EUROPEAN CENTRAL BANK

EUROSYSTEM

Price Synchronization and Cost Pass-through in Multiproduct Firms: Evidence from Danish Producer Prices

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Inflation in a Changing Economic Environment

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Micro Price Stickiness & Monetary Neutrality

- State-dependent models can generate real effects similar to time-dependent price-setting when "selection" weak
  - If multiproduct firms synchronize their price changes (Midrigan 2011, Alvarez & Lippi 2014, Karadi & Reiff 2018)
- Micro evidence on actual price setting by multiproduct firms
  - Bhattarai & Schoenle (2014), Bonomo et al. (2019)
- This paper: Extensive (selection) and intensive margin of price adjustment in response to cost shocks in multiproduct firms
  - Micro data underlying Danish Producer Price Index (PPI)
  - Merge price and firm cost data

Main Results

- Extensive margin (whether to change prices):
  - Imperfect within & across firm synchronization of price changes
  - State-dependent pricing: Probability of changing prices affected by aggregate, industry and firm cost shocks
- Intensive margin (how much to change prices):
  - Despite state-dependence, small “selection” bias
- Cost-shocks pass-through heterogeneous
  - Less than complete (<<1) but immediate for import prices
  - Complete (≈1) but delayed for energy prices/oil supply shocks
  - Firms with 5+ products adjust less to import prices

Roadmap

1. **Data and descriptive statistics**
2. Empirical approach
3. Results

Data: Prices and Firms

- Monthly goods prices for Danish PPI covering 70+% total sales of industrial production, 1993-2017
  - 3500 monthly prices for domestic and export transactions
  - 2900 monthly imported input prices
  - Median duration of price reporting: 115 months
  - 1140 firms (not representative sample)

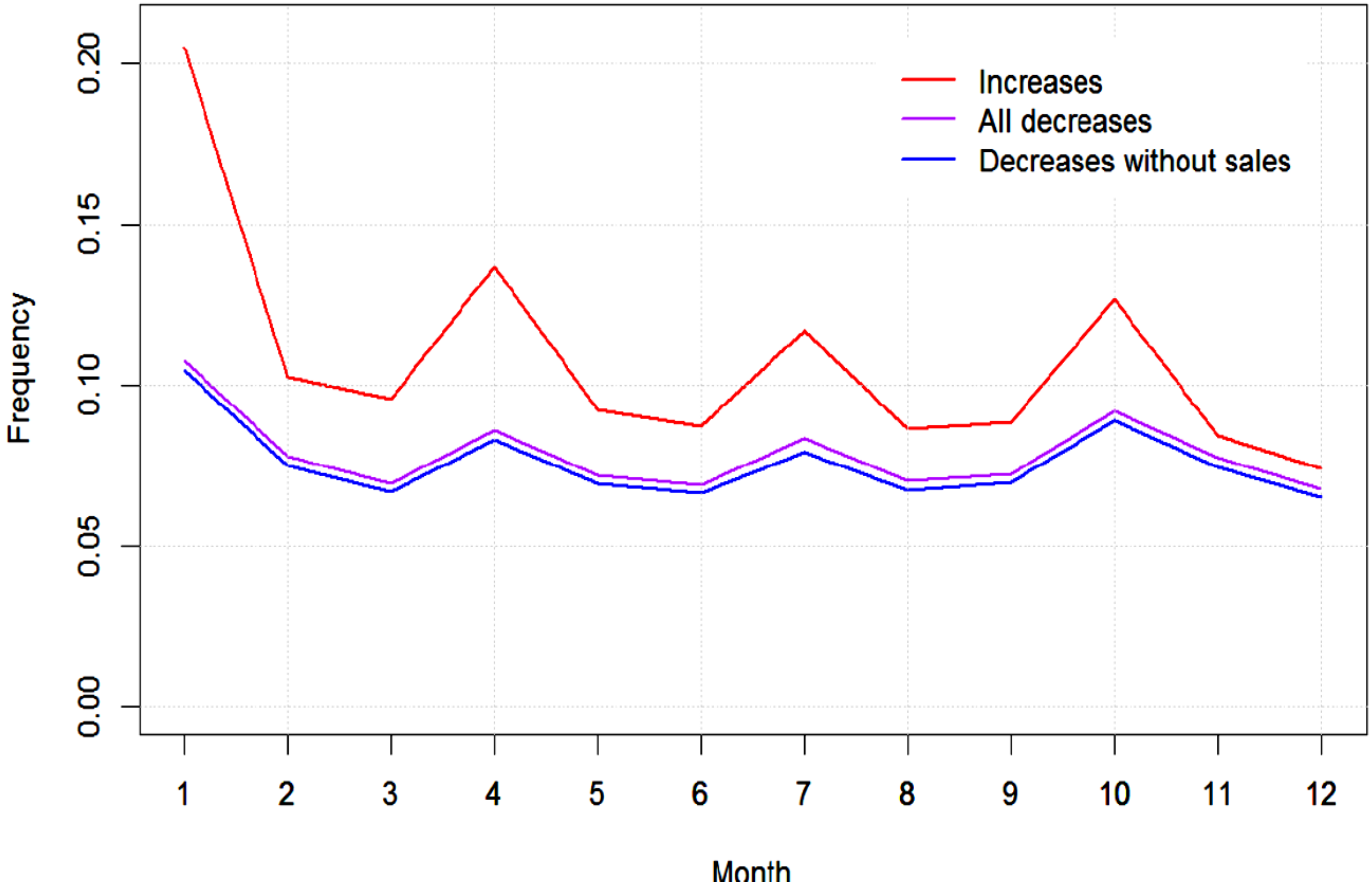
- Merge with firm-level cost data:
  - Accounting data: Annual cost shares, 1994-2016
  - VAT filings: Monthly/quarterly sales & input purchases, 2001-2017
  - Labor costs: Monthly wage bill and hours worked, **2007-2017**

Summary Statistics for Prices and Firms

	All	1	1-3	3-5	5-7	7+
No. of firms	1140	146	548	231	128	87
Median employment (FTE)	155.0	42.6	65.5	138.6	148.3	483.1
Median employment per good	33.2	42.6	26.2	34.8	25.5	48.5
Median age	26.0	25.0	25.0	28.0	24.0	29.0
Share of total prices	100.0	2.1	20.2	22.8	16.7	38.1
Median no. of products	5.0	1.0	3.0	4.0	5.8	11.5

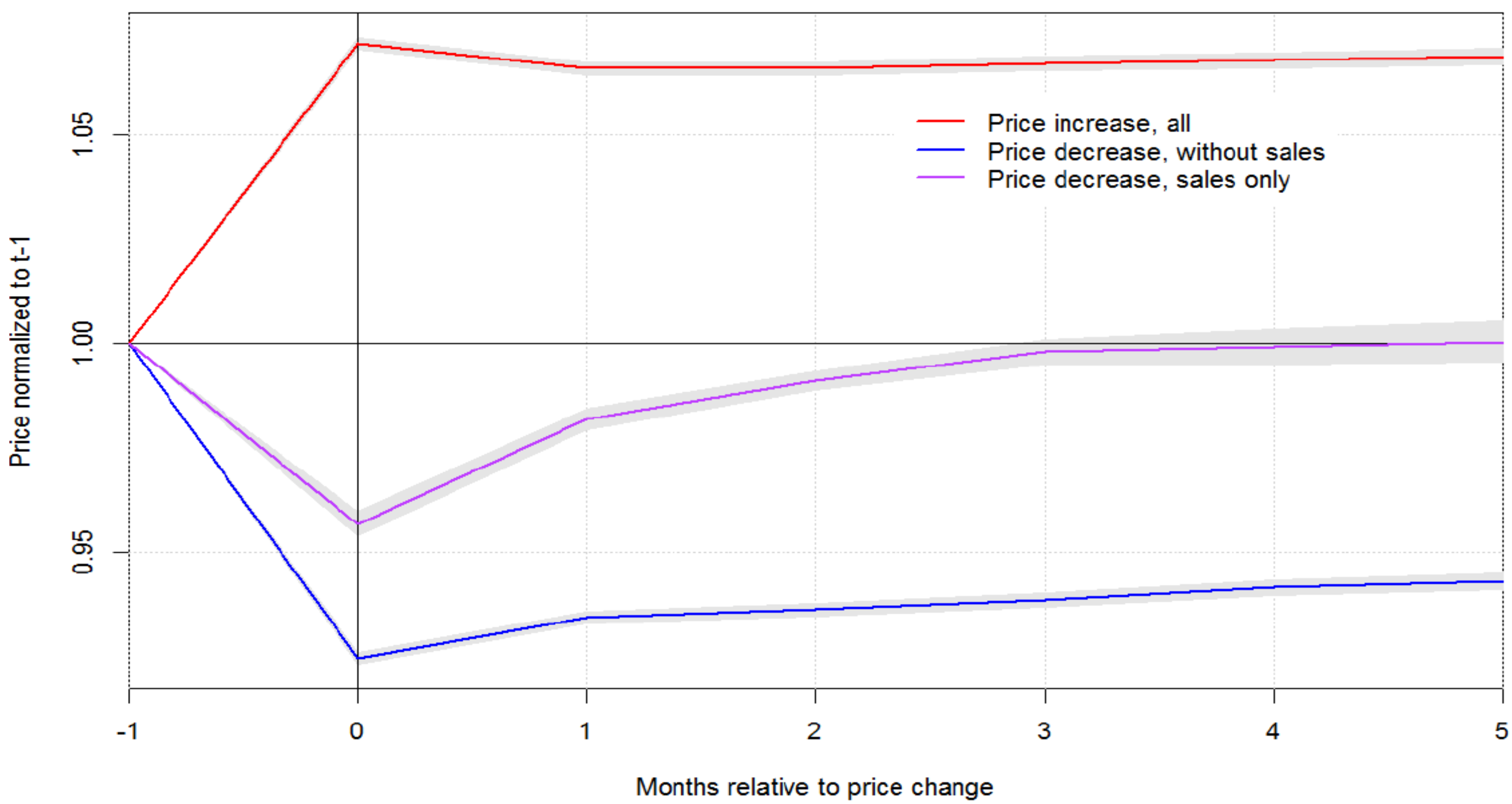
Note: Summary statistics on distribution of firms and prices across distinct bins of single- and multiproduct firms.

Frequency of Price Increases & Decreases



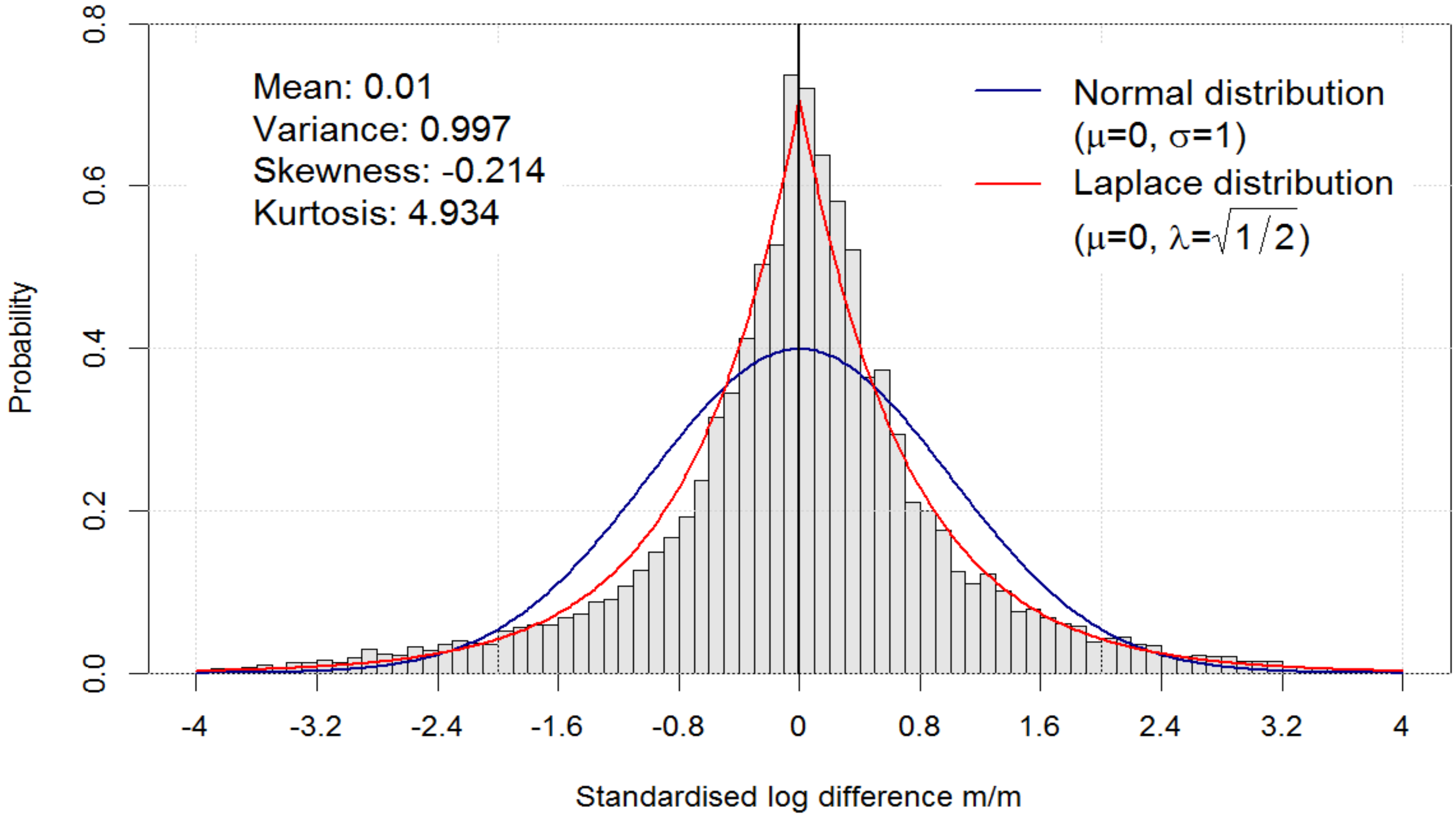
- Median frequency ≈10% => 8 months price duration
- Seasonal patterns in January, April, July, October (Nakamura & Steinsson, 2008 and IPN)

Average Price Changes



- Average absolute size of $\Delta p \approx 7\%$
- “Sales” only 0.3% (3.8% of decreases but smaller drop)

Size Distribution of Non-zero Price Changes



- Large mass of small Δp (Alvarez, Le Bihan & Lippi 2016)
- Distribution very similar across firms' # of goods

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Price Adjustment to Cost Shocks

- Under flex prices, $\Delta p = \Delta \text{markup} + \Delta(\text{marginal cost})$
  - Structural cost pass-through: $\partial \Delta p / \partial(\Delta(\text{marginal cost}))$
  - Pass-through < 1 when markup absorbs cost increases

Price Adjustment to Cost Shocks

- Under flex prices, Δp = Δmarkup + Δ(marginal cost)
  - Structural cost pass-through: ∂Δp/∂(Δ(marginal cost))
  - Pass-through < 1 when markup absorbs cost increases
- Under sticky prices adjustment through extensive and intensive margin
  - With infrequent adjustment downward bias if Δp=0 included
  - Looking only at Δp≠0 leads to selection bias with state-dependent extensive margin
  - Both margins matter for inflationary effects of cost shocks: OLS of Δp on costs gives overall elasticity, but not structural

Estimating Extensive and Intensive Margins

- To correct for selection bias use two-stage "Heckit" approach
- Jointly model both margins following Bourguignon et al. (2007): ***1st stage multinomial logit selection***

$$\Delta p^{*}_{i,j,t} = \beta^1 Z_{i,j,t} + \eta_{i,j,t} \rightarrow \qquad \Pr(r_{i,j,t} = -1, 0, 1) = \Phi\left(\beta Z_{i,j,t}\right)$$

$$\Delta p_{i,j,t,r=1,} = \beta^2 X_{i,j,t,r=1} + u_1$$

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$$\Delta p_{i,j,t,r=1,} = \beta^{2} X_{i,j,t,r=1} + u_{1}$$

  - u correlated with η, assume function of estimated probabilities:

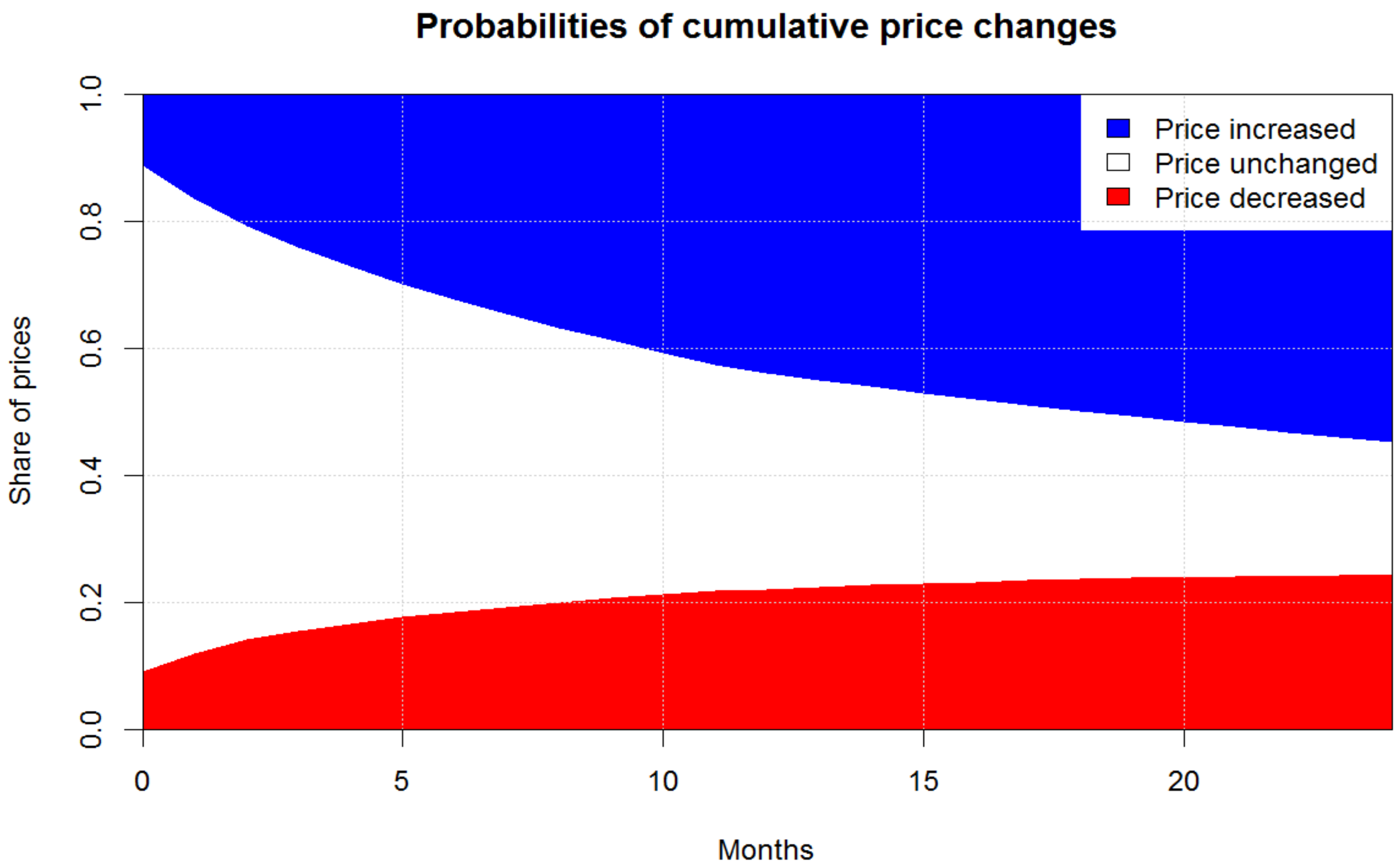
$$\begin{aligned}\Delta p_{i,j,t,r=1} &= \beta^{2} X_{i,j,t,r=1} + u_{1} \\ &= \beta^{2} X_{i,j,t,r=1} + \gamma_{1} m(\Pr_{1}) + \sum_{r=(-1,0)} \gamma_{r}\left(m(\Pr_{r})\frac{\Pr_{r}}{(\Pr_{r}-1)}\right) + \omega_{1}\end{aligned}$$

- Non-parametric identification, X subset of Z

Estimating Extensive and Intensive Margin

- Identification by exploiting price synchronization in multiproduct firms and frequency seasonality (all excluded from 2nd stage X):
  - Share of same and opposite-signed price changes within firm and sector (excluding i-th price)
  - Month fixed effects
  - Also standard deviation of specific price in last 5 years

Dependent Variable in Selection Step



- 40% of cumulated Δp=0 even after 12 months

Estimating Intensive Margin

- Marginal cost = input prices weighted by shares in total variable costs (Amiti et al. 2018)

- Local projections to estimate t+h cost pass-through:

$$\Delta p_{i,j,t+h} = \alpha + \beta^E \varphi^E{}_{j,t-1} \Delta p^E{}_t \quad + \beta^I \varphi^I{}_{j,t-1} \Delta p^M{}_{j,t} + \partial X_{i,j,t} + u_{i,j,t+h}$$

- Firm-level cost shocks:
  - Δenergy price x cost share of energy(t-1) – average 1.7%
  - Δimport prices x cost share of imports(t-1) – average 28%

Estimating Intensive Margin

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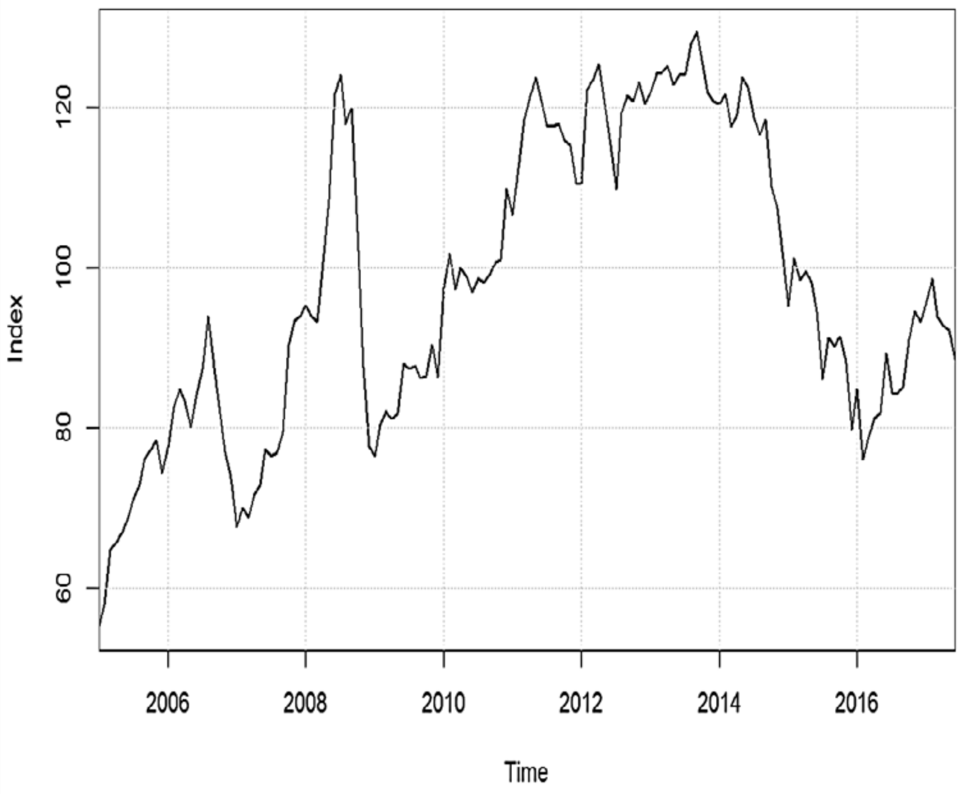
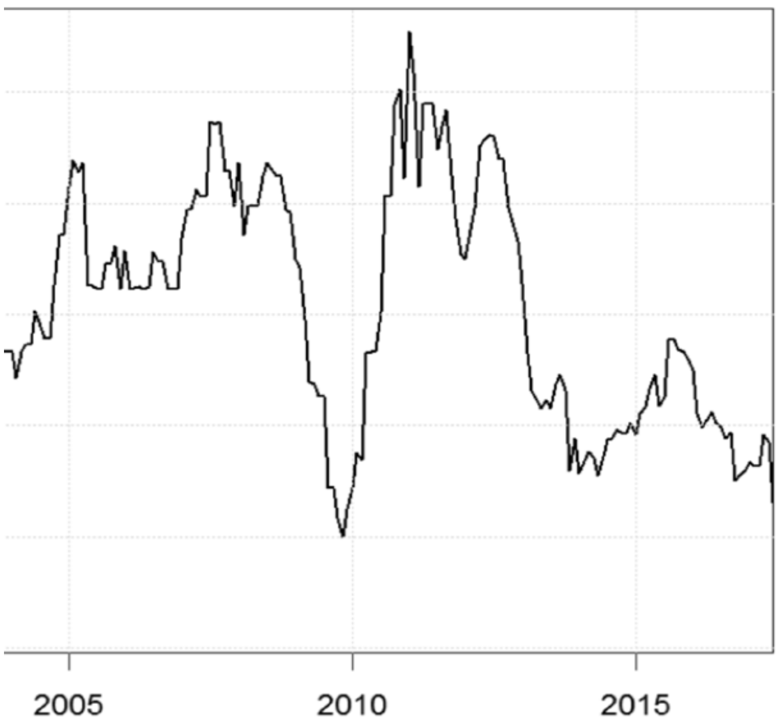
- Firm-level cost shocks:
  - Δenergy price x cost share of energy(t-1) – average 1.7%
  - Δimport prices x cost share of imports(t-1) – average 28%
- Further firm controls (in X): change in firm hourly wages, change in total variable costs, change in total sales; firm size and #products
  - Also proxy for markup with prices of competitors (2 digit level)
  - Aggregate controls: CPI, NEER (and sector FE)

Energy and Imported Input Prices

Danish Energy Price Index



Average Imported Input Price



- Both approximately random walks (shocks *i.i.d.*)
  => Pass-through similar across horizons
- But small common component in energy prices

Roadmap

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3. **Results**

Results #1: Determinants of Extensive Margin

- Within and across firms synchronization of price changes
  - Within-firm share of price changes of opposite sign
  - Increasing in number of products of firm

- Evidence of state-dependent pricing -- Probability of changing prices affected by firm, industry and aggregate shocks
  - 1% increase in CPI raises probability $\Delta p>0$ by 0.56%
  - 1% increase in import prices raises probability $\Delta p>0$ by 0.28%

Extensive Margin: Synchronization

	All		
Marg. effect on probability of price increase		Marg. effect on probability of price decrease	
Fraction of pos. price changes in firm	6.34***	Fraction of pos. price changes in firm	2.28***
	(0.04)		(0.04)
Fraction of neg. price changes in firm	2.74***	Fraction of neg. price changes in firm	4.09***
	(0.04)		(0.03)
Fraction of pos. price changes in industry	0.080	Fraction of pos. price changes in industry	-0.25***
	(0.06)		(0.06)
Fraction of neg. price changes in industry	-0.202**	Fraction of neg. price changes in industry	-0.073
	(0.06)		(0.06)

Imperfect synchronization within and across firms

Extensive Margin: Synchronization

	All		
Marg. effect on probability of price increase		Marg. effect on probability of price decrease	
Fraction of pos. price changes in firm	6.34***	Fraction of pos. price changes in firm	2.28***
	(0.04)		(0.04)
Fraction of neg. price changes in firm	2.74***	Fraction of neg. price changes in firm	4.09***
	(0.04)		(0.03)
Fraction of pos. price changes in industry	0.080	Fraction of pos. price changes in industry	-0.25***
	(0.06)		(0.06)
Fraction of neg. price changes in industry	-0.202**	Fraction of neg. price changes in industry	-0.073
	(0.06)		(0.06)

Imperfect synchronization within and across firms

Extensive Margin: Changing # of Products

	All	1-5	5+
Marg. effect on probability of price increase			
Fraction of pos. price changes in firm	6.34***	5.27***	7.83***
	(0.04)	(0.04)	(0.06)
Fraction of neg. price changes in firm	2.74***	2.39***	2.87***
	(0.04)	(0.05)	(0.07)
Fraction of pos. price changes in industry	0.080	0.333**	0.037
	(0.06)	(0.11)	(0.08)
Fraction of neg. price changes in industry	-0.202**	-0.43***	-0.104
	(0.06)	(0.13)	(0.08)

Within firm synchronization increasing, but effect small

Across firm synchronization decreasing with # of products

Extensive Margin: State Dependence

	All
Marg. effect on probability of price increase	
Fraction of pos. price changes in firm	6.34***
	(0.04)
Fraction of neg. price changes in firm	2.74***
	(0.04)
Fraction of pos. price changes in industry	0.080
	(0.06)
Fraction of neg. price changes in industry	-0.202**
	(0.06)
Avg. price change in industry, excl. firm	0.14***
	(0.03)
Energy price change x lagged energy cost share	-0.371
	(0.38)
Import price change x lagged import cost share	0.28***
	(0.04)
CPI, log difference	0.557*
	(0.28)

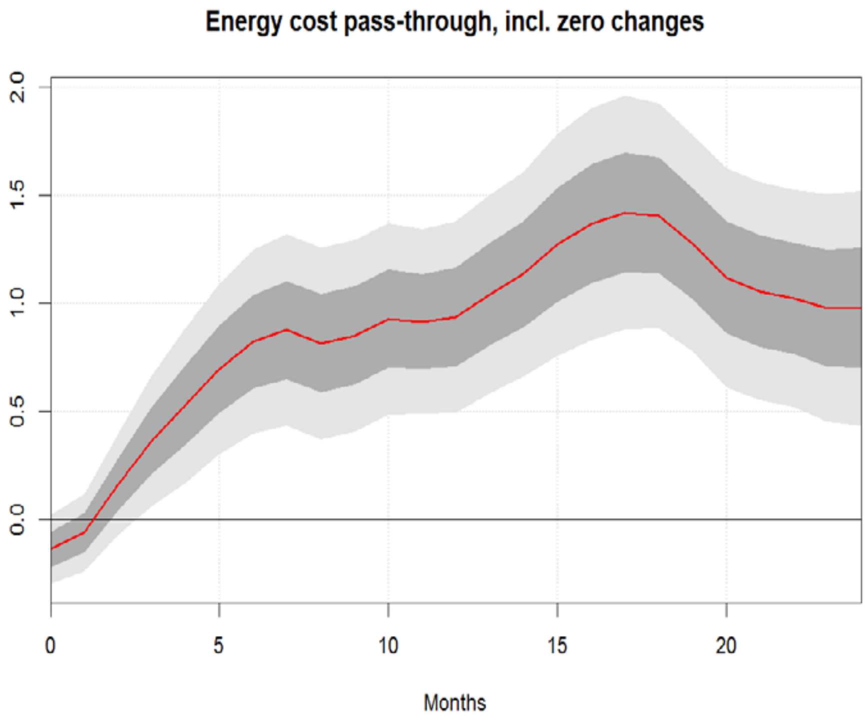
Marg. effect on probability of price decrease	
Fraction of pos. price changes in firm	2.28***
	(0.04)
Fraction of neg. price changes in firm	4.09***
	(0.03)
Fraction of pos. price changes in industry	-0.25***
	(0.06)
Fraction of neg. price changes in industry	-0.073
	(0.06)
Avg. price change in industry, excl. firm	-0.15***
	(0.03)
Energy price change x lagged energy cost share	-0.172
	(0.34)
Import price change x lagged import cost share	-0.29***
	(0.04)
CPI, log difference	-1.00***
	(0.27)

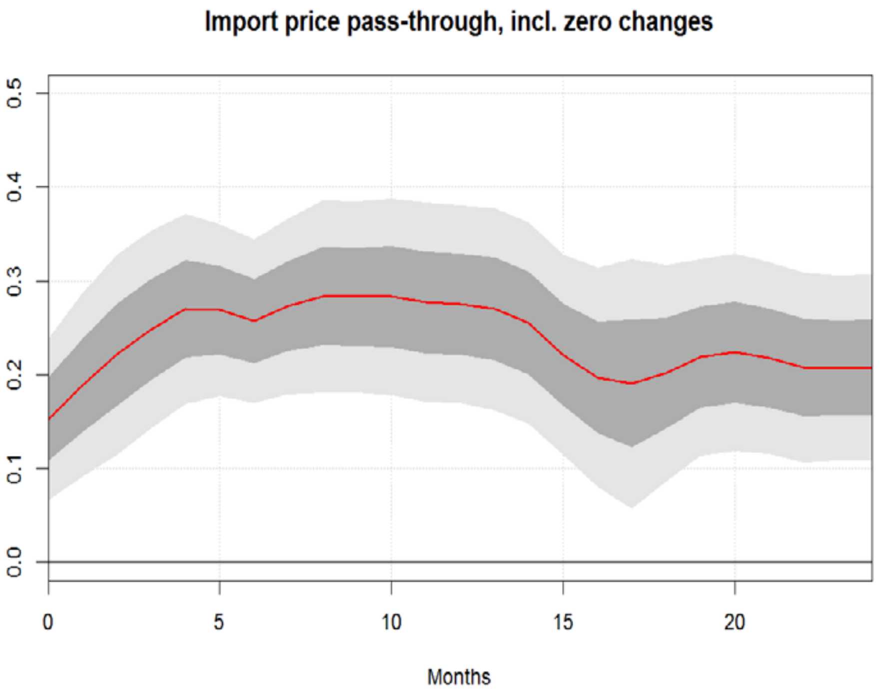
State-dependence wrt industry, firm and aggregate variables (Energy price significant after 3 months)

Results #2: Intensive Margin

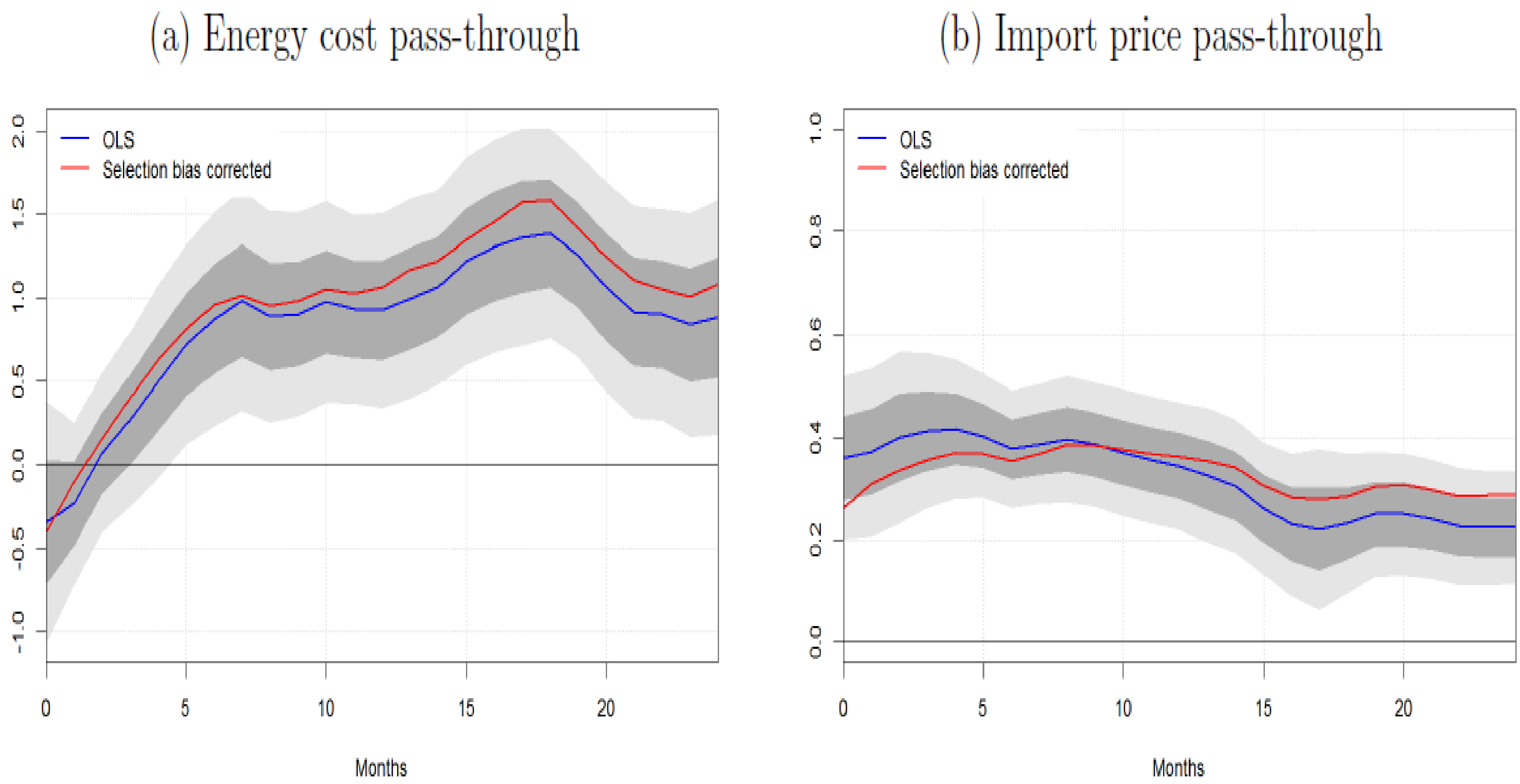
- Despite state-dependence, little evidence of selection bias
  - Bias correction terms significant but small
- Cost-shocks pass-through heterogeneous
  - Less than complete (<<1) but immediate for import prices
  - Complete (≈1) but gradual for energy prices/oil supply shocks
  - Firms with 5+ products adjust less to import prices

Heterogeneous Cost Pass-Through: OLS



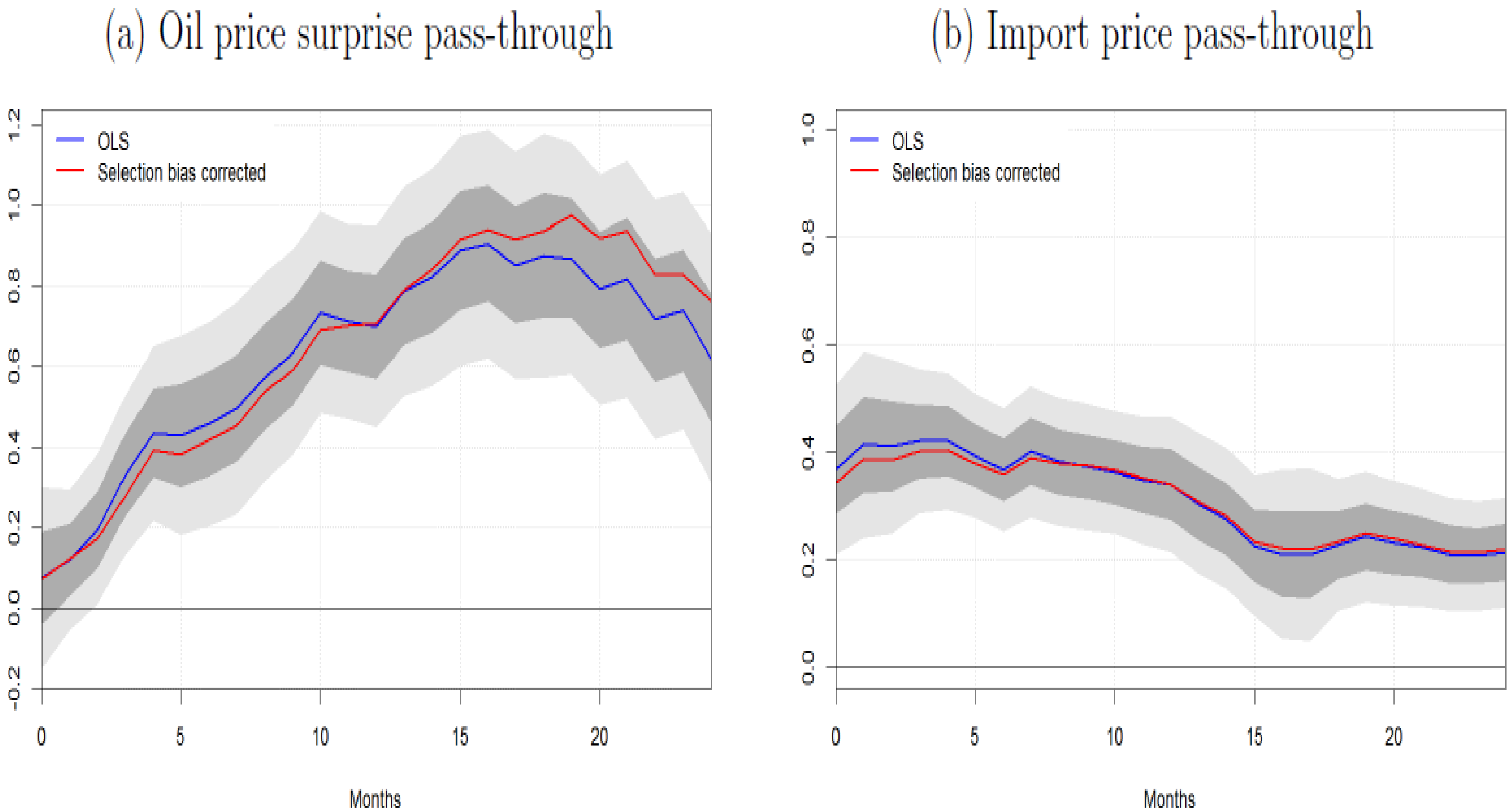


Heterogeneous Cost Pass-Through



Dynamics robust to excluding lags of energy and import costs (Caveat: OLS (HAC) standard errors)

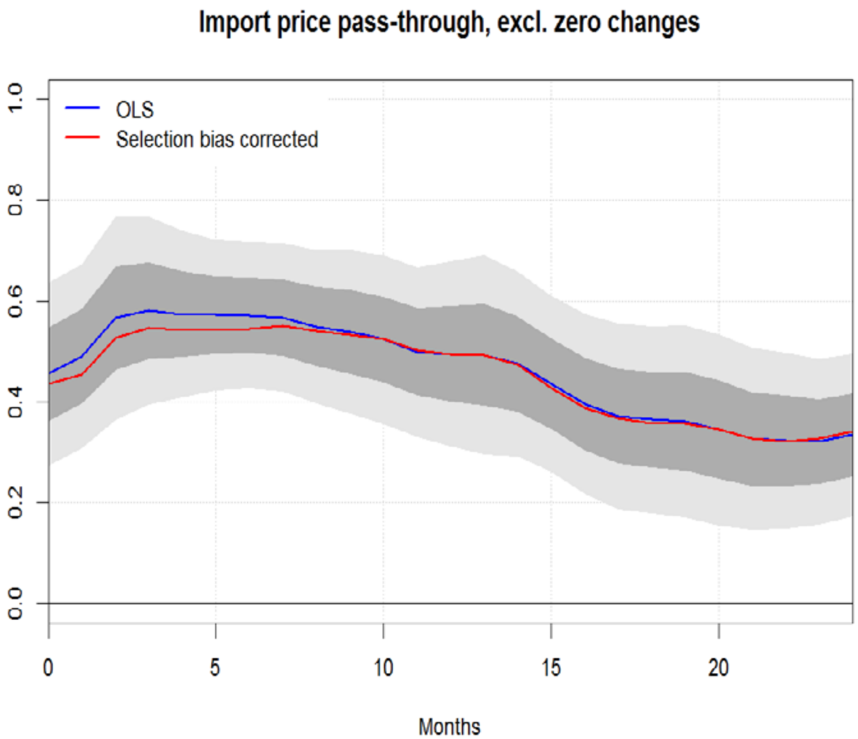
Heterogeneous Cost Pass-Through: Oil Shock



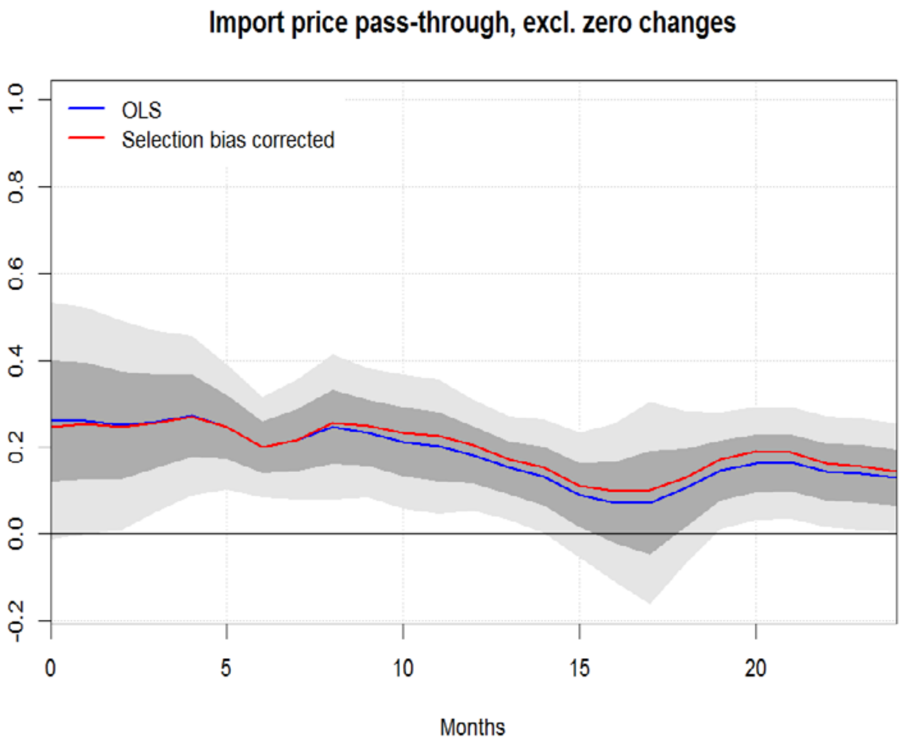
Negative oil supply shock (i.i.d.), Baumeister & Hamilton (2019)

Heterogeneous Cost Pass-Through: # Goods

Firms with # Goods ≤5



Firms with # Goods>5



Heterogeneity in markup adjustment (despite competitors prices)?
But very similar responses to energy prices/oil shocks

To conclude

- Multiproduct firms' extensive and intensive margin of price adjustment
- Synchronization and state-dependence in extensive margin:
  - Price change probability increasing with fraction of other prices changing, higher with more products
  - Affected by firm, industry and aggregate shocks
- Cost and firm heterogeneity in intensive margin:
  - Adjustment to energy/oil shocks larger than to import prices
  - Firms with more products adjust by less to import prices
- Still preliminary, next up: markups, non-linearities, domestic and export prices, monetary shocks,…

Price Setting by Multiproduct Firms

- Does simple Δp pattern depend on # of goods by firm?
  - Alvarez-Lippi (2014): Δp frequency (N) and size depend on n

$$E\left[N\left(\Delta p_i\right)\right] = \frac{n\sigma^2}{\bar{y}} = \frac{n\sigma^2}{\sqrt{2\left(n+2\right)\frac{\sigma^2\psi}{B}}} \uparrow \text{ in } n$$

$$E\left\|\Delta p_i\right\| = \frac{\sqrt{\bar{y}}}{\frac{n-1}{2}Beta\left(\frac{n-1}{2},1/2\right)} = \frac{\left(2\left(n+2\right)\frac{\sigma^2\psi}{B}\right)^{1/4}}{\frac{n-1}{2}Beta\left(\frac{n-1}{2},1/2\right)} \downarrow \text{ in } n$$

- Consistent evidence in Bhattarai & Schoenle (2014) for US PPI
  - We find little relation between # goods and Δp frequency & size

What We Do

- Empirical analysis of relative price adjustment in a currency area during housing bust in the US Great Recession
- Build new dataset of regional (MSA) consumption prices, combined with data on sectoral costs and activity:
  - Based on BLS CPI Research database for 73 MSAs
    - Public CPI data for 27 largest MSAs
    - BLS micro data for smaller MSAs
- Decomposition of real exchange rate adjustment between goods and services (ex-rents) across US MSAs
- Empirical approach: (sectoral) prices, employment, wages,…, regressed on local house prices as a measure of demand – both OLS and IV

Main Results: Missing Internal Devaluation

- Little real exchange rate adjustment to asymmetric housing bust within US "currency area"
  - Evidence that the relative price of (non-tradable) services does not fall more than relative price of (tradable) goods
  - Relative price of goods insensitive to house prices
  - Relative price of services negatively related to house prices
- Heterogeneity in price adjustment across related sectors
  - Price of Food at home falls with bust in house prices – Stroebl & Vavra 2018 (S&V18)
  - Price of Food away from home significantly increases

Selected Literature

- Large literature on the link between regional prices and wages, and regional business cycles (Blanchard & Katz 1992)
- Recent contributions:
  - Local employment and demand effects of house price shocks: Mian, Rao & Sufi (2013), Mian & Sufi (2014), Aladangady (2016), Kaplan, Mitman & Violante (2016)
  - Local prices/markups using store-level scanner data: Coibion et al. (2014), Stroebl & Vavra (2018), Beraja, Hurst & Ospina (2016), Kaplan et al. (2016), Anderson, Rebelo & Wong (2018)
  - Regional Phillips Curves: Fitzgerald & Nicolini (2014)
  - Regional and sectoral adjustment in currency areas: Philippon & Midrigan (2014), Beraja et al. (2016), Martin & Philippon (2017), Galí & Monacelli (2018) – and Nakamura & Steinsson (2014) on fiscal shocks,…

Stylized Adjustment Mechanism

- Demand for locally produced tradables depends on overall aggregate demand in currency area
- Non-tradable (services) demand depends on local demand *D* and relative prices:

$$logY_{l,N} = -\epsilon_N \cdot (1-\alpha_N) \cdot (p_{l,N} - p_{l,T}) + logD^l$$

- A fall in *D* can be cushioned by a fall in relative prices $(p_{l,N} - p_{l,T})$ and in local marginal cost (function of labor demand):

$$p_{l,N} = log\mu_{l,N} + \gamma_N logW_l + (1-\gamma_N) logl_{l,N}$$

$$p_{l,T} = (log\mu_{l,T}) + \gamma_T logW_l + (1-\gamma_T)\log(L_l - l_{l,N})$$

- Ceteris paribus, fall in relative price will result in ***rer*** depreciation:

$$rer_l \downarrow = (p_{l,T} - p_T) + \alpha_{NT} \cdot [(p_{l,NT} - p_{l,T}) \downarrow -(p_{NT} - p_T)]$$

$$rer_l \downarrow = q_{l,G} + \alpha_S \cdot [q_{l,S} \downarrow - q_{l,G}]$$

Procyclical Markup Adjustment?

- S&V18 shows that positive elasticity of scanner grocery prices is due to procyclical markup adjustment
  - Similar finding with BLS index – no "trading down" (Jaimovich, Rebelo & Wong 2108)
- Evidence consistent with non-homothetic preferences (Bertoletti & Etro 2017):

$$\mu^l = 1 + \frac{y^l}{\gamma * costs}$$

  - Markup then falls with local income/wealth if costs acyclical (Anderson, Rebelo & Wong 2018)
- But then why are markups countercyclical in restaurants, and services in general, beyond movements in costs?

Countercyclical Markup Adjustment?

- Static oligopoly model after Atkeson & Burstein (2008): Markup function of market shares and within/across sectors elasticities (θ_j, φ)

$$\mu_j = \frac{\epsilon_j}{\epsilon_j - 1}, \epsilon_j = \theta_j - (\theta_j - \varphi) \cdot share_j$$

  - Markup rises (elasticity falls) when market share rises (# of firms falls) if $(\theta_j - \varphi) > 0$

- Evidence with other measures of markups than labor shares? Bils, Klenow and Malin (2018): try share of intermediate inputs