Energy Supply Shocks' Nonlinearities on Output and Prices

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July 2024

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

1. Introduction
2. SVAR
3. Main Results
4. Summary

Motivation

Questions:

- Is there a **differential effect** of the transmission of retail energy price shocks on prices and output, 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 support micro-founded state-dependent models of nominal rigidities (Alvarez et al., 2011, 2021):

- 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. 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.

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
   - TVAR: credit condition shocks (Balke, 2000); oil shoccks (Mumtaz et al., 2018), monetary policy and liquidity shocks (Canova and Perez Forero, 2024)
   - 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)
   - Markov-switching VAR (Hubrich and Tetlow, 2015)
   - Quantile VAR (Chavleishvili and Manganelli, 2019)

Outline

Threshold VAR

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

where, as in Lenza and Primiceri (2022), s_t is equal to 1 before March 20, $\bar{s}_0$ in March 20, $\bar{s}_1$ in April 20, $\bar{s}_2$ in May 20 and $1 + (\bar{s}_2 - 1)\rho^{j-2}$, $j = 3, \ldots, T$, thereafter.

- Prior for $\bar{s}_0$, $\bar{s}_1$, and $\bar{s}_2$: Pareto distribution with scale and shape parameters equal to one (very fat right tail, consistent with large increases in the variance of the VAR innovations).
- Prior for ρ: Beta distribution with a mode and standard deviation of 0.8 and 0.2, respectively.

Identification and IRFs

- we identify shocks using sign, magnitude and narrative restrictions (Antolín-Díaz and Rubio-Ramírez, 2018) refraining from applying the importance weighting step (Giacomini et al., 2020)
- we compute nonlinear IRFs (Koop et al., 1996) using structural shocks

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

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

Reduced Form

Data for the Euro Area

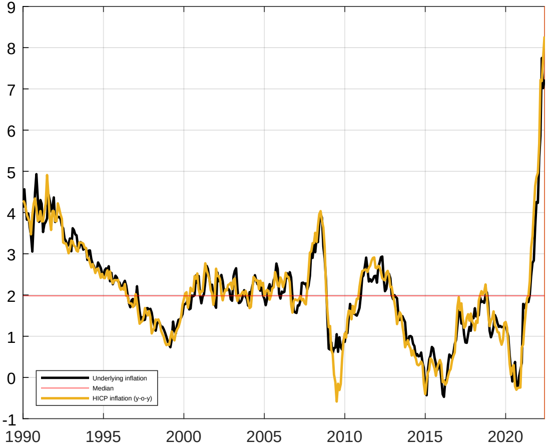
- Energy HICP (i.e. electricity, gas, liquid fuels, solid fuels, heat energy, and fuels and lubricants for personal transport equipment)
- Energy production (i.e. mining and quarrying of energy producing materials; manufacture of coke and refined petroleum products; production and distribution of electricity, gas, steam, and air conditioning)
- Headline HICP (p_t)
- Real GDP (monthly; Chow-Lin interpolation with industrial production, construction production and services production)
- Industrial production
- Shadow short-term interest rate

Model

- Estimation sample: Jan. 1990 - Jun. 2022
- 6 lags
- Minnesota prior and "dummy-initial-observation" prior to account for possible cointegration (Sims, 1993)
- The state variable is $z_t = \sum_{i=0}^{\infty} \alpha(1-\alpha)^i (p_{t-i} - p_{t-1-i})$.

State Variable and Headline Inflation

$$z_t = \alpha(p_t - p_{t-1}) + (1-\alpha)z_{t-1}, \text{ where } \alpha = 0.125.$$
$$z* = 1.98\% \text{ (annualised monthly median)}$$

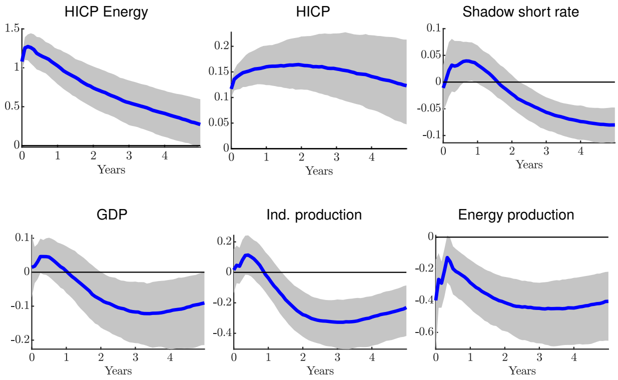


Sign, Magnitude, and Narrative Restrictions

	Energy Supply	**Other Supply**	**Demand**
Variables	*Sign restrictions on the impact matrix A_0^{-1}*		
Energy HICP	+	+	+
Headline HICP	+	+	+
Real GDP		-	+
Industrial production		-	+
Energy production	-		+
Shadow short rate			
Variables	*Magnitude restrictions on the FEVD at $h = 0$*		
Energy HICP	++	+	
Headline HICP	+	++	
Dates	*Narrative sign and signed contribution restrictions*		
08/90 (Gulf War)	$+, u_t^{p_t^e}$		
12/02 (Venezuela)	$+, u_t^{p_t^e}$		
10/21 (Gas cut from Russia)	$+, u_t^{p_t^e}$		
11/21 (Gas cut from Russia)	$+, u_t^{p_t^e}$		
03/22 (Ukraine war)	$+, u_t^{p_t^e}$		

Outline

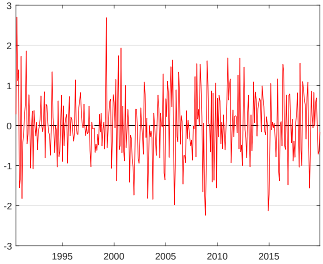
Linear Impulse Response Functions (1 st. dev. shock)



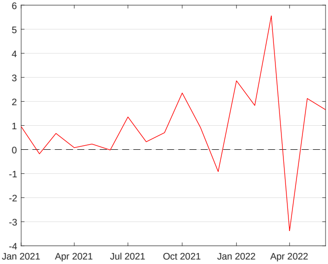
Estimated Energy Supply Shocks using the TVAR

The average energy supply shock between October 2021 and June 2022 is 1.4 std per month

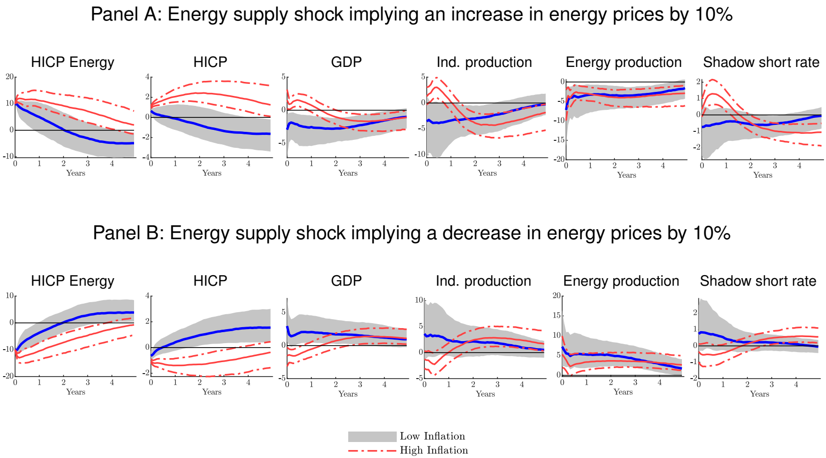
Jul. 90 - Dec. 19



Jan. 21 - Jun. 22



Nonlinear Impulse Response Functions



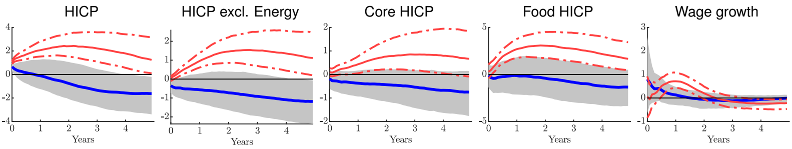
Multipliers for 10% Increase or Decrease in Energy Prices

Median	HICP	Real GDP	Ind. Prod.	Energy Prod.
Increase in energy prices				
Linear 10% rise	1.1	-0.9	-2.0	-3.5
Nonlinear 10% rise: Low	0.6	-3.0	-3.8	-7.3
Nonlinear 10% rise: High	2.4	-1.7	-4.3	-5.3
Nonlinear 40% rise: Low	0.7	-2.9	-3.7	-7.2
Nonlinear 40% rise: High	2.4	-1.7	-4.2	-5.3
Decrease in energy prices				
Nonlinear 10% drop: Low	-0.6	2.9	3.5	7.1
Nonlinear 10% drop: High	-1.4	1.4	3.0	5.4
Nonlinear 40% drop: Low	-0.7	2.9	3.6	7.2
Nonlinear 40% drop: High	-1.2	1.0	2.1	5.4

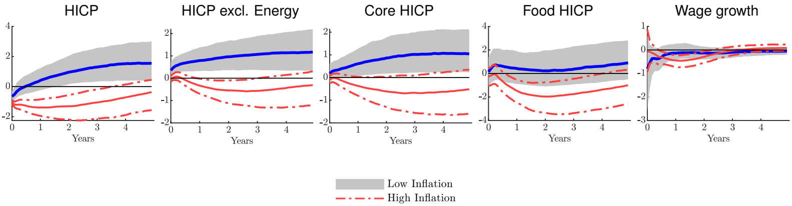
- Size: differences across regimes are broadly symmetric
- Sign: differences within regimes are more apparent if shocks are relatively large and we start in the high inflation regime

Regime-Specific Responses of Prices and Wages

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

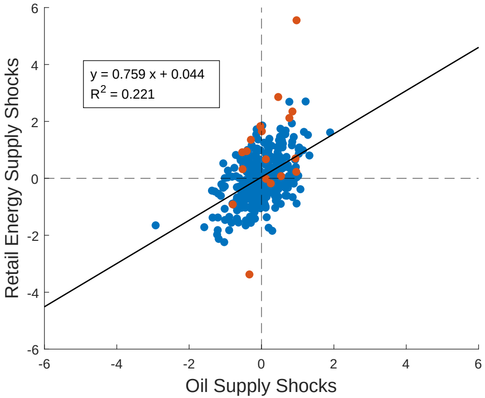


Panel B: Nonlinear IRFs (% response to a shock decreasing in energy prices by 10%):



Retail Energy versus Crude Oil Supply Shocks

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

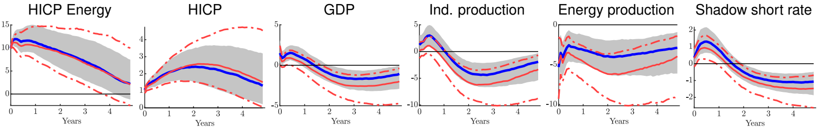


Restrictions with Energy-Intensive Production

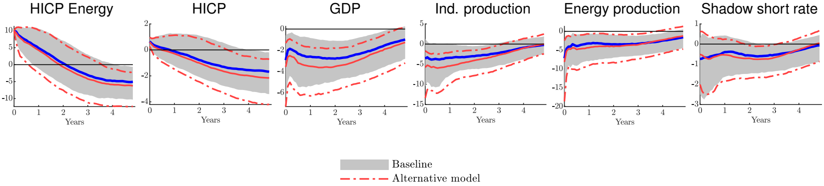
	Energy Supply	Other Supply	Demand
Variables	*Sign restrictions on the impact matrix* A_0^{-1}		
Energy HICP	+	+	+
Headline HICP	+	+	+
Real GDP		-	+
Industrial production		-	+
Energy production	-		+
Shadow short rate			
Energy-intensive production	-		
Variables	*Magnitude restrictions on the FEVD at* $h = 0$		
Energy HICP	++	+	
Headline HICP	+	++	
Dates	*Narrative sign and signed contribution restrictions*		
08/90	$+, u_t^{p_t^e}$		
12/02	$+, u_t^{p_t^e}$		
10/21	$+, u_t^{p_t^e}$		
11/21	$+, u_t^{p_t^e}$		
03/22	$+, u_t^{p_t^e}$		

Nonlinear IRFs with Energy-Intensive Production

Panel A: High-inflation regime IRFs (% response to a shock increasing energy prices by 10%):

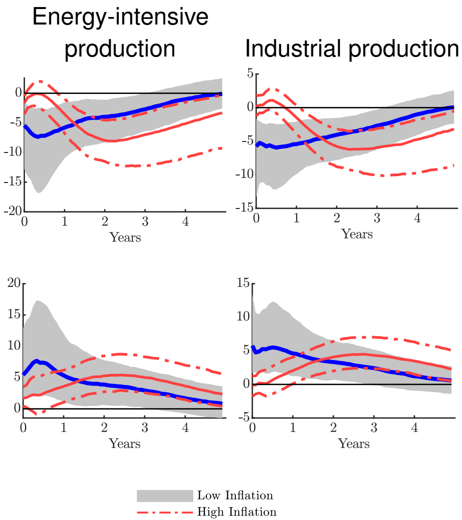


Panel B: Low-inflation regime IRFs (% response to a shock increasing energy prices by 10%):



Nonlinear IRFs with Energy-Intensive Production

Energy supply shocks increasing/decreasing energy prices by 10%

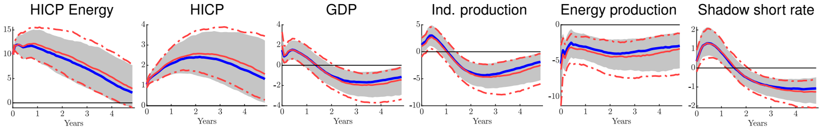


Restrictions with Energy-Specific Demand Shocks

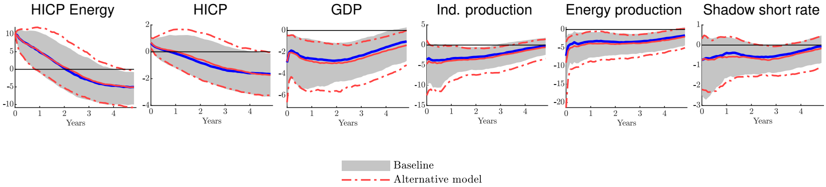
	Energy supply	Other Supply	Other Demand	Energy Demand
Variables	*Sign restrictions on the impact matrix A_0^{-1}*			
Energy HICP	+	+	+	+
Headline HICP	+	+	+	
Real GDP		-	+	
Industrial production		-	+	+
Energy production	-		+	+
Shadow short rate				
Variables	*Magnitude restrictions on the FEVD at $h = 0$*			
Energy HICP	++	+		
Headline HICP	+	++		
	Narrative sign and signed contribution restrictions			
08/90	+, $u_t^{p_t^e}$			
12/02	+, $u_t^{p_t^e}$			
10/21	+, $u_t^{p_t^e}$			
11/21	+, $u_t^{p_t^e}$			
03/22	+, $u_t^{p_t^e}$			
02/12				+, $u_t^{p_t^e}$
11/14				-, $u_t^{p_t^e}$

Nonlinear IRFs with Energy-Demand Schocks

High-inflation regime (% response to an energy supply shock increasing energy prices by 10%):



Low-inflation regime (% response to an energy supply shock increasing energy prices by 10%):



Robustness

Similar results if

- including energy-intensive production
- including energy-specific demand shocks
- including wholesale energy prices
- using a higher threshold for the high-inflation regime (underlying inflation at 2.2%)
- excluding real GDP or the shadow short rate

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
  - higher prices cushion the drop in output in the short term
- Size: differences across regimes are broadly symmetric
- Sign: differences within regimes are more apparent if shocks are relatively large and we start in the high inflation regime

- For policy makers
  - Massive energy supply shocks since October 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

Background

"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"):

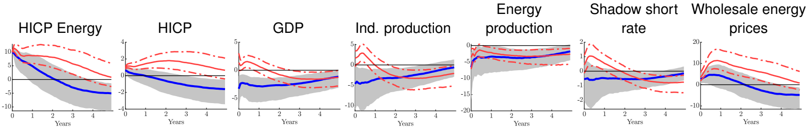
"*Among all shocks that move variable y in the* ***same direction****,*
... shock x is the most important contributor to the observed unexpected movements in variable y"

Advantages:

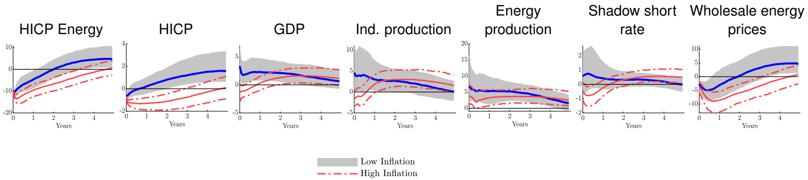
- can deal with forceful policy responses
- allows two contribution restrictions on one variable at same date (cross narrative restrictions)

Nonlinear IRFs with Wholesale Energy Prices: no additional restrictions

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

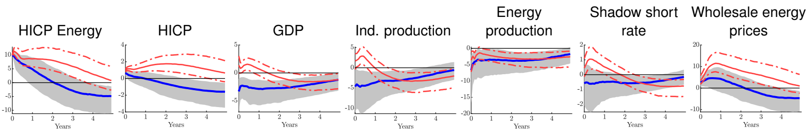


Panel B: Energy supply shock implying a decrease in energy prices by 10%

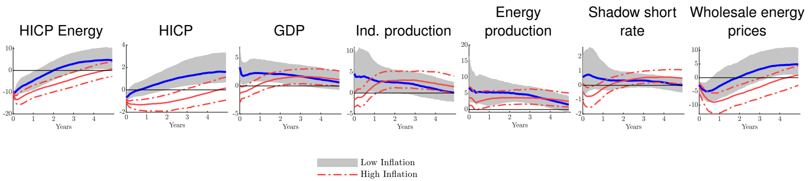


Nonlinear IRFs with Wholesale Energy Prices: with additional restrictions

Panel A: High-inflation regime IRFs (% response to a shock increasing energy prices by 10%):

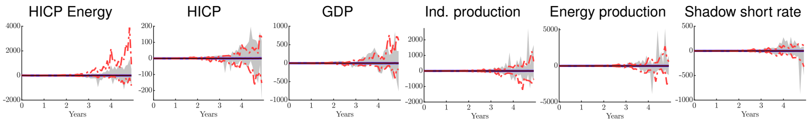


Panel B: Energy supply shock implying a decrease in energy prices by 10% Panel D: Nonlinear IRFs (% response to a shock decreasing retail energy prices by 10%):

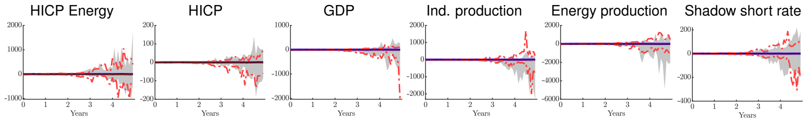


Nonlinear Impulse Response Priors

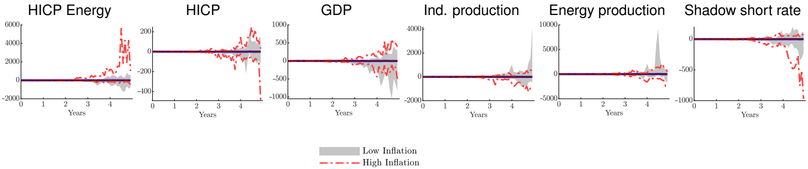
Panel A: % response to an energy supply shock increasing energy prices by 10%:



Panel B: % response to a 1 standard deviation demand shock:

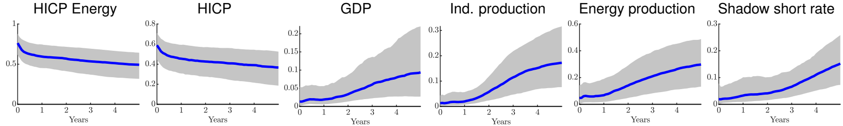


Panel C: % response to a 1 standard deviation other supply shock:

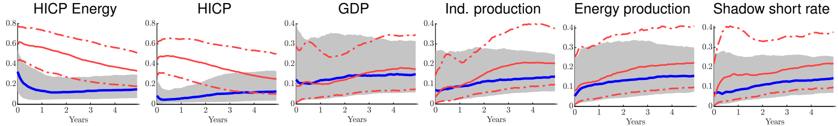


Nonlinear FEVD: Contribution of Energy Supply Shocks

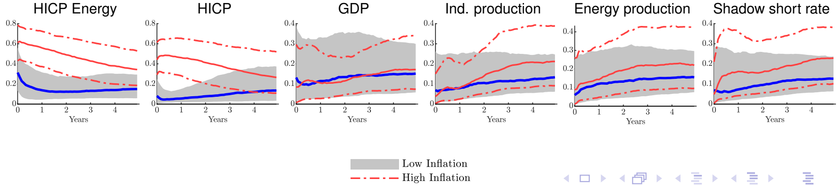
Panel A: Linear model - IRFs (% response to 1 st. dev. shock):



Panel B: Nonlinear FEVD (% response to a shock increasing energy prices by 10%):



Panel D: Nonlinear FEVD (% response to a shock decreasing energy prices by 10%):



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