How to Solve the Price Puzzle?

A Meta-Analysis

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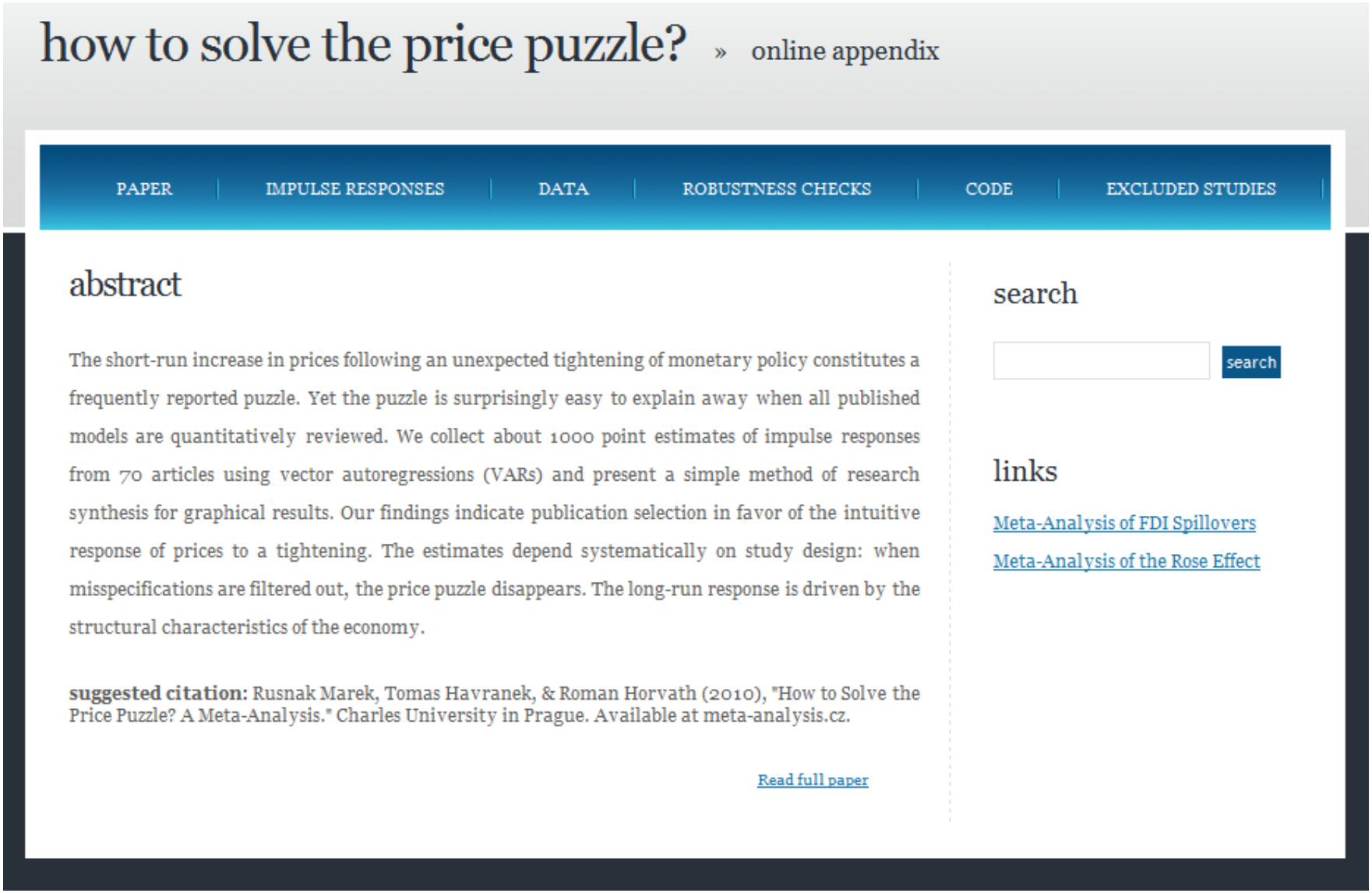
Project Website: www.meta-analysis.cz



Outline

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Definition of the Price Puzzle

- Let the central bank increase the interest rate:
  - Intuitively, prices should fall.
  - But a half of modern empirical studies actually find that in the short run prices increase!
- The price puzzle—an increase in prices after monetary tightening.
- One of the best-known puzzles in macroeconomics.
- It has serious implications for either econometricians or policy makers.

Explanation 1: The Price Puzzle Reflects Reality

- The theoretical solution to the price puzzle.
- Stress on the supply-side effects of monetary transmission.
- Let the central bank increase the interest rate:
  - Since firms depend on credits to finance production, their costs rise, and they may increase prices.
- This is called the cost channel of monetary transmission.

Cost channel

Can only explain price puzzle in the short run.

Explanation 2: The Puzzle is Caused by Bad Estimation

- Models estimating the effects of monetary policy are vulnerable to misspecification in several areas.
  - Omitted variables.
  - Identification.
  - Monetary policy regimes.
  - Measure of monetary policy shock.

Misspecifications

Are the usual suspects when it comes to the price puzzle.

Vector Autoregressions (VARs)

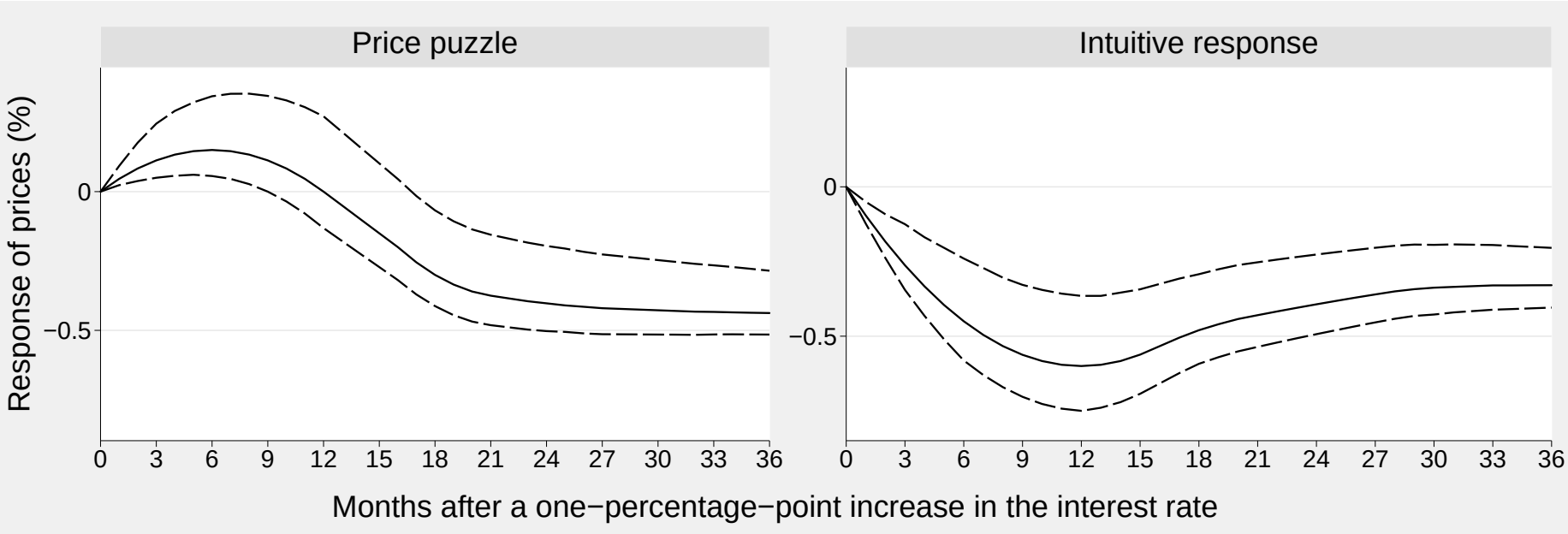
- The dominant framework for estimating the effects of monetary policy is vector autoregression.
- VAR captures interdependencies between multiple time series.
- Let Y be a vector of endogenous variables. VAR is a system of equations:

$$Y_t = C(L)Y_{t-1} + u_t.$$

- In the simplest case, Y consists of prices, output, and interest rates.

Impulse Responses

- The results of VARs are reported graphically in the form of impulse response functions.
- Most frequently: how do prices change when the central bank increases the interest rate by one percentage point?

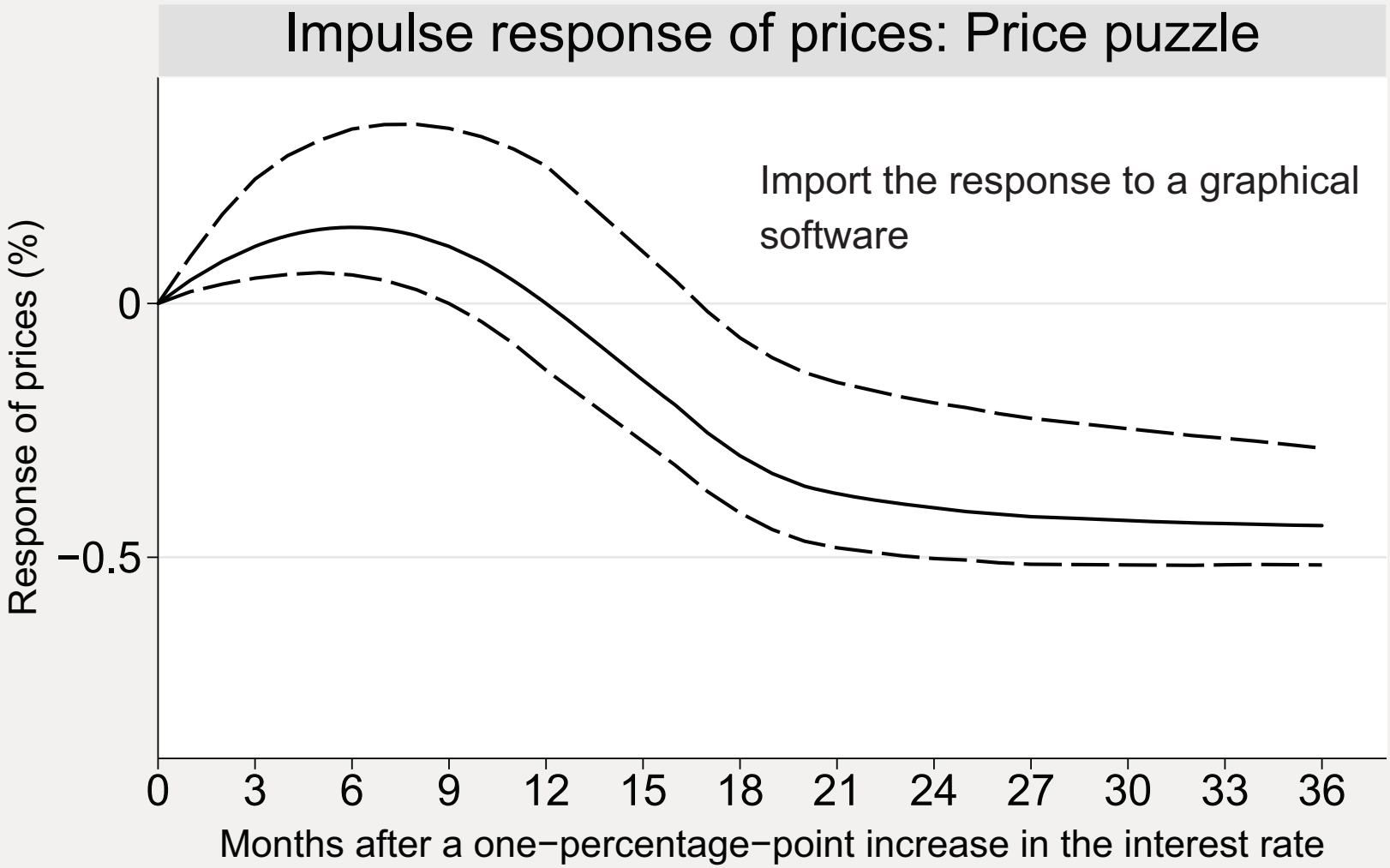


Outline

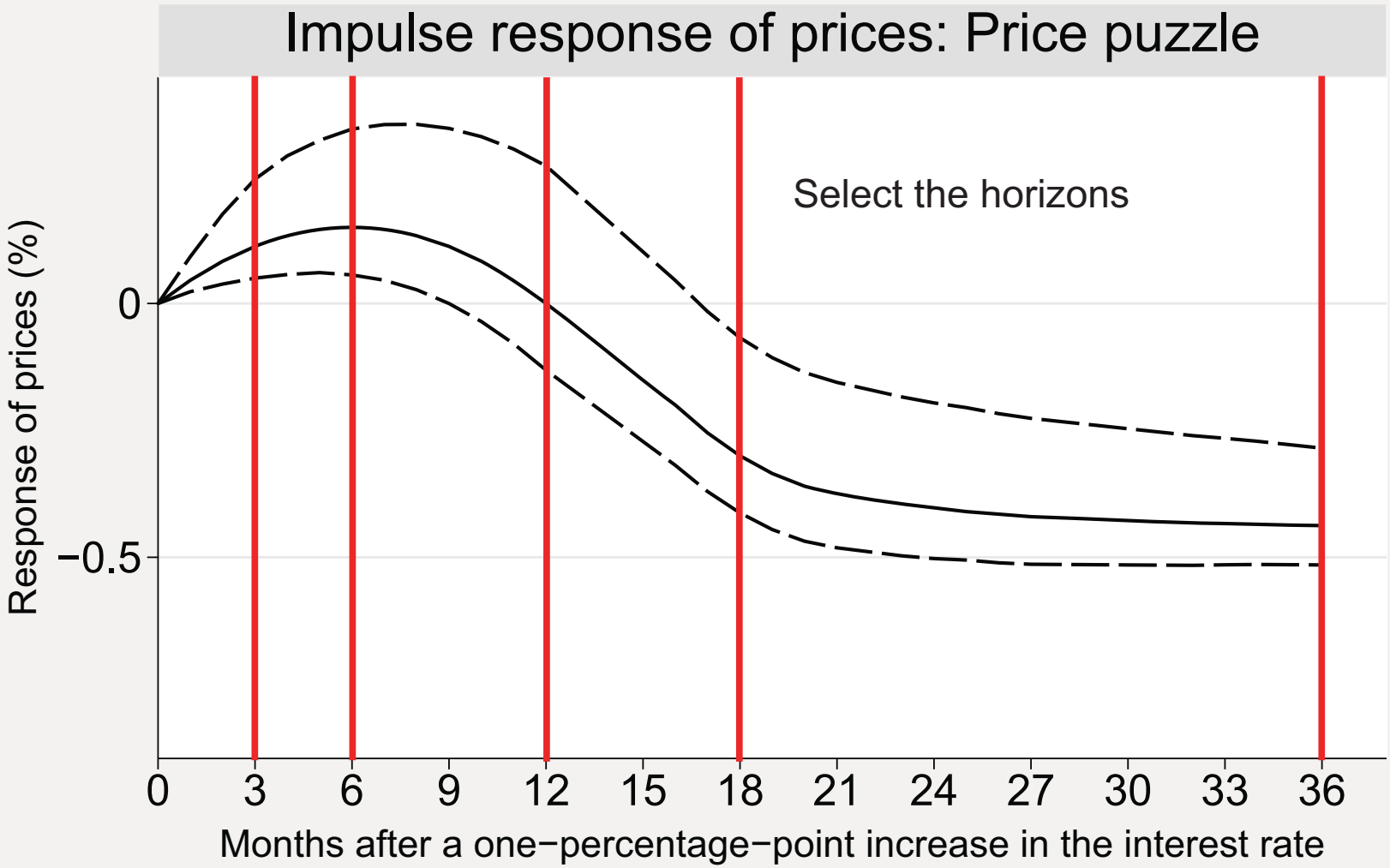
Coding

- Researchers report graphs, but we need data.
- To represent the graphs, let's select five horizons (3, 6, 12, 18, and 36 months).
- How to approximate standard errors when confidence bands are asymmetrical?
  - We measure the distance to the confidence bound closer to zero.
  - This confidence bound determines significance, so it would be associated with publication selection.
- The impulse responses are normalized to represent the effect of a one-percentage-point increase in the interest rate.

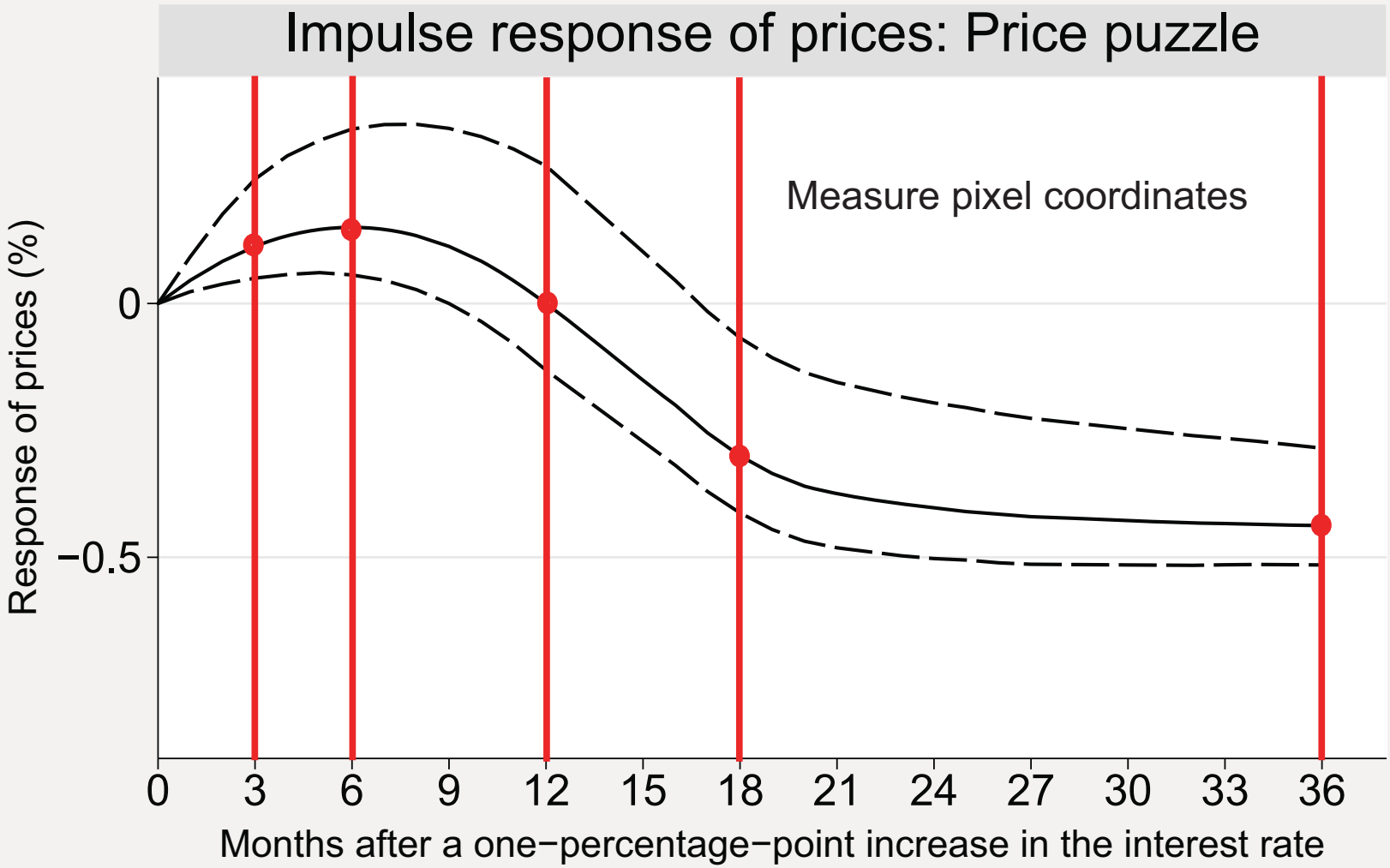
Coding


Impulse response of prices: Price puzzle
Import the response to a graphical software
Response of prices (%)
0
−0.5
0
3
6
9
12
15
18
21
24
27
30
33
36
Months after a one−percentage−point increase in the interest rate

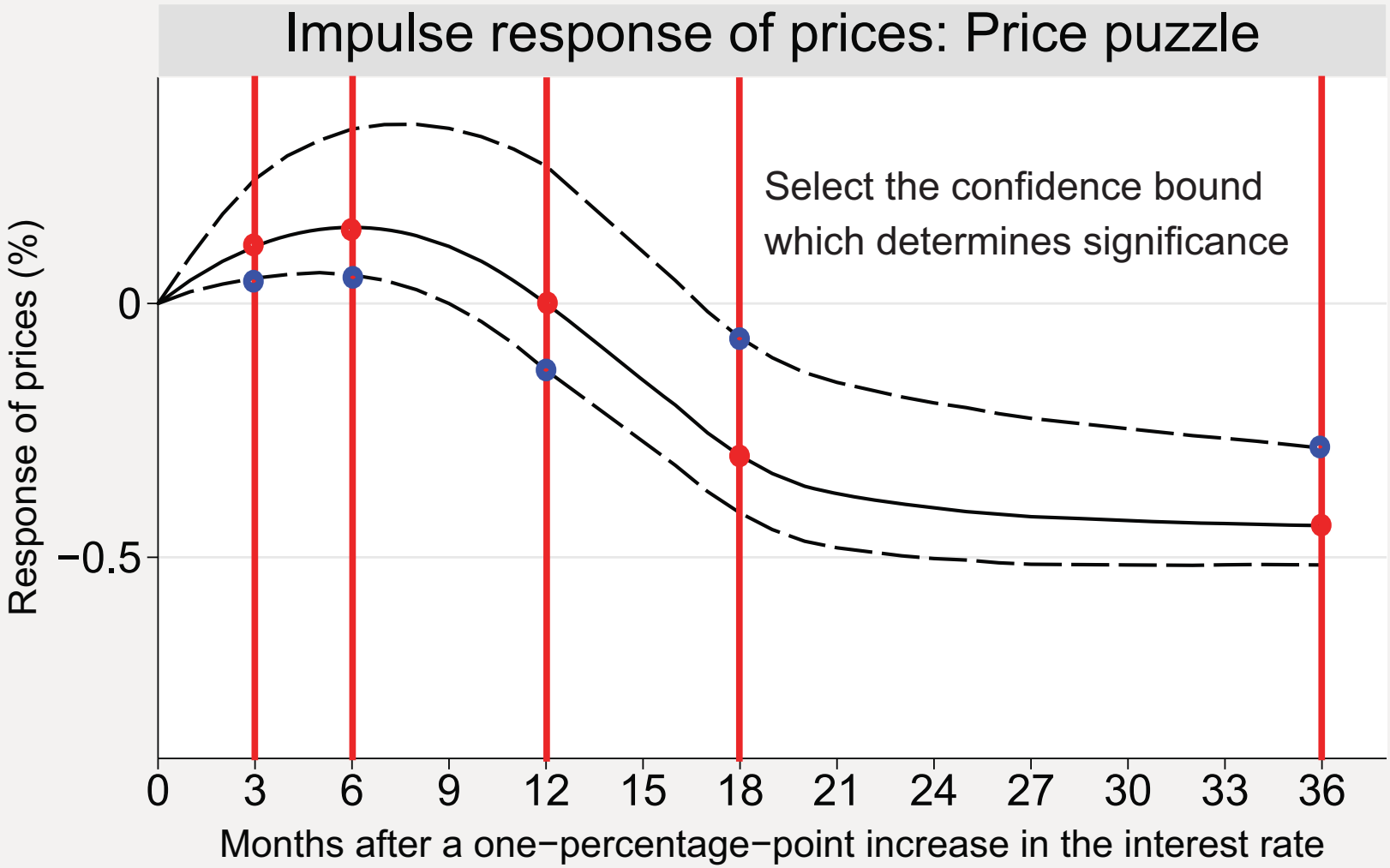
Coding


Impulse response of prices: Price puzzle
Select the horizons
Response of prices (%)
0
−0.5
0
3
6
9
12
15
18
21
24
27
30
33
36
Months after a one−percentage−point increase in the interest rate

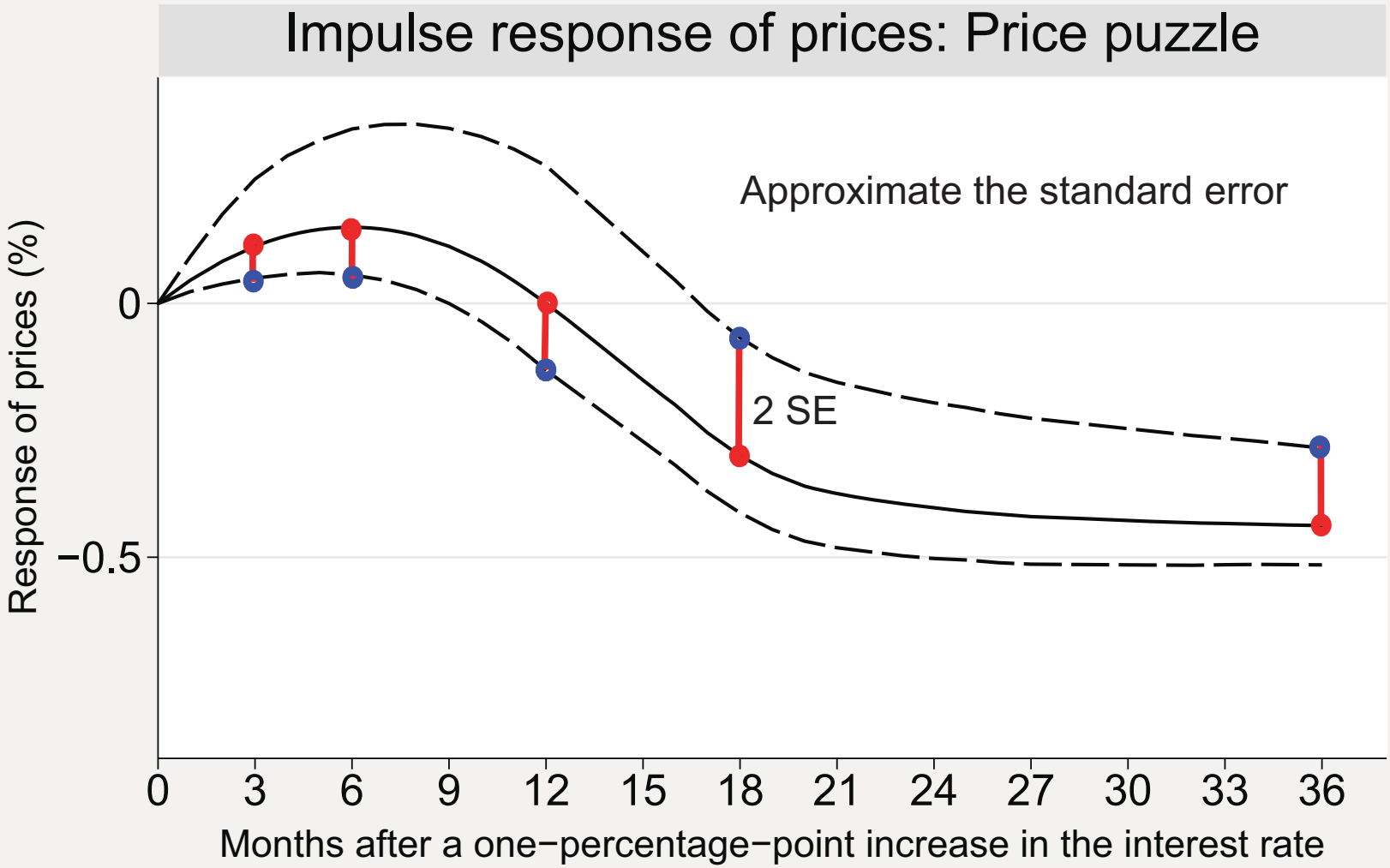
Coding


Impulse response of prices: Price puzzle
Measure pixel coordinates
Response of prices (%)
0
−0.5
0
3
6
9
12
15
18
21
24
27
30
33
36
Months after a one−percentage−point increase in the interest rate

Coding

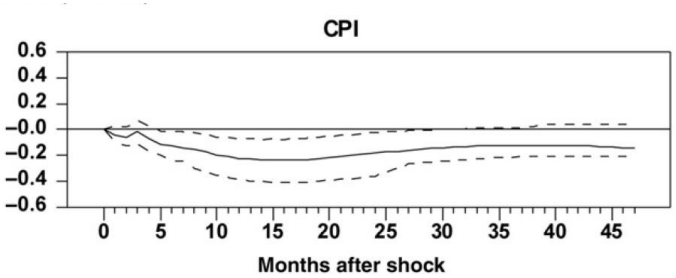

Impulse response of prices: Price puzzle
Select the confidence bound
which determines significance
Response of prices (%)
0
−0.5
0
3
6
9
12
15
18
21
24
27
30
33
36
Months after a one−percentage−point increase in the interest rate

Coding


Impulse response of prices: Price puzzle
Approximate the standard error
2 SE
Response of prices (%)
0
−0.5
0
3
6
9
12
15
18
21
24
27
30
33
36
Months after a one−percentage−point increase in the interest rate

Coding: Example from the Online Appendix

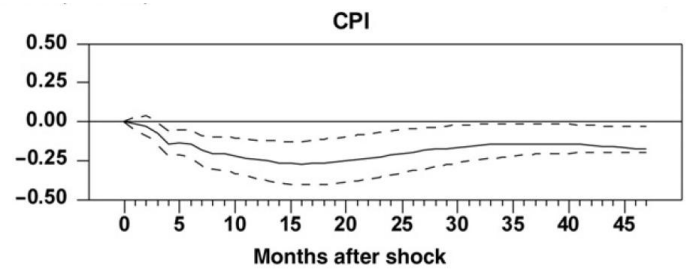
Anzuini & Levy (2007), id: 8



Poland		
horizon	response	confidence interval
3	-0.012	(-0.121, 0.073)
6	-0.133	(-0.255, -0.012)
12	-0.236	(-0.412, -0.085)
18	-0.242	(-0.430, -0.073)
36	-0.139	(-0.23, 0.012)
(no peak)		
15 (bottom)	-0.248	(-0.43, -0.079)

Obtained from: figure 9, page 1157
Frequency: Monthly
Note: Responses are in %.

Anzuini & Levy (2007), id: 9



Poland		
horizon	response	confidence interval
3	-0.092	(-0.155, -0.010)
6	-0.141	(-0.238, -0.058)
12	-0.248	(-0.374, -0.121)
18	-0.272	(-0.403, -0.112)
36	-0.146	(-0.214, -0.058)
(no peak)		
16 (bottom)	-0.277	(-0.403, -0.131)

Obtained from: figure 10, page 1158
Frequency: Monthly
Note: Responses are in %.

Literature Selection

- We searched for journal articles in EconLit, Scopus, and RePEc: `(VAR or 'vector autoregression') and (monetary or 'monetary policy') and (transmission or shock).`
- We were looking for empirical papers using VARs to estimate the effects of a shock to the interest rate on the price level.
- 70 articles contained all the information we needed.
- The 70 primary studies combined receive on average 800 citations in Google Scholar per year.
  - Vector autoregressions are very popular in monetary economics.

Excluded Studies: Example from the Online Appendix

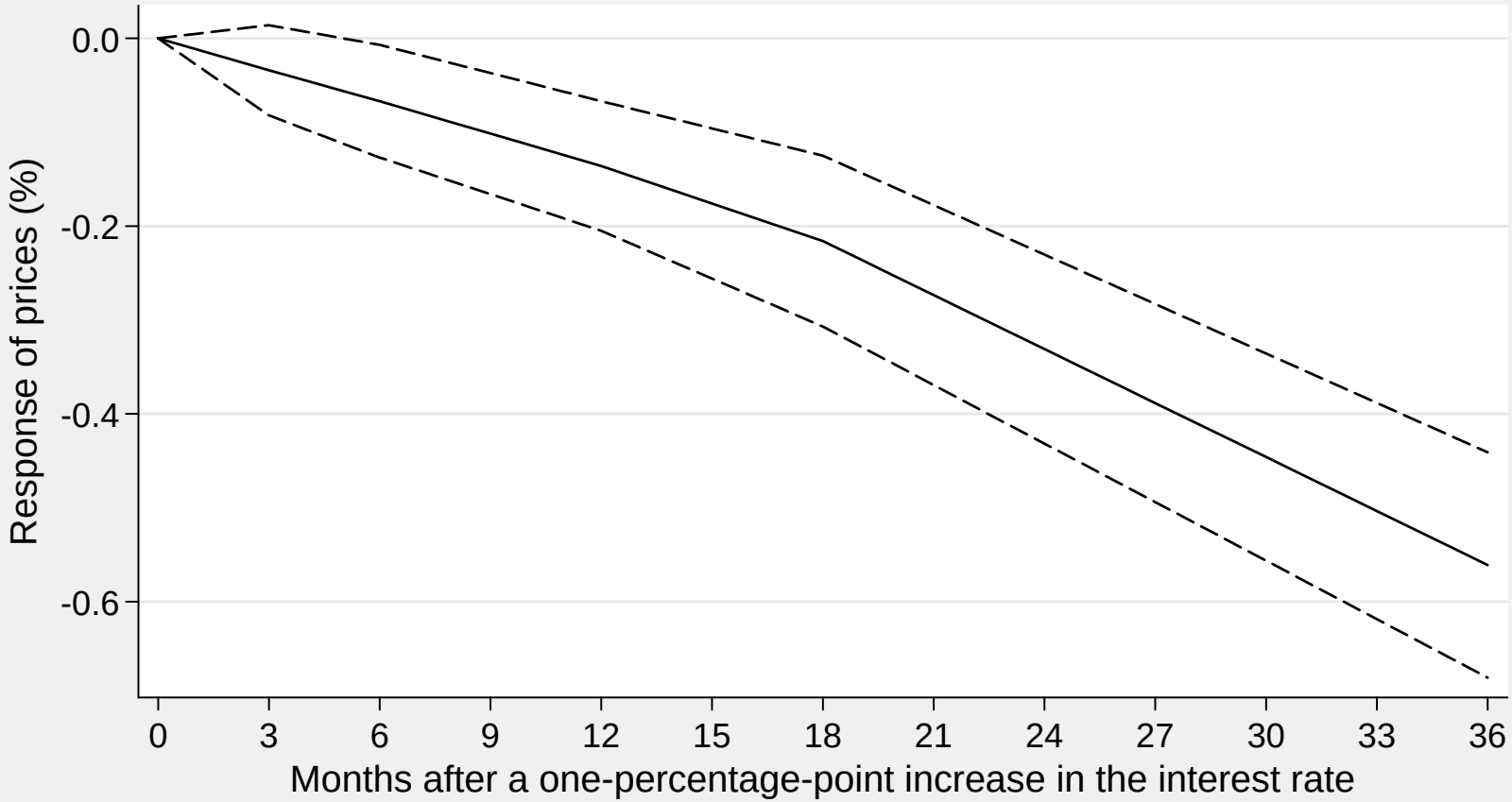
	A	B	C	D	E
1	**Study**	**Outlet**	**Reason for exclusion**	**Year**	**Authors**
2	Bernanke and Blinder (1992)	American Economic Review	No response of price level presented.	1992	Bernanke, Ben
3	Sims (1992)	European Economic Review	Without confidence bands.	1992	Sims, Christopl
4	Karras (1993)	Journal of Macroeconomics	Responses to money supply shock only.	1993	Karras, Georgi
5	Turner (1993)	Scottish Journal of Political Economy	Without confidence bands + no IR to interest rate shock.	1993	Turner, Paul M
6	Dhakal et al. (1994)	Quarterly Review of Economics and Finance	No impulse responses of price level presented.	1994	Dhakal, Dharm
7	Eichenbaum and Evans (1995)	Quarterly Journal of Economics	No impulse responses of price level presented.	1995	Eichenbaum, M
8	Haslag and Hein (1995)	Journal of Monetary Economics	Reserve adjustment magnitude and high powered money shocks	1995	Haslag, Joseph
9	Grilli and Roubini (1996)	European Economic Review	Impulse response of inflation only.	1996	Roubini, Nouri
10	Bomfim (1997)	Economic Inquiry	Monetary policy shock is defined as funds rate spread.	1997	Bomfim, Antul
11	Barran, Coudert and Mojon (1997)	Revue Française d'Économie	No impulse responses of price level presented.	1997	Barran, Fernan
12	Fung and Gupta (1997)	Canadian Journal of Economics	Responses to money supply shock only.	1997	Fung, Benedict
13	Serletis and Chwee (1997)	Macroeconomic Dynamics	Responses to money supply shock only.	1997	Serletis, Apost
14	Ramaswamy and Sloek (1998)	International Monetary Fund Staff Papers	Impulse response of output only.	1998	Ramaswamy, R
15	Dornbush et al. (1998)	Economic Policy	No impulse responses of price level presented.	1998	Dornbusch, Ru
16	Juselius (1998)	Empirical Economics	No impulse responses of price level presented.	1998	Juselius, Katari
17	Sims and Zha (1998)	International Economic Review	No impulse responses presented, forecasting exercise.	1998	Sims, Christopl
18	Fung and Kasumovich (1998)	Journal of Monetary Economics	Responses to money supply shock only.	1998	Fung, Ben Siu-c
19	Lastrapes (1998)	Review of Economics and Statistics	Responses to money supply shock only.	1998	Lastrapes, Will
20	Bernanke and Mihov (1998)	Quarterly Journal of Economics	Shock to interest rate is presented without confidence intervals.	1998	Bernanke, Ben

Excluded studies

Data Properties

- We use all impulse responses: more than 1,000 estimates collected, 209 on average for each horizon.
- The oldest primary study was published in 1992, the median study was published in 2006.
- The median time span of data used by primary studies is 1980–2002.
- All primary studies together use 2,500 unique combinations of countries and quarters.
- Evidence on 31 countries produced by 103 researchers.

Average Impulse Response is Intuitive



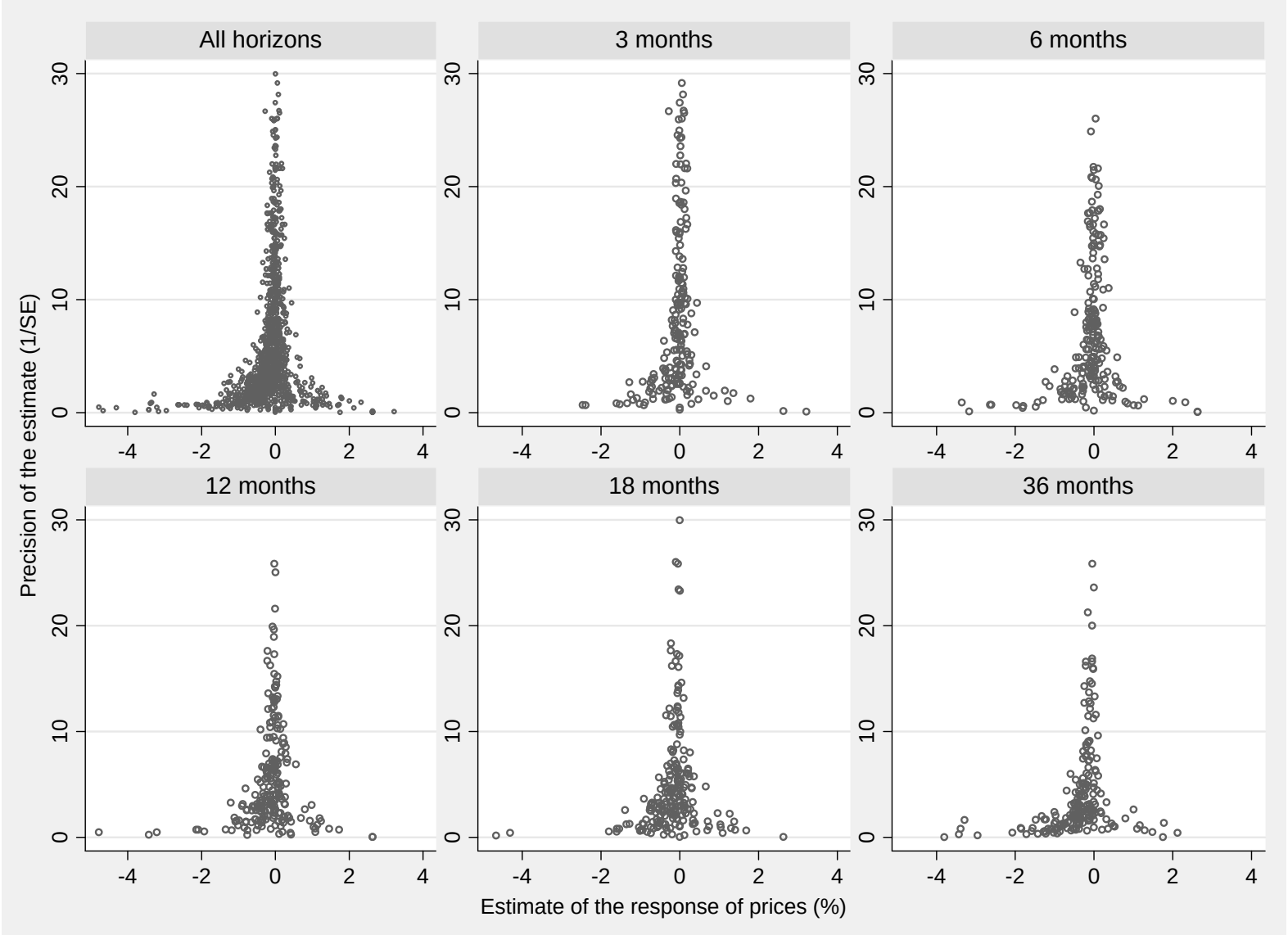
Note: Confidence bands are constructed as +/- one standard error.

Outline

Publication Bias in Vector Autoregressions

- There is no reason why publication selection should be restricted only to numerical results.
- In VARs some researchers treat the price puzzle as a clear indication of misspecification error.
  - We expect that positive responses of prices to monetary tightening will be underrepresented.
- Statistically significant impulse responses are convenient for interpretation.
  - We expect that significant responses of prices will be overrepresented.

VARs: Biased Against the Price Puzzle



Formal Test of Publication Bias (FAT-PET)

- Testing of funnel asymmetry by regressing the estimated response on its standard error (separately for each horizon):

$$\hat{\beta}_i = \underbrace{\beta}_{\text{true effect}} + \underbrace{\beta_0 SE_i}_{\text{publication bias}} + \mu_i. \quad (1)$$

- Controlling for heteroscedasticity and dependence within studies j (mixed-effects weighted least squares):

$$t_{ij} = \frac{\hat{\beta}_{ij}}{SE_{ij}} = \beta_0 + \zeta_j + \beta \left(\frac{1}{SE_{ij}} \right) + \epsilon_{ij}. \quad (2)$$

Results: The Long-Term Effect is Overblown

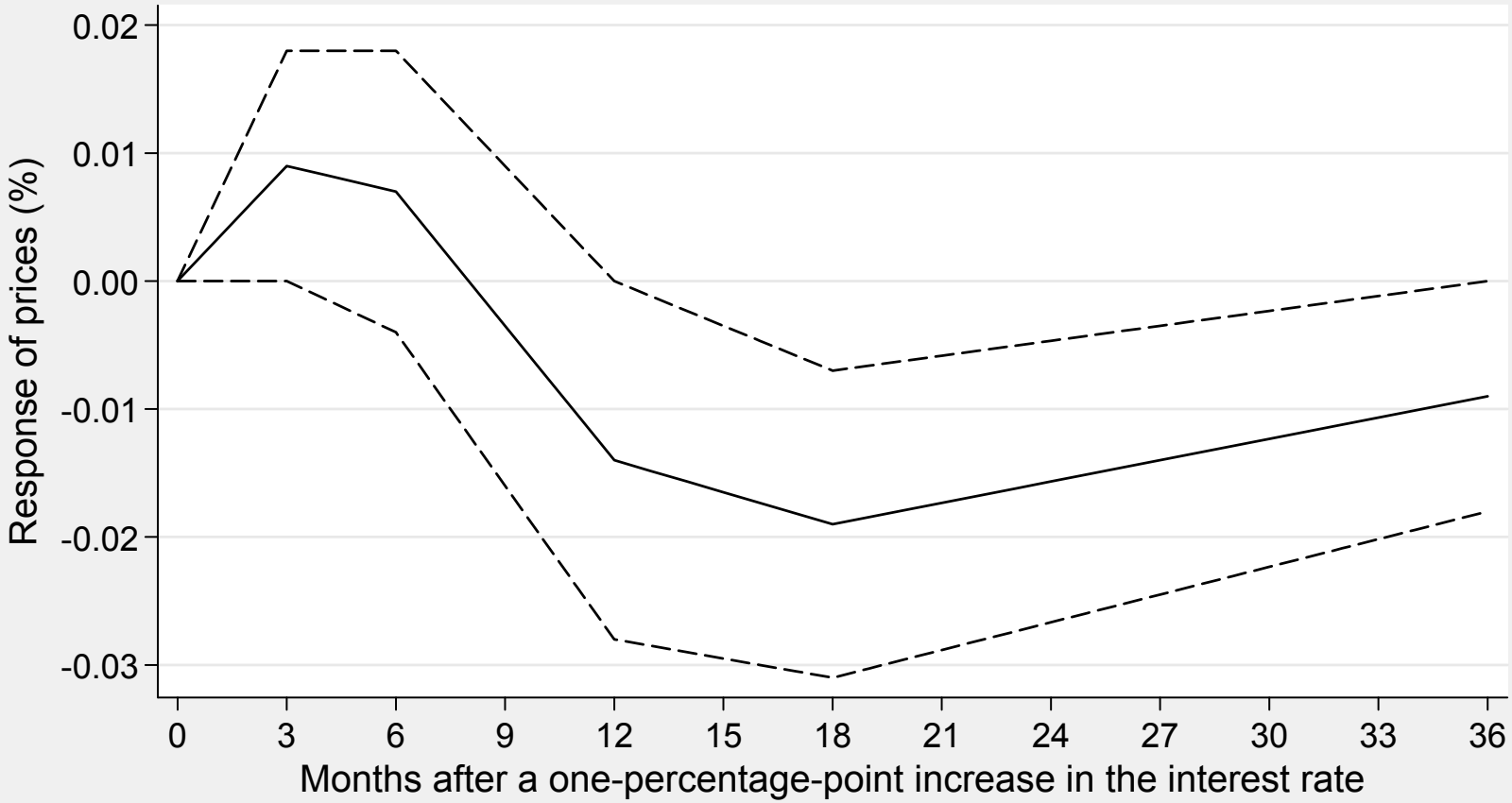
- Publication bias increases in magnitude with the horizon studied:

	Months after monetary tightening				
	3	6	12	18	36
Publication bias	0.058	-0.088	-0.176	-0.325**	-0.806***

Theory competition alleviates publication selection in the short run

- In the short run, there is a theory that may explain price puzzle (the cost channel).
- In the long run, prices should decrease (otherwise why to exercise monetary policy).

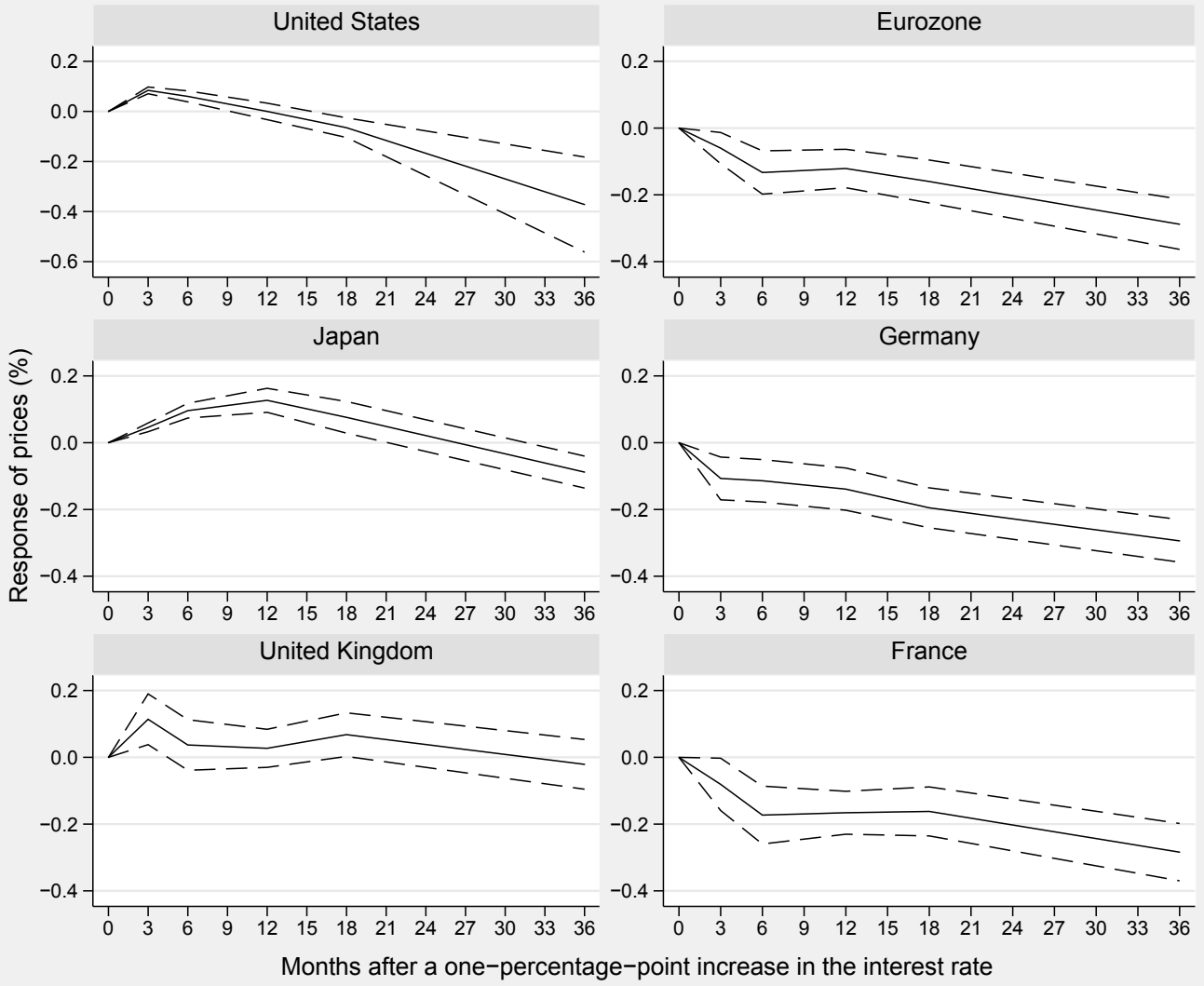
Beyond Publication Bias the Price Puzzle Occurs



Note: Confidence bands are constructed as +/- one standard error.

Outline

Cross-Country Differences in Monetary Transmission



Note: Confidence bands are constructed as +/− one standard error.

Structural Heterogeneity

What may cause cross-country differences? For example:

1. With higher inflation the effect of monetary policy on prices gets weaker. (High inflation hampers the credibility of the central bank.)
2. With a higher openness of the economy the effect on prices gets stronger. (The increase in interest rates strengthens the exchange rate, which cheapens imports.)
3. With a higher degree of central bank independence the effect on prices gets stronger. (Greater credibility of the central bank.)

Country-Level Variables

How to capture structural heterogeneity?

- We use average values of macroeconomic variables corresponding to the country and time span employed in the estimation.
- For instance in the case of inflation: if the impulse response is estimated on the 1990-1999 Italian data, we use the average inflation in Italy for 1990–1999.
- These variables are included in the meta-regression.

Possible Misspecifications

Many misspecifications have been pointed out in the literature and are controlled for in our paper. For example:

1. Omitted commodity prices: many VARs lack a forward-looking element and may thus suffer from the omitted variable bias.
2. GDP used instead of output gap: it is unrealistic to assume that central banks do not take the potential output into account.
3. Recursive identification used: e.g., it assumes that monetary policy affects output and prices only with a lag. Structural VARs, on the other hand, are consistent with the New-Keynesian models.

Multivariate Meta-Regression

- X_k includes 33 variables reflecting structural heterogeneity, methodology, study quality (citations, impact), and authors' affiliation (policymakers, central bankers):

$$t_{ij} = \beta_0 + \zeta_j + \beta \left(\frac{1}{SE_{ij}} \right) + \sum_k \frac{X_{kij}}{SE_{ij}} + \epsilon_{ij}. \quad (3)$$

- OLS with study-level clustered standard errors used as a robustness check.
- All variables included in one regression; jointly insignificant variables are then excluded using the Wald test.

Results: Structural and Method Heterogeneity

Short vs. long run

- Methodology determines the reported short-run response.
  - Misspecifications systematically influence the results: most contribute to the price puzzle.
- Structural heterogeneity determines the long-run response.
  - Estimated signs for country-level variables are consistent with the intuition given above.

- Journal impact and study citations are not significant: quality is well captured by the methods used.

Outline

Rationale for Best Practice

From the multivariate meta-regression

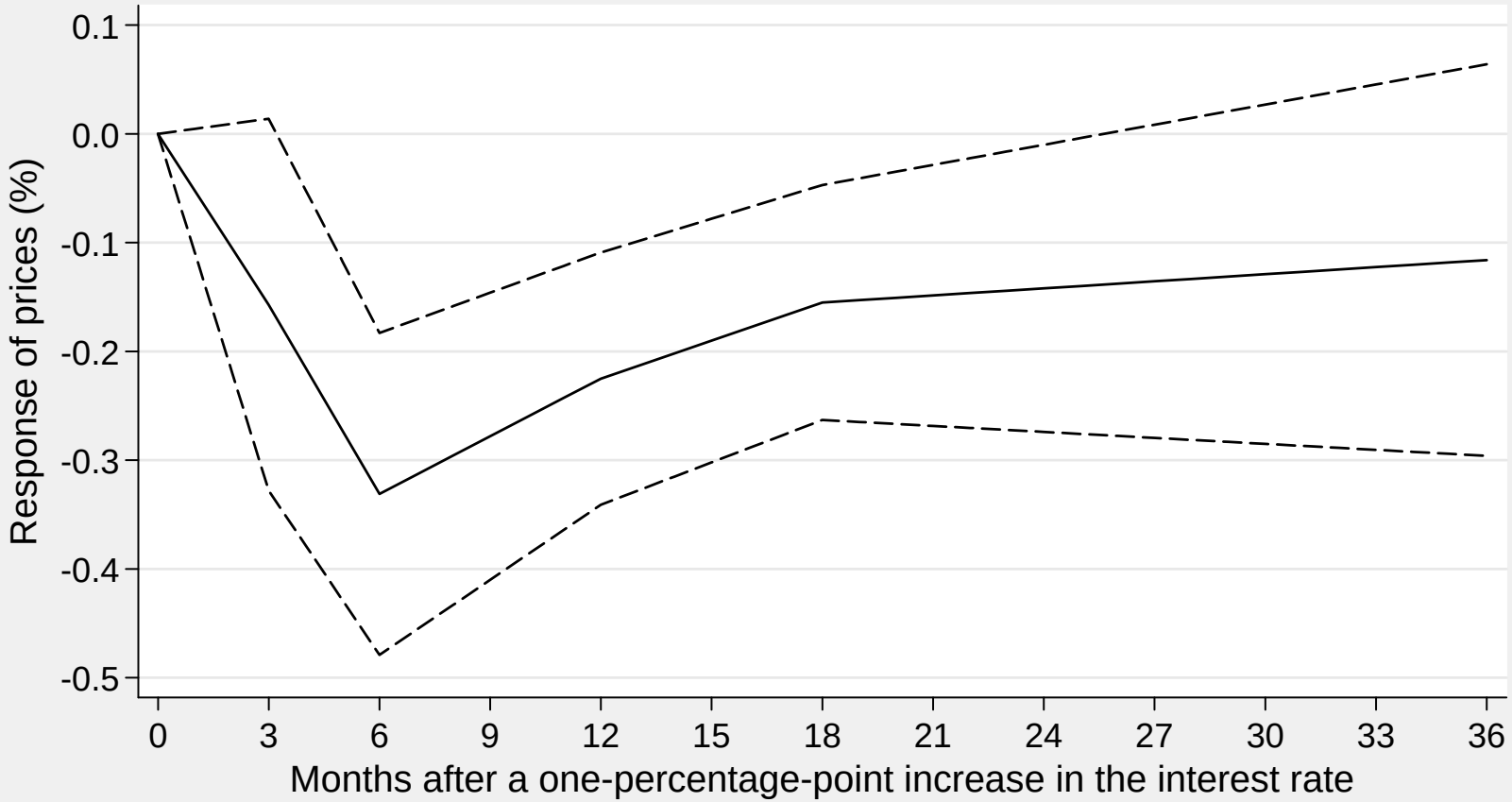
- We have found that misspecifications have systematic influence on results.
- We have also found that the number of observations and age of data are important.

- Can we somehow use this information to improve our estimate of impulse response?
  - Let's plug the preferred values of variables into the multivariate meta-regression.
  - Basically, we create an "ideal" impulse response conditional on consensus in the literature and common sense.

Definition of Best Practice

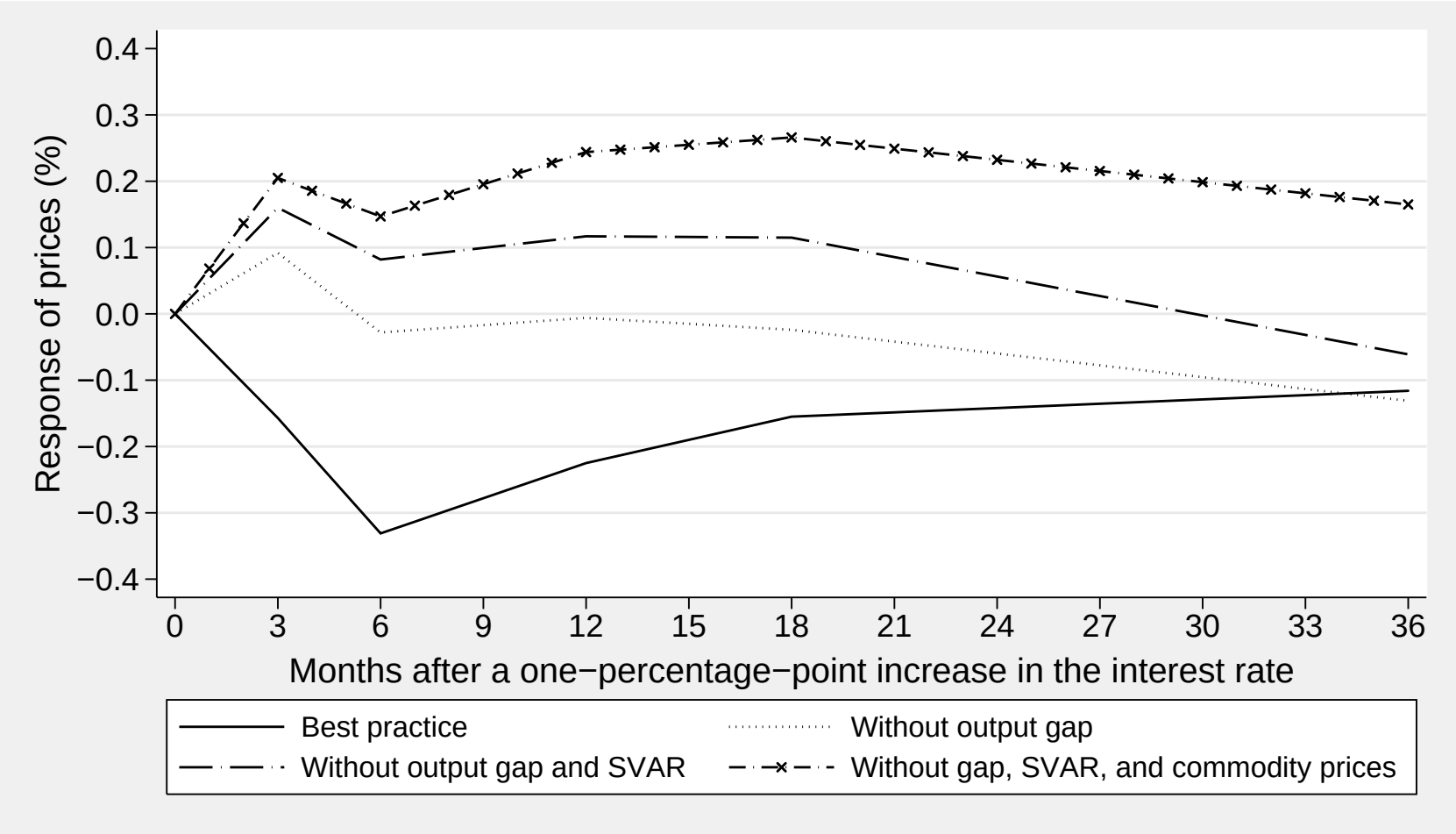
- We plug in sample maximums for the number of observations, new data, . . . , control for all well-known misspecifications.
- Country-level variables and affiliation characteristics are set to sample means.
- The coefficient for $1/SE$ represents the effect of monetary tightening on prices conditional on best practice.
  - Evaluated using the `lincom` command in Stata.
- Best practice is subjective. But our results are robust to many possible definitions.

Best-Practice Impulse Response: No Price Puzzle



Note: Confidence bands are constructed as +/- one standard error.

Misspecifications Cause the Price Puzzle



Conclusion

Summary

1. The reported price puzzle in the short run is due to misspecifications.
2. The reported long-run response of prices is exaggerated because of publication selection.
3. The long-run response is driven by structural country-specific characteristics.

Time for Questions

Thank you. Questions and comments are welcome!