Energy Supply Shocks' Nonlinearities on Output and Prices

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The views expressed in this presentation are those of the authors and do not necessarily reflect those of the European Central Bank or the Eurosystem.

Outline

Motivation

Questions:

- Is there a **differential effect** of the transmission of retail energy price shocks on GDP, industrial production, headline and core prices, when an economy is in a low- or a high-inflation regime?
- **Speed**: how fast is the transmission of shocks?
- **Symmetric effect:** does the transmission depend upon the sign and the size of the shocks?

Literature

1. Empirical analysis based on individual goods prices indicates that
   - prices change infrequently (e.g. Bils and Klenow, 2004; Klenow and Kryvtsov, 2008; Nakamura and Steinsson, 2010; Nakamura and Zerom, 2010; Eichenbaum et al., 2011; Gautier et al., 2022)
   - prices are more flexible in response to large shocks (e.g. Dias et al., 2007; Fougère et al., 2007; Gautier and Saout, 2015; Alvarez et al., 2017; Karadi and Reiff, 2019; Gautier et al., 2022)
   - price change more frequently when inflation is high (Nakamura et al., 2018; Alvarez et al., 2019)

2. These studies support micro-founded state-dependent models of nominal rigidities (Alvarez et al., 2011, 2021). There is little empirical evidence using aggregate prices. Ascari and Haber (2022) use local projections. However, Gonçalves et al. (2024) show that, when the state of the economy is endogenous, the local projections' estimator of the response function tends to be asymptotically biased.

3. Harding et al. (2023) assume the same price stickiness à la Calvo, but propose a nonlinear Philips curve, where the response of inflation to cost-push shocks depends on the initial inflation rate.

Literature

1. Energy supply shocks through oil and linear frameworks (Kilian, 2009; Baumeister and Peersman, 2013; Kilian and Murphy, 2014; Aastveit et al., 2015; Baumeister and Kilian, 2016; Baumeister and Hamilton, 2019; Caldara et al., 2019; Känzig, 2021; Aastveit et al., 2021; Kilian and Zhou, 2022b)
2. Retail energy supply shocks and linear frameworks (Edelstein and Kilian, 2009; Kilian and Zhou, 2022a; Alessandri and Gazzani, 2023; Corsello and Tagliabracci, 2023; De Santis, 2024; Neri, 2024)
3. Non-linear oil models
    - Holm-Hadulla and Hubrich (2017) use a Markov Switching VAR without distinguishing the source of oil price shocks
    - Mumtaz et al. (2018) identify demand and supply oil price shocks using a threshold VAR with sign restrictions
4. Non-linear models
    - Balke (2000) uses a TVAR with Cholesky to identify credit condition shocks
    - STVAR focus on recessions versus expansions states and employ Cholesky identification: monetary policy shocks (Weise, 1999), foreign shocks (Galvão et al., 2007), government spending shocks (Auerbach and Gorodnichenko, 2012; Bachmann and Sims, 2012; Berger and Vavra, 2014), uncertainty shocks (Caggiano et al., 2014) or financial shocks (Galvão and Owyang, 2018)
    - Other nonlinear models are quantile VAR (Chavleishvili and Manganelli, 2019) and Markov-switching VAR (Hubrich and Tetlow, 2015)

Outline

Method

We combine

- threshold VAR (TVAR) of Balke (2000), a simple intuitive way to capture nonlinearities such as a regime switching, asymmetry and multiple equilibria

$$\mathbf{X}_t = (\mathbf{c}_{Low} + \Pi_{Low}(\mathbf{L})\mathbf{X}_{t-1})I\{z_{t-1} < z^*\} + (\mathbf{c}_{High} + \Pi_{High}(\mathbf{L})\mathbf{X}_{t-1})I\{z_{t-1} \geq z^*\} + \mathbf{u}_t,$$
$$z_t = f(p_t - p_{t-1})$$
$$z^* = 2\%(annualised),$$
$$\mathbf{u}_t \sim N(0, \Omega_t),$$
$$\Omega_t = \Omega_{Low} I\{z_{t-1} < z^*\} + \Omega_{High} I\{z_{t-1} \geq z^*\}$$

- narrative identification method of Antolín-Díaz and Rubio-Ramírez (2018) refraining from applying the importance weighting step as suggested by Giacomini et al. (2020), and with signed contribution restrictions by De Santis and Van der Weken (2022)
- Nonlinear IRFs as in Koop et al. (1996) using structural shocks

$$IRF_{\mathbf{S}}^{\mathbf{X}}(\epsilon_{S,t}, \Gamma_{t-1}(z_{t-1})) \equiv \mathbb{E}(\mathbf{X}_{S,t+k} | (\Gamma_{t-1}(z_{t-1}), \epsilon_{S,t})) - \mathbb{E}(\mathbf{X}_{S,t+k} | \Gamma_{t-1}(z_{t-1})),$$

where $S \in \{0, 1\}$ indicates whether the economy is in the low- or high-inflation regime at time $t + k$.

“Signed” Contribution Restrictions

Antolín-Díaz and Rubio-Ramírez (2018)’s approach (“weak”):

“*shock x is the most important contributor to the observed unexpected movements in variable y*”

De Santis and Van der Weken (2022)’s approach (“signed”):

“*Among all shocks that move variable y in the* ***same direction****,*
... shock x is the most important contributor to the observed unexpected movements in variable y”

Advantages:

- can deal with forceful policy responses
- allows two contribution restrictions on one variable at same date (cross narrative restrictions)

Reduced Form

Data for the Euro Area

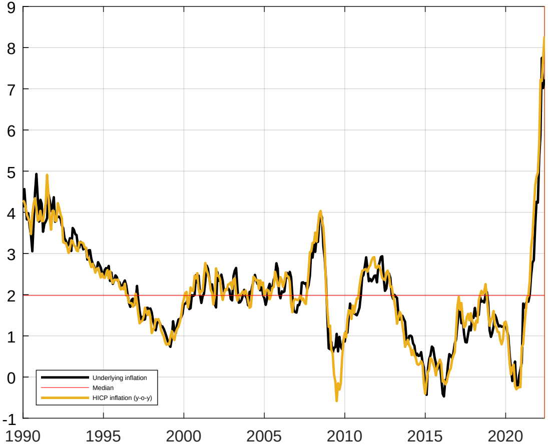
- HICP Energy
- HICP (p_t)
- Real GDP (monthly; Chow-Lin interpolation with industrial production, construction production and services production)
- industrial production
- High-energy intensive sector output (i.e. chemicals and basic metals)

Model

- Estimation sample: 1990M01—2019M12. Analysis: 1990M01—2022M06
- 6 lags
- Minnesota prior and "dummy-initial-observation" prior to account for possible cointegration (Sims, 1993)
- The state variable is defined using an Exponentially Weighted Moving Average (EWMA): $z_t = \sum_{i=0}^{\infty} \alpha(1-\alpha)^i (p_{t-i} - p_{t-1-i})$. Hence, z_t is a function of the entire history of p_t

State Variable and Headline Inflation

$$z_t = \alpha(p_t - p_{t-1}) + (1-\alpha)z_{t-1}, \text{ where } \alpha = 0.125.$$
$$z* = 1.99\% \text{ (annualised monthly median, in-sample)}$$



Identifying Assumptions

Table: Sign and narrative restrictions

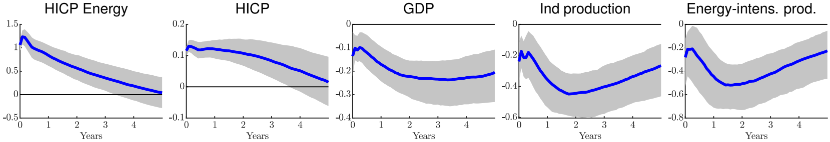
	Energy Supply	Other Supply	Demand
Variables	*Sign restrictions on the impact matrix A_0^{-1}*		
Energy HICP	+		+
HICP		+	+
Real GDP		-	+
Industrial production		-	+
Energy-intensive industrial production	-		
	Narrative sign and signed contribution restrictions		
08/90-09/90	$+, \uparrow u_t^{p_t^e}$		
12/02-01/03	$+, \uparrow u_t^{p_t^e}$		
10/21-11/21	$+, \uparrow u_t^{p_t^e}$		
03/22-04/22	$+, \uparrow u_t^{p_t^e}$		

Narrative restrictions are associated to adverse geopolitical events:

- Gulf War in Aug 1990 (Caldara et al., 2019; Känzig, 2021)
- General national strike in Venezuela in Dec 2002 (Caldara et al., 2019; Känzig, 2021)
- Gas cut from Russia in Oct 2021 and Ukraine war in Mar 2022 (out-of-sample)

Outline

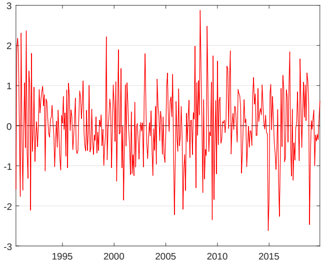
Linear Impulse Response Functions (1 st. dev. shock)



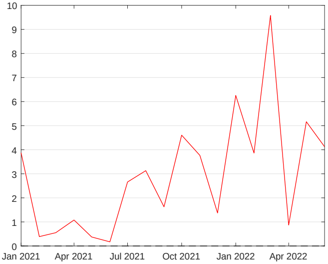
Estimated Energy Supply Shocks using the TVAR

The cumulative energy supply shocks between July 2021 and June 2022 is massive: 3.9 std per month on average!!!

In-sample: Jul. 90 - Dec. 19



Out-of-sample: Jan. 21 - Jun. 22

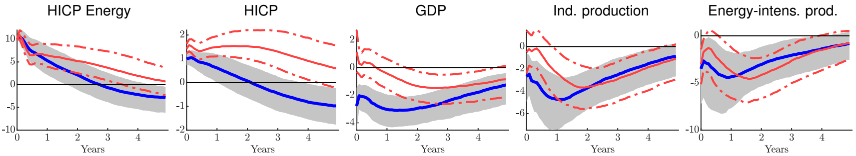


The energy supply shocks are

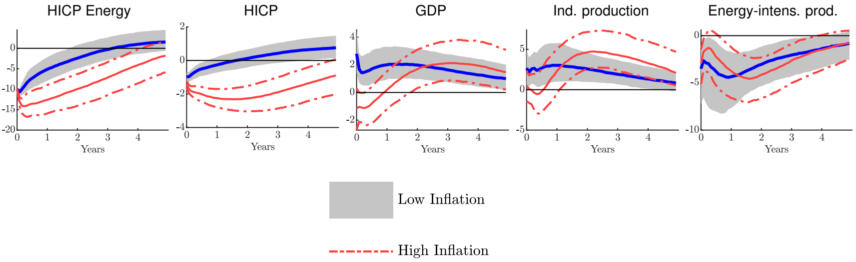
- 3.0 std per month on average, if Mar-Apr 22 narratives are excluded
- 2.3 std per month on average, if Oct-Nov 21 and Mar-Apr 22 narratives are excluded

Nonlinear Impulse Response Functions

Panel A: Energy supply shock implying an increase in energy prices by 10%

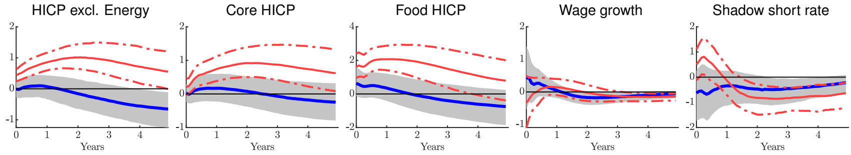


Panel B: Energy supply shock implying a decrease in energy prices by 10%

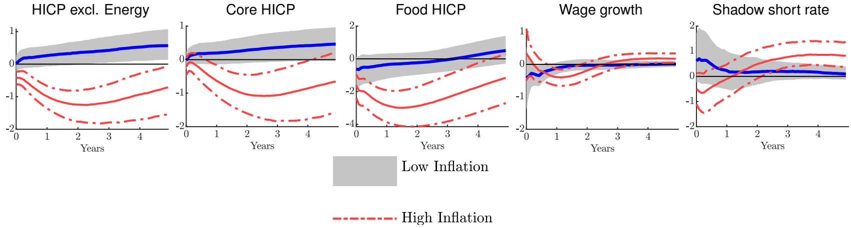


Responses of Inflation excl. Energy, Core, Food and Wages

Panel A: Nonlinear IRFs (% response to a shock increasing energy prices by 10%):

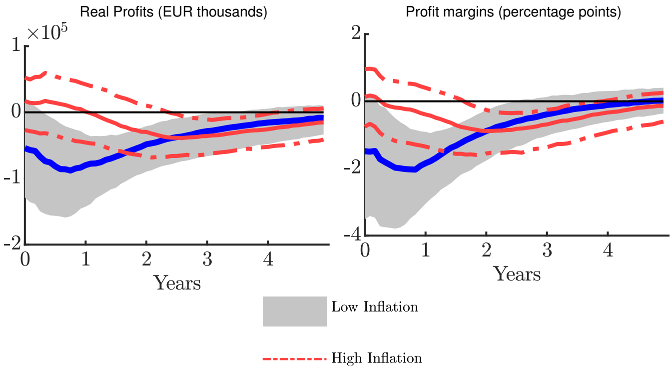


Panel B: Nonlinear IRFs (% response to a shock decreasing in energy prices by 10%):

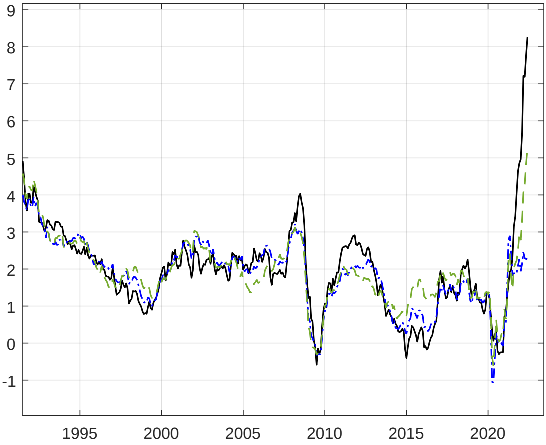


Responses of Corporate Profits to Energy Supply Shocks

Nonlinear IRFs (response to a shock increasing energy prices by 10%):



HICP: Counterfactual without the Energy Supply Shocks



Black line: Annual HICP inflation ($p_t - p_{t-12}$, %)
Green line: Linear counterfactual
Blue line: TVAR counterfactual

Counterfactual with the Energy Supply Shocks set to zero

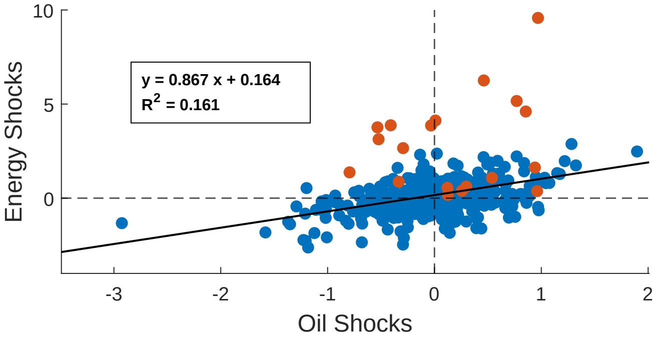
Variables in June 2022 in absence of energy supply shocks

Variables (log diff, y-o-y, %)	**Obs**	**Linear**	**TVAR**
Energy HICP	35.1	10.1	6.4
HICP	8.3	5.3	2.3
GDP	2.7	5.8	2.7
Industrial production	2.1	8.4	4.5
Energy-intensive production	-3.0	4.0	5.0

TVAR excludes Mar-Apr 22 narratives

Retail Energy versus Crude Oil Supply Shocks

Our energy supply shocks versus oil supply shocks by Känzig (2021)



Robustness

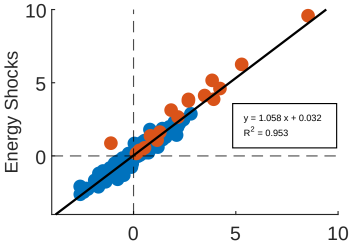
Similar results if

- excluding the narratives in 2021 and 2022

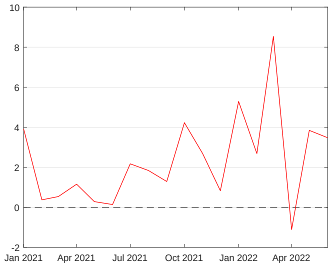
Energy Supply Shocks without Mar. 22 Narrative

The cumulative energy supply shocks between July 2021 and June 2022 is massive: 36 standard deviations !!!

In-sample: Jul. 90 - Dec. 19



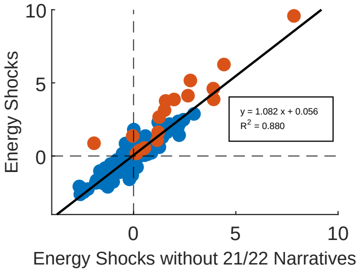
Out-of-sample: Jan. 21 - Jun. 22



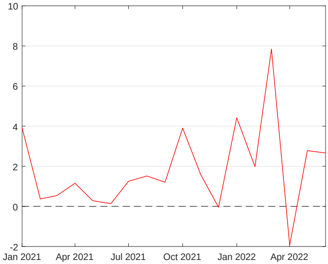
Energy Supply Shocks without Oct. 21 and Mar. 22 Narrative

The cumulative energy supply shocks between July 2021 and June 2022 is massive: 27 standard deviations !!!

In-sample: Jul. 90 - Dec. 19



Out-of-sample: Jan. 21 - Jun. 22



Robustness

Similar results if

- excluding the narratives in 2021 and 2022
- including energy-specific demand shocks

Sign and Narrative Restrictions with Energy-Specific Demand Shocks

	Energy Supply	Other Supply	Other Demand	Energy-Specific Demand
Variables	*Sign restrictions on the impact matrix* A_0^{-1}			
Energy HICP	+		+	+
Headline HICP		+	+	
Real GDP		-	+	
Industrial production		-	+	
Energy-intensive industrial production	-			-
	Narrative sign and signed contribution restrictions			
08/90-09/90	$\uparrow u_t^{p_t^e}$			
12/02-01/03	$\uparrow u_t^{p_t^e}$			
10/21-11/21	$\uparrow u_t^{p_t^e}$			
03/22-04/22	$\uparrow u_t^{p_t^e}$			
02/12-02/12				$\uparrow u_t^{p_t^e}$
11/14-11/14				$\downarrow u_t^{p_t^e}$

Robustness

Similar results if

- excluding the narratives in 2021 and 2022
- including energy-specific demand shocks
- the model is fully set identified

Sign and Narrative Restrictions in a fully Set-Identified TVAR

	Energy Supply	**Other Supply**	**Demand**
Variables	*Sign restrictions on the impact matrix* A_0^{-1}		
Energy HICP	+	-	+
Headline HICP		+	+
Real GDP		-	+
Industrial production		-	+
Energy-intensive industrial production	-	-	+
	Narrative sign and signed contribution restrictions		
08/90-09/90	$\uparrow u_t^{p_t^e}$		
12/02-01/03	$\uparrow u_t^{p_t^e}$		
10/21-11/21	$\uparrow u_t^{p_t^e}$		
03/22-04/22	$\uparrow u_t^{p_t^e}$		

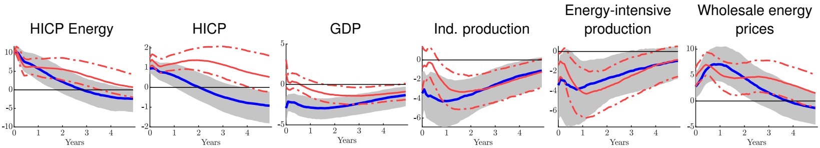
Robustness

Similar results if

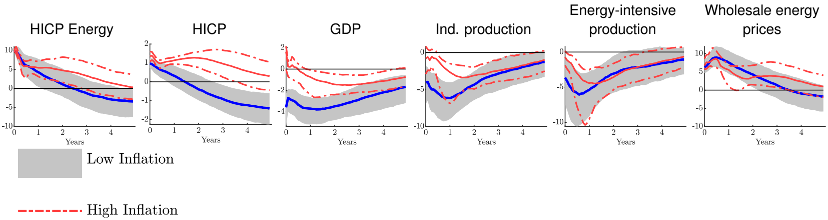
- excluding the narratives in 2021 and 2022
- including energy-specific demand shocks
- the model is fully set identified
- using the wholesale energy prices

Using the wholesale energy prices

Panel A: TVAR without restrictions on wholesale energy prices



Panel B: TVAR with restrictions on wholesale energy prices



Robustness

Similar results if

- excluding the narratives in 2021 and 2022
- including energy-specific demand shocks
- the model is fully set identified
- using the wholesale energy prices
- using a 2.2% threshold obtained form a grid search

Outline

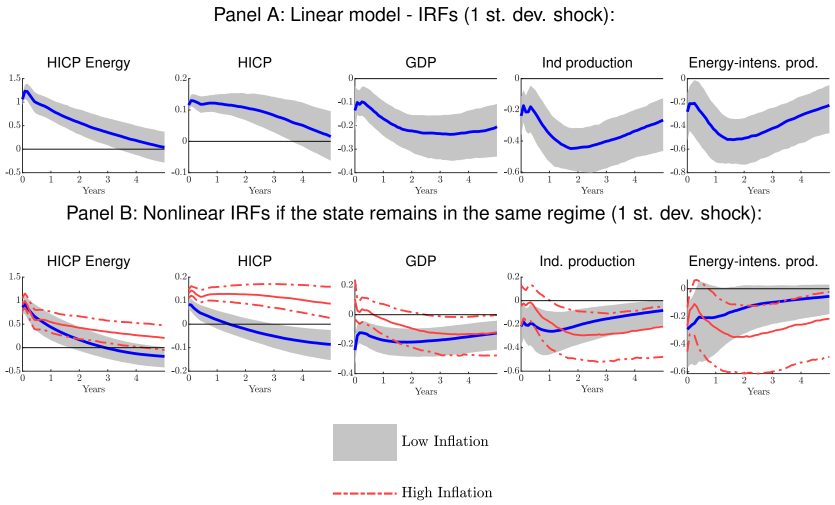
Summary

- Energy supply shocks in the low-inflation regime
  - non-energy prices are sticky
  - output drops
- Energy supply shocks in the high-inflation regime
  - persistent effect on headline and core HICP
  - core inflation declines after 1 year y-o-y and after 6 months q-o-q
  - higher prices cushion the drop in output in the short term
  - broadly symmetric effects of adverse and favourable shocks
  - broadly symmetric effects of large and small shocks (not shown)

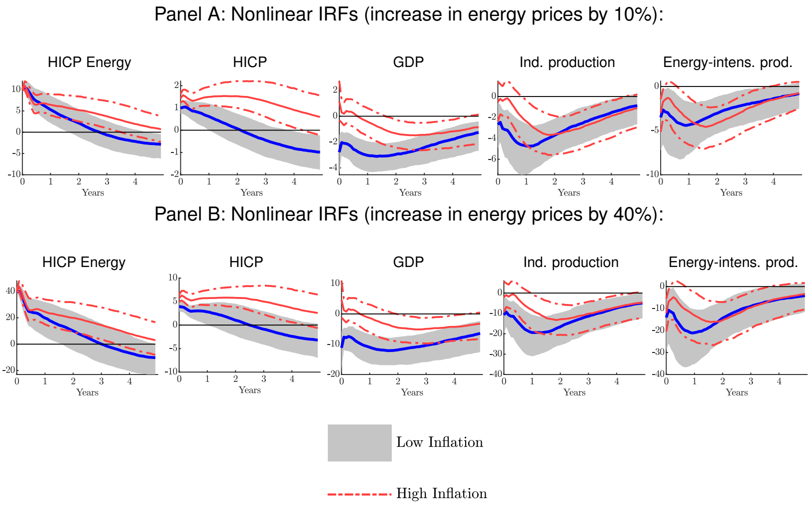
- For policy makers
  - Massive energy supply shocks since July 2021
  - Risk of permanent drop of the energy-intensive sector output
- For DSGE modellers
  - prices are sticky only in the low-inflation regime
  - state-dependent models of nominal rigidities (Alvarez et al., 2011, 2021) or nonlinear Philips' curves (Harding et al., 2023)

Background

Impulse Response Functions

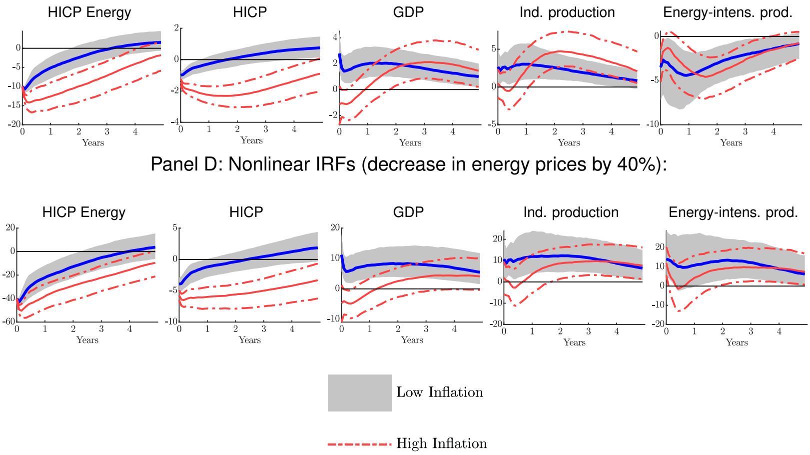


Nonlinear IRFs: Increase in Energy Prices



Nonlinear IRFs: Decrease in Energy Prices

Panel C: Nonlinear IRFs (decrease in energy prices by 10%):



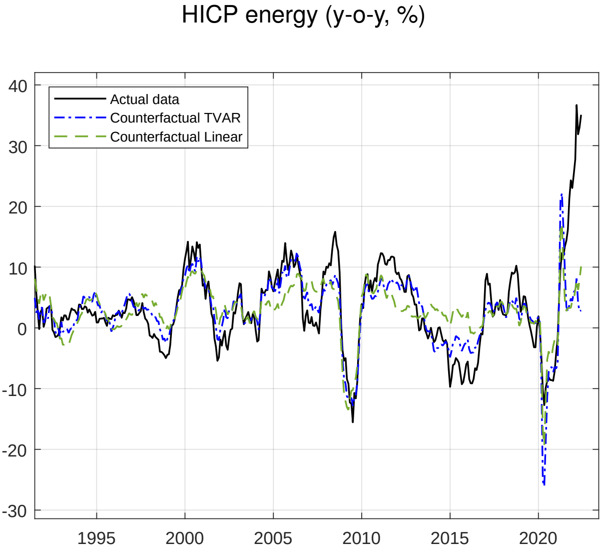
Multipliers for 10% Increase or Decrease in Energy Prices

Largest impact (in absolute value) after a 10% increase or decrease in energy prices (due to an energy supply shock)

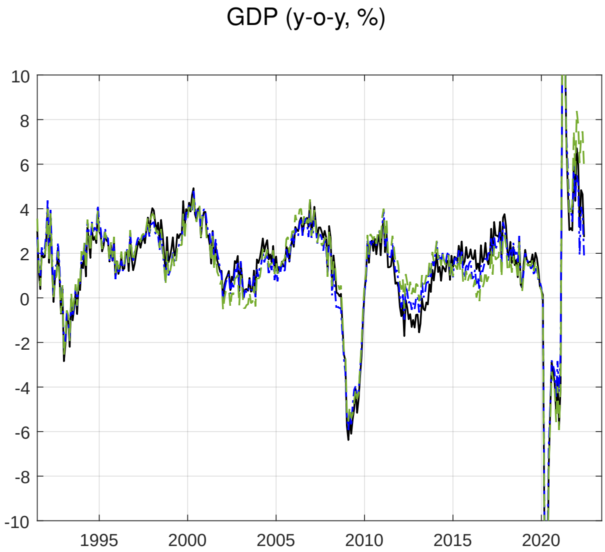
		HICP			GDP			Ind. production			Energy-intens. prod.	
	16%	50%	84%	16%	50%	84%	16%	50%	84%	16%	50%	84%
		HICP			GDP			Ind. production			Energy-intensive prod.	
	16%	50%	84%	16%	50%	84%	16%	50%	84%	16%	50%	84%
Linear 10% rise	1.0	1.2	1.4	-3.4	-2.3	-1.5	-5.8	-4.3	-3.0	-7.0	-4.9	-3.1
NL 10% rise: Low	0.7	1.0	1.4	-4.3	-3.1	-2.0	-7.4	-4.7	-2.7	-7.8	-4.4	-1.6
NL 10% rise: High	1.3	1.6	1.8	-2.6	-1.5	-0.5	-5.6	-3.7	-1.8	-7.0	-4.6	-2.3
NL 40% rise: Low	0.7	1.0	1.3	-4.2	-3.0	-2.0	-7.4	-4.9	-2.9	-8.9	-5.3	-2.5
NL 40% rise: High	1.3	1.6	1.8	-2.4	-1.3	-0.3	-5.1	-3.3	-1.3	-6.6	-4.0	-1.6
NL 10% drop: Low	-1.2	-1.0	-0.7	1.5	2.8	4.5	1.0	3.0	5.7	1.2	3.5	7.2
NL 10% drop: High	-3.0	-2.3	-1.6	0.9	2.1	3.8	2.7	4.7	7.2	2.8	5.4	8.3
NL 40% drop: Low	-1.3	-1.0	-0.7	1.4	2.8	4.5	1.2	3.1	5.3	1.1	3.5	7.2
NL 40% drop: High	-1.9	-1.6	-1.3	0.0	1.1	2.5	0.8	2.5	4.4	1.4	3.0	5.1

Notes: This table shows the largest impact (in absolute value) of a normalised 10% increase or decrease in energy prices due to energy shocks on HICP, GDP, the industrial production and the production of the energy-intensive sector in low- and high-inflation regimes as well as in the linear setting. Four different energy supply shocks are considered, which increase or decrease energy prices by 10% and 40%. The table provides the median (50%) response and the 16%-84% credible set range.

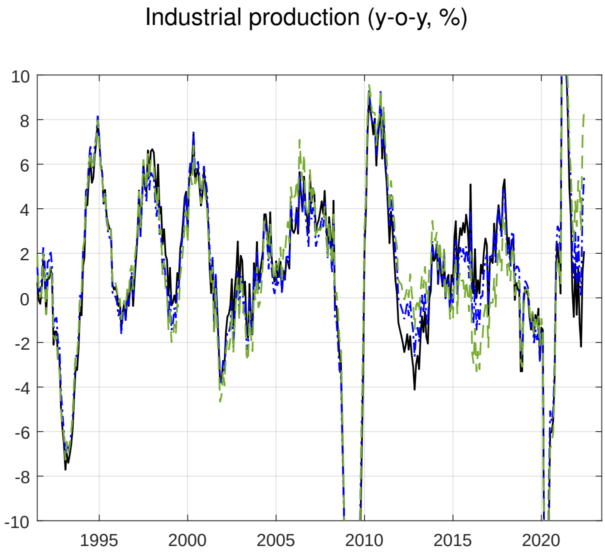
Counterfactual without the Estimated Energy Supply Shocks



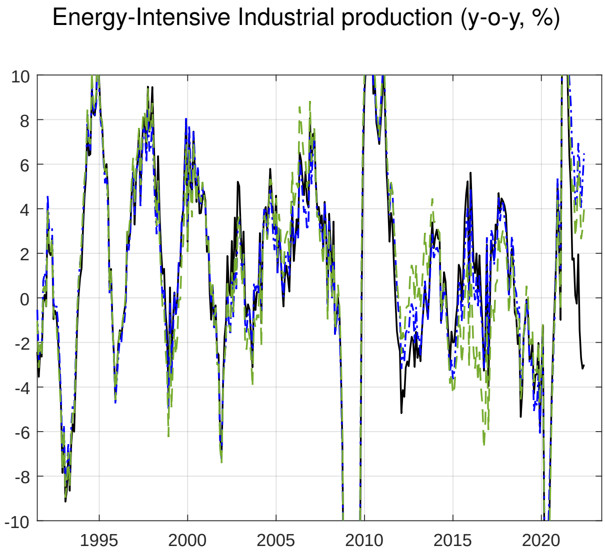
Counterfactual without the Estimated Energy Supply Shocks



Counterfactual without the Estimated Energy Supply Shocks



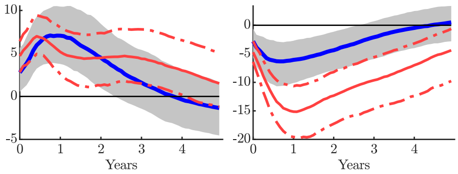
Counterfactual without the Estimated Energy Supply Shocks



Wholesale Energy Price's Response to Energy Shocks

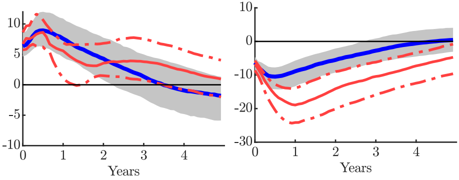
A: TVAR without restrictions on wholesale energy prices

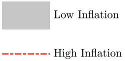
Nonlinear: 10% increase | Nonlinear IRF: 10% decrease



B: TVAR with restrictions on wholesale energy prices

Nonlinear IRF: 10% increase | Nonlinear IRF: 10% decrease





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