Sticky Prices and Monetary Policy: Evidence from Disaggregated U.S. Data

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Background: Conflicting evidence on "sticky" prices
and inflation persistence

- Aggregate evidence: Price indices "sticky," and aggregate inflation persistent in long samples
  - VARs: IRFs to monetary policy shocks (e.g., Christiano, Eichenbaum, Evans 1999)
    - Price index little affected for first 6Q
  - Persistence: Fuhrer and Moore [1995], Galì and Gertler [1999]
    - but possibly lower persistence since mid 80's (Cogley and Sargent [2001, 2005], Pivetta and Reis [2003], Levin and Piger [2003], Clark [2003])

$\Longrightarrow$ Main motivations for sticky-price models
(Rotemberg and Woodford 1997, CEE 2005)

Existing evidence on disaggregated prices (sectoral level)

- Bils and Klenow [2004]: Prices change frequently, inflation largely transient
  - 350 categories of CPI
  - Median duration between price changes: 4.3 months
    $\Longrightarrow$ much less stickiness than typically assumed

    but caveat (Nakamura and Steinsson [2006]):
    – Accounting for sales, median duration 8-11 mo.
  - Disaggregated inflation mostly transient

- Conditional on change, prices change by large amount: 13% on average (Klenow and Kryvstov [2004])

- P. Kehoe: "[Disaggregated evidence is] a challenge for sticky price enthusiasts" (RED Newsletter, 2004)

Goals of this paper

- Attempt to reconcile facts on aggregate and disaggregated PCE and PPI prices

- Disentangle fluctuations in disaggregated prices due to macro vs sectoral disturbances
  - Are responses to macro and sectoral shocks similar?

- Document the effect of monetary policy at a disaggregated level
  - Clarify why existing studies argue disaggregated price responses inconsistent with sticky-price models

- Provide some new facts that might be helpful in developing macro models

Outline

1. Econometric Framework

2. Data

3. Empirical evidence

   (a) Sources of fluctuations in:
   * sectoral inflation / "macro" comp. / sector-specific comp.

   (b) Effects of shocks:
   * sectoral / "macro" / monetary

4. Conclusion

1. Econometric Framework:
Factor Augmented Vector Autoregression (FAVAR)

(Bernanke, Boivin and Eliasz [2005]: BBE)

- Idea: estimate common factors (C_t) from large data set
  – C's have *pervasive* effects potentially on all indicators

- Augments standard VAR with extra information

- Not necessary to define measures for diffuse concepts (e.g. "real-activity")

- Can decompose each series into common and series-specific components

- Can trace out the response of all data series to macro disturbances

  – Broader picture of the effect of the shock

  – More complete check on the plausibility of identification scheme

Factor Augmented Vector Autoregression: FAVAR

Observation equation:

$$X_t = \Lambda C_t + e_t$$

Transition equation (VAR):

$$C_t = \Phi(L) C_{t-1} + v_t$$

where

$$C_t = \begin{bmatrix} F_t \\ R_t \end{bmatrix}$$

R — set of observable series (here Fed funds rate)

F — set of unobservable factors ("economic activity," "inflation,"...)

X — large panel of informational series

e — series-specific component (potentially serially and weakly cross correlated)

Note: Dynamics allowed in observation equation

Estimation: Two - Step Principal Components

Stock and Watson [2002], BBE [2005]

- **Step 1: Observation equation**
  - Estimate factors, C_t, by principal components of $X_{[T \times N]}$

  $\Longrightarrow$ Consistently recovers space spanned by both R_t and F_t (when N large)
  - $\hat{F}_t$ obtained by extracting out the effect of R_t on $\hat{C}_t$
  - Obtain loadings by OLS regression:

$$X_t = \Lambda \begin{bmatrix} \hat{F}_t \\ R_t \end{bmatrix} + e_t$$

- **Step 2: Transition equation**
  - Estimate VAR in $\hat{F}_t, R_t$ using standard methods
  - Implementation accounts for generated regressors

2. Data

- For FAVAR: 653 monthly series; 1976:1-2005:6; Transformed for stationarity (for prices: log changes)
  - 111 series macro indicators of BBE ($\sim$ Stock and Watson)
  - 194 series on PCE deflators and 194 on real consumption (NIPA)
    - E.g. New domestic autos, cereals, watches and jewelry, taxicabs, ...
  - 154 disaggregated PPI series (6-digit NAICS codes/4-digit SIC codes)
    - available from 1976 to 2005

- Data on industry characteristics:
  - $C4$ (Census): %sales of largest 4 firms in industry
  - Average gross profit rates (Annual survey of manufacturing, 1997-2001)

3. Empirical Evidence on Disaggregated Prices

- For all price series

$$\pi_{it} = \lambda_i' C_t + e_{it}$$

where $\pi_{it} = \log\left(p_{it}/p_{it-1}\right)$

  - * $\lambda_i' C_t =$ fluctuations due to common components ("macro" factors)

    * $e_{it} =$ fluctuations due to sector-specific conditions (idiosyncratic component)

3A. Sources of fluctuations in disaggregated prices

		Standard deviation			
		π_{it}	$\lambda_i' C_t$	e_{it}	R^2
Aggregated series					
PCE	Total	0.24	0.21	0.11	0.77
	Durables	0.33	0.25	0.21	0.60
	Nondurables	0.42	0.30	0.30	0.50
	Services	0.24	0.19	0.14	0.63
Disaggregated series					
All	Mean	1.15	0.33	1.08	0.15
	Median	0.75	0.27	0.71	0.12
	Min	0.23	0.08	0.13	0.01
	Max	11.67	1.85	11.59	0.68
PCE	Mean	0.97	0.29	0.92	0.17
PPI	Mean	1.36	0.38	1.29	0.13

Sources of fluctuations in disaggregated prices

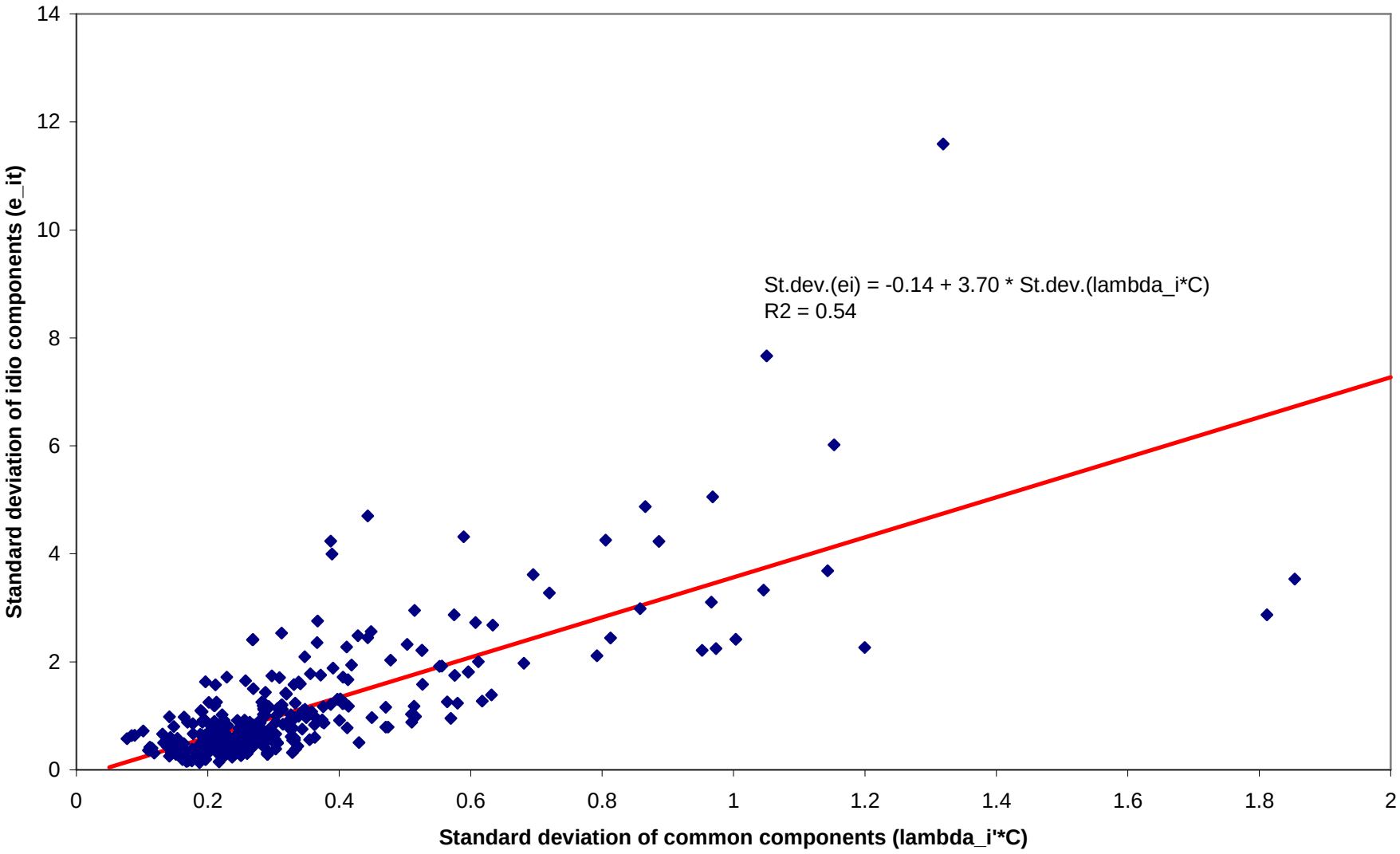
- Most fluctuations in PCE aggregates due to macro factors ($R^2 = 0.77$ for PCE total)

- Disaggregated series much more volatile than aggregates
  – Most of volatility due to sector-specific disturbances ($R^2 = 0.15$)
  – Considerable heterogeneity across sectors: mostly due to idio. shocks

- Volatility of common and sector-specific components
  strongly positively correlated
  – Firms that adjust often to sectoral shocks adjust them to changed macro conditions too?

Volatility of common and sector-specific components

Figure 1: Volatility of common and sector-specific components



Sources of persistence in disaggregated prices

For each component $(\pi_{it}, \lambda_i' C_t, e_{it})$, estimate $AR(p)$ process

Persistence $= \rho(1)$

		π_{it}	$\lambda_i' C_t$	e_{it}
Aggregated series				
PCE	Total	0.90	0.95	0.13
	Durables	0.88	0.97	0.08
	Nondurables	0.44	0.91	0.22
	Services	0.91	0.98	0.01
Disaggregated series				
All	Mean	0.29	0.91	-0.03
	Median	0.30	0.93	-0.02
	Min	-2.32	0.39	-1.83
	Max	0.96	0.99	0.87
PCE	Mean	0.30	0.92	-0.05
PPI	Mean	0.28	0.90	0.01

Sources of persistence in disaggregated prices

- Aggregate PCE inflation very persistent for total ($\rho(1) = 0.9$), durables, non-durables, services
  – Likely biased upward (Pesaran and Smith [1995], Imbs, Mumtaz, Ravn, Rey [2005])
  – High persistence may be due to break in mean (Levin and Piger [2003], Clark [2003])

- Disaggregated series much less persistent: $\rho(1) = 0.29$
  – Altissimo, Mojon and Zaffaroni [2004], Clark [2003]
  – but large heterogeneity across sectors

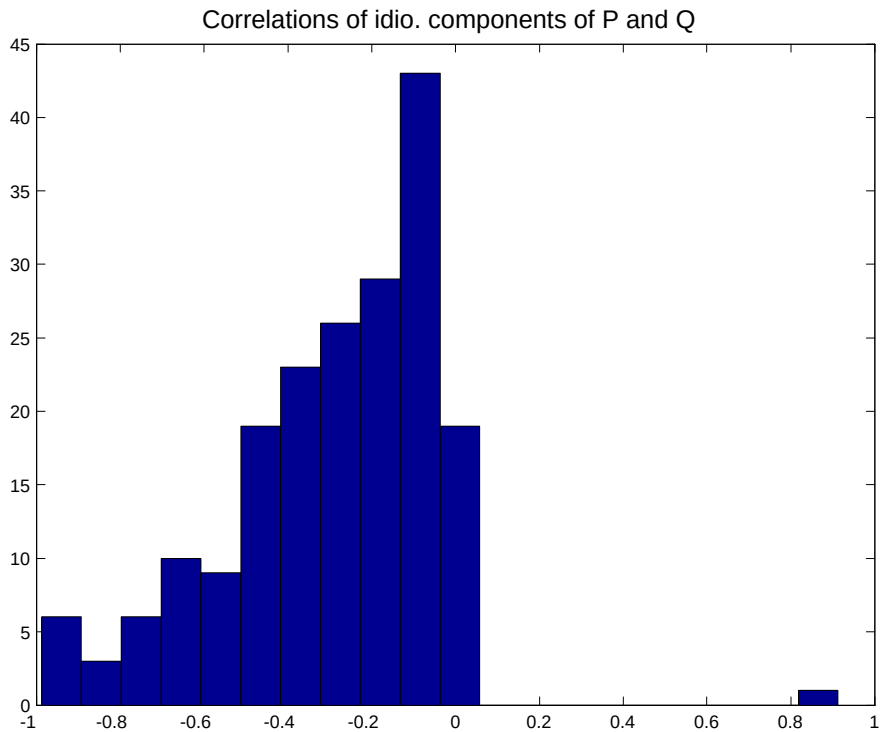
- All of persistence in disaggregate series due to macro factors ($\rho(1) = 0.91$)
  – Sector-specific factors basically uncorrelated

- Suggests that macro shocks have a persistent effect on inflation (not only policy)

$\Longrightarrow$ Explains why sticky-price models are successful in macro applications

Sources of fluctuations in sector-specific components

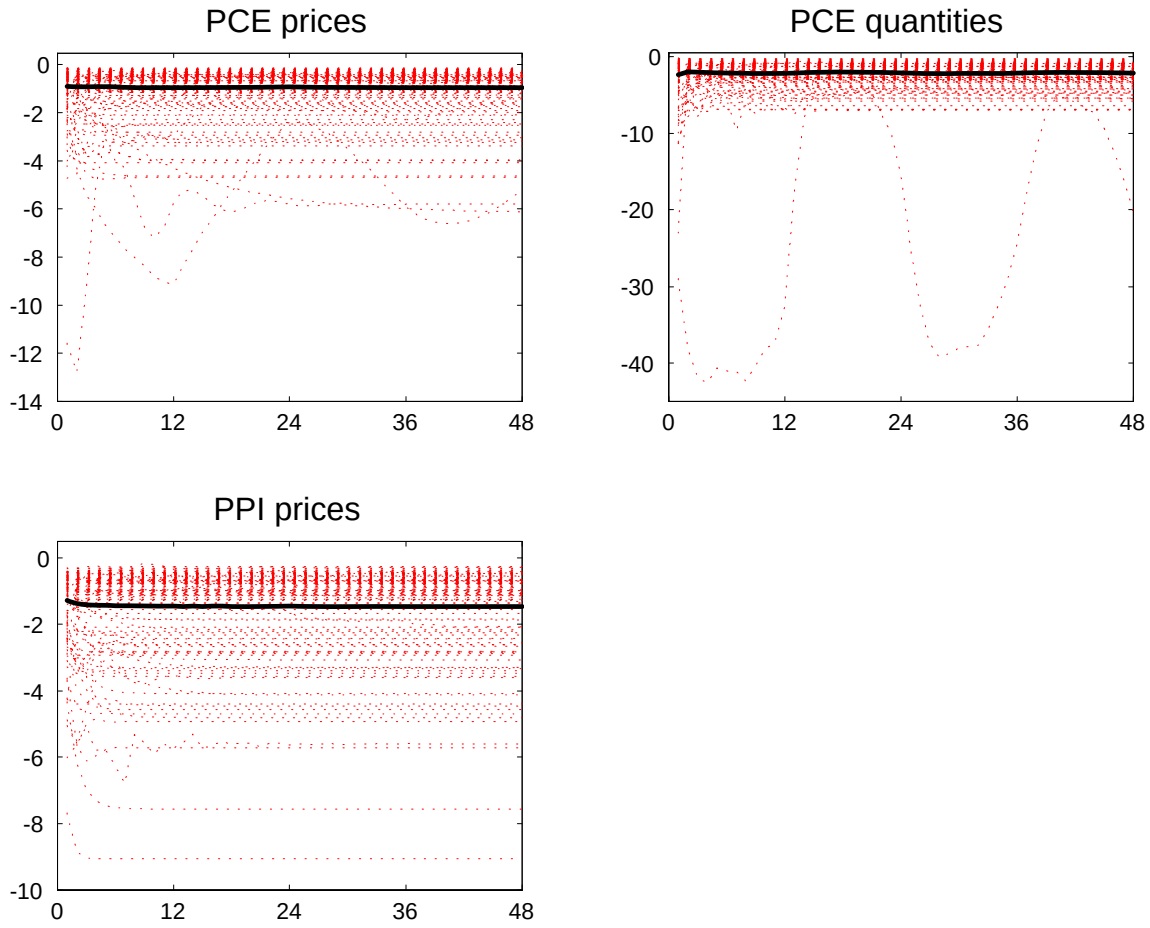
- PCE prices and quantities:



  – Most correlations significantly negative

- Suggests sector-specific components affected mostly by supply shocks (productivity)

3B. Response to shocks to sector-specific component

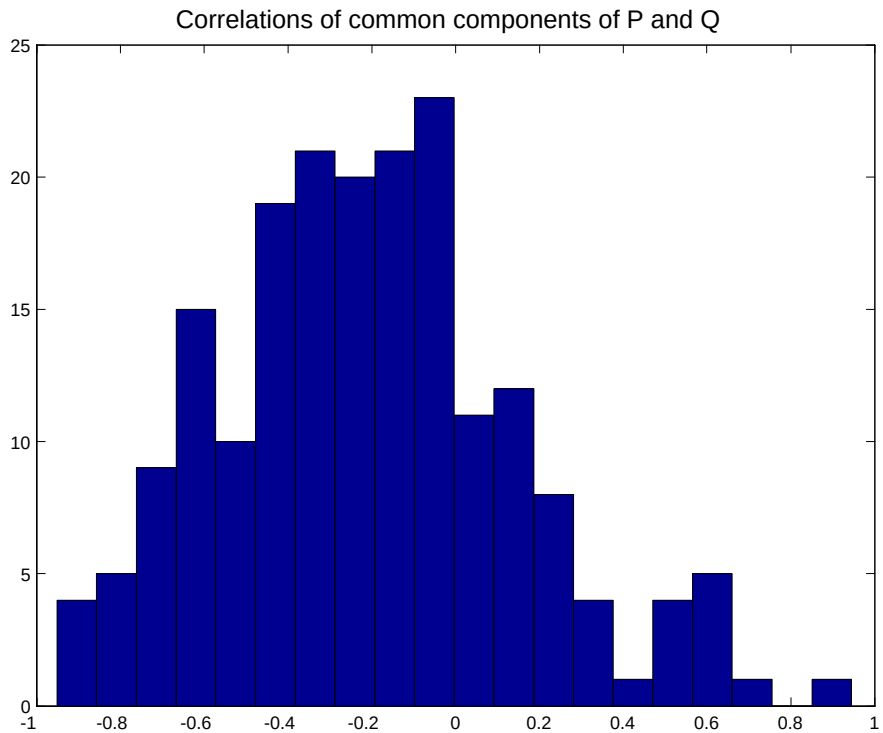


– Disaggregate prices and quantities move immediately to new level (no subsequent predictable change)

– Consistent with sectoral productivity shocks

Sources of fluctuations in common ("macro") components

- PCE prices and quantities:

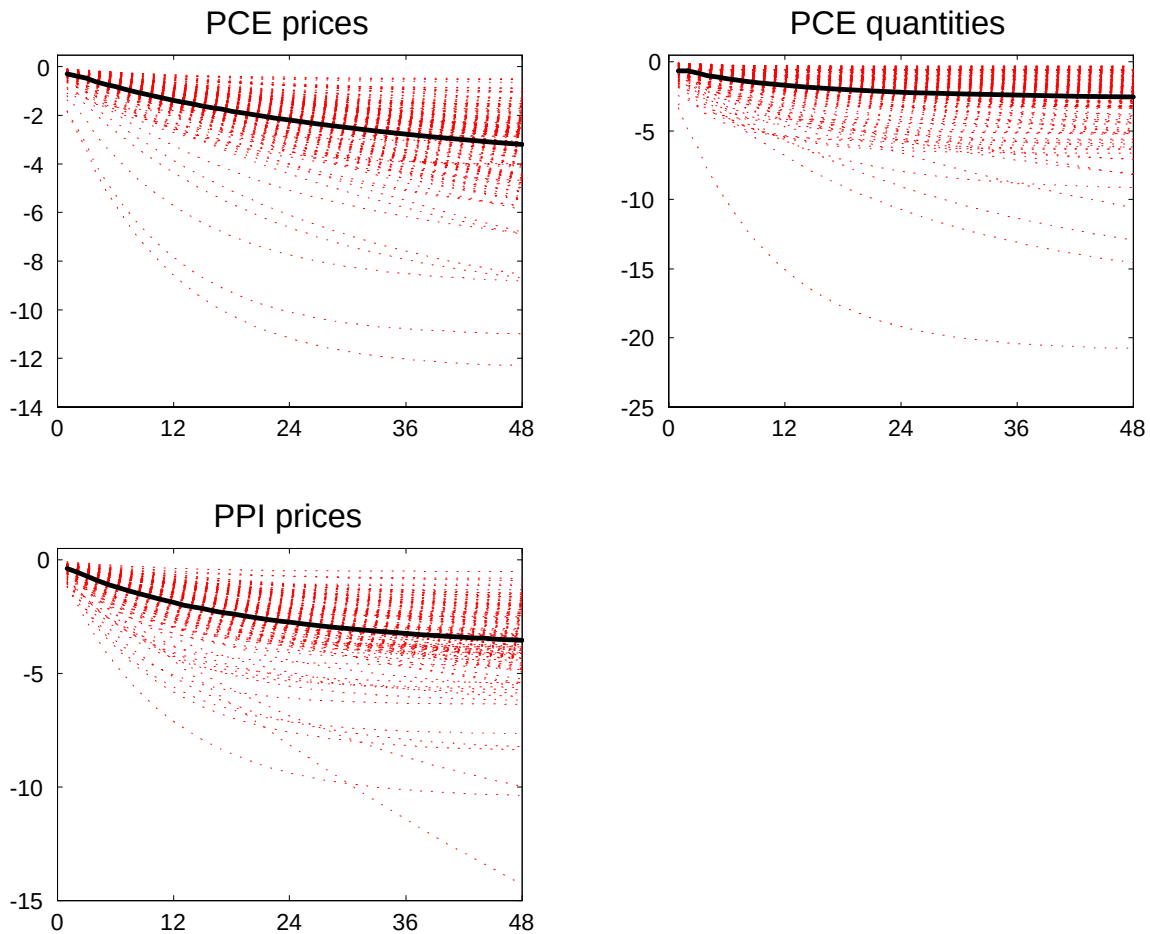


  - Correlations distributed over -1 to +1 interval

- Suggests common components affected both by supply and demand shocks

Response to shocks to common ("macro") component

– Rough estimate: no structural interpretation



– Disaggregate prices and quantities move little on impact and but further subsequent change is predicted

– Long-term permanent effect on prices and quantities

Effects of monetary policy shocks

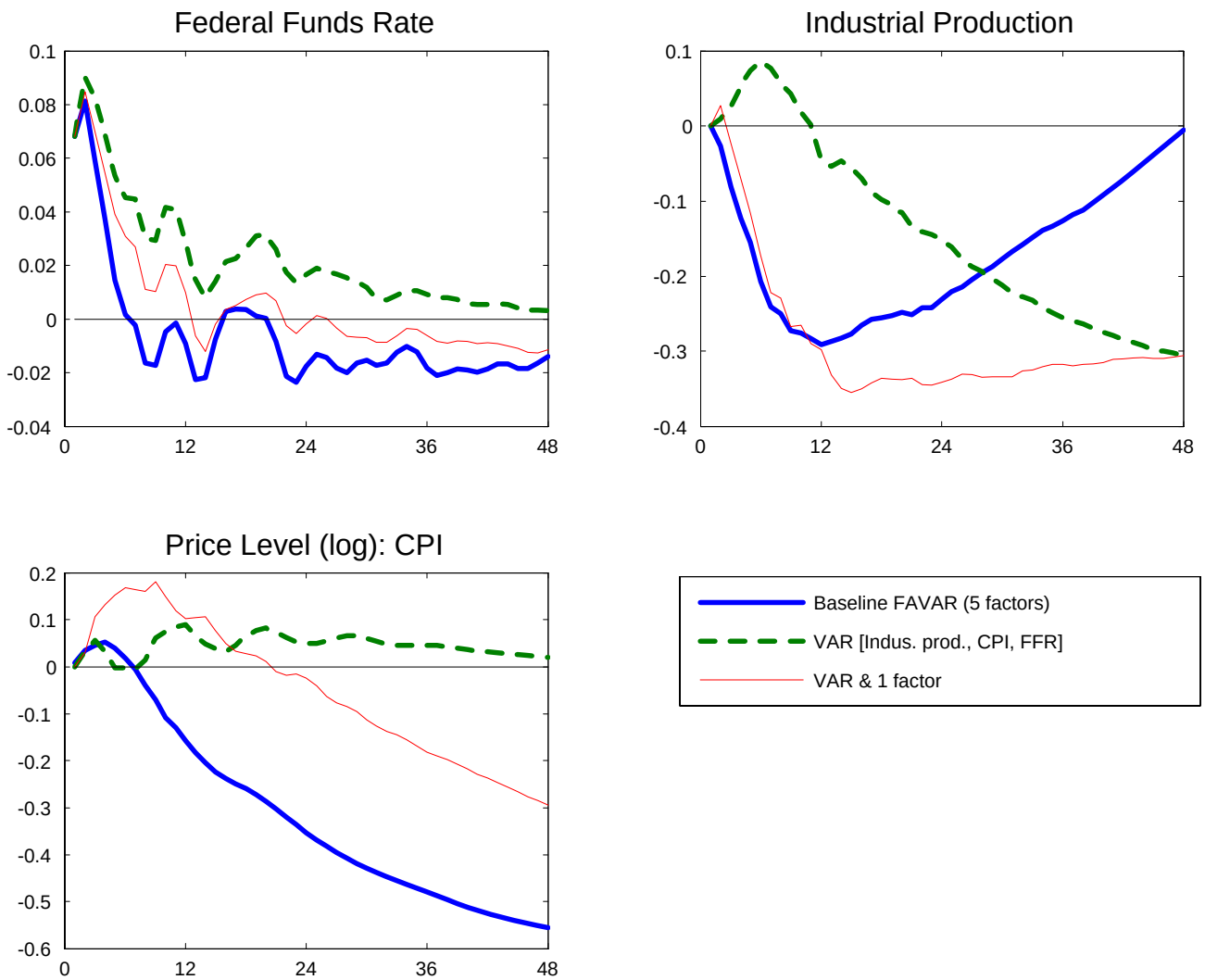
- Identification of policy shock: recursive

$$\begin{bmatrix} F_t \\ R_t \end{bmatrix} = \Phi(L) \begin{bmatrix} F_{t-1} \\ R_{t-1} \end{bmatrix} + \Psi \varepsilon_t$$

  Restrict Ψ so that prices and real activity measures (but not financial variables) do not respond within month to changes in R

- Compare FAVAR (5 latent factors) with standard VAR (FFR, indus. prod., CPI)

Estimated responses to an identified monetary policy shock



FAVAR vs. VAR

- VAR:
  – large "price puzzle"
  – large response of indus. prod after 4 years (not plausible)

- FAVAR: more "reasonable" responses

- One explanation (Sims [1992], BBE):

  – VARs use few variables: unlikely to span the info set used by policymakers, financial market participants

  – Omitted info. $\Longrightarrow$ biased parameters, impulse responses ("price puzzle")

  – FAVAR addresses issues by enclosing large info set

- Other advantage of FAVAR: yields directly responses of all series in data set
  $\Longrightarrow$ Can look at disaggregated effects of policy shocks

Effects of monetary policy shocks on disaggregated prices

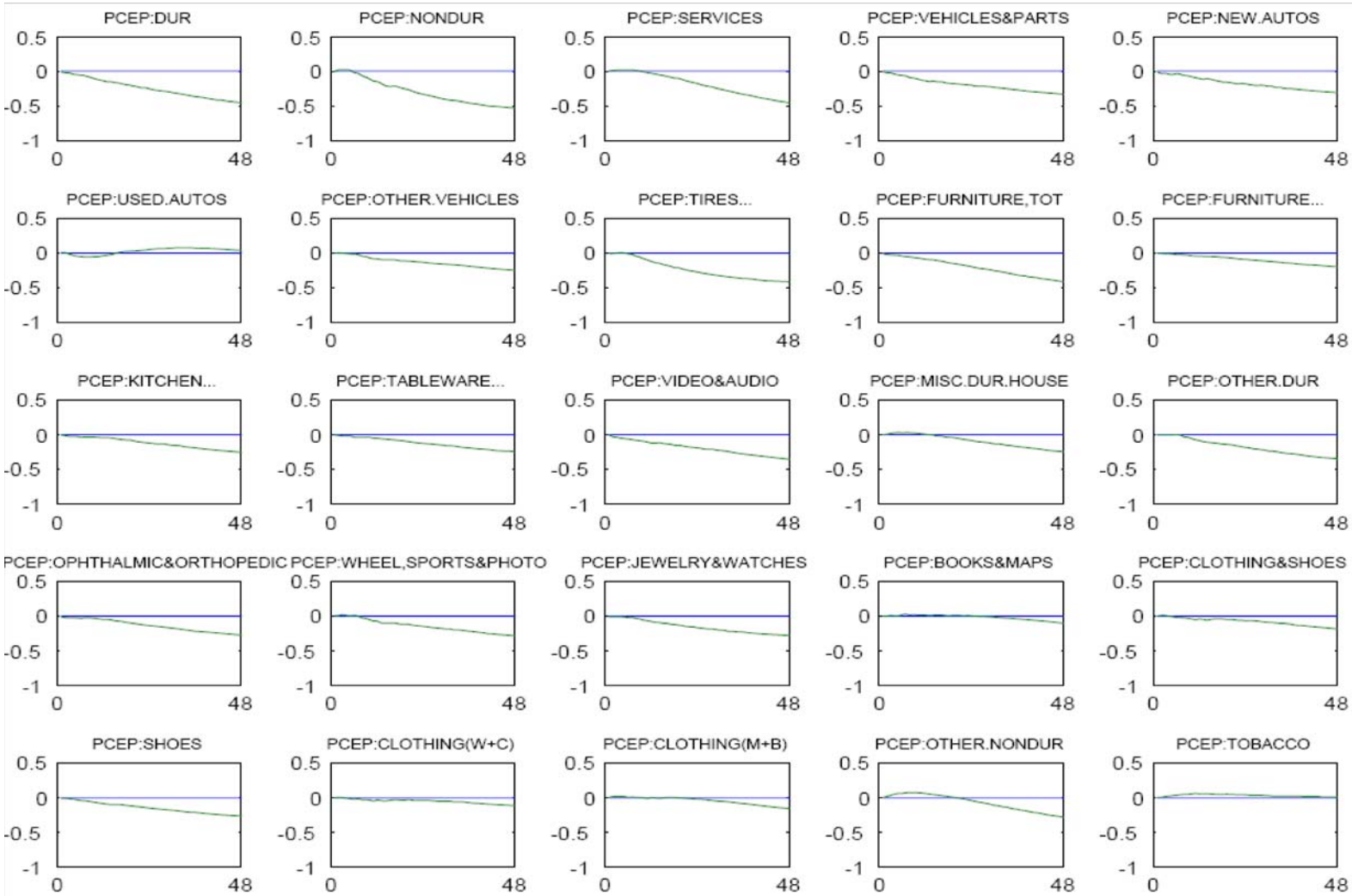
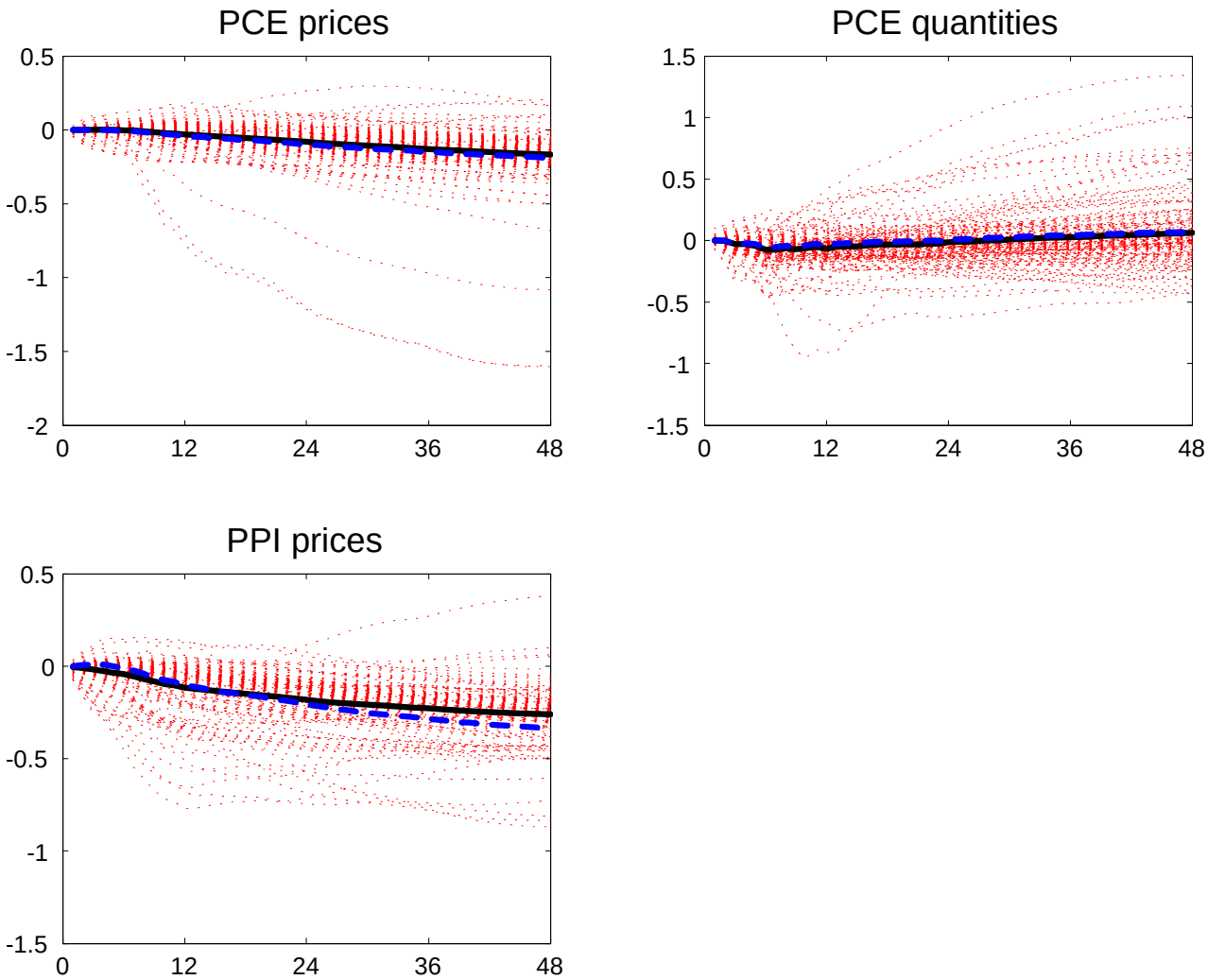


Figure 3a: Estimated impulse responses to an identified monetary policy shock

Responses to monetary policy shock



Effects of monetary policy tightening on disaggregated prices

- Slow and sluggish response to monetary policy

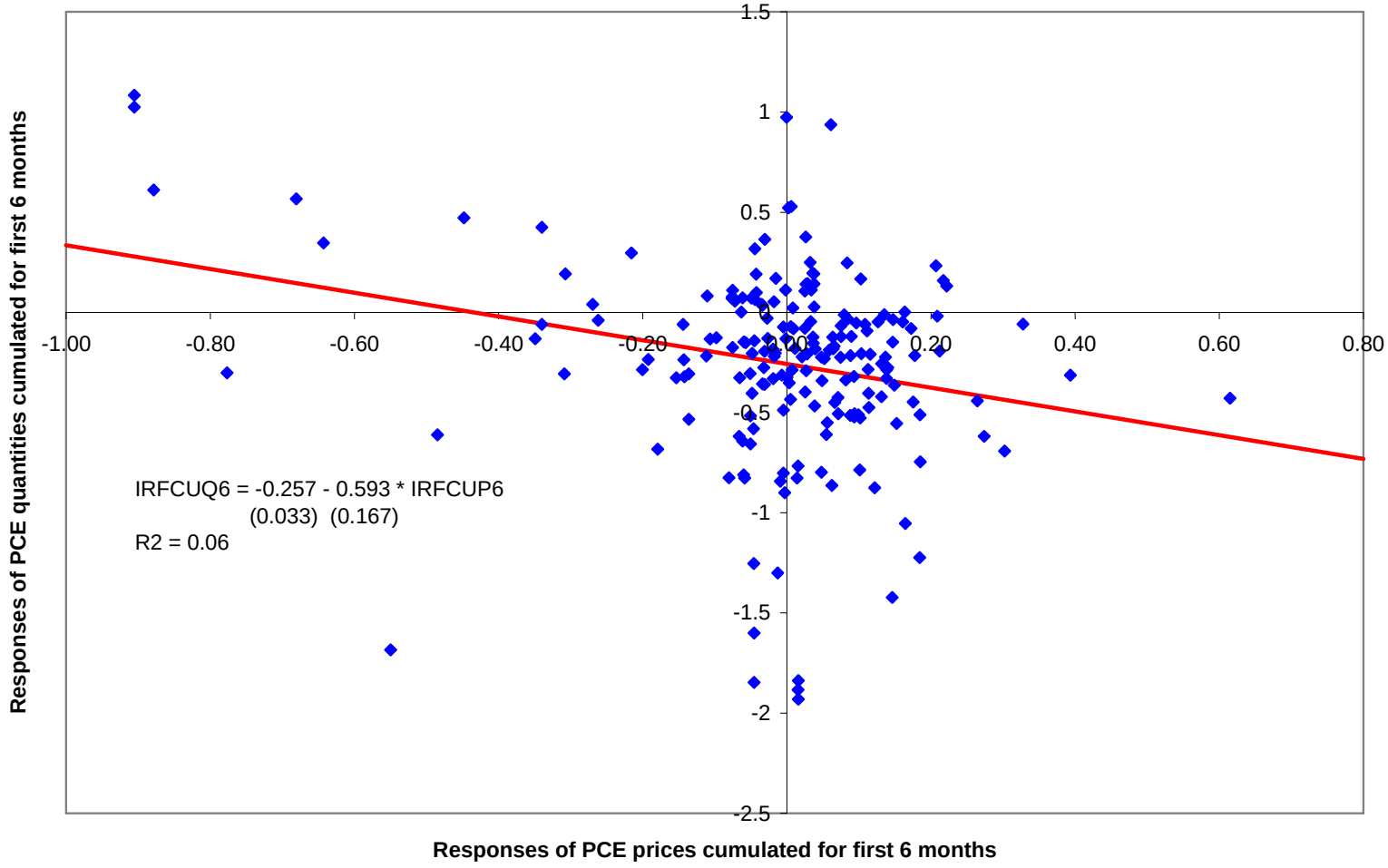
- Most prices fall months after shock: little evidence of "price puzzle"

- In contrast to existing studies:

  – Bils, Klenow and Kryvtsov (2003):
  – estimate responses of 123 components of CPI
  – regress individual prices on MP shock estimated separately in VAR
  – find that ratio (flex/sticky) prices ratio rises following mon. tightening
  $\Longrightarrow$ reject sticky-price models
  ...BUT "price puzzle"!

  – Balke and Whynne (2003)
  – similar but for PPI: reject "sticky-price models" due to large price puzzle in VAR

Figure 5: Impulse responses of PCE prices and quantities to monetary shock



– PCE categories in which prices fall the least tend to be those in which real consumption falls the most

Understanding differences in producer-price responses

- Match cumulated price responses $\left(IRFCU_{i,h}\right)$ to monetary policy shock with industry characteristics

$$IRFCU_{i,h} = \alpha + \beta_1 comp_i + \beta_2 Sd(e)_i + \beta_3 rho\,(e)_i + \epsilon_i$$

$comp_i$ — degree of competition (Avg profit rate or Mkt share of largest 4 cie.)
$Sd(e)_i$ — volatility of idiosyncratic component
$rho\,(e)_i$ — persistence of idio comp.
$d1$, $d2$, $d3$ — sectoral dummies

- Robust findings:
– more competitive industries (lower gross profit rates) respond more to monetary policy shocks (more negative price response)
– industries with more volatile and persistent idiosyncratic shocks adjust prices more rapidly to monetary shocks

Table 6: Cross-sectional dispersion in price responses for first 6 months after the shock

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Constant	-0.569	-0.156	0.142	-0.195			-0.151
	(0.106)**	(0.072)*	(0.039)**	(0.036)**			(0.132)
Gross Profit	1.540				1.598		1.013
	(0.355)**				(0.368)**		(0.449)*
Invc4		-0.683					
		(2.034)					
Sd(e)			-25.932				-22.549
			(4.157)**				(3.769)**
rho(e)				-0.524			-0.243
				(0.129)**			(0.116)*
d1					-0.681	-0.643	
					(0.138)**	(0.161)**	
d2					-0.608	-0.677	
					(0.138)**	(0.282)*	
d3					-0.529	-0.554	
					(0.103)**	(0.225)*	
d1*profit						1.454	
						(0.447)**	
d2*profit						1.857	
						(0.864)*	
d3*profit						1.699	
						(0.874)	
Observations	149	149	151	151	149	149	149
R-squared	0.13	0.00	0.42	0.09	0.27	0.27	0.50

Robust standard errors in parentheses. (*) denotes significant at 5%; (**) denotes significant at 1%

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Cross-sectional variation in producer prices

- constant < 0: no price puzzle
- Gross profit > 0: More compet. (lower profits) $\Longrightarrow$ more price response to mon. pol. shocks
- More competition measured by inv(C4) has no significant effect (as in BK)
- More volatile sector (higher St.dev.(e_i)) $\Longrightarrow$ more price response to mon. pol. shocks

Bils-Klenow argue: disaggregated prices inconsistent with simple Calvo model

- Calvo model predicts: "higher price stickiness reduces magnitude of innovations to inflation and increases inflation persistence" (assuming specific process for marginal cost)
  $\Longrightarrow$ correl$(\rho_{\pi i}, \sigma_{\pi i}) < 0$

Estimated correlations

	st.dev.(π_{it})	st.dev.$(\lambda_i' C_t)$	st.dev.(e_{it})
$\rho\,(\pi_{it})$	-0.38		
$\rho\,(\lambda_i' C_t)$		-0.46	
$\rho\,(e_{it})$			-0.08

- Calvo model consistent with correlations for common components. BK finding due to sector-specific shocks.

4. Conclusion

- Used **FAVAR** to disentangle fluctuations in sectoral inflation series due to macro (i.e., common) and sector-specific factors

- Allows to trace out the effects of monetary shocks on disaggregated prices and quantities.

Main finding #1: Sources of inflation fluctuations

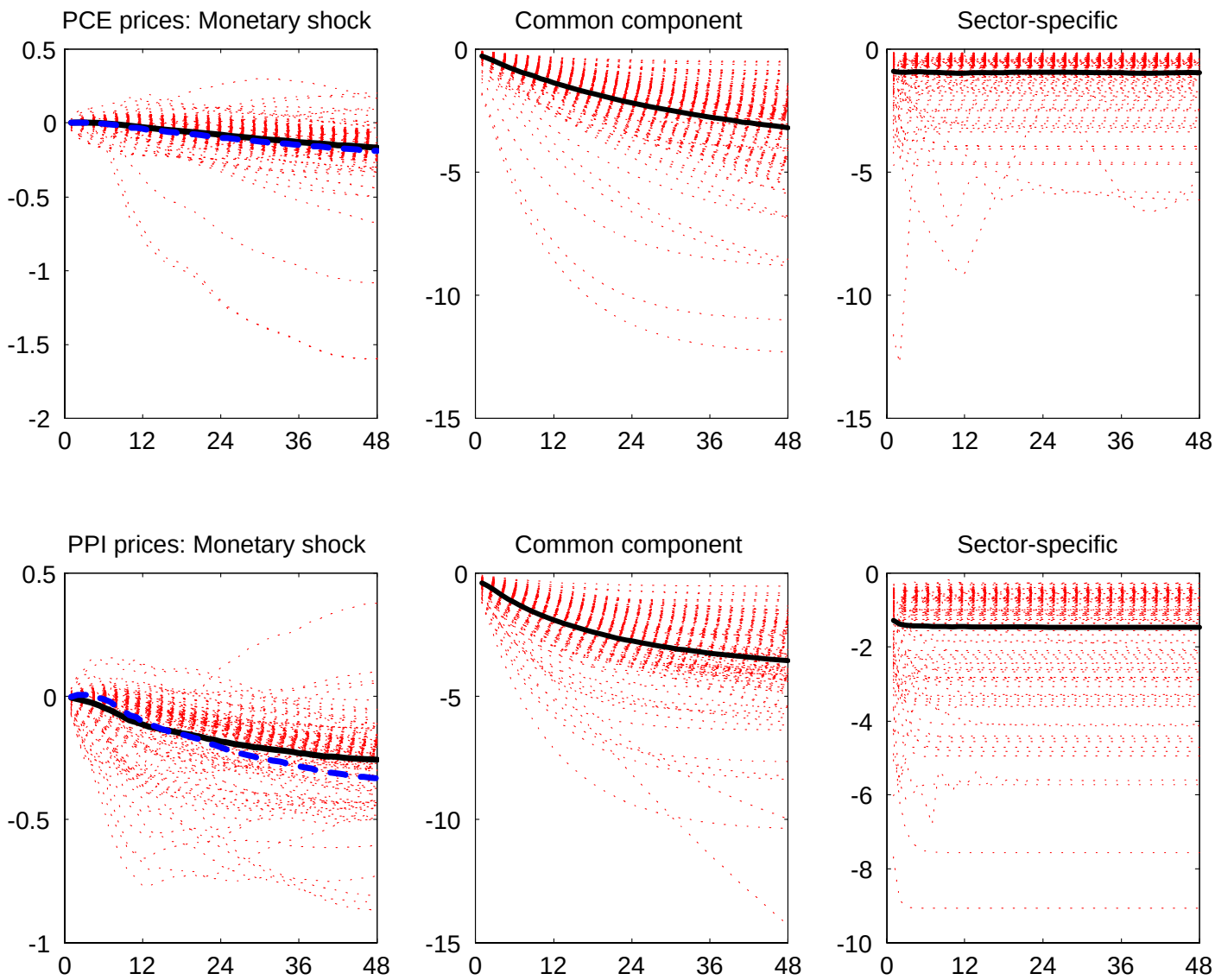
- Most fluctuations in sectoral inflation due to sector-specific factors
  – only 15% of inflation fluctuations due to macro factors

- Sectors in which prices are adjusted frequently, they are adjusted frequently to macro and idio shocks

- Inflation persistence due to macro component
  – Sector-specific components not persistent (on average)

Main finding #2: price responses to various shocks:

monetary policy , common comp., and sector-specific shock



Main finding #2: prices respond differently to macro and idio shocks

1. Sector-specific shocks (supply shocks)
   – immediate and permanent change in sectoral price and quantity

2. Shocks to common components (demand and supply shocks)
   – small impact on prices and quantities, larger effect thereafter

3. Monetary shocks:
   – prices change little in first few months, then move progressively
   – small price puzzle: FAVAR includes relevant information ($\neq$ existing results)
   – hump-shaped response of real consumption in categories
   – Across sectors: large price change $\Longleftrightarrow$ small real consumption changes
   – Prices fall less in industries with ...
   * high profit shares (more market power)
   * low volatility / persistence of price fluctuations due to sector-specific shocks

Conclusion (cont.)

- Important to distinguish between "macro" and sector-specific shock to understand price movements

- Sticky-price models adequate to explain response of aggregate prices, but would need models that can explain responses of disaggregate prices to macro and idio shocks

- Promising avenues:

  - Gertler – Leahy [2006]: state-dependent pricing model with volatile prices due to sector-specific shocks, and sluggish price response to monetary shocks

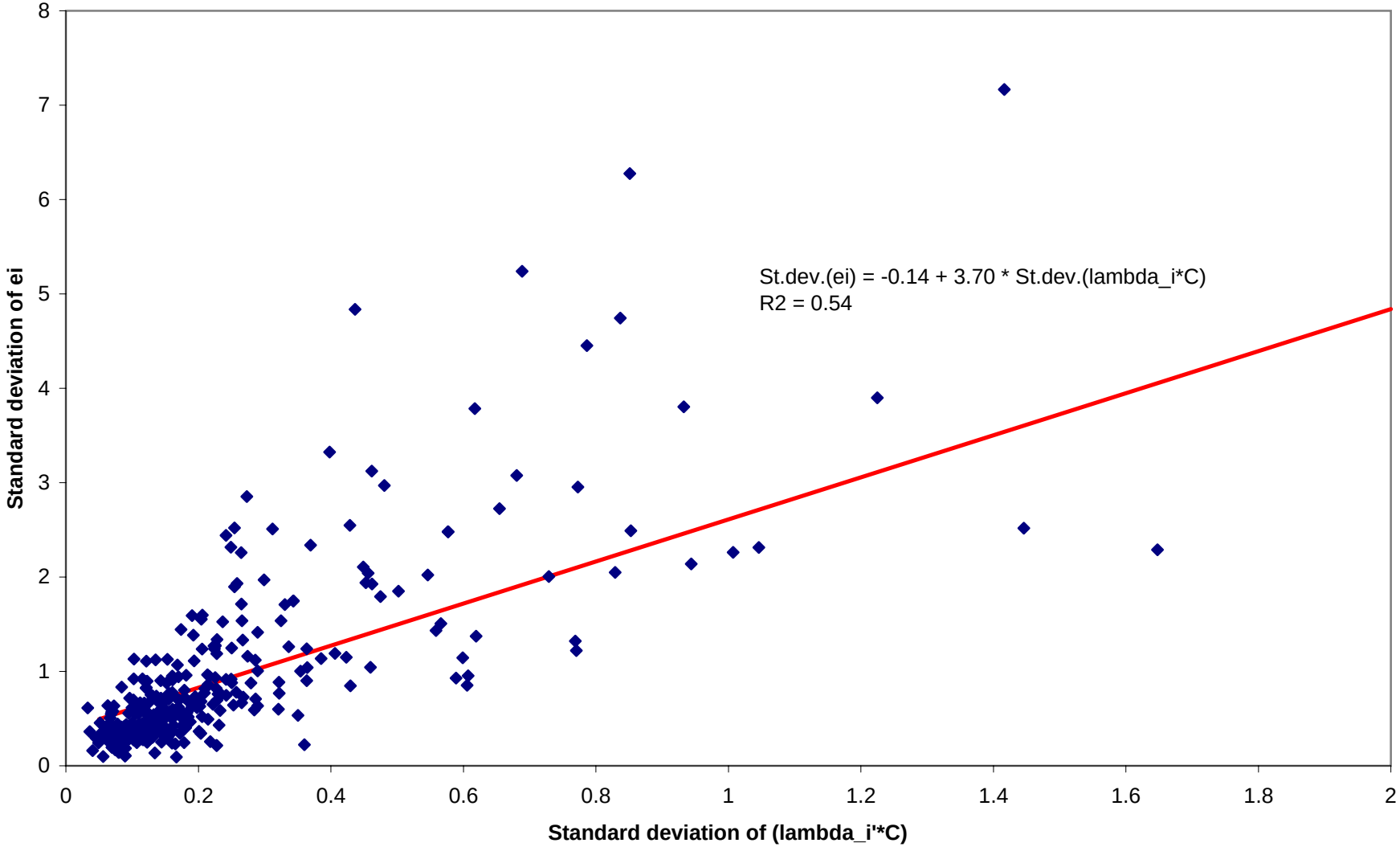
  - Carvalho [2006]: Calvo model with heterogeneity in price stickiness; possible that prices respond quickly to sector-specific shocks and sluggishly to aggregate shocks

  - Rational inattention: Sims [2003], Mankiw – Reis [2002], Reis [2006], Mackowiack-Wiederholdt [2006]

Table 1: Volatility and persistence of inflation series (Post-1984)

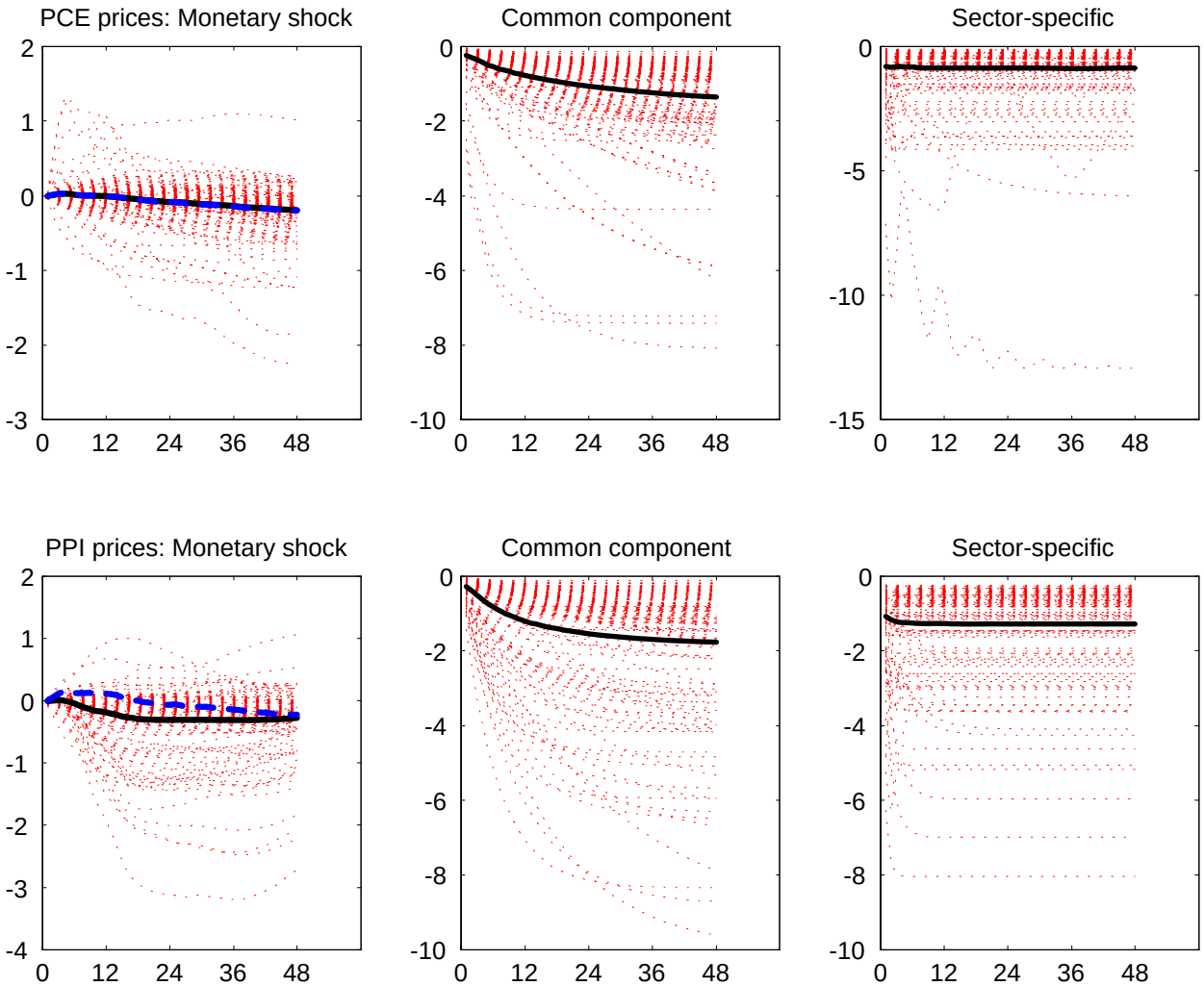
		Standard deviation				Persistence		
		Inflation	Common comp.	Sector-specific	R2	Inflation	Common comp.	Sector-specific
Aggregated series								
PCE	Total	0.16	0.14	0.08	0.73	0.33	0.71	0.01
	Durables	0.26	0.16	0.20	0.39	0.78	0.95	0.12
	Nondurables	0.40	0.33	0.21	0.71	0.14	0.59	0.30
	Services	0.16	0.08	0.13	0.29	0.58	0.96	-0.16
Disaggregated series								
All	Average	0.97	0.25	0.93	0.10	0.09	0.81	-0.01
	Median	0.64	0.16	0.62	0.07	0.06	0.85	-0.02
	Minimum	0.11	0.03	0.09	0.00	-1.95	-0.24	-1.20
	Maximum	7.31	2.79	7.17	0.76	1.03	0.97	0.81
	Std	0.98	0.29	0.94	0.10	0.35	0.15	0.30
PCE	Average	0.86	0.23	0.81	0.12	0.06	0.82	-0.05
PPI	Average	1.11	0.26	1.07	0.07	0.13	0.81	0.04

Volatility of common and sector-specific components (Post-84)



Robustness Checks: Post-84 price responses to shocks:

monetary policy , common comp., and sector-specific shock



Robustness Checks: Post-84 responses of consumption:

monetary policy , common comp., and sector-specific shock

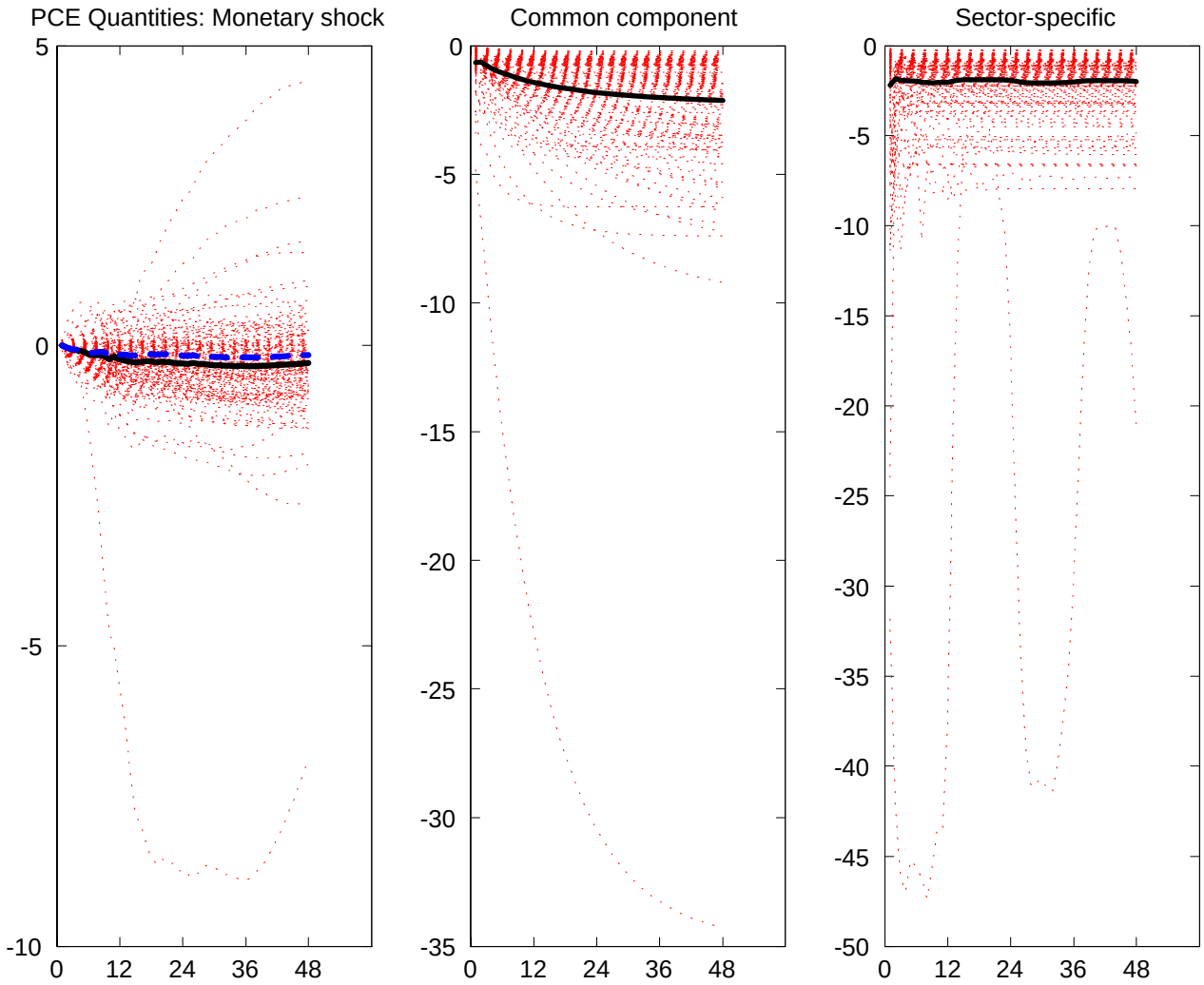


Table 7: Cross-sectional dispersion in price responses for first 12 months after the shock

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Constant	-1.890	-0.629	0.002	-0.774			-0.878
	(0.264)**	(0.181)**	(0.134)	(0.093)**			(0.319)**
Gross Profit	4.597				4.699		2.973
	(0.882)**				(0.883)**		(0.998)**
Invc4		-3.023					
		(4.752)					
Sd(e)			-59.502				-47.903
			(13.709)**				(12.032)**
rho(e)				-1.844			-1.105
				(0.323)**			(0.270)**
d1					-2.055	-1.846	
					(0.321)**	(0.323)**	
d2					-1.987	-1.812	
					(0.294)**	(0.404)**	
d3					-1.822	-2.357	
					(0.278)**	(0.692)**	
d1*profit						3.909	
						(0.818)**	
d2*profit						4.045	
						(1.163)**	
d3*profit						6.876	
						(2.644)*	
Observations	149	149	151	151	149	149	149
R-squared	0.16	0.00	0.31	0.15	0.41	0.42	0.46

Robust standard errors in parentheses. (*) denotes significant at 5%; (**) denotes significant at 1%