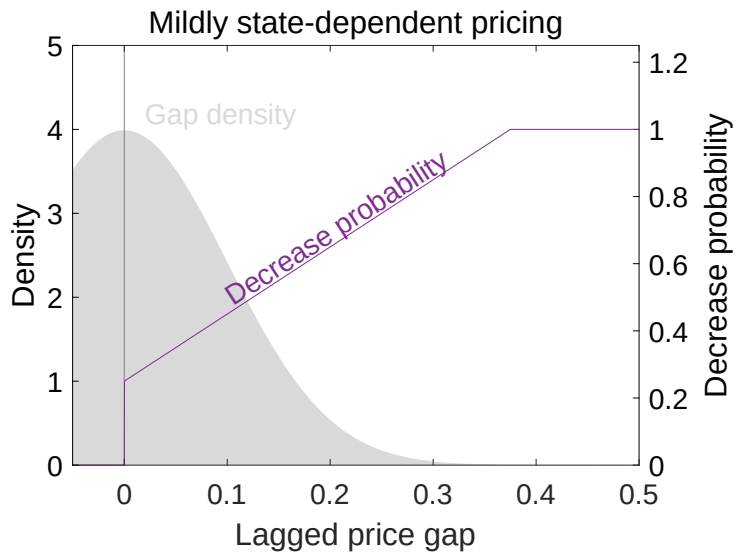
- π^-: inflation from positive gaps
- Density: $f_t(x)$



Decomposing inflation: An accounting identity

$$\pi_t = \pi_t^+ + \pi_t^- = \int_{x<0} -x\Lambda(x)f_t(x)dx + \int_{x\geq 0} -x\Lambda(x)f_t(x)dx$$

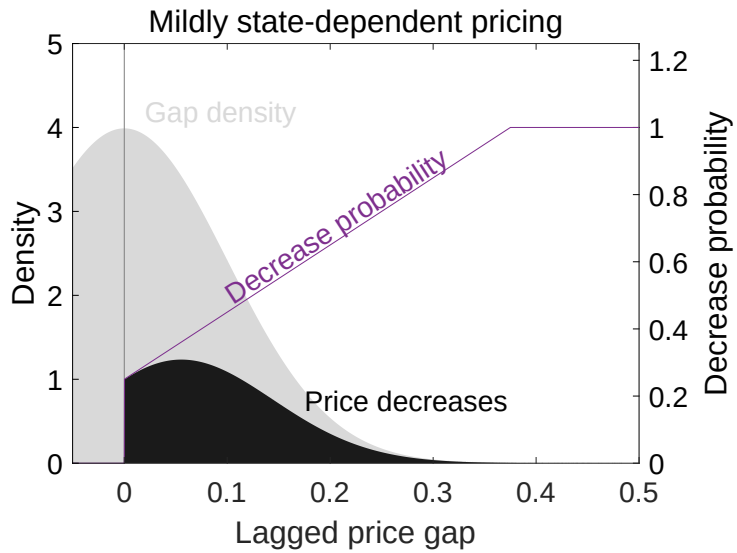
- π^-: inflation from positive gaps
- Density: $f_t(x)$
- Hazard: $\Lambda(x)$



Decomposing inflation: An accounting identity

$$\pi_t = \pi_t^+ + \pi_t^- = \int_{x<0} -x\Lambda(x)f_t(x)dx + \int_{x\geq 0} -x\Lambda(x)f_t(x)dx$$

- π^-: inflation from positive gaps
- Density: $f_t(x)$
- Hazard: $\Lambda(x)$
- Desired change = - gap: $-x$



Evidence for state-dependence

- Decomposition

$$\pi_t^- = \int_{x \geq 0} -x\Lambda(x)f(x)dx = \bar{x}^-\bar{\Lambda}^- + \underbrace{\int_{x \geq 0} -x\left(\Lambda(x) - \bar{\Lambda}^-\right) f_t(x)}_{\text{state-dependence}},$$

- 'State-dependence': increasing hazard (Λ): higher gaps change w/ higher probability
- We brought evidence
- Inconsistent with time-dependent (constant hazard) models (Calvo, 1983)

Margins of adjustment

- Conditional on a permanent shock m

$$\frac{\partial \pi^-}{\partial m} = \underbrace{\bar{\Lambda}^-}_{\text{intensive}} + \overbrace{\underbrace{-\bar{x}^- \frac{\partial \bar{\Lambda}^-}{\partial m}}_{\text{gross extensive}} + \underbrace{\int_{x \geq 0} -x \left(\Lambda'(x) - \frac{\partial \bar{\Lambda}^-}{\partial m} \right) f(x)}_{\text{selection}}}^{\text{extensive}}$$

- Intensive margin: those that adjust, adjust by less
- Gross extensive margin: more decreases, less increases
- Selection: new decreases after the shock are far from their optimum

Margins of adjustment, cont.

	Data	Time-dependent	(S,s) & Convex hazard	Linear hazard
Intensive margin	✓	✓	✓	✓
Gross extensive margin	✓	✗	✓	✓
Selection	✗	✗	✓	✗

Margins of adjustment, cont.

- Time-dependent (constant hazard) frameworks (Calvo, 1983)

  ▸ calvo

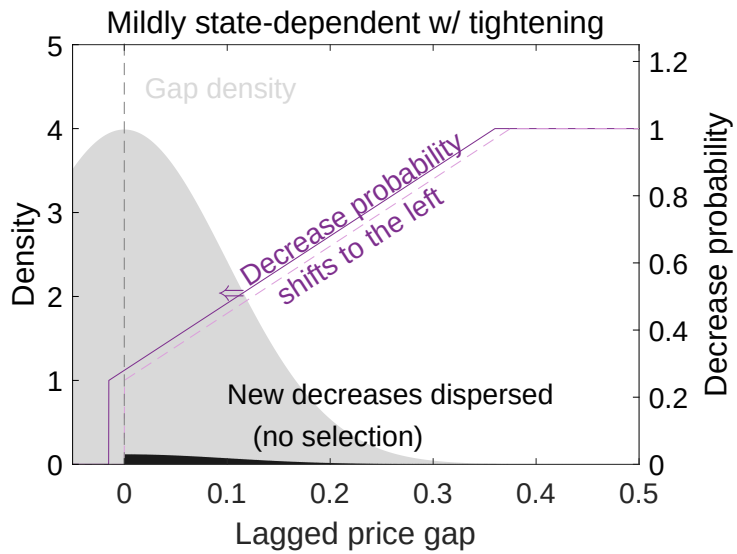
  - Only intensive margin
  - Strength depends on frequency
  - Inconsident with our evidence: gross extensive margin

- Classic (S,s) models (Caplin and Spulber, 1987; Golosov and Lucas, 2007) ▸ Ss
  - All margins are active
  - Extra flexibility through both gross extensive margin and selection
  - Inconsistent with our evidence: no selection

Margins of adjustment, cont.

Our evidence broadly consistent with mildly state-dependent models (Dotsey et al., 1999; Woodford, 2009) with linear and flat hazard

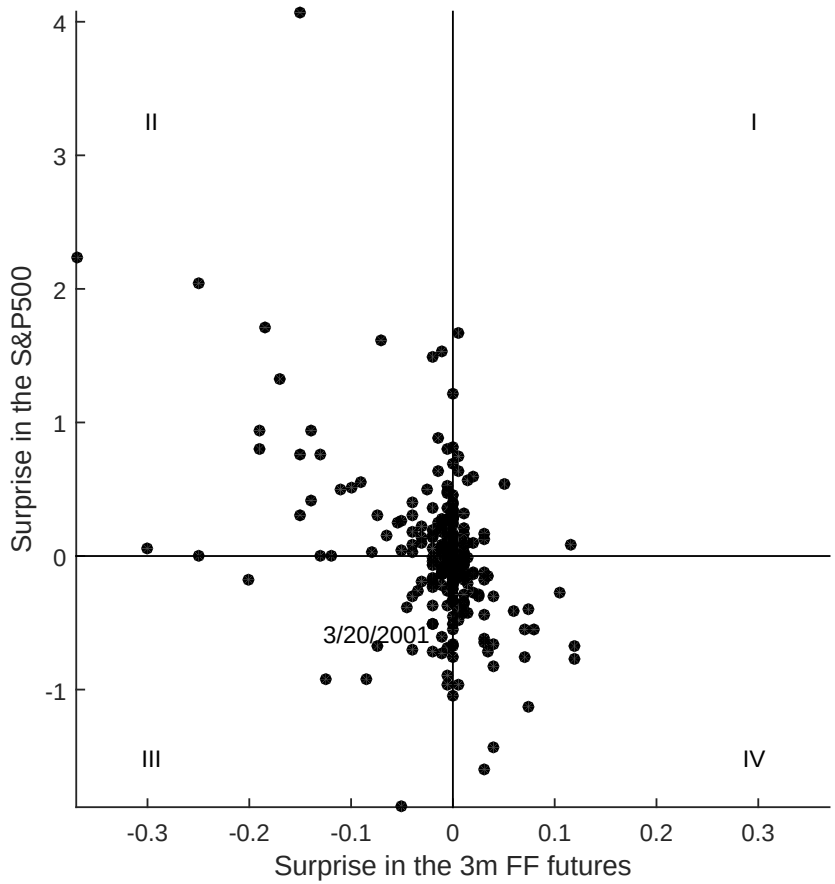
- Gross extensive margin: aggregate shock shifts increase/decrease frequencies
- No selection: insignificant interaction



Conclusion

- Use granular supermarket and PPI data to measure selection
- We have found that
  1. State dependence: adjustment probability increases with gap
  2. No selection: Conditional adjustment independent of price gap
  3. Adjustment through the intensive and gross extensive margin
- Implications
  - Inconsistent with standard time-dependent (Calvo, 1983) or state-dependent (Golosov and Lucas, 2007) models
  - Consistent with mildly state-dependent models (Dotsey et al., 1999; Woodford, 2009; Alvarez et al., 2020)
  - Implies sizable monetary non-neutrality

High-frequency surprises



Back

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IRi: data cleaning

- Posted prices:

$$P_{psw} = \frac{TR_{psw}}{Q_{psw}},$$

  - TR is the total revenue
  - Q is the quantity sold for each product
  - p in store s in week w

- Cleaning
  - Round to the nearest penny (8.7%)
  - Private label products: new products at relabeling
  - Drop products that are not available the whole year

Back

IRi: sales-filtering

- Sales: high-frequency noise (Anderson et al., 2017)
- Modal-price filter of Kehoe and Midrigan (2014)
- Reference prices P^f_{psw} on weekly data
  - 13-week two-sided modal price
  - Iterative updating to align the change of P^f_{psw} with P_{psw}
  - Reference price changes less than a third of posted price changes
- Results are robust to using posted prices
- Monthly prices P_{pst}: mode of weekly prices

◂ Back

IRi: Expenditure weights

- Fixed-weight index (as CPI). Annual weights $t \in y$

$$\omega_{psy} = \frac{TR_{psy}}{\sum_p \sum_s TR_{psy}}$$

- Posted and reference-price inflation $(i = p, f)$

$$\pi_t^i = \sum_s \sum_p \omega_{pst} \left(p_{pst}^i - p_{pst-1}^i \right)$$

- Sales-price inflation

$$\pi_t^s = \pi_t^p - \pi_t^f$$

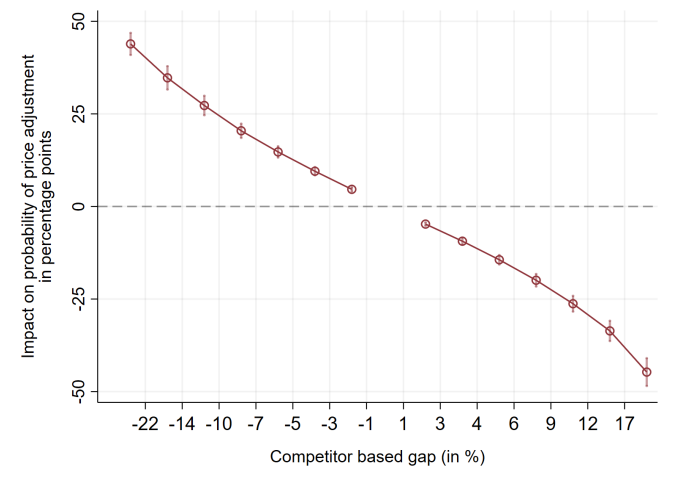
- Seasonal adjustment using monthly dummies

Back

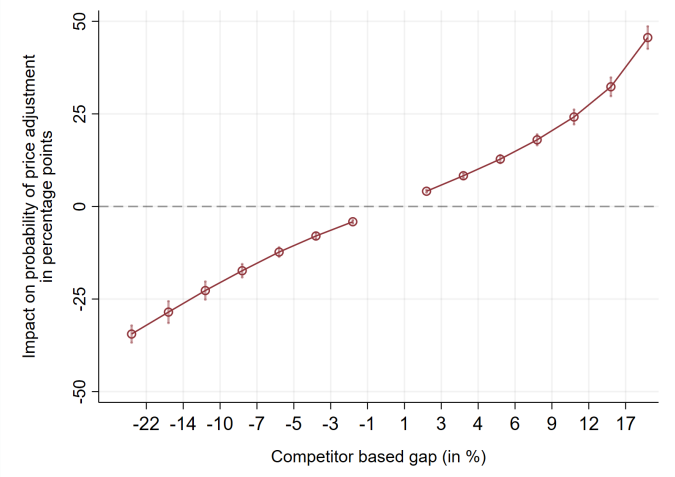
Gap group-dummies, within product-store, 24m

- Hazard close to linear and quite symmetric
  - Heterogeneity is controlled for (item, time FEs)
  - Predicted frequency in 24 months

Price increases



Price decreases



Back

Average moments

Annualized inflation		Frequency	
Posted	Reference	Posted	Reference
1.84 %	1.75%	36.2%	10.8%

Reference frequency		Reference size	
Increase	Decrease	Increase	Decrease
6.6%	4.2%	12.5%	-15.1%

Back

Gross extensive margin

- Micro-data: how do standard moments adjust to aggregate shocks Average moments

- Frequency:

$$\xi^{\pm}_{t,t+h} = \sum_i \bar{\omega}_{it,t+h} I^{\pm}_{it,t+h},$$

- Size

$$\psi^{\pm}_{t,t+h} = \frac{\sum_i \bar{\omega}_{it,t+h} I^{\pm}_{it,t+h} (p_{it+h} - p_{it-1})}{\xi^{\pm}_{t,t+h}}.$$

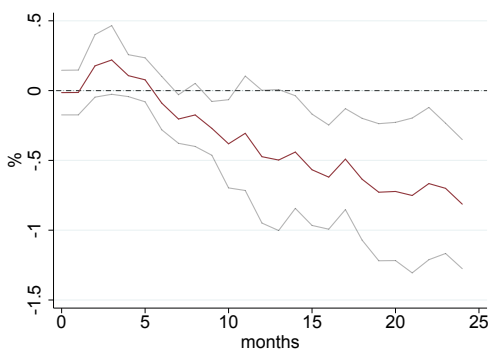
- Decomposition

$$p_{t+h} - p_{t-1} = \pi_{t,t+h} = \xi^{+}_{t,t+h} \psi^{+}_{t,t+h} + \xi^{-}_{t,t+h} \psi^{-}_{t,t+h},$$

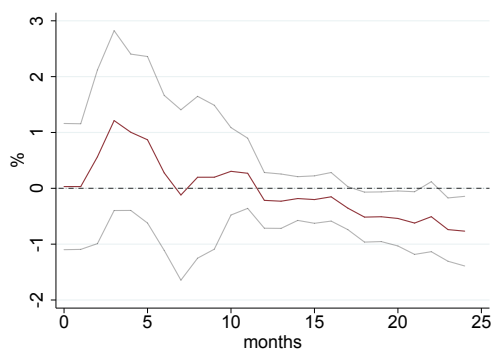
Back

Price changes

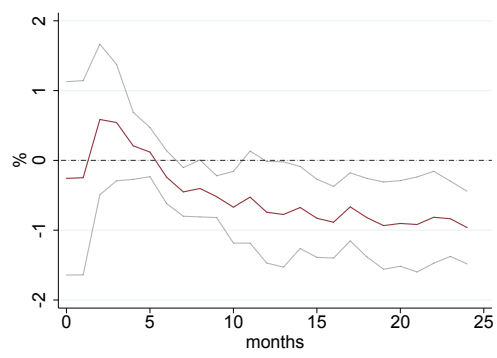
Price level



Cumulative frequency



Cumulative size

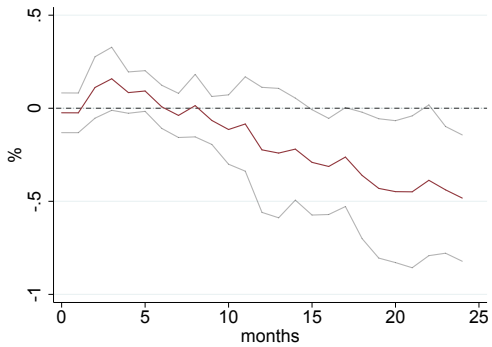


- Decline in frequency only marginally significant
- Average size declines
- Broadly in line with both time-dependent (Calvo, 1983) and state-dependent (Golosov and Lucas, 2007) models

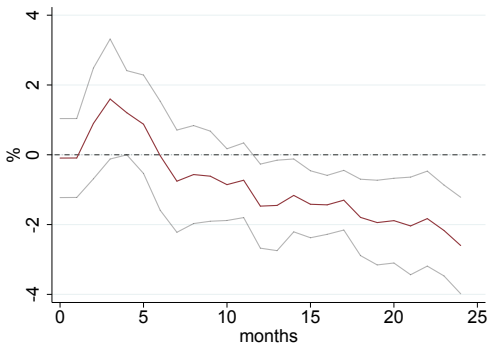
Back

Less increases, more decreases

Price increase



Cumulative frequency



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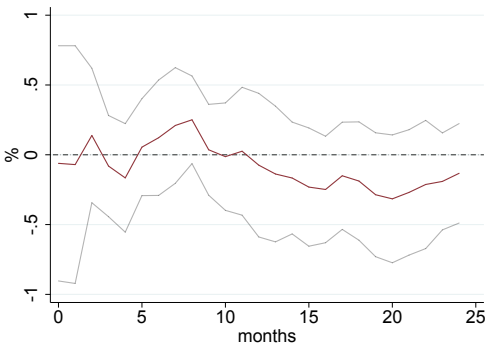
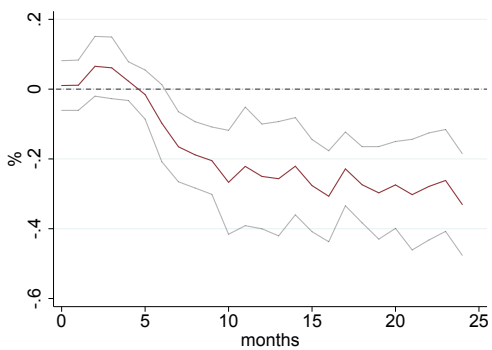
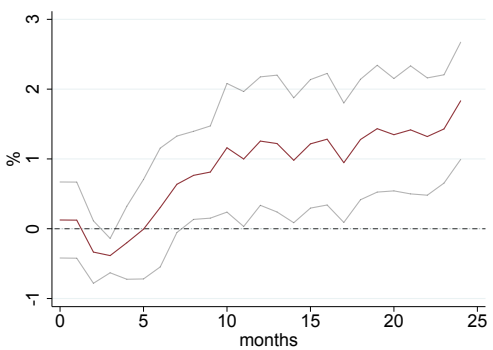


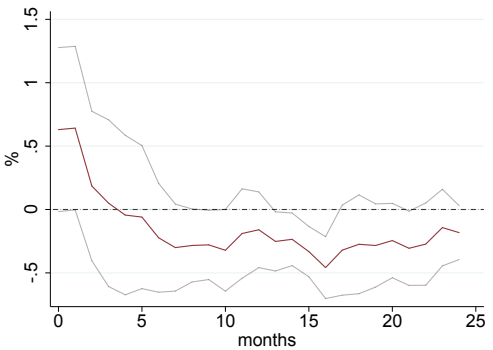
Price decrease



Cumulative frequency



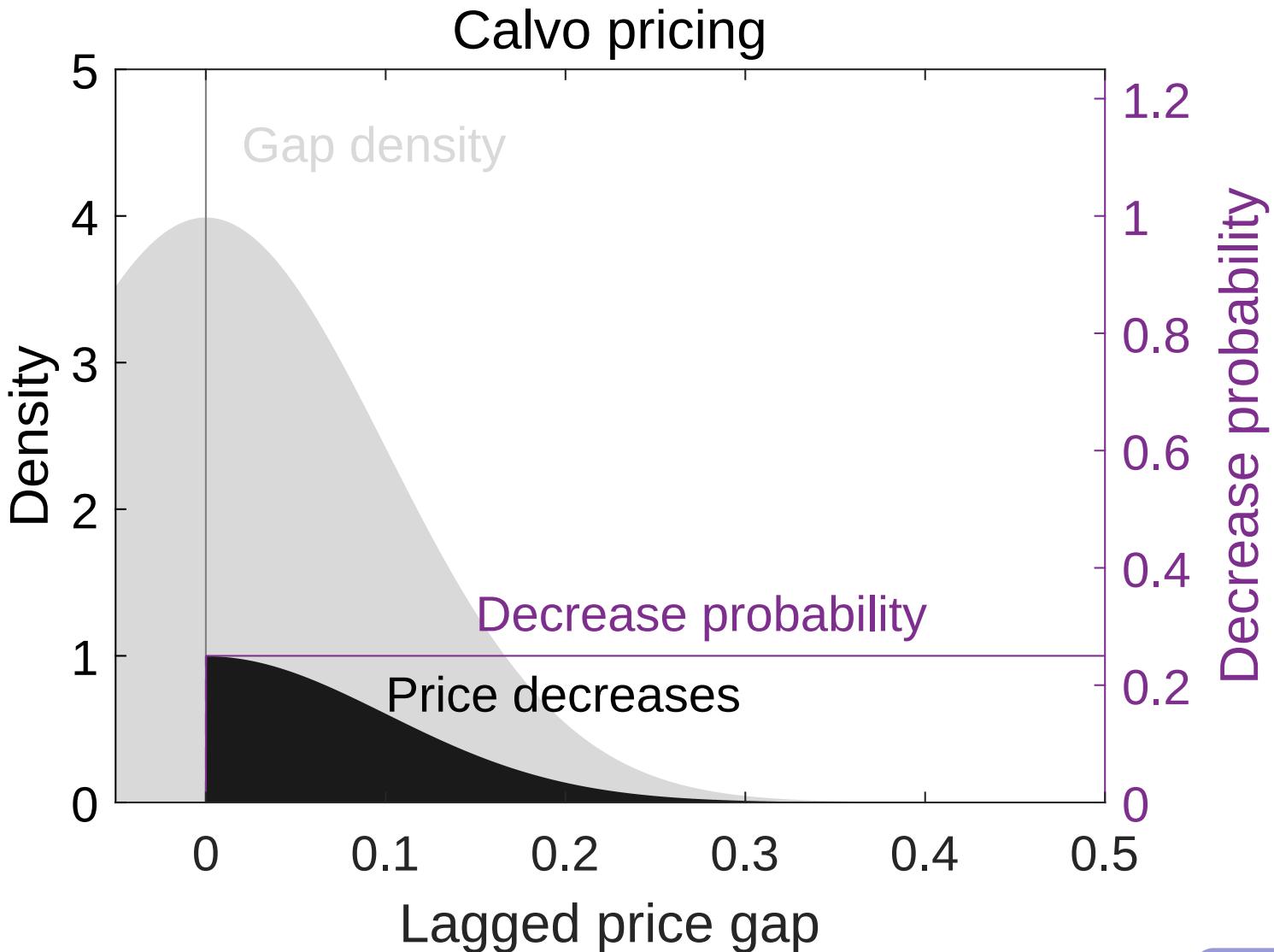
Cumulative size



- Adjustment mostly through the gross extensive margin

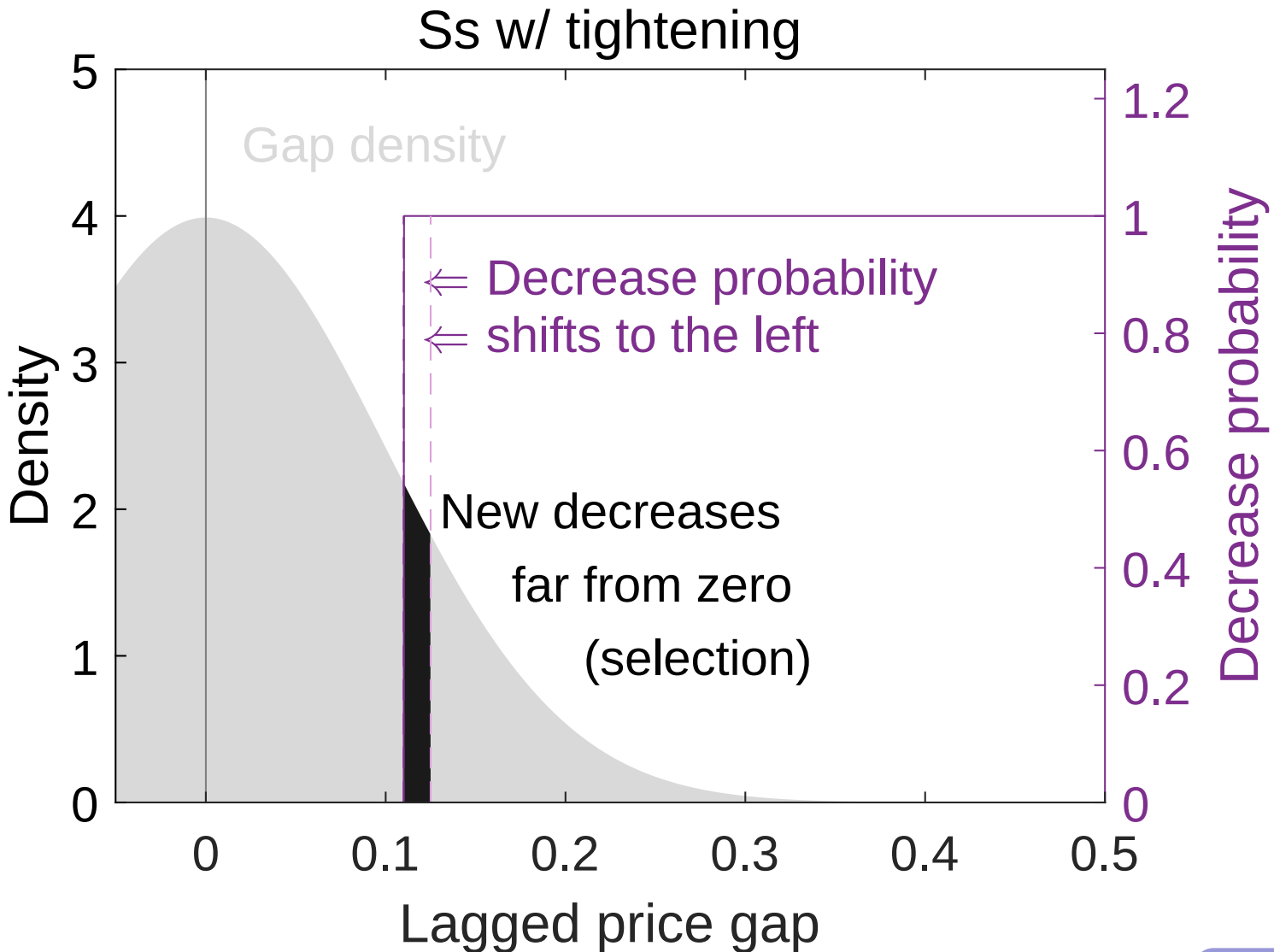
Back

Time-dependent model (Calvo, 1983)



Back

Selection in an sS model (Golosov and Lucas, 2007)



Back

Nonlinearity II: Probit

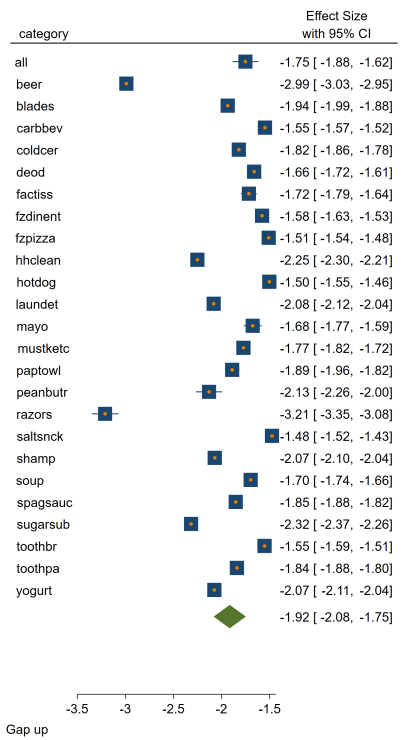
	(1)	(2)	(3)
	Multinomial probit		Ordered probit
	Incr. $\left(I^{+}_{pst,t+24}\right)$	Decr. $\left(I^{-}_{pst,t+24}\right)$	Change $(I_{pst,t+24})$
Gap (x_{pst-1})	-3.15^{***}	3.37^{***}	-4.24^{***}
Shock (ebp_t)	-0.11^{***}	0.05^{***}	-0.10^{***}
Selection $(x_{pst-1}\hat{\text{ebp}}_t)$	-0.05	-0.21^{**}	0.04
Age (T_{pst-1})	0.01^{*}	-0.03^{***}	0.02^{***}
Freq. incr. (ξ^{+}_{psM})	5.17^{***}	2.91^{***}	1.79^{***}
Freq. decr. (ξ^{-}_{psM})	3.02^{***}	5.84^{***}	-1.33^{***}
Product x store FE	✗	✗	✗
Calendar-month FE	✓	✓	✓
Time FE	✗	✗	✗
N	$16.1M$	$16.1M$	$14.3M$

Back

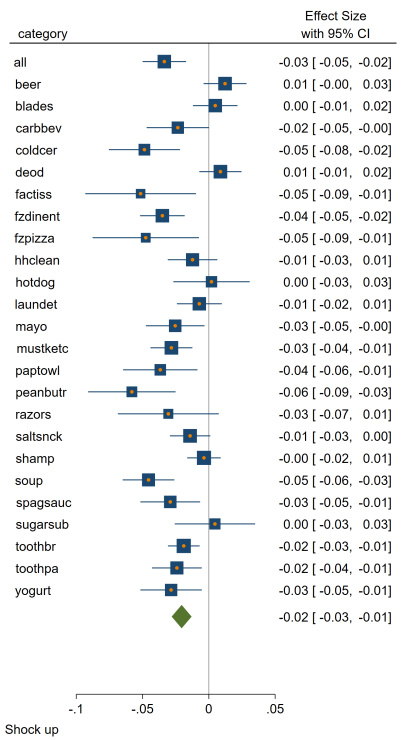
Heterogeneity across product categories

- Heterogeneous demand elasticities might bias our baseline
- Separate estimates across product categories: price increases

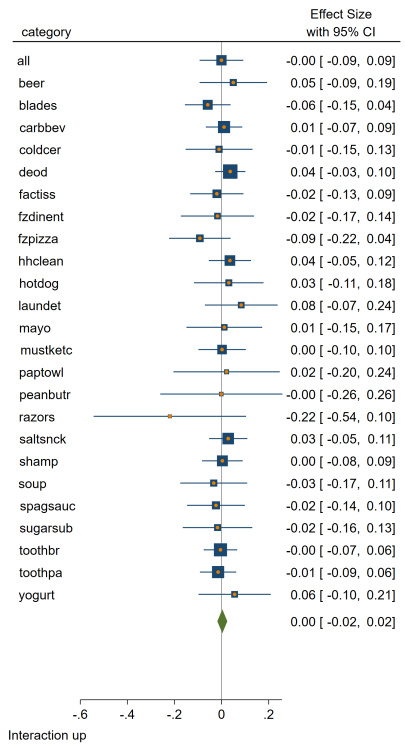
Gap



Shock



Selection

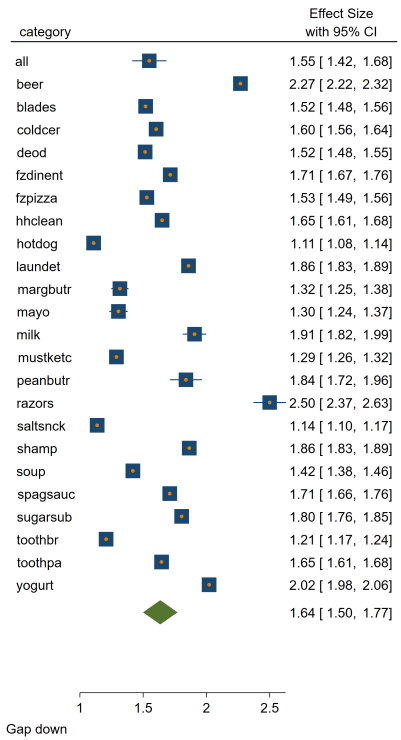


Back

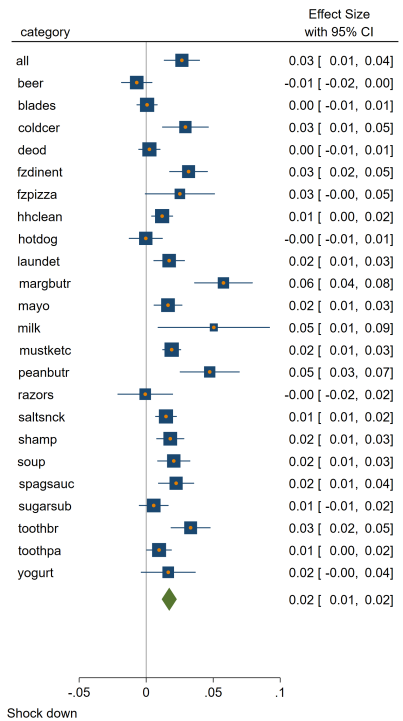
Heterogeneity across product categories, cont.

- Separate estimates across product categories: price decreases

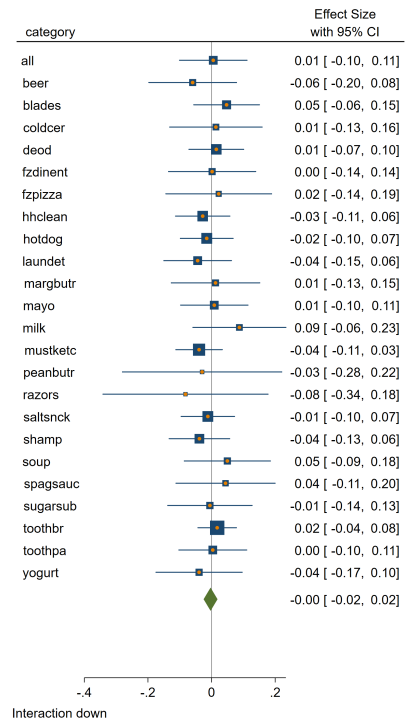
Gap



Shock



Selection



- Robust results

Back

Reset-price gap

- Alternative price-gap proxy
- Reference price reset gap $x_{pst} = p^{f}_{pst} - p^{f*}_{pst}$
- Reset-price (p^{f*}_{pst}) is as in Bils et al. (2012)

$$p^{f*}_{pst} = \begin{cases} p^{f}_{pst} & \text{if } I_{pst} = 1 \\ p^{f*}_{pst-1} + \pi^{f*}_{ct} & \text{otherwise,} \end{cases}$$

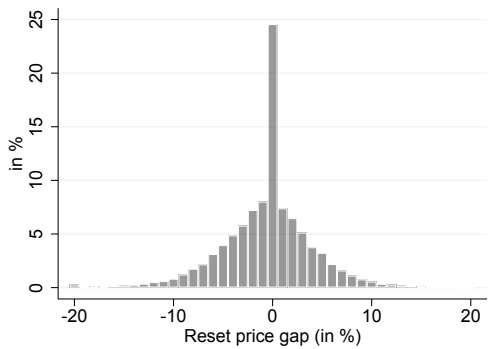
where π^{f*}_{ct} is category-level reset-price inflation:

$$\pi^{f*}_{ct} = \sum_{p \in c} \frac{\omega_{pst} I_{pst} \left(p^{f*}_{pst} - p^{f*}_{pst-1} \right)}{\sum_{p \in c} \omega_{pst} I_{pst}}$$

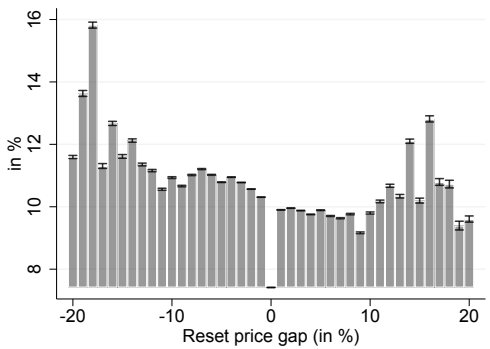
Back

Reset price gap

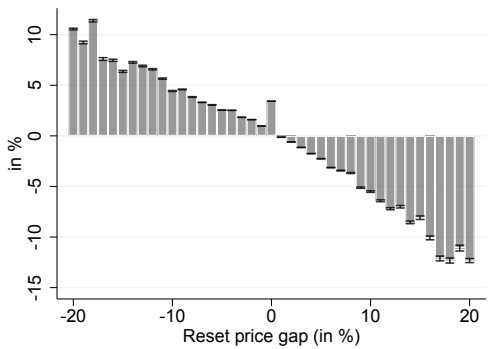
Density



Frequency



Size



Back

Results, reset-price gap, credit shock, h=24m

	(1)	(2)	(3)	(4)	(5)	(6)
	Price increases $\left(I^{+}_{pst,t+24}\right)$			Price decreases $\left(I^{-}_{pst,t+24}\right)$		
Gap (x_{pst-1})	-0.45^{***}	-0.48^{***}		0.34^{***}	0.37^{***}	
Shock ($\hat{ebp}_t$)	-0.04^{***}		-0.04^{***}	0.03^{***}		0.03^{***}
Selection ($x_{pst-1}\hat{ebp}_t$)	-0.14	-0.13		0.12	0.14	
Age (T_{pst-1})	0.01^{***}	0.01^{***}	0.01^{***}	0.01^{***}	0.02^{***}	0.01^{***}
Positive gap (x^{+}_{pst-1})			-0.39^{***}			0.33^{***}
Negative gap (x^{-}_{pst-1})			-0.49^{***}			0.35^{***}
Pos. sel. ($x^{+}_{pst-1}\hat{ebp}_t$)			0.11			-0.03
Neg. sel. ($x^{-}_{pst-1}\hat{ebp}_t$)			-0.27^{**}			0.21^{*}
N	$16.1M$	$16.1M$	$16.1M$	$16.1M$	$16.1M$	$16.1M$
within R^2	2.6%	0.3%	2.6%	1.3%	0.3%	1.3%

Back

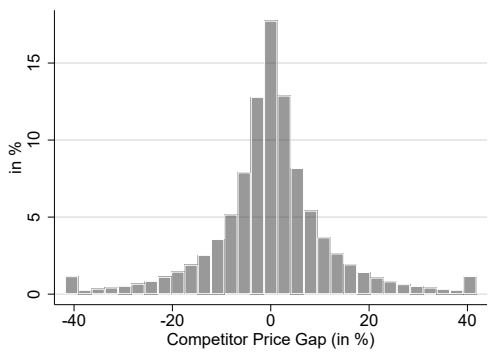
PPI microdata

- Coverage
  - 1981-2012 monthly data
  - Representative of the US economy
- No sales filtering

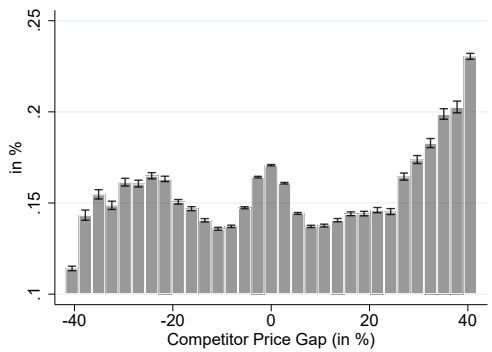
Back

Competitors' price gap

Density



Frequency



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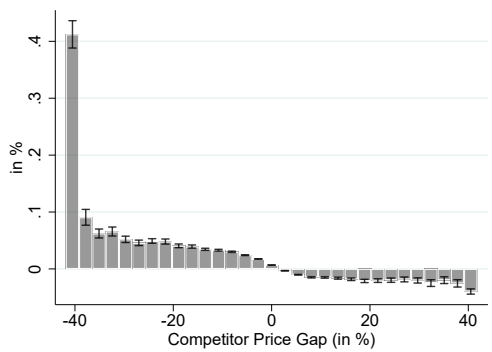


Back

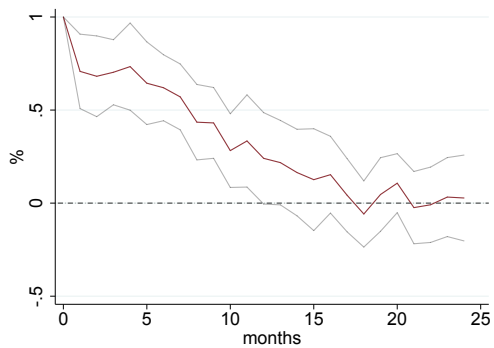
PPI: gaps

- Size: clear negative relationship with the gaps
- Frequency:
  - Increases with competitors' gap eventually
  - Initially decreases with higher gap

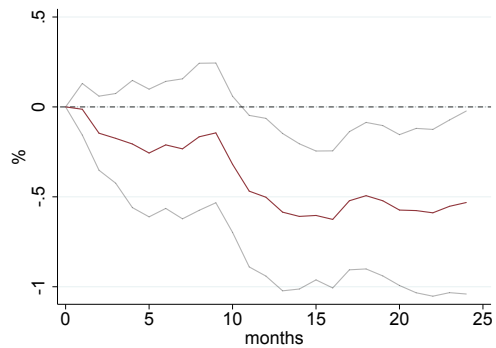
Back

Credit shock

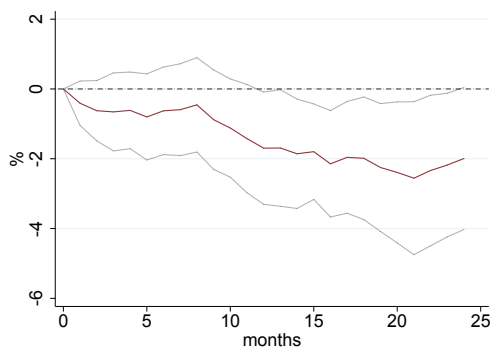
Excess bond premium



1-year Treasury



PPI



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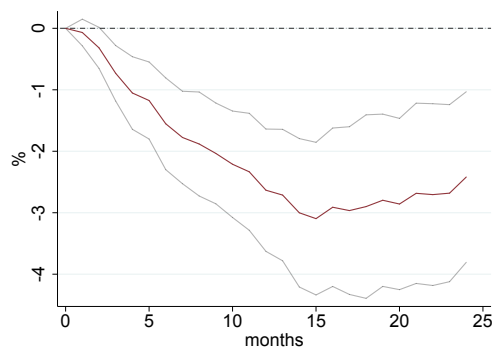

Back

Results, competitors' price gap, credit shock, h=24m, PPI

	(1)	(2)	(3)	(4)
	Increases $\left(I^{+}_{pst,t+24}\right)$		Decreases $\left(I^{-}_{pst,t+24}\right)$	
Gap (x_{pst-1})	-0.23^{***}	-0.23^{***}	0.22^{***}	0.22^{***}
Shock (ebp_t)	-0.023^{***}		0.021^{***}	
Selection ($x_{pst-1}\hat{\text{ebp}}_t$)	0.00	-0.00	-0.00	-0.00
Age (T_{pst-1})	0.035^{***}	0.035^{***}	0.01^{***}	0.01^{***}
Product x store FE	✓	✓	✓	✓
Calendar-month FE	✓	✗	✓	✗
Time FE	✗	✓	✗	✓
N	$9.7M$	$9.7M$	$9.7M$	$9.7M$
Within R^2	4.4%	3.5%	4.3%	3.7%

Back

PPI: selection

- Results are robust using longer and wider-coverage data
- Gap: significant unconditional impact on frequency
- Aggregate shock: shifts the probability of adjustment
- No selection:
  - No evidence of interaction:
  - Conditional on the shock, not adjusting prices with larger gap

Back

Impulse responses to monetary policy shocks

- High-frequency identification of monetary policy shocks (Gertler and Karadi, 2015; Nakamura and Steinsson, 2018)
  - Intra-day financial market surprises around press statements
  - Control for information shocks using the co-movement of interest rates and stock prices (Jarociński and Karadi, 2020)
- Calculate relevant price-setting moments
- Estimate impulse responses using local projections (Jordà, 2005)

Back

High-frequency identification of monetary policy shocks

- Central bank announcements generate unexpected variation in interest rates: can be used to assess monetary non-neutrality.
- Surprises
  - Measure change in interest rates in a 30-minute window around policy announcements
  - Only central bank announcements systematically impacts surprises
- FOMC press statements (8 times a year)

Back

Interest rate

- Preferred interest rate: 3-months federal funds futures rate
  - Closely controlled by the FOMC
  - Incorporates next FOMC meeting: with near-term forward guidance
  - Does not affected by 'timing' surprises
  - It stays active after ZLB is reached

Back

Controlling for central bank information shocks

- Issue: announcements can reveal information
  - not just about policy,
  - but also about the central bank's economic outlook.
- Use responses in stock markets (Jarociński and Karadi, 2020)

Scatter

  - Negative co-movement in interest rates and stock prices: monetary policy shocks
  - Positive co-movement: central bank information shocks
- 'Poor man's sign restriction': use events when the co-movement was negative

Back

Local projections

- Run a series of OLS regressions h (Jordà, 2005)

$$x_{t+h} - x_t = \alpha_h + \beta_h \Delta i_t + \Gamma_h \Psi(L) X_t + u_{t,h},$$

  - x: variable of interest, e.g. (log) price level
  - Δi_t: high-frequency monetary policy shock
  - $\Gamma_h \Psi(L) X_t$: set of controls: various lags of cpi, ip, de1y

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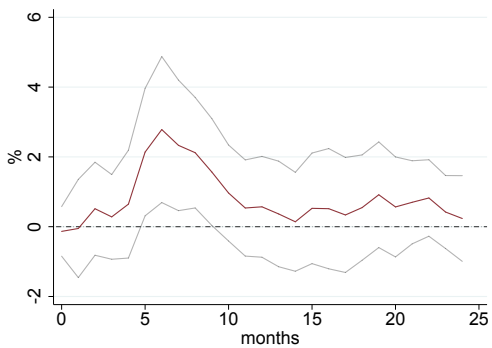
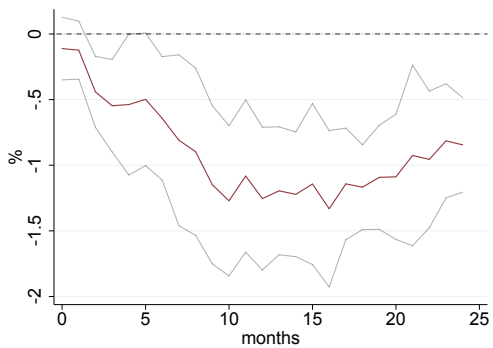
Impulse responses of key macroeconomic variables to a monetary policy tightening

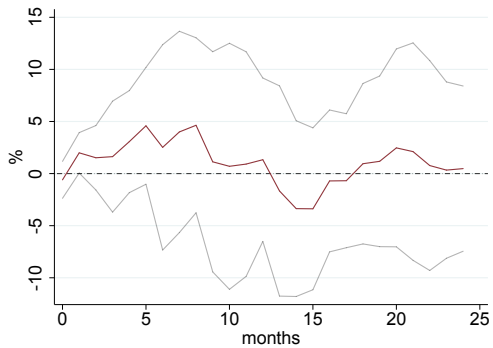
1-year Treasury



Core CPI



IP



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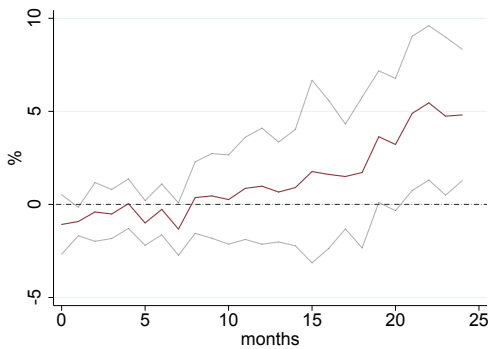
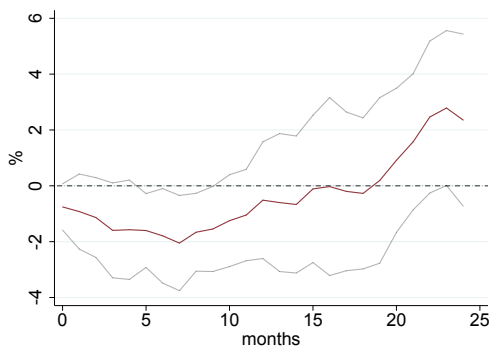
Impulse responses of key macroeconomic variables to a monetary policy tightening

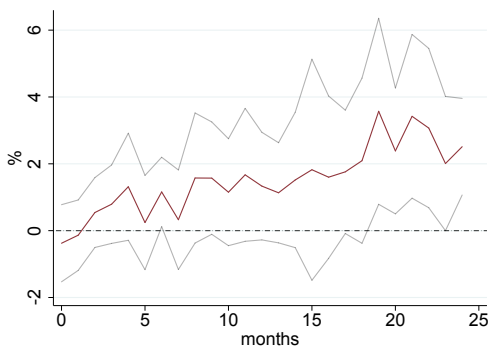
Posted-price index



Reference-price index



Sales-price index



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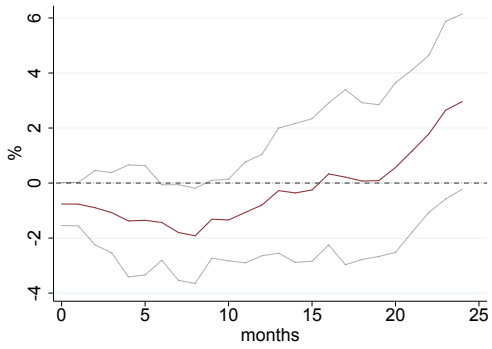
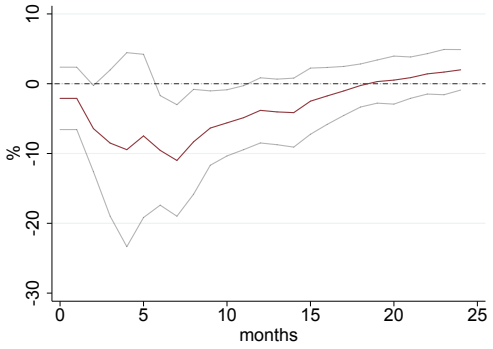
Price changes

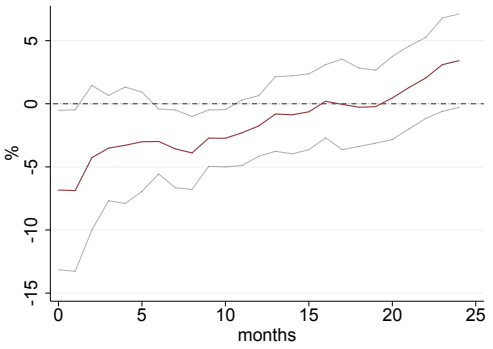
Price level



Cumulative frequency



Cumulative size



- Aggregate frequency drops
- Size declines

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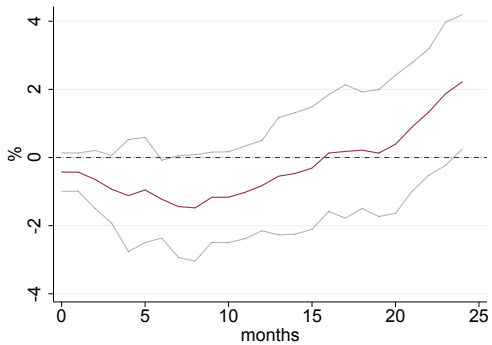
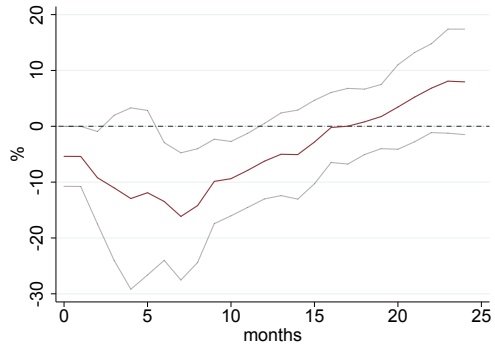
Less increases more decreases

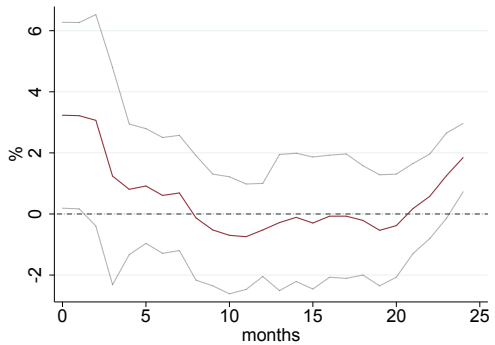
Price increase



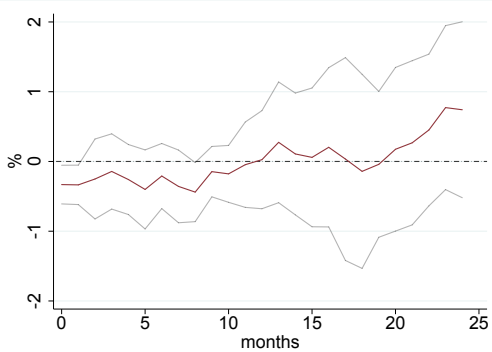
Cumulative frequency



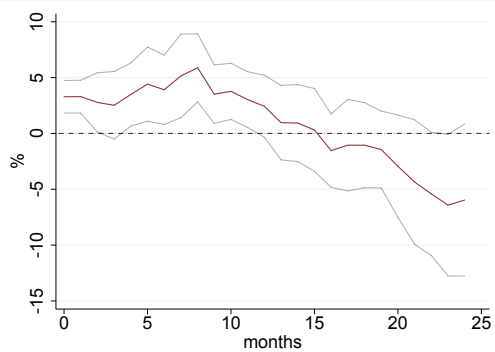
Cumulative size



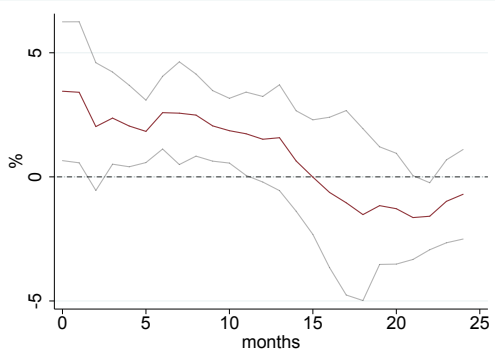
Price decrease



Cumulative frequency



Cumulative size



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Results, competitors' price gap, MP shock, h=12m

	(1)	(2)	(3)	(4)	(5)	(6)
	Price increases $\left(I^{+}_{pst,t+12}\right)$			Price decreases $\left(I^{-}_{pst,t+12}\right)$		
Gap (x_{pst-1})	−1.71***	−1.71***		1.36***	1.36***	
Shock (Δi_t)	−0.03*		−0.03	0.01*		0.01*
Selection ($x_{pst-1}\Delta i_t$)	−0.07	−0.07		0.07	0.07	
Age (T_{pst-1})	0.03***	0.03***	0.03***	0.01***	0.01***	0.01***
Positive gap (x^{+}_{pst-1})			−1.92***			1.93***
Negative gap (x^{-}_{pst-1})			−1.58***			1.01***
Pos. selection ($x^{+}_{pst-1}\Delta i_t$)			−0.05			0.05
Neg. selection ($x^{-}_{pst-1}\Delta i_t$)			−0.08			0.08
Product x store FE	✓	✓	✓	✓	✓	✓
Calendar-month FE	✓	✗	✓	✓	✗	✓
Time FE	✗	✓	✗	✗	✓	✗
N	23.7M	23.7M	23.7M	23.7M	23.7M	23.7M
Within R^2	16.4%	14.7%	16.5%	13.3%	12.7%	13.8%

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MP shock: selection

- Robustly no evidence for selection
- Significant shift in adjustment probability in supermarket prices

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Robustness to dropping fixed effects

	(1)	(2)	(3)	(4)
	Increases $\left(I^{+}_{pst,t+24}\right)$		Decreases $\left(I^{-}_{pst,t+24}\right)$	
Gap (x_{pst-1})	-1.75^{***}	-0.99^{***}	1.55^{***}	0.90^{***}
Shock (ebp_t)	-0.03^{***}	-0.04^{***}	0.03^{***}	0.03^{**}
Selection ($x_{pst-1}\hat{\text{ebp}}_t$)	-0.00	-0.01	0.01	0.02
Age (T_{pst-1})	0.02^{***}	-0.01^{**}	0.00^{**}	-0.03^{***}
Product x store FE	✓	✗	✓	✗
Calendar-month FE	✓	✓	✓	✓
Time FE	✗	✗	✗	✗
N	$16.1M$	$16.1M$	$16.1M$	$16.1M$
Within R^2	18.5%	8.9%	17.3%	9.3%

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Robustness to using posted prices

	(1)	(2)	(3)	(4)
	Increases $\left(I^{+}_{pst,t+24}\right)$		Decreases $\left(I^{-}_{pst,t+24}\right)$	
	Reference	Posted	Reference	Posted
Gap (x_{pst-1})	-1.75^{***}	-1.46^{***}	1.55^{***}	1.25^{***}
Shock (ebp_t)	-0.03^{***}	-0.04^{***}	0.03^{***}	0.03^{***}
Selection ($x_{pst-1}\hat{\text{ebp}}_t$)	-0.00	-0.01	0.01	0.02
Age (T_{pst-1})	0.02^{***}	0.01^{***}	0.00^{**}	-0.01^{***}
Product x store FE	✓	✓	✓	✓
Calendar-month FE	✓	✓	✓	✓
Time FE	✗	✗	✗	✗
N	$16.1M$	$18.6M$	$16.1M$	$18.6M$
Within R^2	18.5%	17.6%	17.3%	14.8%

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Robustness to excluding the Great Recession

	(1)	(2)	(3)	(4)
	Increases $\left(I^{+}_{pst,t+24}\right)$		Decreases $\left(I^{-}_{pst,t+24}\right)$	
	2001-2012	2001-2007	2001-2012	2001-2007
Gap (x_{pst-1})	-1.75^{***}	-1.74^{***}	1.55^{***}	1.50^{***}
Shock (ebp_t)	-0.03^{***}	-0.03^{***}	0.03^{***}	0.02^{***}
Selection ($x_{pst-1}\hat{\text{ebp}}_t$)	-0.00	0.06	0.01	-0.06
Age (T_{pst-1})	0.02^{***}	0.02^{***}	0.00^{**}	0.01^{***}
Product x store FE	✓	✓	✓	✓
Calendar-month FE	✓	✓	✓	✓
Time FE	✗	✗	✗	✗
N	$16.1M$	$9.9M$	$16.1M$	$9.9M$
Within R^2	18.5%	17.7%	17.3%	16.5%

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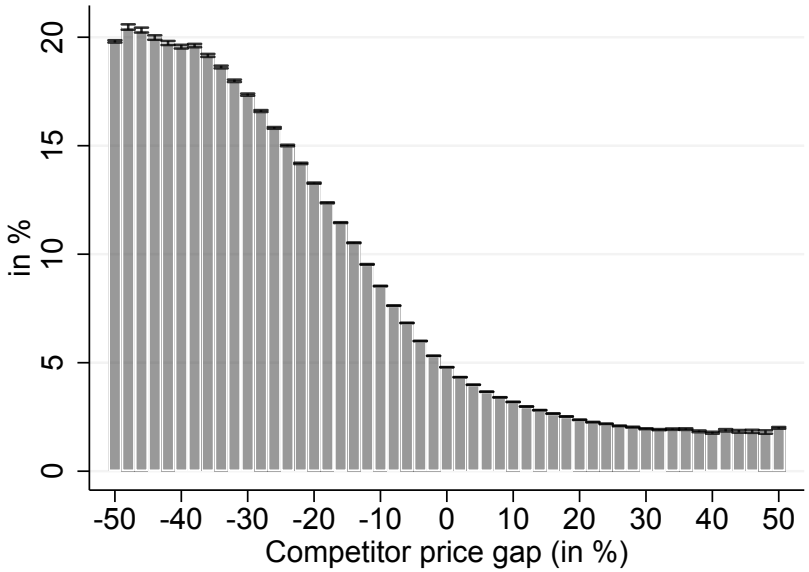
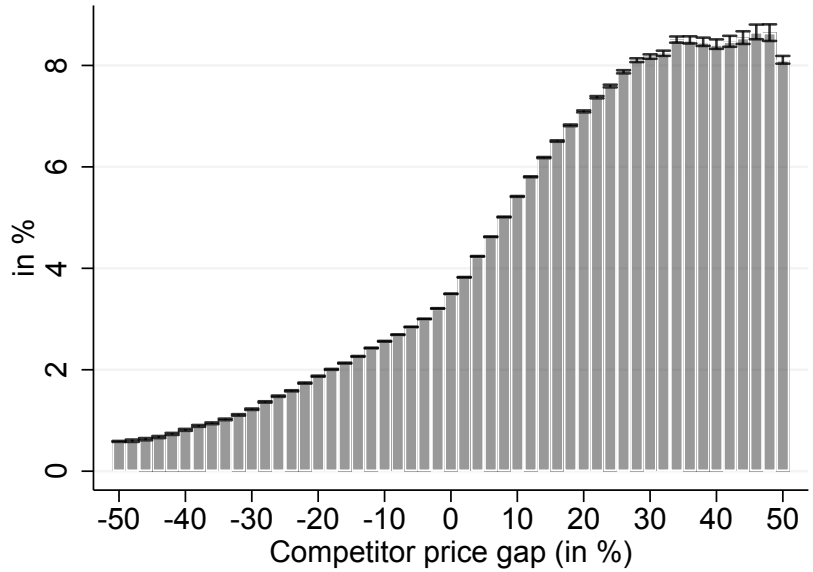
Competitors' price gap, cont.

Increase frequency



Decrease frequency



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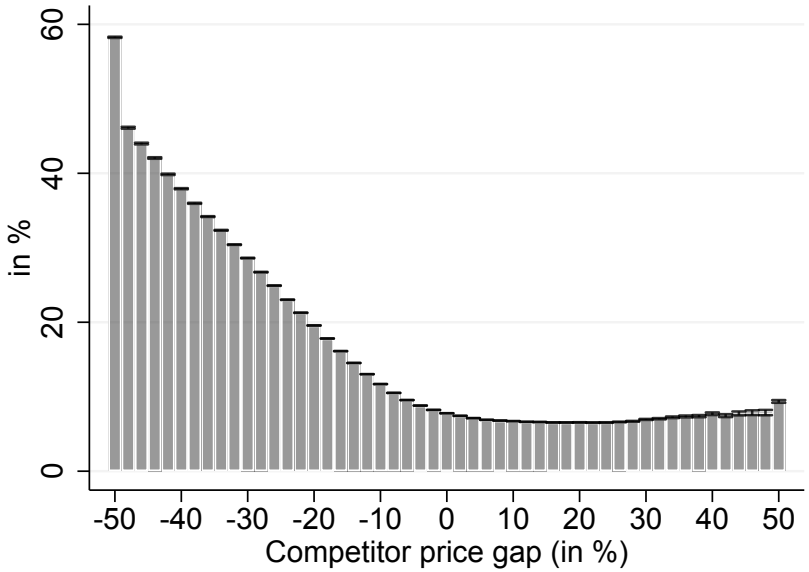
Competitors' price gap, cont.

Increase size



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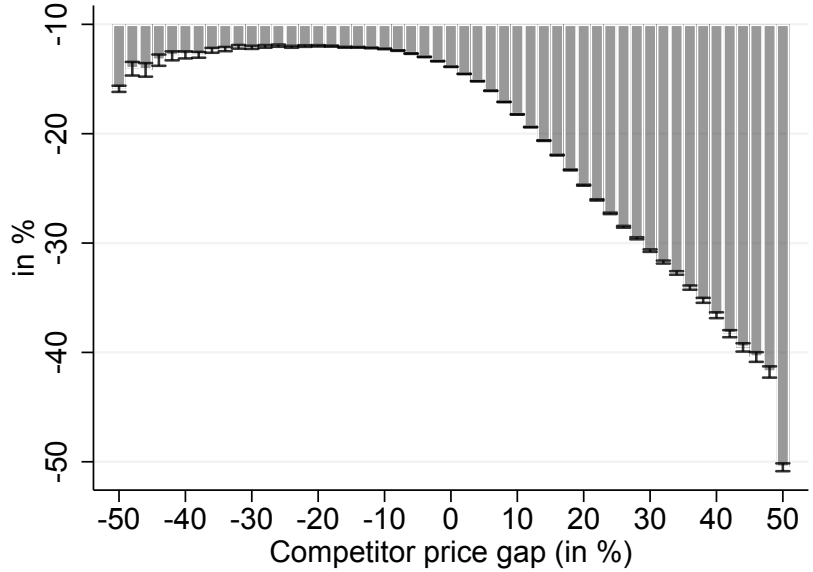

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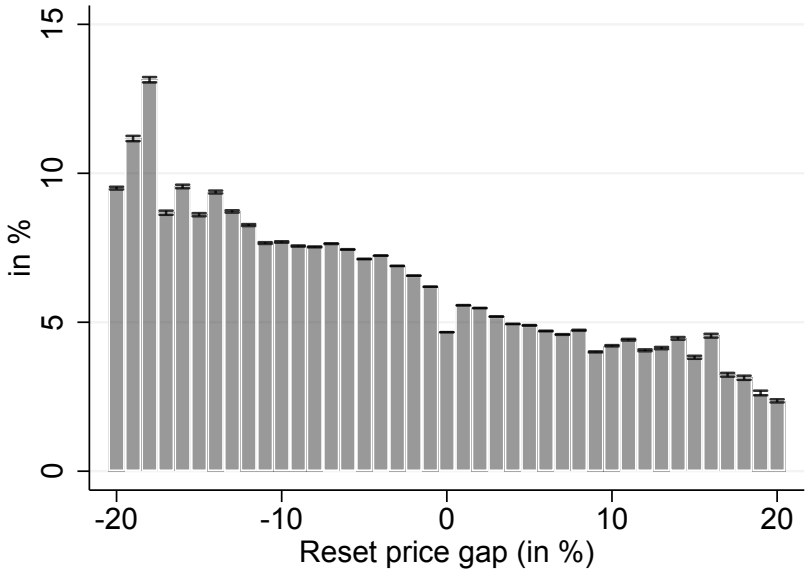
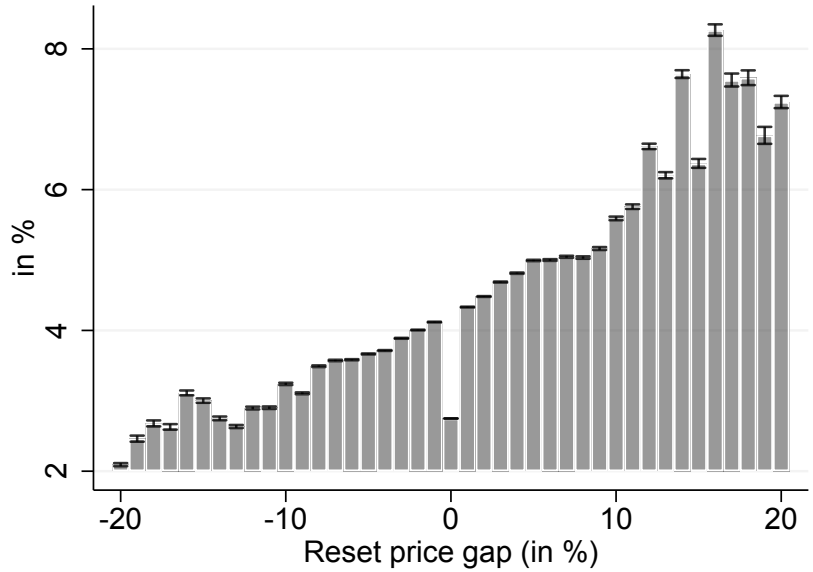
Reset price gap, cont.

Increase frequency



Decrease frequency



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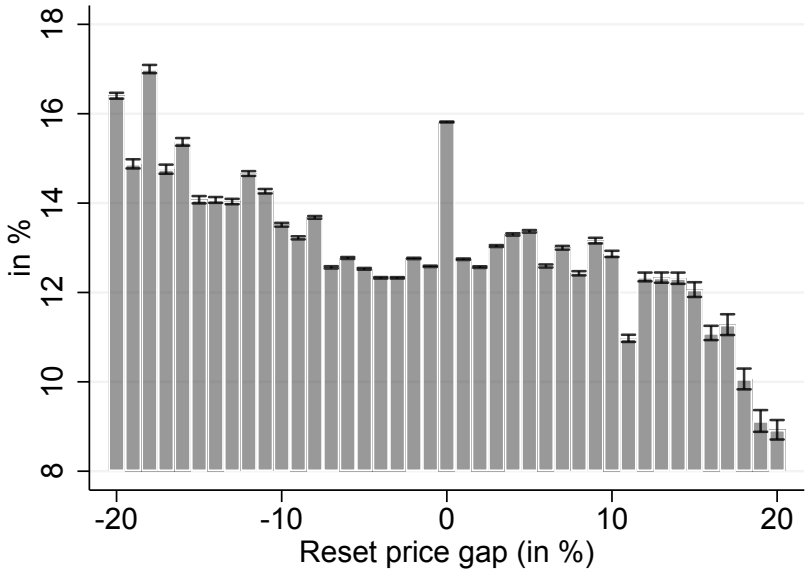
Reset price gap, cont.

Increase size



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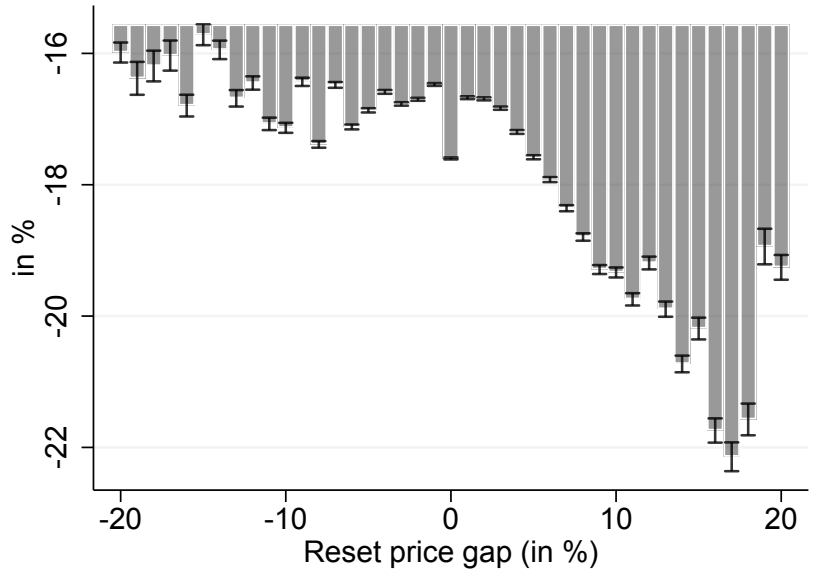

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Robustness to dropping fixed effects

	(1)	(2)	(3)	(4)
	Increases $\left(I^{+}_{pst,t+24}\right)$		Decreases $\left(I^{-}_{pst,t+24}\right)$	
Gap (x_{pst-1})	-1.75^{***}	-0.99^{***}	1.55^{***}	0.90^{***}
Shock (ebp_t)	-0.03^{***}	-0.04^{***}	0.03^{***}	0.03^{**}
Selection ($x_{pst-1}\hat{\text{ebp}}_t$)	-0.00	-0.01	0.01	0.02
Age (T_{pst-1})	0.02^{***}	-0.01^{**}	0.00^{**}	-0.03^{***}
Product x store FE	✓	✗	✓	✗
Calendar-month FE	✓	✓	✓	✓
Time FE	✗	✗	✗	✗
N	$16.1M$	$16.1M$	$16.1M$	$16.1M$
Within R^2	18.5%	8.9%	17.3%	9.3%

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Robustness to using posted prices

	(1)	(2)	(3)	(4)
	Increases $\left(I^{+}_{pst,t+24}\right)$		Decreases $\left(I^{-}_{pst,t+24}\right)$	
	Reference	Posted	Reference	Posted
Gap (x_{pst-1})	-1.75^{***}	-1.46^{***}	1.55^{***}	1.25^{***}
Shock (ebp_t)	-0.03^{***}	-0.04^{***}	0.03^{***}	0.03^{***}
Selection ($x_{pst-1}\hat{\text{ebp}}_t$)	-0.00	-0.01	0.01	0.02
Age (T_{pst-1})	0.02^{***}	0.01^{***}	0.00^{**}	-0.01^{***}
Product x store FE	✓	✓	✓	✓
Calendar-month FE	✓	✓	✓	✓
Time FE	✗	✗	✗	✗
N	$16.1M$	$18.6M$	$16.1M$	$18.6M$
Within R^2	18.5%	17.6%	17.3%	14.8%

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Robustness to excluding the Great Recession

	(1)	(2)	(3)	(4)
	Increases $\left(I^{+}_{pst,t+24}\right)$		Decreases $\left(I^{-}_{pst,t+24}\right)$	
	2001-2012	2001-2007	2001-2012	2001-2007
Gap (x_{pst-1})	-1.75^{***}	-1.74^{***}	1.55^{***}	1.50^{***}
Shock (ebp_t)	-0.03^{***}	-0.03^{***}	0.03^{***}	0.02^{***}
Selection ($x_{pst-1}\hat{\text{ebp}}_t$)	-0.00	0.06	0.01	-0.06
Age (T_{pst-1})	0.02^{***}	0.02^{***}	0.00^{**}	0.01^{***}
Product x store FE	✓	✓	✓	✓
Calendar-month FE	✓	✓	✓	✓
Time FE	✗	✗	✗	✗
N	$16.1M$	$9.9M$	$16.1M$	$9.9M$
Within R^2	18.5%	17.7%	17.3%	16.5%

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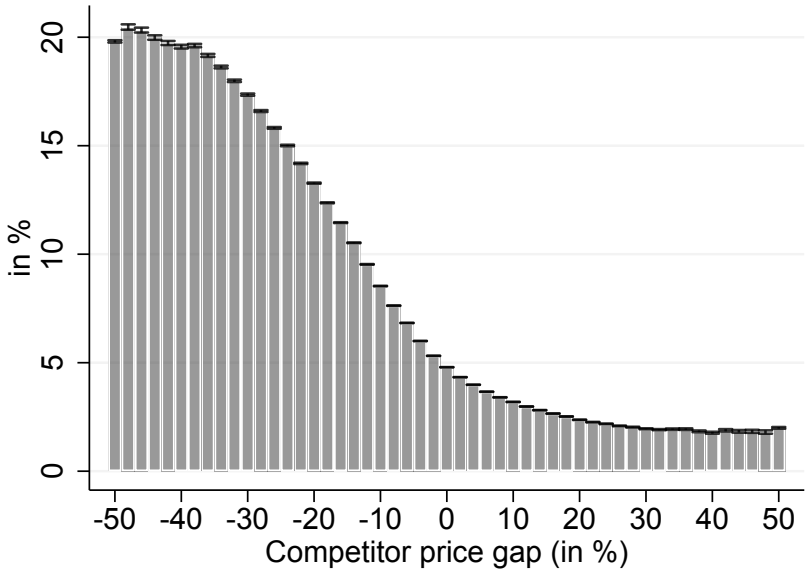
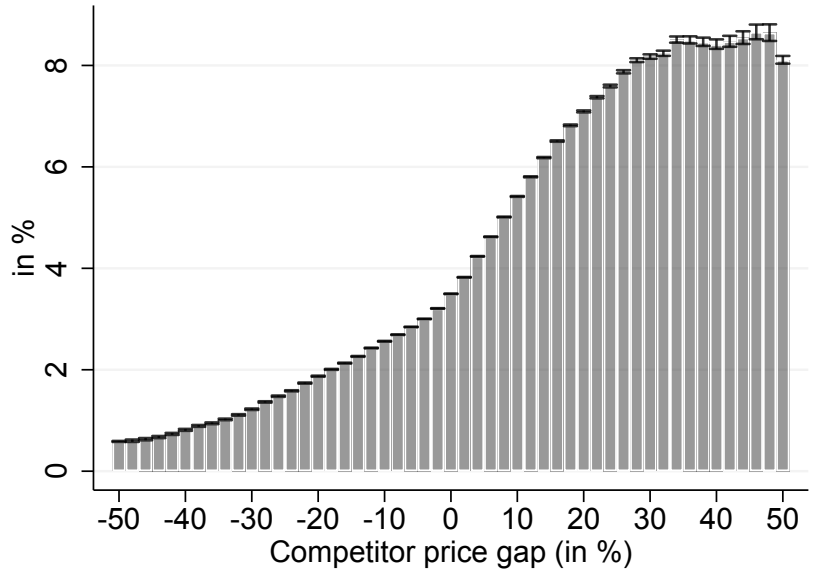
Competitors' price gap, cont.

Increase frequency



Decrease frequency



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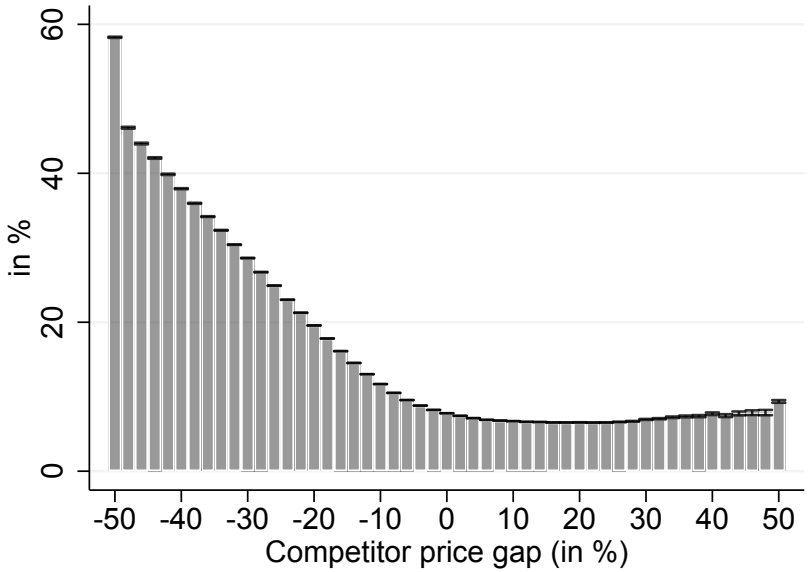
Competitors' price gap, cont.

Increase size



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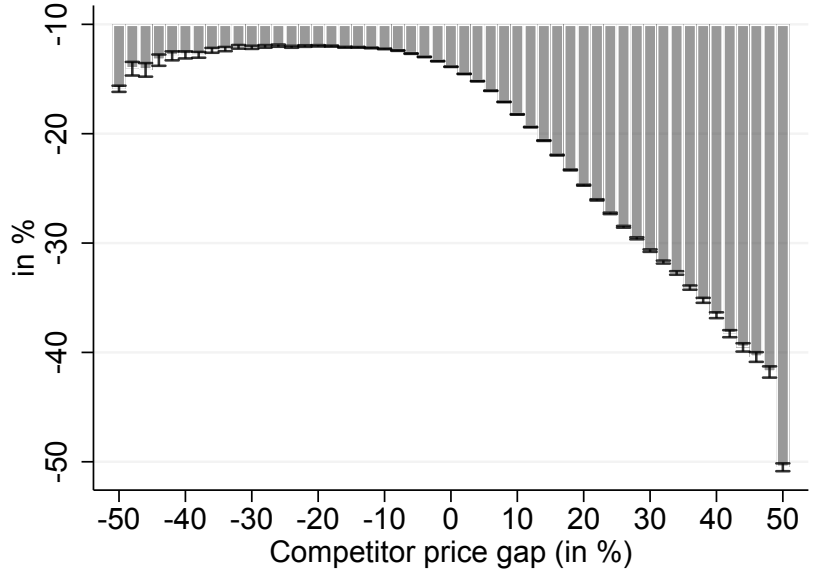

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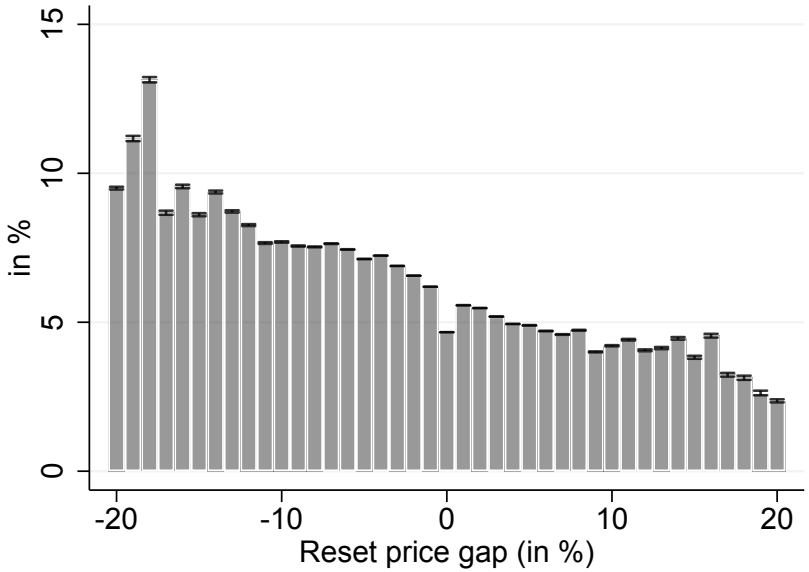
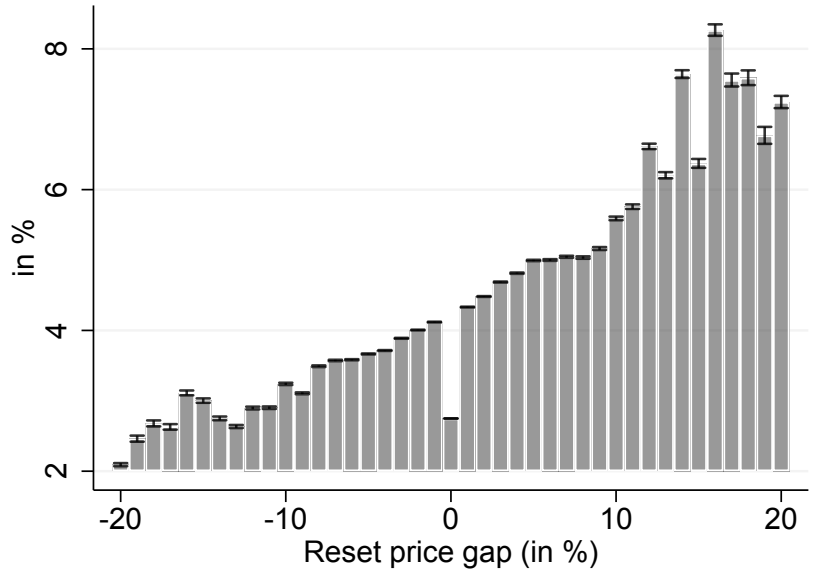
Reset price gap, cont.

Increase frequency



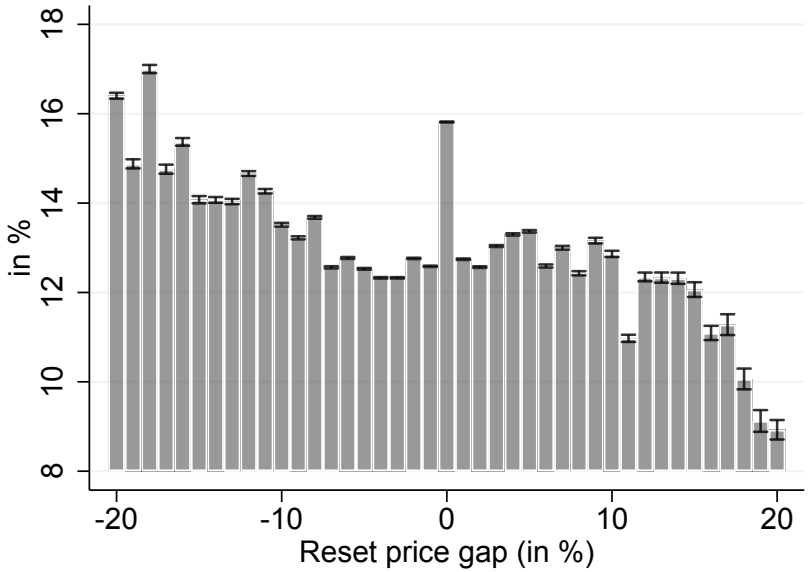
Decrease frequency



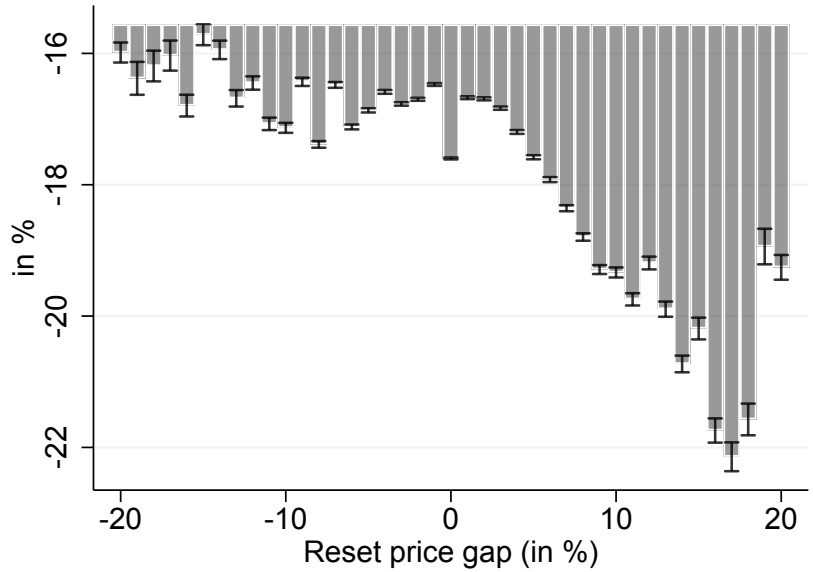
Back

Reset price gap, cont.

Increase size



Decrease size



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