Nonlinearities with de-anchored inflation expectations

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Research Question I

Do **negative shocks** to **long run inflation expectations** have the same effects as **positive shocks?**

What we know

- **Long-run inflation expectations play a central role for monetary policy** $\rightarrow$ *(de)anchored inflation target*
- The literature concentrates on explaining **microdata surveys**.
  - Exogenous changes in inflation expectations do affect fundamental **economic decisions by households and businesses** - Coibion et al. (2019-2022).
  - Expectations are **biased and volatile** - D'Acunto et al. (2022), Coibion et al. (2019).

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  - Expectations are **biased and volatile** - D'Acunto et al. (2022), Coibion et al. (2019).
- **The 2% target since 2012 is an AVERAGE TARGET:** it implies **a degree of time-variation**, i.e. the central bank may temporarily aim for inflation above or below 2%.
- **Shapiro and Wilson (2022 Restud):** FOMC Implicit Inflation Target was around 1.5% between 2000 and 2011. It was lower than the announced 2%, even after 2012.

- **Shocks to LR inflation expectations: symmetric and not regime dependent**: Neri (2023), Lukmanova and Rabitsch (2021), Mumtaz and Theodoridis (2023)
- **Sign asymmetry in shock transmission**: Barnichon and Matthes (2018), Barnichon, Debortoli, Matthes et al. (2022), Nadav-Ben, Ramey and Zubairy (2023) → *using LP analysis*
- **Shock transmission and inflation regimes**: Castelnuovo, Pellegrino and Særkjær (2023) → *uncertainty shocks*
- **Shocks to inflation expectations shocks and firm dynamics**: Ascari, Fasani, Grazzini and Rossi (2023)

The literature has only concentrated to linear and symmetric effects of shocks to the inflation target

In what we differ

We take a macroeconomic perspective by assessing the effects of **shocks to the implicit inflation target rate (PTR)**. A measure estimated by the FED using **long-run inflation expectations.**

→ Long-horizon inflation expectations are mainly driven by shocks to the implicit inflation target in the medium long-run horizon.

We investigate the sign asymmetry of the shocks

In what we differ

OUR CONTRIBUTION:

(I) We propose a **Threshold VAR** with endogenous inflation regimes and extend Mumtaz and Theodoridies (2023) to the nonlinear case by maximizing **Generalized FEV of PTR**.

(II) With the Nonlinear VAR we investigate implied **sign asymmetry** of the shock.

(III) We propose **medium-scale DSGE model with firm dynamics** to rationalize the results found in the empirical analysis.

What we find

- **A positive shock** to LR inflation expectations (i.e. a shock that increases them) **is inflationary and expansionary**, while **a negative shock** (i.e. a shock that decreases them) **is recessionary and deflationary**.

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- **Positive** versus **Negative** Shocks: **Negative shocks have a stronger effect** on Y, C, I, Net Entry than positive shocks.

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- **Positive** versus **Negative** Shocks: **Negative shocks have a stronger effect** on Y, C, I, Net Entry than positive shocks.
- **Policy Implication:** for CB it is fundamental to monitor LR inflation expectations, but especially in response to negative shocks occurring.

Intuitions: Role of Investment Margins

First order effects

- **A positive shock to the inflation target** is expansionary and inflationary ==> real rate declines, aggregate demand increases
- **Investment in capital increases** (intensive margin)
- **Investment in new firms (Entry) increases** (extensive margin)
- **A negative shock to the inflation target** is recessionary and deflationary ==> The responses are symmetric
- **This explains the results up to a first order approximation**

Intuitions: Role of Investment Margins

Second Order Effect

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Intuitions: Role of Investment Margins

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- "wait and see strategy" for investment decisions in new capital (intensive margin) and new firms (extensive margin)
- **In response to a negative inflation target shock** ==>**Uncertainty amplifies** the negative responses of the two investment margins
- **In response to a positive inflation target shock** ==> **Uncertainty dampens** the positive responses of the two investment margins

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- **This explains the sign asymmetries**

Empirical Analysis

Empirical model

A Bayesian Threshold VAR model

$$Y_t = \left[c_1 + \sum_{j=1}^{P} B_{1,j} Y_{t-j} + \Omega_1^{1/2} e_t \right] S_t + \left[c_2 + \sum_{j=1}^{P} B_{2,j} Y_{t-j} + \Omega_2^{1/2} e_t \right] (1 - S_t) \tag{1}$$

where S_t is an indicator function such that $S_t = 1 \Leftrightarrow Z_{t-d} \leq Z^*$

- The threshold variable Z_t is the annual growth in CPI. The threshold level Z^* is estimated in the model (**median of 3.9pp**).
- The model identifies two regimes: low inflation regime and high inflation regime.
- The estimation employs Bayesian techniques (MH within Gibbs sampler)

Data

Quarterly model from 1962Q1 to 2019Q4 in 5 variables with 4 lags as in Mumtaz and Theodoridis (2023):

$$Y = \begin{bmatrix} \textbf{Implicit inflation Target Rate (PTR)} \\ \log(\text{RGDP}) \\ \log(\text{CPI}) \\ \text{3m T-bill rate} \\ \text{10y bond yield} \end{bmatrix}$$

Adding one at a time to the baseline model the following variables:

$$\begin{bmatrix} \log(\text{Firms' Net Entry}) \\ \log(\text{Consumption}) \\ \log(\text{Investment}) \end{bmatrix}$$

- PTR: Ten-year inflation expectations from the FRB/US model database (spliced series using SPF from 1991 onward).
- Firms' net entry as in Lewis and Winkler (2017) - update.
- Other variables from FRED-QD database.

Shock Identification and Generalized IRFs

Identification of the Target shock:

- We **identify this shock as the one that explains the largest proportion of the forecast error of PTR at horizon k=40 quarters** as in Mumtaz and Theodoridis (2023) but **with max of Generalized FEV**.
- **Rationale:** *Over the medium to long-run horizons the role of implicit inflation target inflation shocks dominates fluctuations in long-run inflation expectations.*

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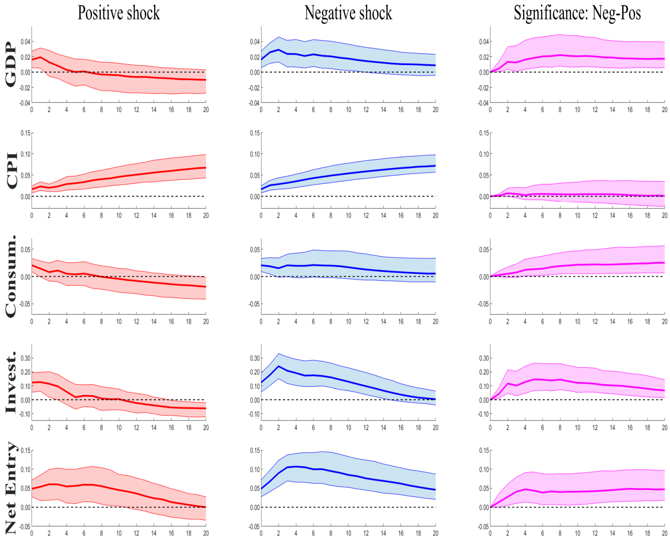
- To detect sign and regime asymmetry we compute **Generalized Impulse Responses Functions** (**Koop et al. (1996)**)

$$GIRF_t^S = E(Y_{t+k} \setminus \Psi_t, Y_{t-1}^S, \mu) - E(Y_{t+k} \setminus \Psi_t, Y_{t-1}^S) \qquad (2)$$

where Ψ_t denotes all the parameters of the model, $k = 40$ is the forecasting horizon under consideration, $S = 0, 1$ denotes the regime and μ is the shock.

Evidence - Sign Asymmetries



Sanity Checks

Sanity Checks

Model Selection Test: DIC (Deviance Information Criteria) prefers

- the TVAR with inflation regimes (-9131) wrt. the Linear VAR (-6934);
- the TVAR with inflation regime (-9131) wrt. TVAR with boom and bust regimes (-8799):
- the TVAR with inflation regime (-9131) wrt. MS with exogenous regimes (-1325).

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Correlations with other shocks: not correlated with oil shocks, TFP, News, Monetary, Fiscal shocks. figure

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Robust wrt. LP with linear and squared target shocks. ==> Advantage of our TVAR: it allows us to account for nonlinearities both at estimation and identification stage. figure

Robustness Analysis

Robustness checks

Testing over different model specifications:

- **sample period**
  - **Restricted:** up to 2007q4 to avoid the GR and ZLB
  - **Extended:** up to 2022q4 to include Covid19 period figure

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- **regime threshold**
  - **Assuming dogmatic prior at** 6% for inflation regime threshold
  - **Assuming dogmatic prior at** 3% for inflation regime threshold ==> Particularly helpful to show that the asymmetry does not come from the great moderation sample. figure

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- **variance-covariance matrix**
  - **Different TVAR specification:** regime-independent Ω figure

Theoretical Analysis

Theoretical Model

Baseline model as in Fasani, Mumtaz, and Rossi (2022).
Four agents: households, firms, a monetary and fiscal authority.
The main ingredients are:

- those of a medium-scale as in Christiano et al. (2005):
  - sticky nominal wages and prices as in Rotemberg (1982);
  - external habits in consumption;
  - investments in physical capital(intensive margin) with convex investments adjustment costs and variable capacity utilization for capital;
- investments in new firms (extensive margin)
  ==> Intensive and Extensive margin of firm investments decisions ==> **Key to get amplification and asymmetric effect**. details

Theoretical Model

Agents Estimate the Inflation Target. firms estimate the inflation target $\widehat{\pi}_t^*$ in setting their price under Rotemberg (1982) pricing.

Price adjustment cost is $\Gamma_{i,t} = \frac{\theta_p}{2}\left\{\frac{P_{i,t}}{(\widehat{\pi}_t^*)^{\alpha} P_{i,t-1}} - 1\right\}^2 Y_t$.

The estimated target evolves according to (in log-dev from ss) - Gürkaynak et al. (2005), Neri (2023):
$\widehat{\pi}_t^* = \rho_{\pi^*}\widehat{\pi}_{t-1}^* + \mu\left(\frac{1}{4}\sum_{i=1}^{4}\widehat{\pi}_{t-i-1} - \widehat{\pi}_{t-1}^*\right) + \varepsilon_{\pi^*,t}$, where $\widehat{\pi}_t$ is inflation, $\rho_{\pi^*} \in (0,1)$ and $\varepsilon_{\pi^*,t} \sim N\left(0, \sigma_{\pi^*}^2\right)$.

- **The shock $\varepsilon_{\pi^*,t}$** captures exogenous changes in firms' estimate of the target.
- **The parameter μ is the gain.** It measures the strength with which firms revise their estimate of the target based on the deviations of past inflation from the previous period estimate.

Theoretical Model

Taylor-type rule and Inflation Target:

$$\ln\left(\frac{1+i_t}{1+i}\right) = \phi_R \ln\left(\frac{1+i_{t-1}}{1+i}\right) +$$
$$+(1-\phi_R)\left(\phi_\pi \log\left(\frac{\pi_t}{\bar{\pi}_t}\right) + \phi_y \log\left(\frac{y_t}{y}\right) + \phi_{dy} \log\left(\frac{y_t}{y_{t-1}}\right)\right)$$

The Inflation Target is time varying:
Ireland (2007), Cogley, Primiceri and Sargent (2010):

$$\ln\left(\frac{\bar{\pi}_{t+1}}{\bar{\pi}}\right) = \rho_\pi \ln\left(\frac{\bar{\pi}_t}{\bar{\pi}}\right) + \sigma_\pi u_{\varepsilon,t+1}$$

Model solution: simulation and estimation

- **Model solution**: Second-order approximation of the non-linear DSGE Models
- **Impulse response functions**
  - benchmark: in deviation from the stochastic steady state in the absence of shocks (IRF)
  - robustness: in deviation from the ergodic mean (GIRF)
- **Model estimation**: estimation of the key model parameters via IRFs matching (empirical vs theoretical ones)

Model IRFs: Sign Asymmetries

Positive vs. Negative shock with initial guess

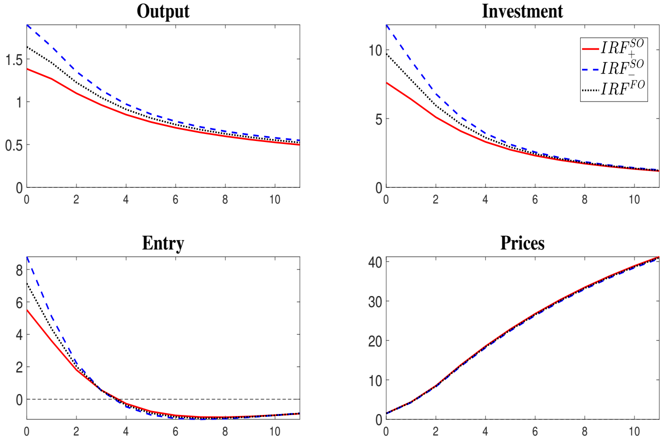


Figure: **Model dynamics: FO vs SO Approximation**

Model IRFs: Sign Asymmetries
Inspecting the channels

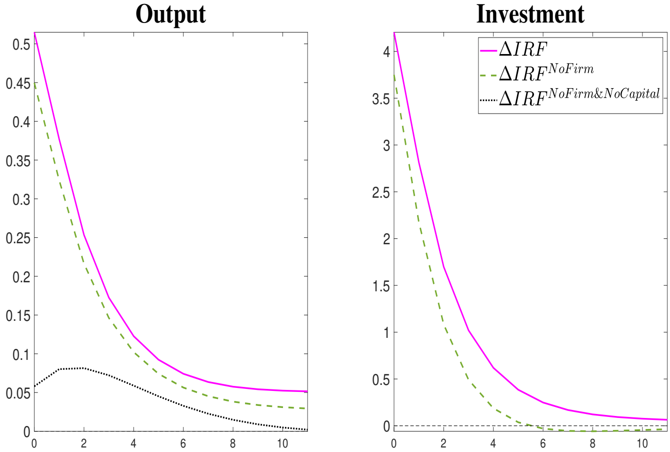


Figure: **Model dynamics:** IRF^{-} **minus** IRF^{+}

Simulating the Model to different innovations
Inflation Target Shock ranging ±4%

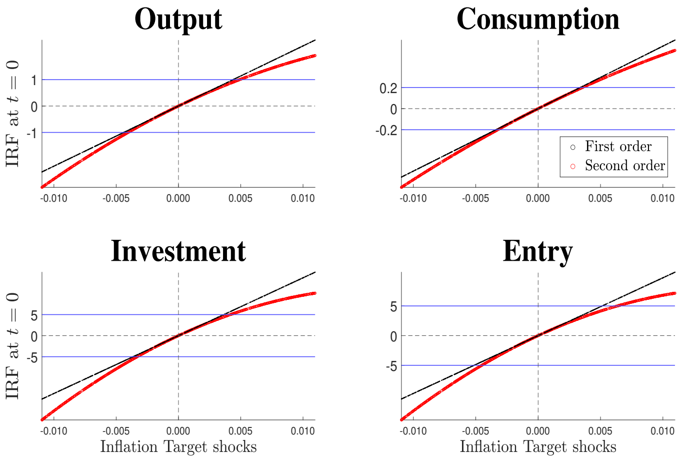
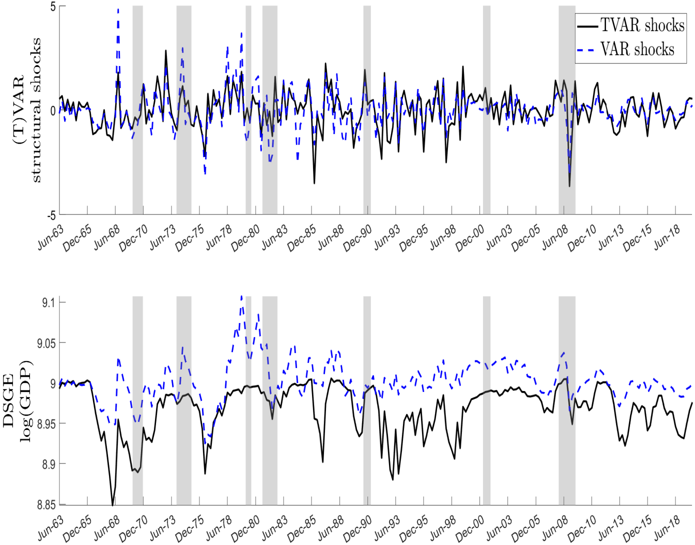


Figure: **Impact response: FO vs SO Approximation**

Simulating the Model with TVAR and VAR shocks
Uncertainty and downside risk



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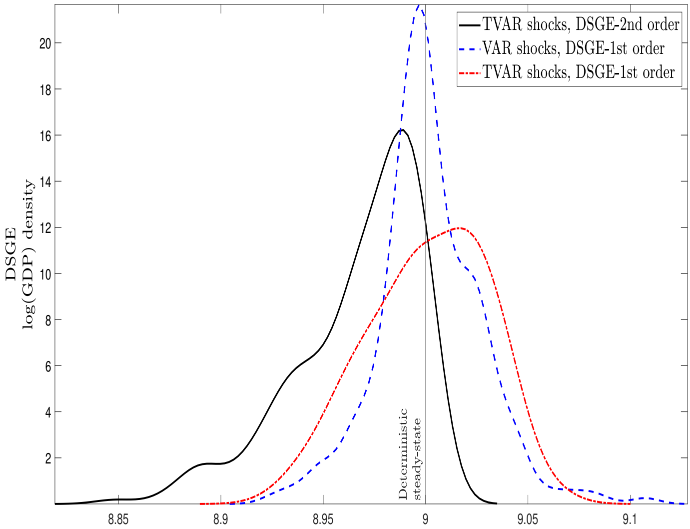


IRF Matching Estimation

Estimated Parameters

Parameter	Description	Estimate
γ_p	Rotemberg adjustment cost - Price	42.94
γ_w	Rotemberg adjustment cost - Wage	68.60
γ_i	Capital adjustment cost	4.98
σ_π	Standard deviation of inflation target shock	0.0061
ρ_π	Persistence inflation target shock	0.88
ϕ_π	Inflation feedback coefficient	2.86
ϕ_y	Output feedback coefficient	0.01
ϕ_{dy}	Output growth feedback coefficient	0.04
ϕ_R	Interest rate smoothing	0.0002
γ_2	Capital utilization coefficient	1.02
ς_e	Entry congestion coefficient	2.15
ς_x	Exit congestion coefficient	1.13
σ_C	Inverse elasticity of substitution	1.13
σ_L	Labor supply elasticity	2.15
h	Consumption habit coefficient	0.34
μ	Gain in inflation expectations	0.014

Model IRFs, Negative shock
IRFs with Estimated Parameters

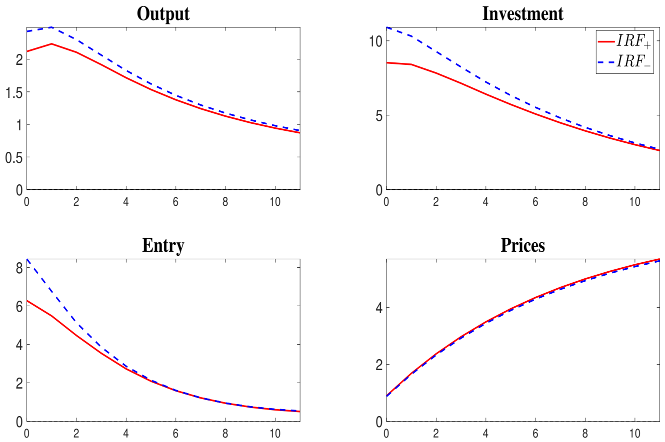
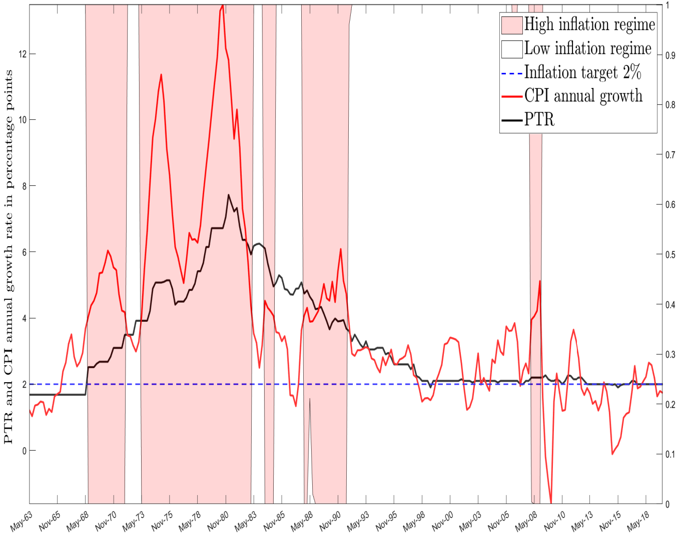


Figure: **Model Dynamics with estimated parameters**

Conclusions

- Shocks that increase (decrease) LR inflation expectations are expansionary and inflationary (recessionary and deflationary). They **affect output, consumption, investment, inflation, firm entry**
- **Sign Asymmetries**: shocks that decrease LR inflation expectations have stronger effects than shocks that increase LR inflation expectations
- **Investments (Intensive and Extensive margins)**: are key to get the non-linear and asymmetric effects
- **Policy implication**: be aware of negative shocks to LR inflation expectations.
- **Next Steps**: Tvar with simulated data

PTR and inflation regimes



PTR and inflation regimes

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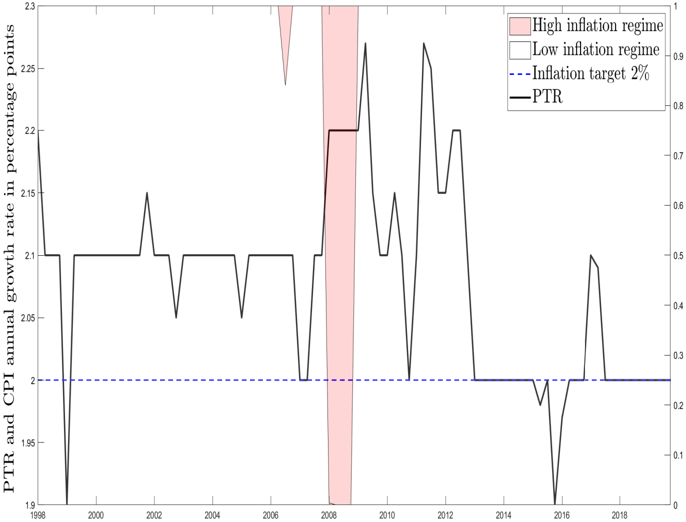

Sign Asymmetries: further variables

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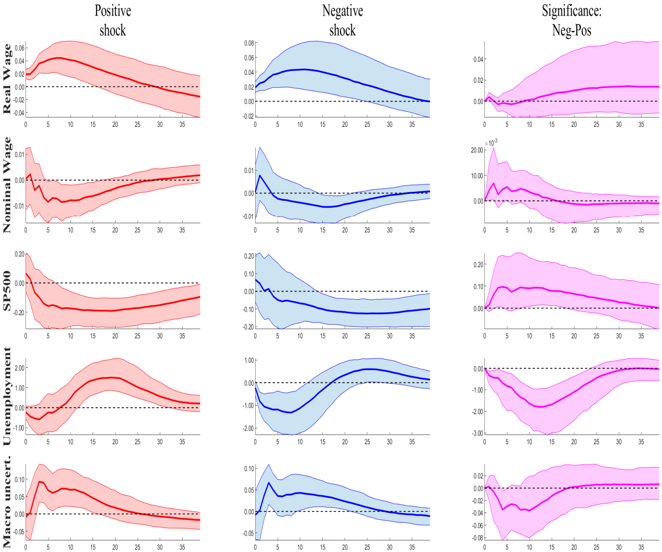

High and Low Inflation Regimes

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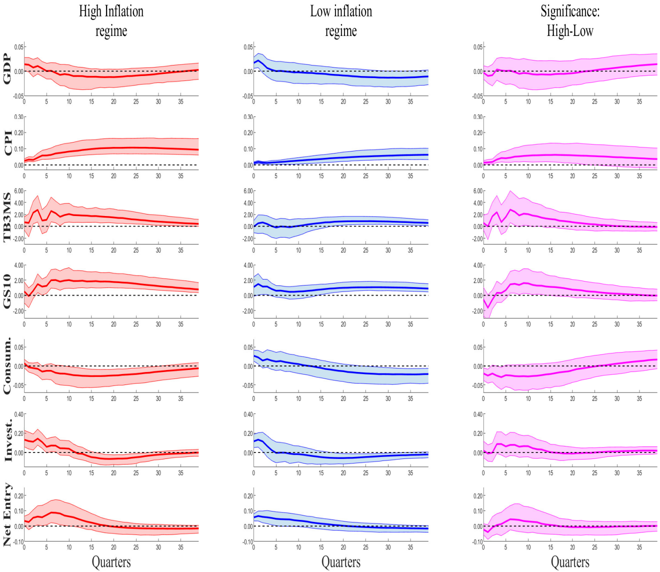
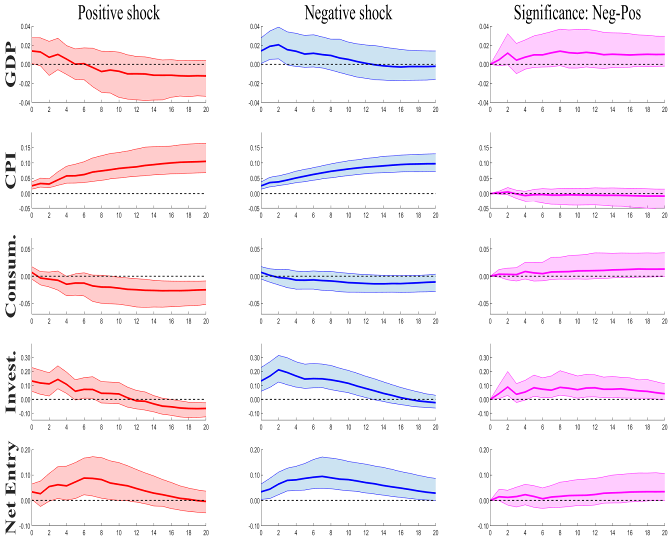


Sign Asymmetries in High Inflation regime



Sign Asymmetries in Low Inflation regime

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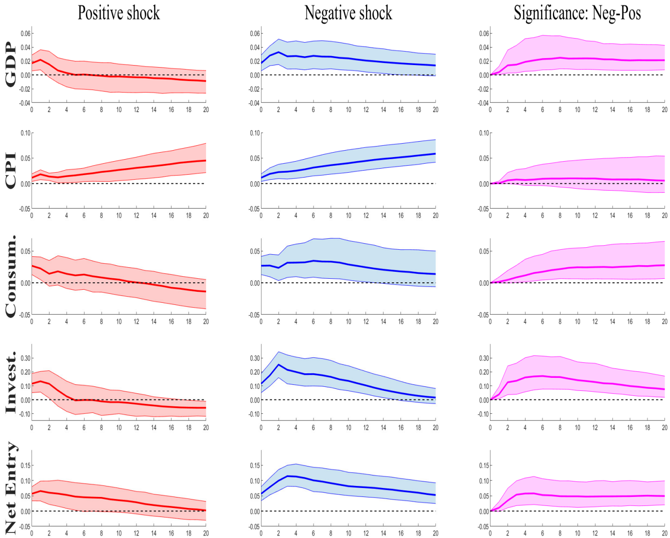

Forecast Error Variance Decomposition

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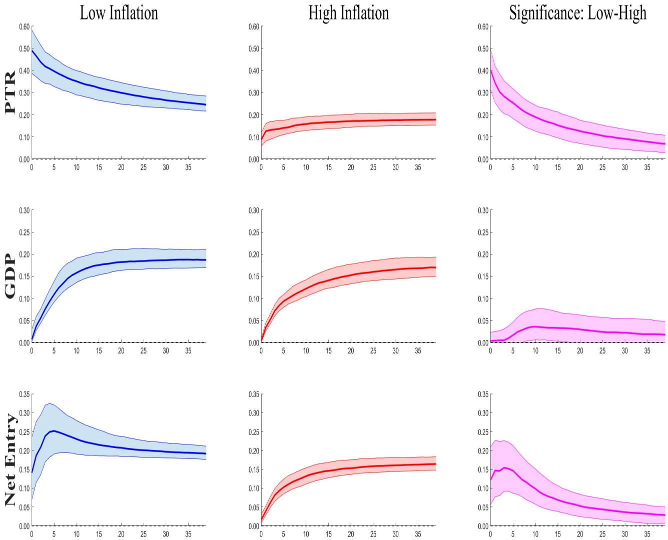
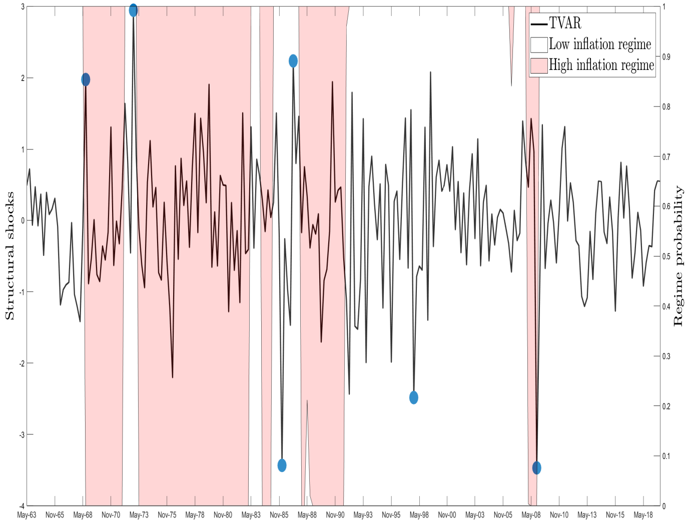


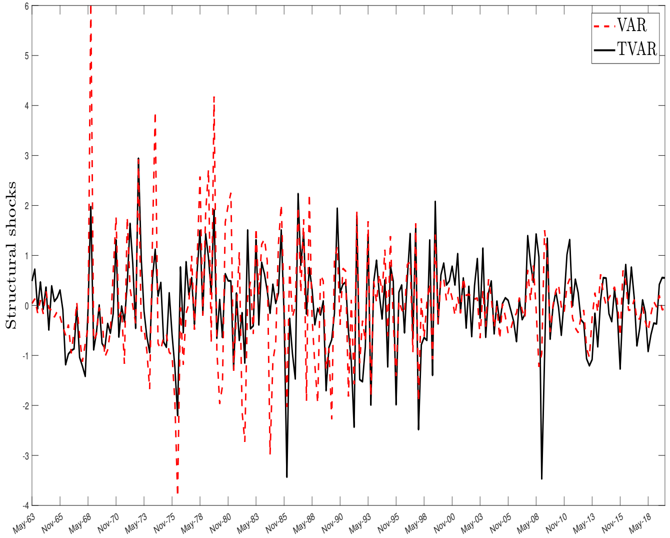


TVAR
Low inflation regime
High inflation regime
Structural shocks
Regime probability
May-63
Nov-65
May-68
Nov-70
May-73
Nov-75
May-78
Nov-80
May-83
Nov-85
May-88
Nov-90
May-93
Nov-95
May-98
Nov-00
May-03
Nov-05
May-08
Nov-10
May-13
Nov-15
May-18

Date	Shock	Declarations and empirics	Source
1968:Q3	1.97	*"Inflationary psychology were prevalent and pervasive."*	FOMC meeting
1972:Q4	2.94	(Newspaper) *"headlines significantly contributed to inflationary psychology."*	FOMC meeting
1986:Q1	-3.43	*"Public confident of reduction in trend inflation rate."*	Richmond Fed
1987:Q1	2.24	*"Expected inflation rates contributed to the sharp steepening of the yield curve."*	Kansas Fed
1997:Q4	-2.48	*"Survey of inflation expectations were "impressive"* for *the sizable drop in long-term expectations."*	FOMC meeting
2008:Q4	-3.47	*"More explicit indication of their views on what longer run rate of inflation would forestall the development of expectations that inflation would decline below desired levels."*	FOMC meeting

Structural shocks

Shocks in TVAR and VAR - 5 variables back



Structural shocks correlations

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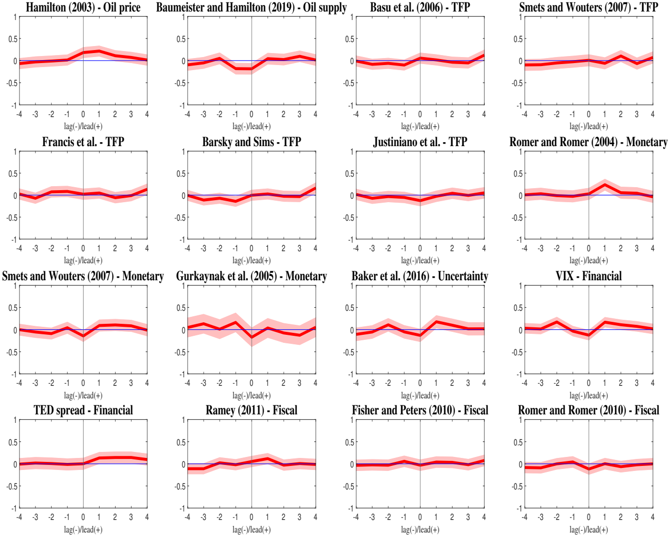

TVAR vs Local Projections

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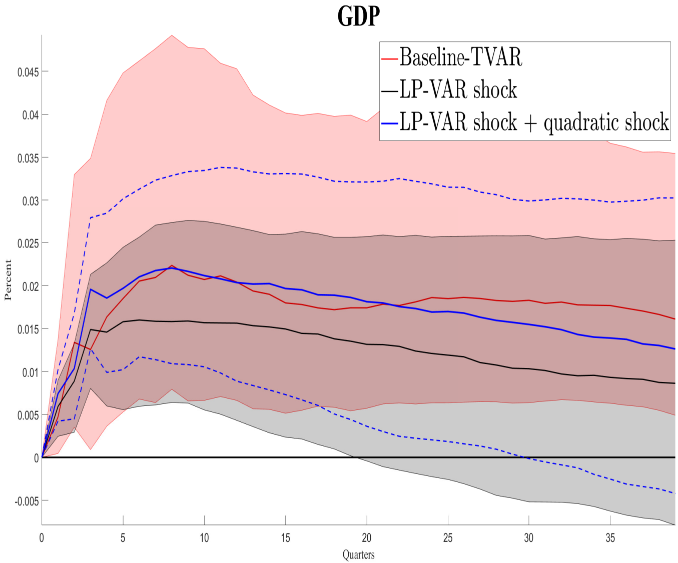
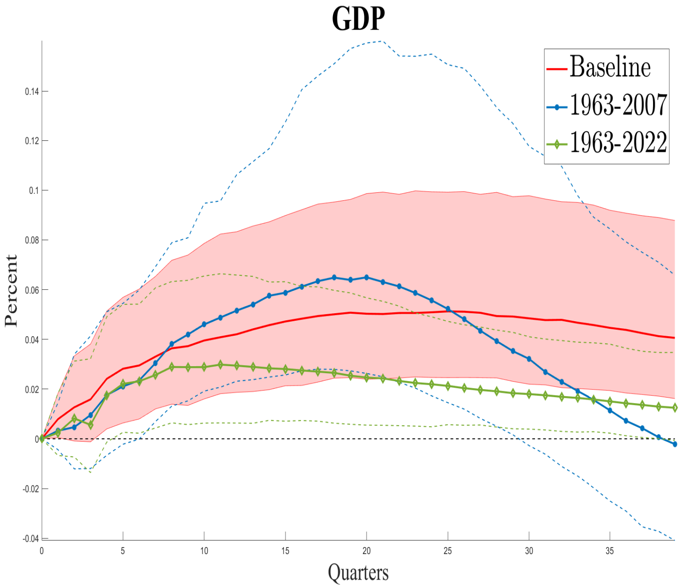


Significance: Negative minus Positive

Positive values indicate higher impact for negative shocks

back



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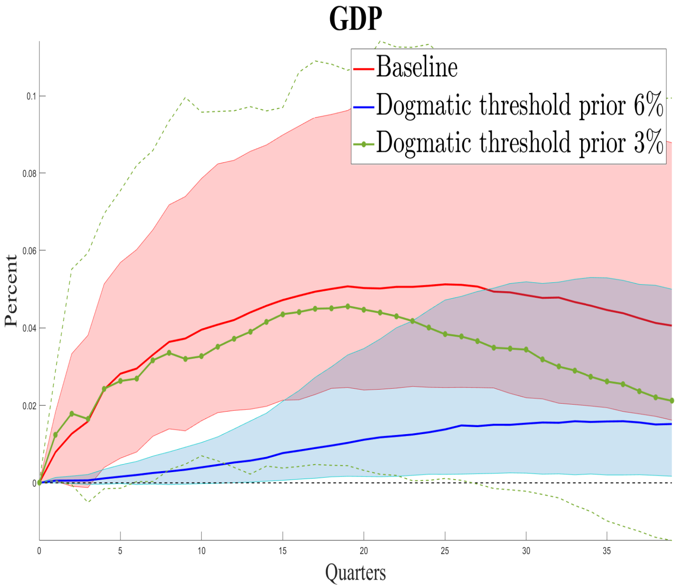
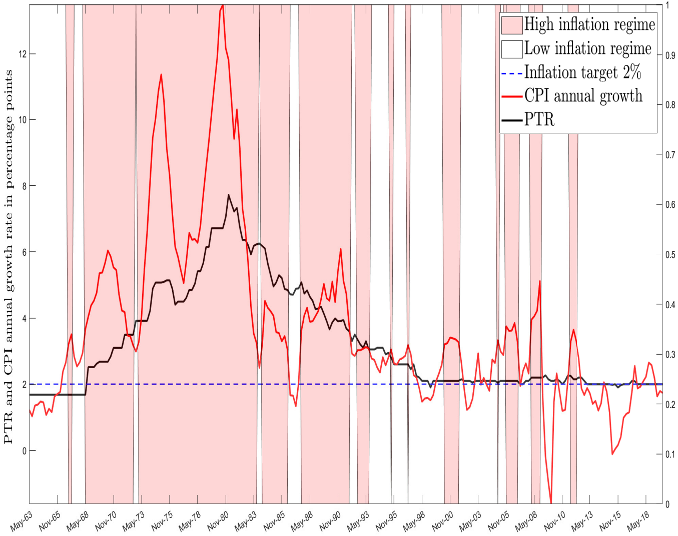


PTR and inflation regimes
Dogmatic threshold prior 3%



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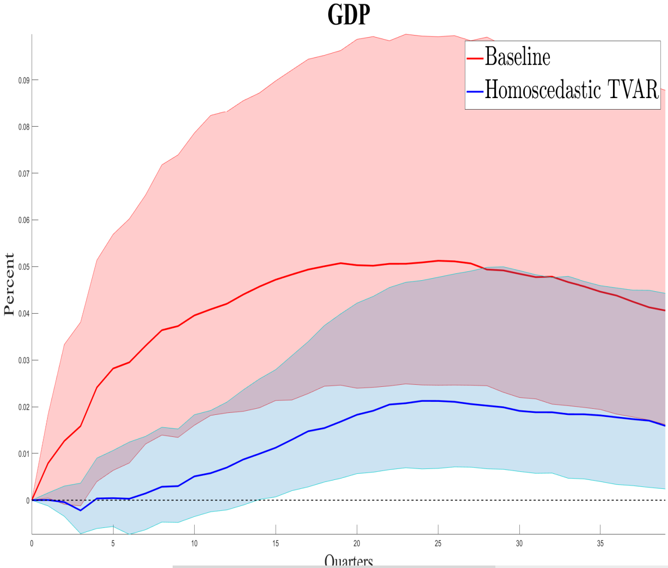

Theoretical Model

Entry Condition: At the beginning of the period, households invest in new firms until the following entry condition is satisfied:

$$v_t\left(\widetilde{z}\right) = FEX_t, \tag{3}$$

that is until the average firm's value equals the entry costs.

The value of the firm facing the average productivity corresponds to the stock price of the economy:

$$v_t\left(\widetilde{z}_t\right) = \beta E_t\left[\frac{\lambda_{t+1}}{\lambda_t}\left(\left(1-\eta_{t+1}\right)\left(v_{t+1}\left(\widetilde{z}_{t+1}\right) + j_{t+1}\left(\widetilde{z}_{t+1}\right)\right) + \eta_{t+1} l v_{t+1}\right)\right], \tag{4}$$

Exit Condition: Both new entrants and incumbent firms decide to produce as long as $z_{\iota,t} \geq \overline{z}_t$, which is above the **cutoff level of productivity** that makes the sum of current and discounted future profits equal to the liquidation value, lv_t. Thus the exit condition is:

$$v_t\left(\bar{z}_t\right) = lv_t, \tag{5}$$

where the value of the firm with a productivity level equal to the marginal value $\overline{z}_t$ is:

$$v_t\left(\bar{z}_t\right) = j_t\left(\bar{z}_t\right) + \beta E_t\left[\frac{\lambda_{t+1}}{\lambda_t}\left(1-\eta_{t+1}\right) v_{t+1}\left(\bar{z}_{t+1}\right)\right]. \tag{6}$$

back

Model IRFs: Different shocks

Target vs. Estimated Target shock