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Financial conditions and monetary policy: the importance of non-linear effects

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Policymaking in an age of shifts and breaks

Speech by Christine Lagarde, President of the ECB, at the annual Economic Policy Symposium "Structural Shifts in the Global Economy" organized by Federal Reserve Bank of Kansas City in Jackson Hole, 25 August 2023.

Unprecedented shocks during 2020 – 2023
Covid-19 pandemic.
War in Europe.
New geopolitical landscape.
Accelerating climate change.

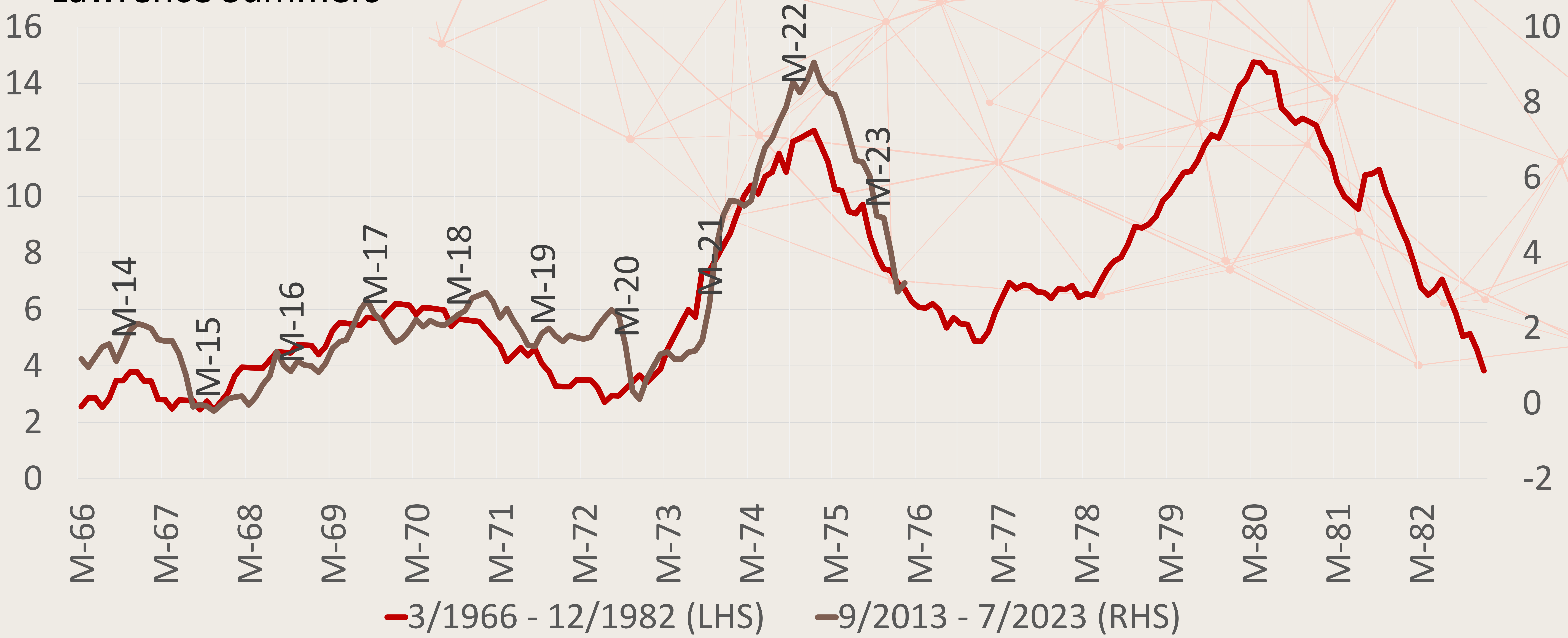
Effects
Partial shutdown of the global economy.
Changes in energy markets.
Changes in trade patterns.
Forcing to decarbonize the economy.

Impacts of these shifts on central banking
Return of high inflation globally.
Inflation forced central banks to tighten monetary policy.
We may be entering an age of shifts in economic relationships and breaks in established regularities.

We rely on past regularities to understand the distribution of shocks we are likely to face, how they will transmit through the economy, and how policies can best respond to them. But if we are in a new age, past regularities may no longer be a good guide for how the economy works. So, how can we continue to ensure stability?

Consumer Price Index: Total All Items for the United States, Growth rate same period previous year, Monthly, Not Seasonally Adjusted

"This picture should be sobering to anyone convinced that we have reattained price stability."
Lawrence Summers



Source: U.S. Bureau of Labor Statistics.

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Shifts in the global economy
1) profound **changes in the labor market** and the nature of work → more inelastic labor supply and digitalization.
2) **energy transition**, which in tandem with accelerating climate change is triggering profound transformations in global energy markets → more inelastic energy supply.
3) deepening **geopolitical divide** and a **global economy that is fragmenting** into competing blocs → more inelastic aggregate supply.

Two questions about key economic relationships
1) **are the shocks driving economic fluctuations changing?** From demand driven fluctuations to supply side shocks due to climate change, with oil and gas becoming less elastic while renewables still face intermittency and storage challenges, and trade fragmentation and de-globalization. Policy responses as defense spending, investment in energy transition and digital transformation that move the economy.
2) **how do these shocks transmit through the economy?** With higher investment needs, inelastic supply curves and more flexible price- and wage-setting behaviors, there will be larger relative price shocks.

Robust policymaking in an age of shifts and breaks
1) provide **clarity** on 2% inflation objective, and on unwavering commitment to deliver on it.
2) need **flexibility** in our analysis by constructing policy frameworks that capture the complexity we face and provide a hedge against it. In the ECB's case future decision contingent on inflation outlook, the dynamics of underlying inflation and the strength of monetary policy transmission.
3) **humility** to be clear about the limits of what we currently know and what our policy can achieve.

Source: *https://www.ecb.europa.eu/press/key/date/2023/html/ecb.sp230825~77711105fe.en.html*

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Inflation, central bank reforms, exchange rate flexibility, and inflation targeting regime

Average inflation	1980-1989	1990-1999	2000-2009	2010-2017	Positive reforms towards CB independence	Exchange rate flexibility	Year of Inflation Targeting introduction
Brazil	121.7	147.1	6.6	6.4	1988	1999	1999
Chile	19.9	11.8	3.5	2.5	1975 and 1989	1999	1999
Colombia	20.8	19.9	6.1	3.8	1992	1999	1999
Mexico	69.9	20.5	5.2	3.9	1985 and 1993	1995	2001
Peru	111.0	78.5	2.6	3.1	1992	2002	2002

What was the role played by the inflation formation processes, monetary policy, and shock volatilities in these disinflationary episodes?

Monetary Small Open Economy General Equilibrium Model

- Open-economy IS curve:

$$y_t = E_t\{y_{t+1}\} - \big(\tau + \alpha(2-\alpha)(1-\tau)\big)\big(r_t - E_t\pi_{t+1} - \rho_a a_t + \alpha E_t\{q_{t+1}\}\big) + \alpha(2-\alpha)\tfrac{1-\tau}{\tau}E_t\{\Delta y^*_{t+1}\}$$

- Open-economy Phillips curve:

$$\pi_t = \frac{\beta}{1+\beta\chi_p\xi_t^{sp}}E_t\{\pi_{t+1}\} + \frac{\chi_p\xi_t^{sp}}{1+\beta\chi_p\xi_t^{sp}}\pi_{t-1} + \alpha\beta E_t\{\Delta q_{t+1}\} - \alpha\Delta q_t + \frac{\kappa\xi_t^{sp}}{\tau+\alpha(2-\alpha)(1-\tau)}(y_t - \bar{y}_t)$$

- Interest rate rule:

$$r_t = \rho_r\xi_t^{sp}r_{t-1} + \big(1-\rho_r\xi_t^{sp}\big)\big(r_\pi\xi_t^{sp}\pi_t + r_y\xi_t^{sp}y_t + r_{\Delta e}\xi_t^{sp}\Delta e_t\big) + \sigma_{r,\xi_t^{vol}}\varepsilon_{r,t}$$

- Nominal exchange rate $\left(\frac{\#\text{ of } LCU}{1\ USD}\right)$ determination:

$$\pi_t = \Delta e_t + (1-\alpha)\Delta q_t + \pi_t^*$$

- Evolution of technology

$$a_t = \rho_a a_{t-1} + \sigma_{a,\xi_t^{vol}}\varepsilon_{a,t}$$

Summary of the parameter estimates

Interest rate rule:

$$r_t = \rho_r \xi_t^{sp} r_{t-1} + \left(1 - \rho_r \xi_t^{sp}\right)\left(r_\pi \xi_t^{sp} \pi_t + r_y \xi_t^{sp} y_t + r_{\Delta e} \xi_t^{sp} \Delta e_t\right) + \sigma_{r,\xi_t^{vol}} \varepsilon_{r,t}$$

High / Low: $r_\pi \xi_t^{sp}$	ρ_r	r_π	r_y	$r_{\Delta e}$
Brazil	0.76 / 0.64	2.31 / 1.27	0.30 / 0.50	0.30 / 0.43
Chile	0.67 / 0.54	2.50 / 0.81	0.25 / 0.42	0.17 / 0.12
Colombia	0.75 / 0.61	2.51 / 0.91	0.30 / 0.67	0.20 / 0.38
Mexico	0.68 / 0.48	1.70 / 0.91	0.28 / 0.56	0.13 / 0.74
Peru	0.58 / 0.46	1.94 / 1.01	0.47 / 0.64	0.19 / 0.25

Open-economy Phillips curve:

$$\pi_t = \frac{\beta}{1+\beta\chi_p\xi_t^{sp}} E_t\{\pi_{t+1}\} + \frac{\chi_p \xi_t^{sp}}{1+\beta\chi_p\xi_t^{sp}} \pi_{t-1} + \alpha\beta E_t\{\Delta q_{t+1}\} - \alpha \Delta q_t + \frac{\kappa \xi_t^{sp}}{\tau + \alpha(2-\alpha)(1-\tau)} (y_t - \bar{y}_t)$$

High / Low: $\kappa \xi_t^{sp}$	$E_t\{\pi_{t+1}\}$	π_{t-1}	$E_t\{\Delta q_{t+1}\}$	$(y_t - \bar{y}_t)$
Brazil	0.74 / 0.80	0.25 / 0.19	-0.09	2.35 / 1.72
Chile	0.64 / 0.70	0.35 / 0.30	-0.11	0.62 / 0.39
Colombia	0.73 / 0.58	0.26 / 0.42	-0.18	3.47 / 1.42
Mexico	0.62 / 0.56	0.37 / 0.44	-0.16	2.80 / 2.17
Peru	0.83 / 0.70	0.16 / 0.30	-0.12	4.54 / 2.18

Mexico: switching parameters and shocks estimates and regime probabilities

High interest rate response	Low interest rate response
$r_t = 0.68r_{t-1} + (1-0.68)(1.70\pi_t + 0.28y_t + 0.13\Delta e_t)$	$r_t = 0.48r_{t-1} + (1-0.48)(0.91\pi_t + 0.56y_t + 0.74\Delta e_t)$

High Phillips curve	Low Phillips curve
$\pi_t = 0.62E_t\{\pi_{t+1}\} + 0.38\pi_{t-1} - 0.16\Delta q_t + 2.80(y_t - \bar{y}_{t-1})$	$\pi_t = 0.56E_t\{\pi_{t+1}\} + 0.44\pi_{t-1} - 0.16\Delta q_t + 2.17(y_t - \bar{y}_{t-1})$

High shocks volatility	Low shocks volatility
$\sigma_{a,\xi_t^{vol=h}} = 7.51$	$\sigma_{a,\xi_t^{vol=l}} = 3.03$

$H_{h,l}^{mp} = 0.06$

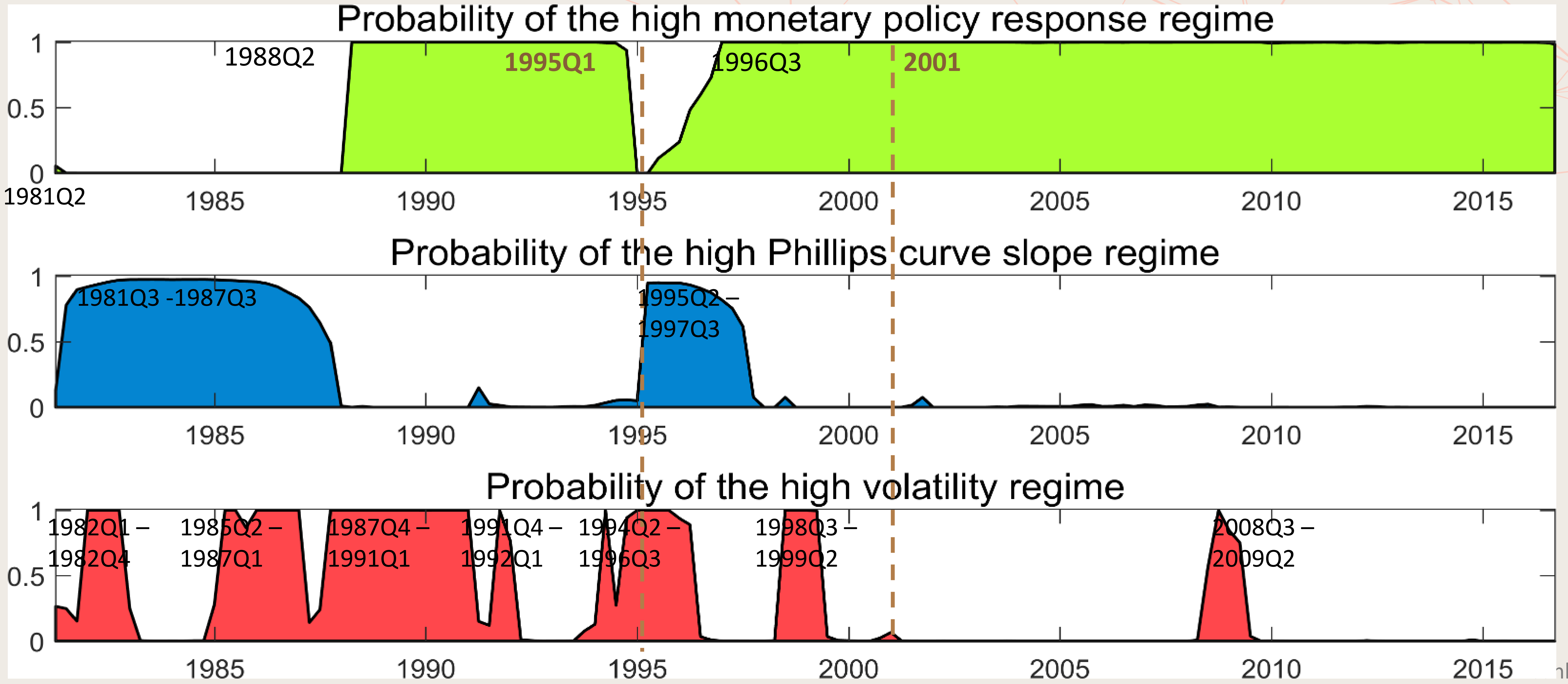
$H_{l,h}^{mp} = 0.09$

$H_{h,l}^{pc} = 0.14$

$H_{l,h}^{pc} = 0.09$

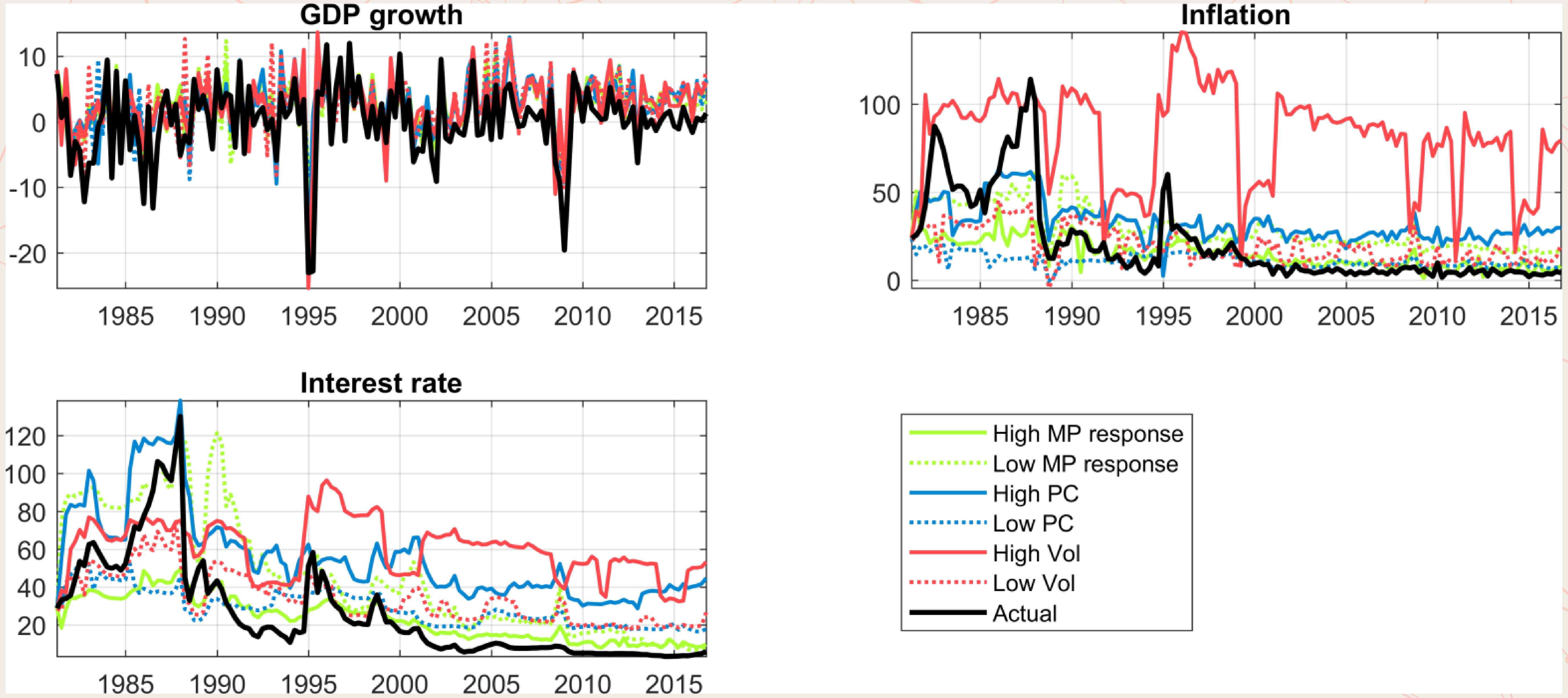
$H_{h,l}^{vol} = 0.10$

$H_{l,h}^{vol} = 0.19$



Mexico: counterfactuals

In Mexico, regime switch to H_MP, L_PC and especially L_Vol help to explain the observed reduction of inflation and its volatility without implying higher interest rates, neither lower or more volatile output.



	Output Growth		Inflation		Interest Rate	
	M	SD	M	SD	M	SD
High MP	2.69	4.41	15.26	8.30	23.23	11.38
Low MP	2.97	5.17	29.55	12.29	45.58	31.77
High PC	2.46	4.33	32.38	11.04	55.90	24.04
Low PC	2.42	3.99	11.08	3.89	28.91	9.46
High Vol	2.34	4.71	81.99	27.70	60.41	14.72
Low Vol	2.58	5.08	19.81	10.31	33.71	13.19
Actual	0.00	5.73	21.00	24.78	25.76	26.36

Conclusions

	Inflation Targeting	Change in monetary policy	Change in slope of PC	Change in Volatility
Brazil	1999	↑ 1999Q3	↑ 1999Q3	↓ 1999Q4
Chile	1999	↓ 2008Q1-200894	↑ 2007Q2 – 2009Q1	↑ 2008Q1 – 2010Q4
Colombia	1999	↑ 1999Q1	↓ 1999Q2	↓ 1999Q1
Mexico	2001	↑ 1988Q2	↓ 1987Q4	↓ 1996Q3
Peru	2002	↑ 2003Q2	↓ 2004Q1	↓ 2001Q4

Inflation and its volatility relative to data under the alternative counterfactuals

	High MP	Low MP	High PC	Low PC	High Vol	Low Vol
Brazil	-5.1 / -1.3	3.7 / 0.2	0.8 / -0.8	0.1 / 0.0	1.2 / -1.4	-0.4 / 0.1
Chile	-1.3 / 1.1	1.0 / 1.8	0.3 / 1.4	0.3 / 1.3	-0.3 / 1.4	0.5 / 1.4
Colombia	-1.1 / -2.2	13.2 / 2.4	6.5 / 3.9	-2.3 / -0.3	1.2 / 0.7	1.9 / -0.6
Mexico	-5.7 / -16.5	8.6 / -12.5	11.4 / -13.7	-9.9 / -20.9	61.0 / 2.9	-1.2 / -14.5
Peru	-0.3 / -0.8	3.7 / 4.9	0.7 / 3.7	-0.1 / -0.2	5.8 / 1.9	0.2 / 1.2

Episodic nature of financial factors

"… a reason why statistically significant and macroeconomically important linkages have been elusive is because the importance of financial factors tends to be episodic in nature.

In "normal times," firms make investment decisions on the basis of whether a project's expected rate of return exceeds the user cost of capital, and then having made that decision, seek the financing. In such times, the financing decision is, in some sense, subordinate to the real-side decisions of the firm; credit "doesn't matter."

In other times, when the financial system is not operating normally, financial frictions become important as lending terms and standards tighten, making the interest rate a much less reliable metric of the cost of funds, broadly defined. During such times, which we will call stress events; credit can seem like it is the only thing that matters."

Kirstin Hubrich and Robert J. Tetlow (2015). **Financial stress and economic dynamics: The transmission of crises**. Journal of Monetary Economics, 70: 100 -115.

This paper

- Provides evidence of the importance of considering switching parameters (non-linearities) and switching variance (heteroscedasticity) when analyzing macro-financial linkages in the US.
- To do so, we estimate Markov-switching Vector Autoregression (**MS-VAR**) and a Markov-switching Dynamic Stochastic General Equilibrium (**MS-DSGE**) macroeconomic models with financial frictions in long-term debt instruments developed by Carlstrom, Fuerst and Paustian (2017, AEJ: Macro).
- Based on a Maximum Likelihood model fit criterion, the introduction of Markov-switching in parameters and variances improves the fit of macroeconomic VAR models with financial variables.
- Likewise, the introduction of Markov-switching in parameters and especially in variances, also greatly improves the Maximum Likelihood fit of the DSGE macroeconomic models with financial frictions.

This paper

- To fit the data, an estimated time-invariant DSGE produces larger shocks relative to a DSGE model with Markov-switching in parameters.
- An estimated DSGE without Markov-switching in parameters misinterprets structural regime switches as large shocks events.
- Meanwhile, an estimated DSGE without Markov-switching in shocks overestimates the high coefficients regimes.
- The impulse response functions are markedly different depending on the regime the economy is under.
- Using the MS-DSGE model specification with the best fit to the data (*2S2R3V*) we:
  - (i) provide evidence on how financial conditions have evolved in the US since 1962,
  - (ii) show how the Federal Reserve Bank has responded to the evolution of term premiums,
  - (iii) perform counterfactual analysis of the potential evolution of macroeconomic and financial variables under alternative financial conditions and monetary policy responses.

Financial conditions, economic activity and monetary policy

“To the extent that the decline in forward rates can be traced to a decline in the term premium*, …, the effect is financially stimulative and argues for greater monetary policy restraint, all else being equal. Specifically, if spending depends on long-term interest rates, special factors that lower the spread between short-term and long-term rates will stimulate aggregate demand. Thus, when the term premium declines, a higher short-term rate is required to obtain the long-term rate and the overall mix of financial conditions consistent with maximum sustainable employment and stable prices.”

FRB Chairman Ben S. Bernanke, March 20, 2006, “***Reflections on the Yield Curve and Monetary Policy***.”

***Term premium**: extra compensation required by investors for bearing interest rate risk associated with short-term yields not evolving as expected.

US GDP Growth, Federal Funds Rate and Term Premium

Correlation between the cyclical components of 1) GDP and term premium = −0.53; 2) federal funds rate and term premium = −0.36; 3) GDP and federal funds rate is 0.47.

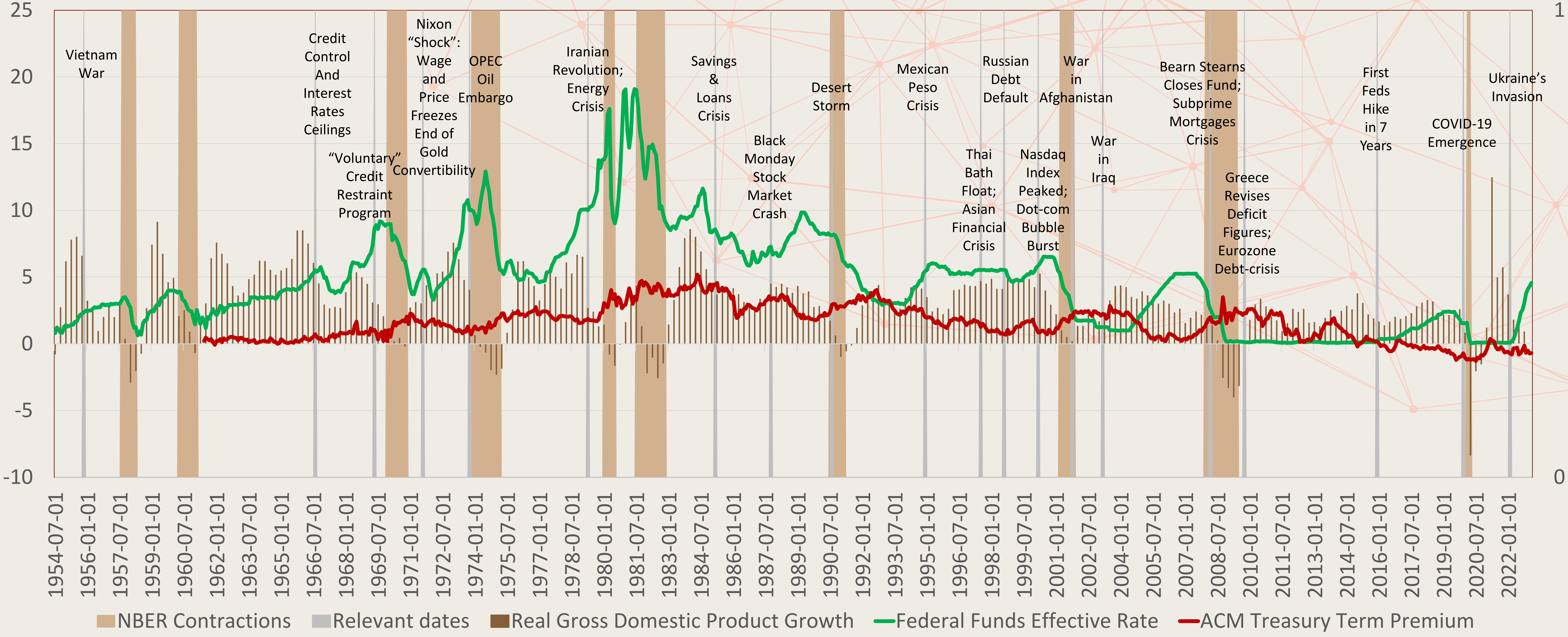


Figure 1: GDP is the growth rate of the real gross domestic product (GDPC1 in Fred Economic Data from the Federal Reserve Bank of St. Louis), federal funds rate is the effective federal funds rate (FEDFUNDS also in Fred Economic Data), term premium is the 10-year Treasury term premium computed following the methodology of Adrian, Crump and Moench (2013) and reported by the Federal Reserve Bank of New York (ACM10TP), and contractions are as dated by the NBER's Business Cycle Dating Committee.

MS-VAR

- The specification adopts the spirit of smoothly time-varying parameters in VAR models presented by Primiceri (2005, RES), Cogley and Sargent (2005, RED) and Bianchi and Melosi (2017, AER). Following Hubrich and Tetlow (2015, JME) consider a nonlinear vector stochastic process of the following form:

$$y_t' A_0(s_t^c) = \sum_{l=1}^{p} y_{t-1}' A_l(s_t^c) + z_t' B(s_t^c) + \varepsilon_t' \Xi^{-1}(s_t^v) \qquad (1)$$

where $\boldsymbol{y}$ is a vector of endogenous variables, $\boldsymbol{z}$ is a matrix of exogenous variables and $\boldsymbol{\varepsilon}$ is a vector of innovations, while $A_0(s_t^c)$, $A_l(s_t^c)$ and $B(s_t^c)$ are matrices of Markov-switching parameters and $\Xi^{-1}(s_t^v)$ is a matrix of Markov-switching variances.

$s^m, m = \{c, v\}$ are unobservable (latent) state variables, one for intercepts and coefficients, $\boldsymbol{c}$, and one for variances, $\boldsymbol{v}$. The values of s_t^m are elements of $\{1, 2, \cdots, h^m\}$ and evolve according to a first-order Markov process:

$$\Pr(s_t^m = i | s_{t-1}^m = k) = p_{ik}^m, \qquad i, k = 1, 2, \cdots, h^m$$

- Our set of endogenous variables is: $y_t = [C, P, R, M, Tp]'$, where $\boldsymbol{C}$ denotes the quarterly growth in personal consumption expenditures; $\boldsymbol{P}$ is CPI inflation; $\boldsymbol{R}$ is the nominal federal funds rate; $\boldsymbol{M}$ is growth in the nominal M2 monetary aggregate; and $\boldsymbol{Tp}$ represents the 10-year Treasury term premium from reported by the Federal Reserve Bank of New York (ACM10TP).

MS-VAR evidence of switching coefficients and/or switching variance

Model specification	Posterior density
$1c1v$	-2134.26
$2c1v$	-2116.98
$1c2v$	-2091.26
$2c2v$	-2087.19
$2cTPR3v$	-2074.19
$2cTPC3v$	-2071.41
$2cTPCP3v$	-2066.24
$3c3v$	-2052.12
$2cTP3v$	-2039.96
$1c3v$	-2014.16
$2cRMC3v$	-2008.31
$2cTPRM3v$	-1996.48
$2cRM3v$	-1986.39
$2c3v$	-1961.13*

Table 1: MS-VAR estimation results. Posterior modes are in logarithms for the estimated models

Why MS-DSGE?

- Give economic interpretation to changes in parameters and variances.
  - Parameters: financial frictions and monetary policy response to financial conditions.
  - Variances: volatility of credit market shocks.
- Analyze potential mechanisms.
- Perform counterfactual experiments.

Model: households

Each household chooses consumption, C_t, labor supply, H_t, short-term deposits in the financial intermediary (FI), D_t, investment bonds, F_t, investment, I_t, and next-period physical capital K_{t+1} to:

$$\max_{\{C_{t,} H_t, D_t, F_t, I_t, K_{t+1}\}_{t=0}^{\infty}} E_0 \left\{ \sum_{t=0}^{\infty} \beta^t e^{rn_t} ln(C_t - hC_{t-1}) - L\frac{H_t^{1+\eta}}{1+\eta} \right\} \quad (2)$$

subject to:

$$C_t + \frac{D_t}{P_t} + P_t^k I_t + \frac{F_{t-1}}{P_t} \leq W_t H_t + R_t^k K_t - T_t + \frac{D_{t-1}}{P_t} R_{t-1} + \frac{Q_t(F_t - \kappa F_{t-1})}{P_t} + div_t \quad (3)$$

$$K_{t+1} \leq (1-\delta)K_t + I_t \quad (4)$$

$$P_t^k I_t \leq \frac{Q_t(F_t - \kappa F_{t-1})}{P_t} \quad (5)$$

Households do not have access to long-term bonds, while FIs do, creating a market segmentation.

Equation (5) is a loan-in-advance constraint through which all investment purchases must be financed by issuing "investment bonds" that are acquired by the FI. The endogenous behavior of the distortion related to Lagrange multiplier of the loan-in-advance constraint is fundamental for the real effects arising from market segmentation.

Model: financial intermediaries (1)

FIs choose net worth, N_t, and dividends, div_t, to maximize its value function, V_t, given by:

$$V_t \equiv \max_{\{N_t, div_t\}_{t=0}^{\infty}} E_0\{\textstyle\sum_{t=0}^{\infty}(\beta\zeta)^t \Lambda_t div_t\} \quad (6)$$

subject to the resource constraint:

$$div_t + N_t[1 + f(N_t)] \leq \frac{P_{t-1}}{P_t}\left[\left(R_t^L - R_{t-1}^d\right)L_t + R_{t-1}^d\right]N_t \quad (7)$$

$$\text{where } f(N_t) \equiv \frac{\psi_{n,\varepsilon_t^{ff}}}{2}\left(\frac{N_t - N_{ss}}{N_{ss}}\right)^2$$

and the incentive compatibility constraint that ensures that the FI repays deposits, given that depositors can seize at most a fraction $(1 - \Psi_t)$ of the FI's assets:

$$E_t V_{t+1} \geq \Psi_t E_t\left\{R_{t+1}^L\left(\frac{D_t}{P_t} + N_t\right)\right\} \quad (8)$$

Model: financial intermediaries (2)

- Assuming that $\Psi_t \equiv \Phi_t\left[1+\frac{1}{N_t}\left(\frac{E_t g_{t+1}}{E_t x_{t+1}}\right)\right]$, is a function of net worth in a symmetric manner with $f(N_t)$, the binding incentive constraint (8), which yields leverage as a function of aggregate variables but independent of each FI's net worth, is given by:

$$E_t \frac{P_t}{P_{t+1}} \Lambda_{t+1}\left[\left(\frac{R^L_{t+1}}{R^d_t}-1\right)L_t+1\right] = \Phi_t L_t E_t \frac{P_t}{P_{t+1}} \Lambda_{t+1}\frac{R^L_{t+1}}{R^d_t} \quad (9)$$

- Then, the FI's optimal accumulation decision is given by:

$$\Lambda_t[1+N_t f'(N_t)+f(N_t)] = E_t \beta\zeta\Lambda_{t+1}\frac{P_t}{P_{t+1}}\left[\left(R^L_{t+1}-R^d_t\right)L_t+R^d_t\right] \quad (10)$$

- where $\Phi_t \equiv e^{\phi_t}$ is a credit shock that in logarithms follows an AR(1) process:

$$\phi_t = \left(1-\rho_\phi\right)\phi_{ss}+\rho_\phi\phi_{t-1}+\boldsymbol{\sigma}_{\phi,\xi^{vol}_t}\varepsilon_{\phi,t} \quad (11)$$

  where $\sigma_{\phi,\xi^{vol}_t}$ is the standard deviation of the stochastic volatility of the credit shock, $\varepsilon_{\phi,t}\sim i.i.d.N\left(0,\sigma^2_\phi\right)$, whose ξ^{vol}_t subscript denotes that it is allowed to change across regimes at time t. When we allow for regime switching in volatilities, regimes will be classified by the magnitude of this shock.

- Increases in ϕ_t will exacerbate the hold-up problem, and act as “credit shocks”, which will increase the spread and lower real activity.

Model: the effect of financial frictions

- To gain further intuition of the financial frictions, first log-linearize the FI incentive compatibility constraint (9) and the FI optimal net worth accumulation decision (10) to get:

$$E_t(r_{t+1}^L - r_t) = \frac{1}{L_{ss}-1} l_t + \left[\frac{1+L_{ss}(s-1)}{L_{ss}-1}\right] \phi_t \quad (12)$$

and

$$\psi_{n,\xi_t^{ff}} n_t = \left[\frac{sL_{ss}}{1+L_{ss}(s-1)}\right] E_t(r_{t+1}^L - r_t) + \left[\frac{(s-1)L_{ss}}{1+L_{ss}(s-1)}\right] l_t \quad (13)$$

Equation (12) is quantitatively identical to the corresponding relationship in the more complex costly state verification (CSV) environment of Bernanke, Gertler and Gilchrist (1999).

- Combining (12) and (13), we get the following expression:

$$E_t(r_{t+1}^L - r_t) = \frac{1}{L_{ss}} \boldsymbol{\psi_{n,\xi_t^{ff}}} n_t + (s-1)\phi_t \quad (14)$$

This expression shows the importance of $\psi_{n,\xi_t^{ff}}$ for the supply of credit. If $\psi_{n,\xi_t^{ff}} = 0$, the supply of credit is perfectly elastic, independent of the financial intermediaries net worth. As $\psi_{n,\xi_t^{ff}}$ becomes larger, the financial friction becomes more intense and the supply of credit depends positively on the financial intermediaries net worth.

Model: Central Bank Policy

- We assume that the central bank follows a term premium (tp_t) augmented Taylor rule over the short rate (T- bills and deposits):

$$ln(R_t) = \rho_{R,\xi_t^{mp}} ln(R_{t-1}) + \left(1 - \rho_{R,\xi_t^{mp}}\right)\left(\tau_{\pi,\xi_t^{mp}} \pi_t + \tau_{y,\xi_t^{mp}} y_t^{gap} + \boldsymbol{\tau_{tp,\xi_t^{mp}}} tp_t\right) + \sigma_{r,\xi_t^{vol}} \varepsilon_{r,t} \quad (16)$$

where $y_t^{gap} \equiv \frac{Y_t - Y_t^f}{Y_t^f}$ denotes the deviation of output from its flexible price counterpart, π_t t is CPI inflation rate, and $\varepsilon_{r,t}$ is an exogenous and auto-correlated policy shock with AR(1) coefficient ρ_m

- The term premium is defined as the difference between the observed yield on a ten-year bond and the corresponding yield implied by applying the expectation hypothesis (EH) of the term structure to the series of short rates.

MS-DSGE solution methods

- The Markov-switching system can be cast in a state-space form by collecting all the endogenous variables in a vector X and all the exogenous variables in a vector Z:

$$B_1(\xi_t^{sp})X_t = E_t\{A_1(\xi_t^{sp}, \xi_{t+1}^{sp})X_{t+1}\} + B_2(\xi_t^{sp})X_{t-1} + C_1(\xi_t^{sp})Z_t$$

$$Z_t = R(\xi_t^{sp})Z_{t-1} + \epsilon_t \qquad \text{with} \qquad \epsilon_t \sim N(0, \Sigma^{vo}) \tag{17}$$

where ξ^{sp} and ξ^{vo} are Markov chains for the structural parameters and volatilities and the matrices $B_1(\xi_t^{sp})$, $A_1(\xi_t^{sp}, \xi_{t+1}^{sp})$, $B_2(\xi_t^{sp})$, $C_1(\xi_t^{sp})$ and $R(\xi_t^{sp})$ are function of the model parameters.

- To solve the system we use the Newton methods developed in Maih (2015) which extend the one proposed by Farmer, Waggoner and Zha (2011) and concentrates in minimum state variable solutions of the form:

$$X_t = \Omega^*(\xi^{sp}, \theta^{sp}, H)X_{t-1} + \Gamma^*(\xi^{sp}, \theta^{sp}, H)Z_t(\xi^{vo}, \theta^{vo}) \tag{22}$$

- The presence of unobserved variables and unobserved Markov states of the Markov chains implies that the standard Kalman filter cannot be used to compute the likelihood, so we use the Kim and Nelson (1999) filter.

MS-DSGE estimation methods

- We use the Bayesian approach to estimate the model:
  1. We compute the solution of the system using an algorithm found in Maih (2015) and employ a modified version of the Kim and Nelson (1999) filter to compute the likelihood with prior distribution of the parameters.
  2. Construct the posterior kernel with the estimates from stochastic search optimization routines.
  3. We use the posterior mode as the initial value for the Metropolis Hastings algorithm with 50,000 iterations.
  4. Utilize mean and variance of the last 40,000 iterations from (3) to run the main Metropolis Hastings algorithm.
- Observables: US data from 1962q1 to 2017q3 of
  - Real GDP growth
  - Real gross private investment
  - Real wages: nominal compensation in the non-farm business sector divided by the consumption deflator
  - Annualized inflation
  - Labor input from non-farm business sector hours.
  - Interest rate
  - Treasury term premium from New York Fed web-site.

MS-DSGE evidence of switching coefficients and/or switching variance

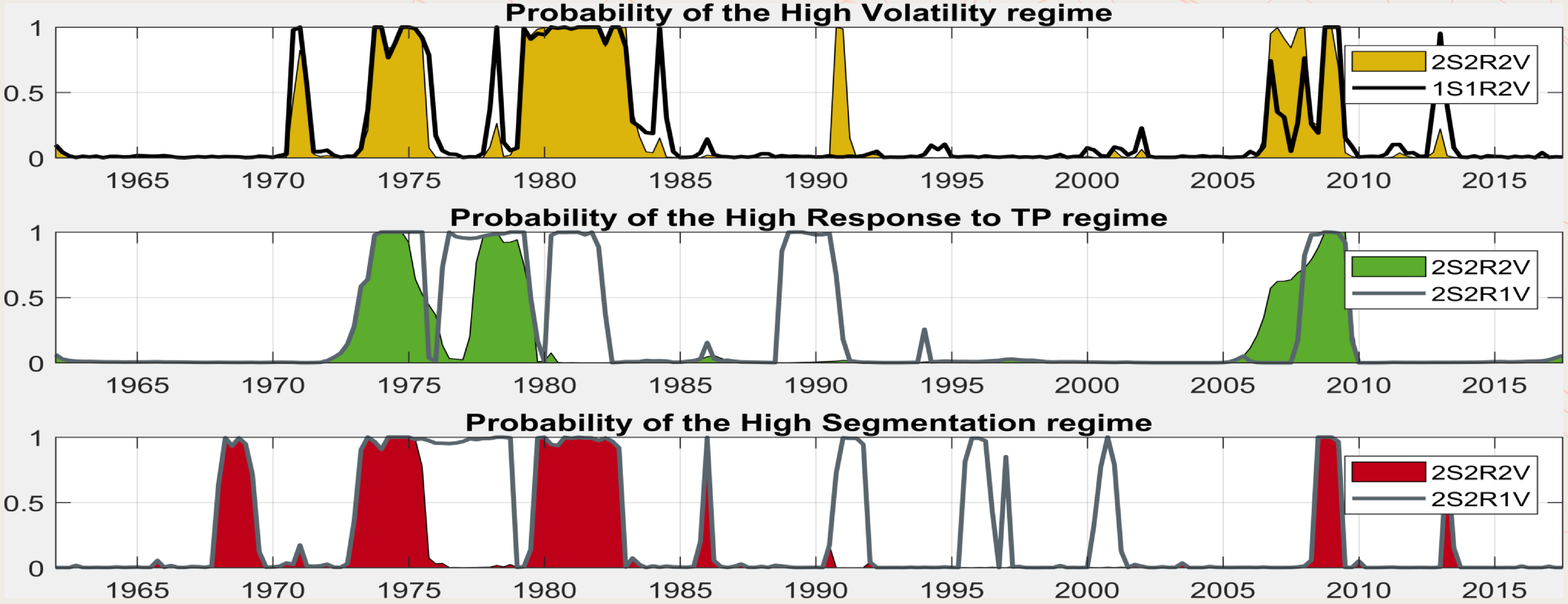
# of Markov chains	# of States	Specification	Marginal Likelihoods	Market segmentation		Term premium response		Credit shock volatility		
				$\psi_{n,\xi_t^{ff}=1}$	$\psi_{n,\xi_t^{ff}=2}$	$\tau_{tp,\xi_t^{mp}=1}$	$\tau_{tp,\xi_t^{mp}=2}$	$\sigma_{\phi,\xi_t^{vol}=1}$	$\sigma_{\phi,\xi_t^{vol}=2}$	$\sigma_{\phi,\xi_t^{vol}=3}$
				Density: Uniform		Density: Normal		Density: Inverse Gamma		
1	1	1S1R1V	-2,985.05	0.89	-	-0.46	-	4.01	-	-
2	2	1S1R2V	-2,601.51	0.84	-	-0.49	-	7.01	2.99	-
2	3	1S1R3V	-2,599.17	0.59	-	-0.52	-	6.98	5.35	2.78
2	2	2S1R1V	-2,714.86	1.49	0.69	-0.84	-	6.04	-	-
3	4	2S1R2V	-2,544.11	0.97	0.36	-0.50	-	6.40	2.61	-
3	6	2S1R3V	-2,548.58	0.65	0.19	-0.50	-	6.72	5.31	3.09
2	2	1S2R1V	-2,757.08	0.81	-	-0.97	-0.52	6.29	-	-
3	4	1S2R2V	-2,577.19	0.68	-	-0.82	-0.24	6.53	3.05	-
3	6	1S2R3V	-2,567.76	0.66	-	-0.96	-0.38	6.56	5.33	2.69
3	4	2S2R1V	-2,701.63	1.39	0.63	-1.10	-0.46	5.74	-	-
4	8	2S2R2V	-2,538.06	0.91	0.25	-0.90	-0.30	6.27	3.19	-
4	12	2S2R3V	-2,530.12	0.90	0.22	-0.86	-0.30	6.87	6.13	3.01

Table 3: DSGE and MS-DSGE Estimation Results.

Note. The table reports the Marginal Data Densities for the estimated models. In the column Specification, S, R and V correspond to segmentation, interest rate and volatilities, respectively. The posterior mode is reported for all the parameters.

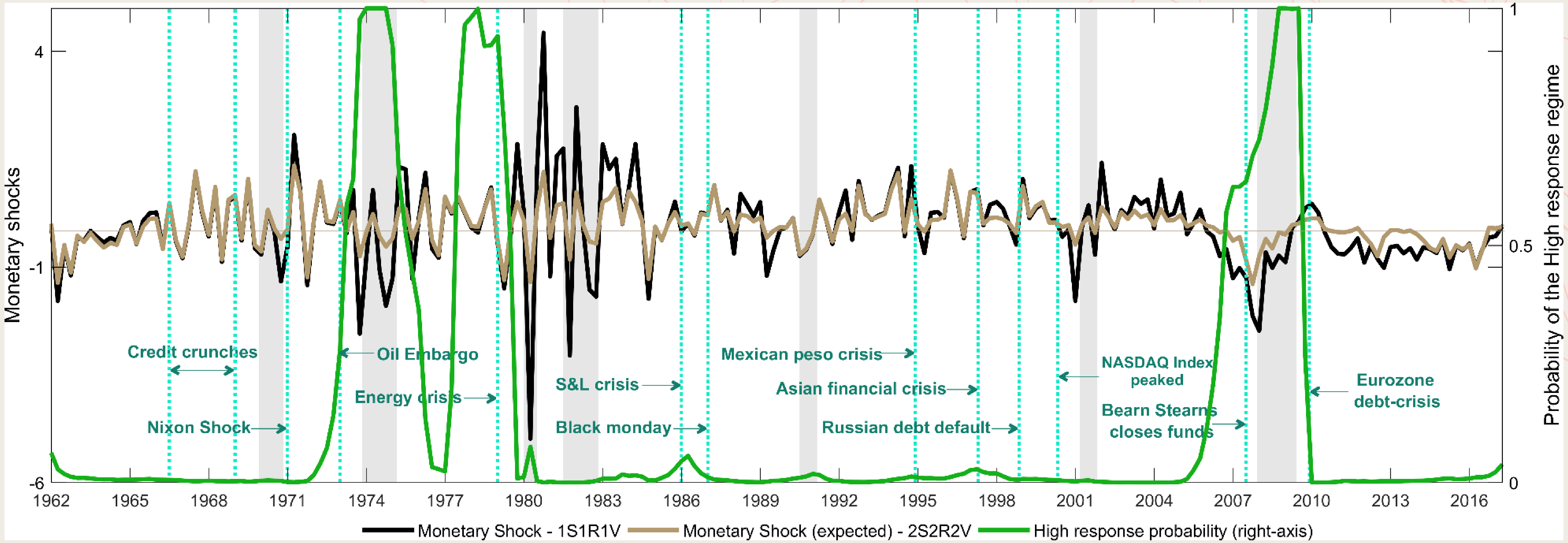
Comparison of estimated probabilities for parameters and volatilities baseline 2S2R2V

2S2R2V versus 1S1R2V versus 2S2R1V

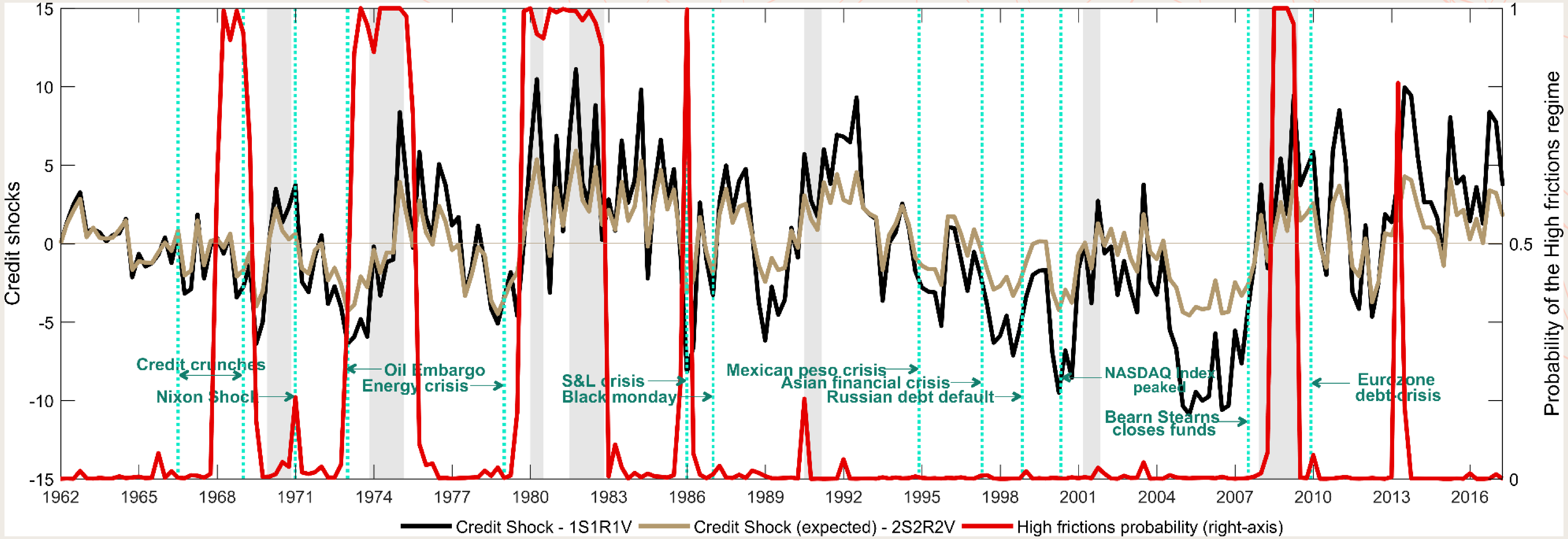


model:	222			112	221	
switching on:	S	R	V	V	S	R
# periods probability > 50%:	35	31	37	36	61	48
% of total sample	16%	14%	17%	16%	27%	22%
models to be compared:				222 vs 112	222 vs 221	
switching on:				V	S	R
# of periods when probability > 50% in both models:				31	35	26
% of 112 or 221:				86%	57%	54%

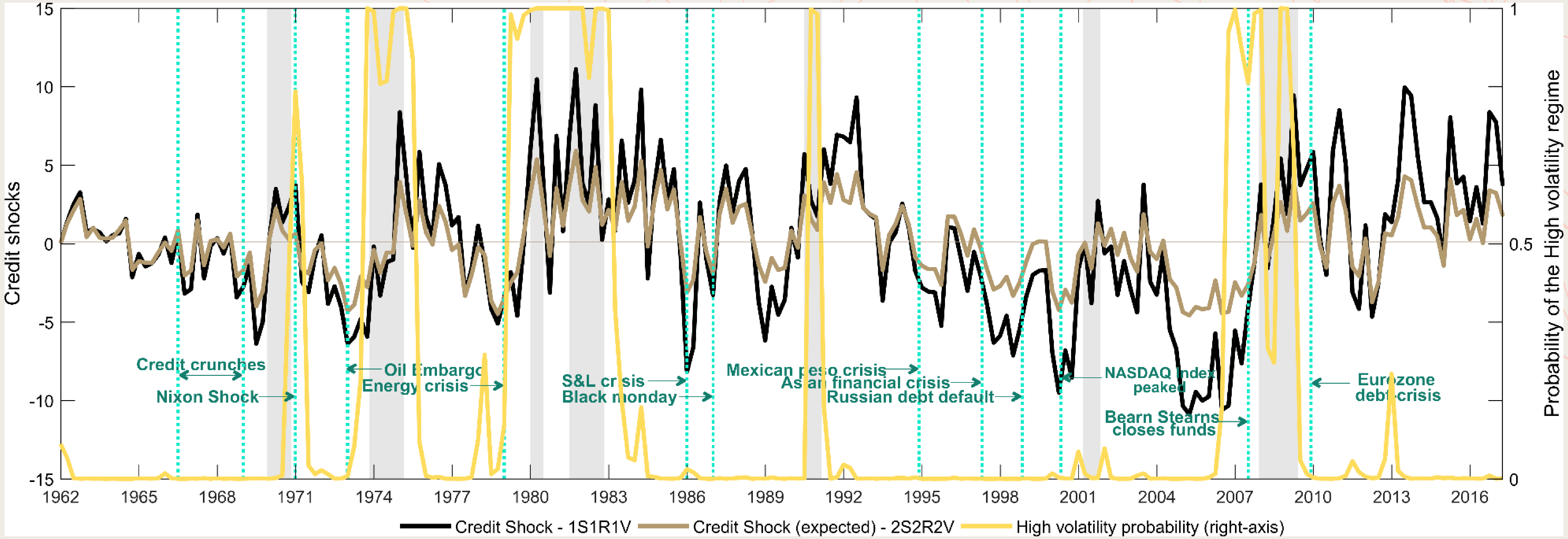
Monetary policy shocks with and without regime switching (2S2R2V vs 1S1R1V) and probability of high monetary policy response to the term premium



Credit shocks with and without regime switching (2S2R2V vs 1S1R1V) and probability of high credit frictions

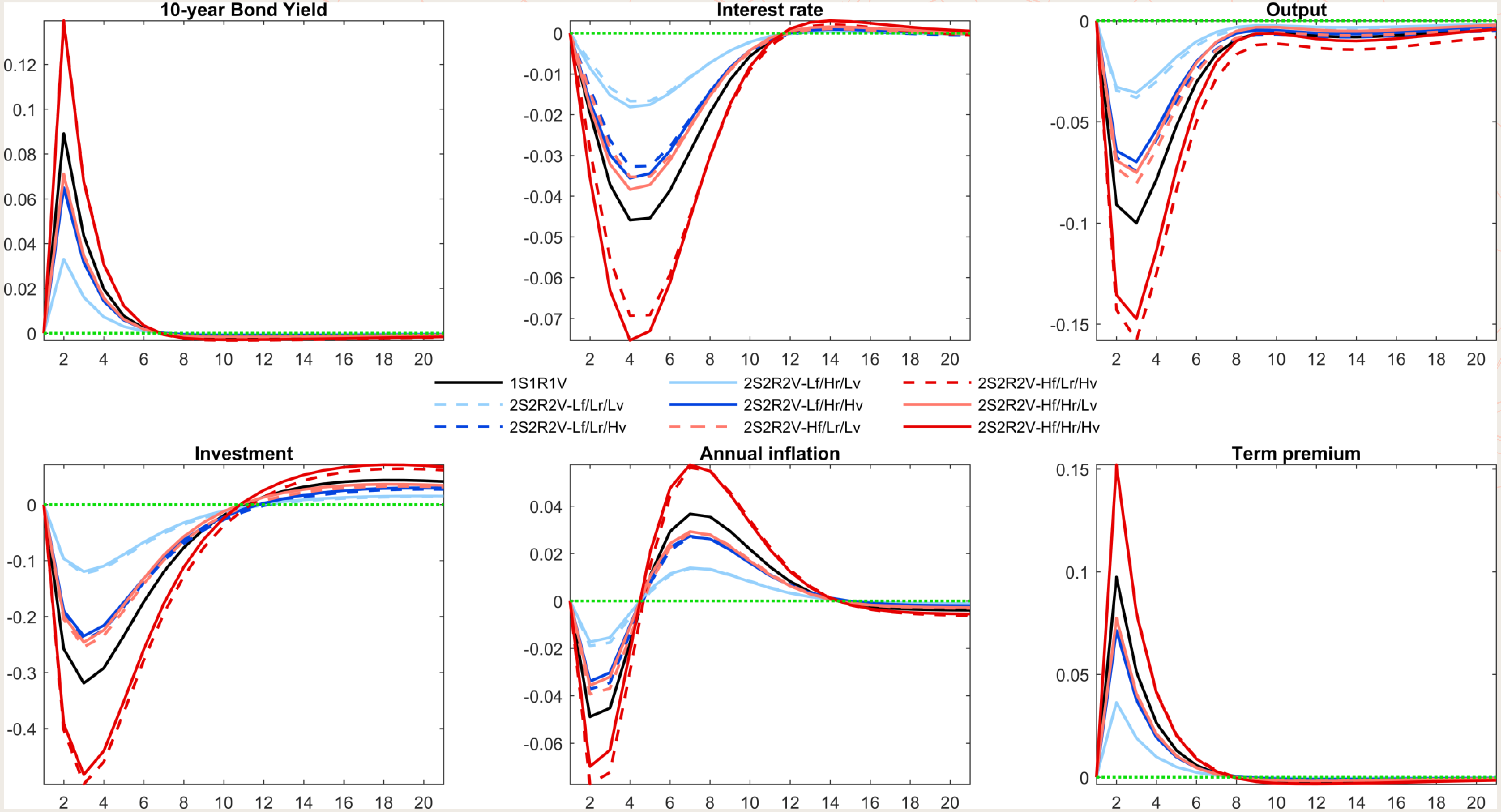


Credit shocks with and without regime switching (2S2R2V vs 1S1R1V) and probability of high credit shocks



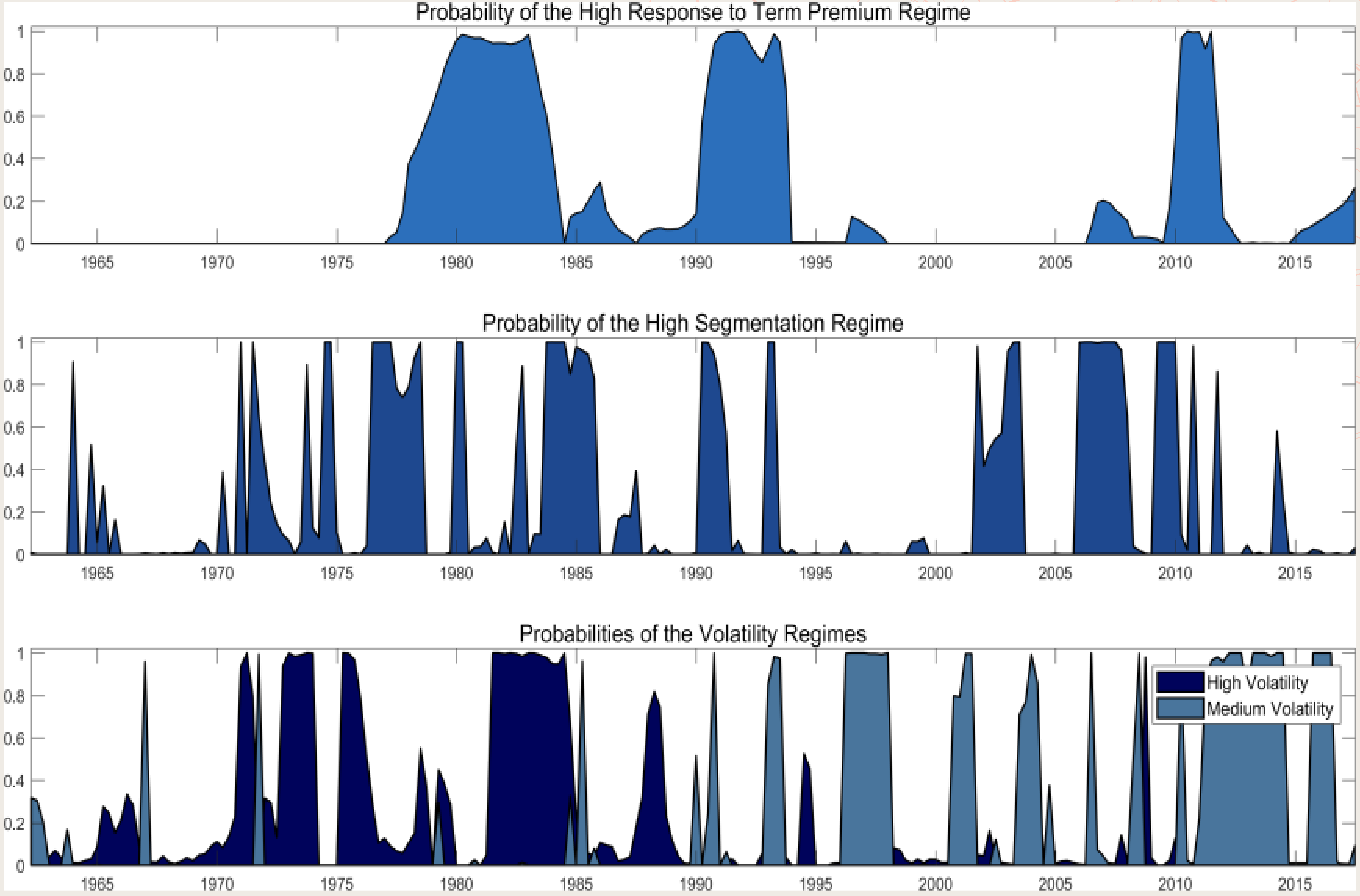
Impulse response functions to a Credit Shock

1S1R1V versus 2S2R2V



IRFs of the MS-DSGE model to a one standard deviation credit shock under alternative regimes for financial frictions, monetary policy and volatility. High financial frictions regimes are presented in red-like colors, while low ones are presented in blue-like colors. High monetary policy response regimes are presented in solid lines, while low ones are presented in dashed lines. High volatility regimes have dark colors, while low ones are presented in light ones.

Regime probabilities of the 2S2R3V MS-DSGE model



Probabilities at the posterior mode.

43 quarters (19.3%) when the interest rate response to the term premium is estimated high: 1978q4 – 1983q4, 1990q2 – 1993q4, and 2010q1 – 2011q4.

59 quarters (27%) of high financial frictions: 1971q1 – 1971q4, 1976q3 – 1978q3, 1983q4 – 1985q4, 1990q2 – 1991q2, 2002q3 – 2003q3, 2006q1 – 2008q1, and 2009q2 – 2010q1.

34 quarters (15.2%) of large probability of high credit shock volatility, 46 quarters (20.6%) with large probability of medium credit shock volatility and 142 quarters (63.7%) with large probability of low credit shock volatility.

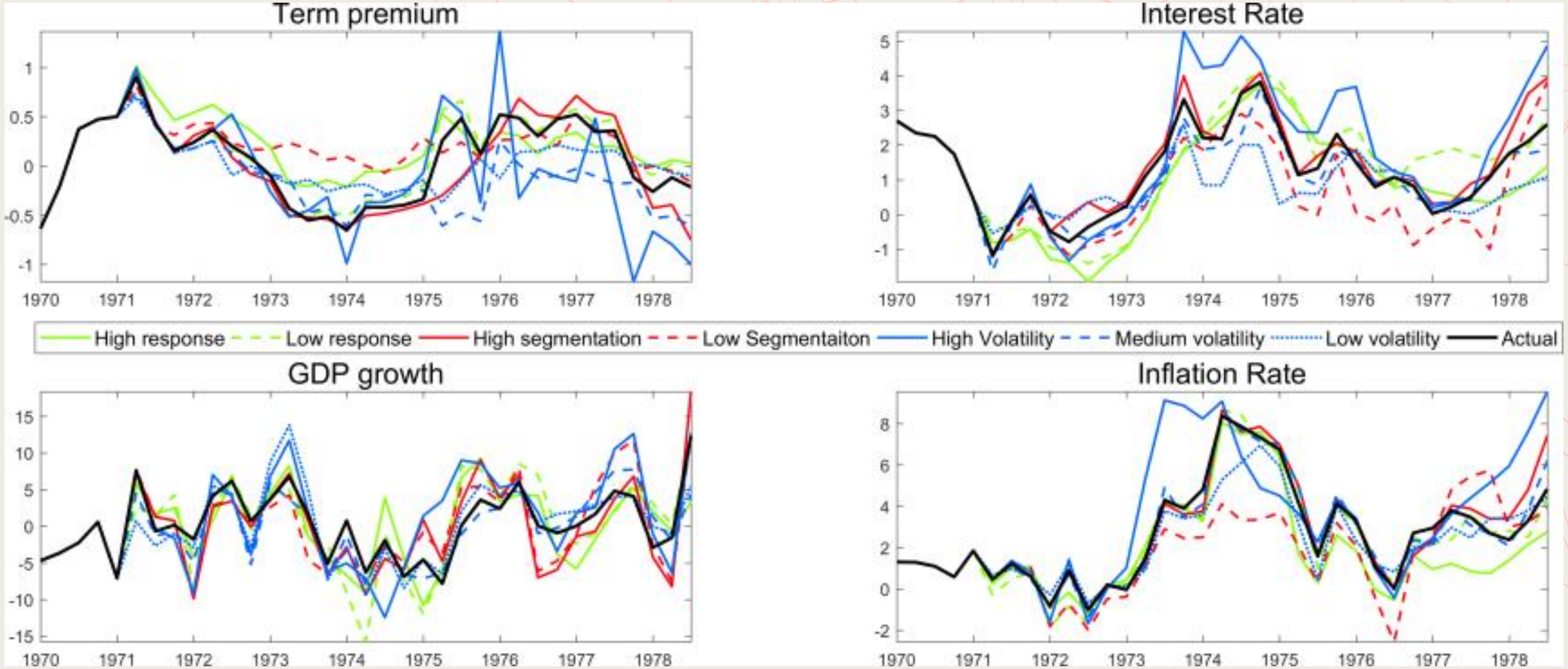
Counterfactuals

- To further explore the effects of financial conditions and monetary policy, we run six counterfactual exercises:

Episode	High financial frictions	High or medium credit shocks variance	High monetary policy response to term premium
1971q1 – 1978q3 (31q)	15	14	0
1978q4 – 1983q4 (21q)	5	10	21
1990q2 – 1993q4 (15q)	7	4	15
2000q4 – 2004q2 (15q)	5	8	0
2006q1 – 2009q4 (16q)	13	4	0
2010q1 – 2011q4 (8q)	2	4	8

- We suppose what could have happened if:
  - Financial frictions: high (solid) or low (dashed).
  - Credit shock volatility: high (solid), medium (dashed) or low (dotted).
  - Monetary policy: high (solid) or low (dashed).

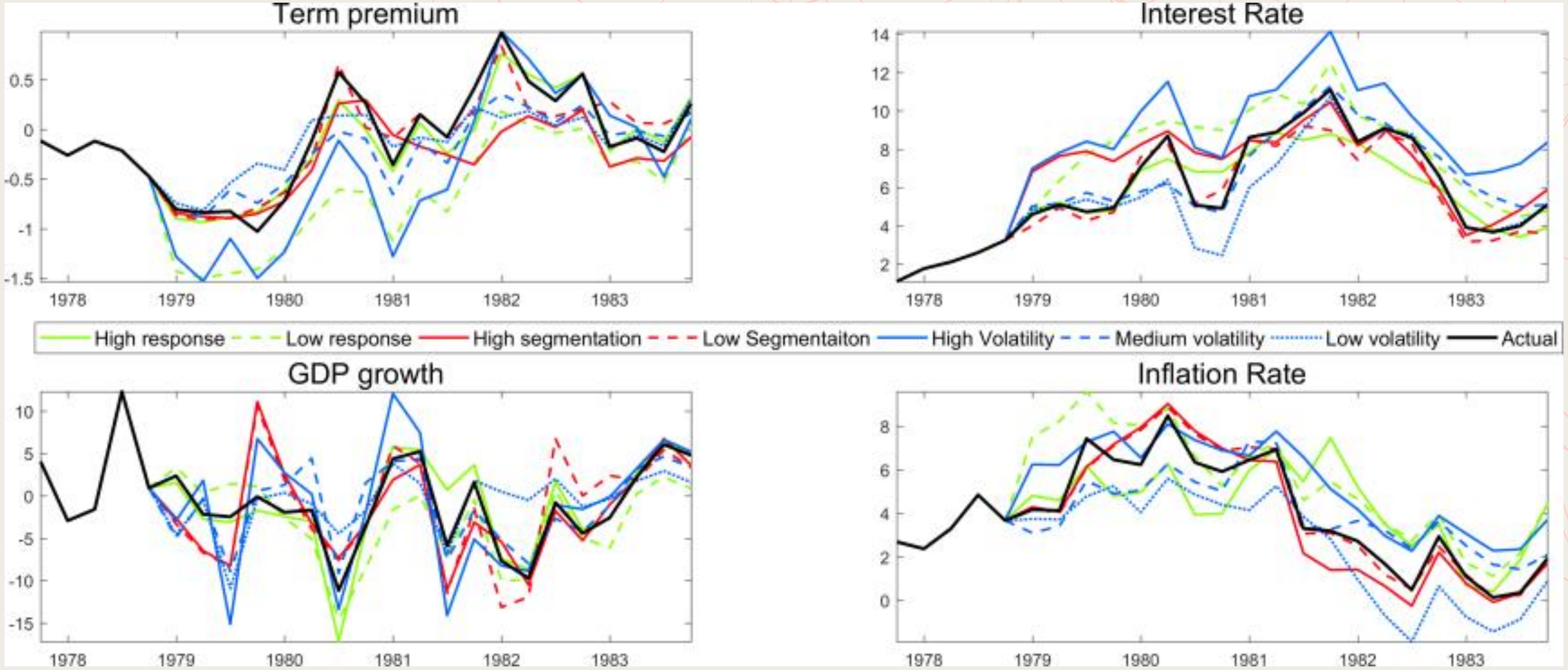
1971q1 – 1978q3 (31q): 15 HF, 14 HS, 0 HM



	Term premium	Interest rate	GDP growth	Inflation rate
If LF _ _ _	Closer to SS	Increase less	Larger	More moderate
If LS . . .	Closer to SS	Lower and less volatile	Higher and less volatile	Lower and less volatile
If HM _____	Closer to SS	Lower	Lower	Lower

If the monetary authority had responded more aggressively, it could have attained lower inflation at the cost of lower GDP.

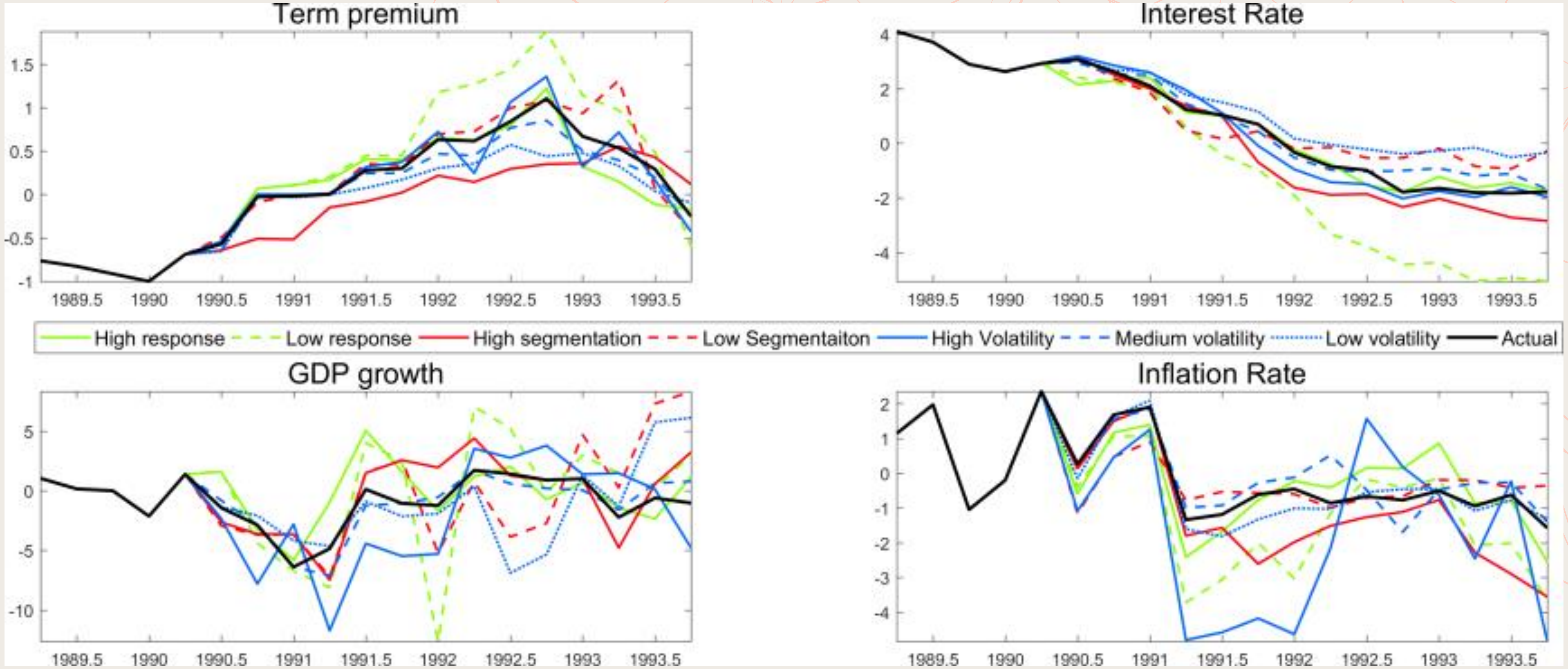
1978q4 – 1983q4 (21q): 5 HF, 10 HS, 21 HM



	Term premium	Interest rate	GDP growth	Inflation rate
If LF _ _ _				
If LS . . .	Higher closer to SS	Lower	Less volatile	Lower
If LM _ _ _	Lower below SS	Higher	Higher	Higher

High monetary policy response to financial factors helped to mitigate inflation at the cost of economic activity.

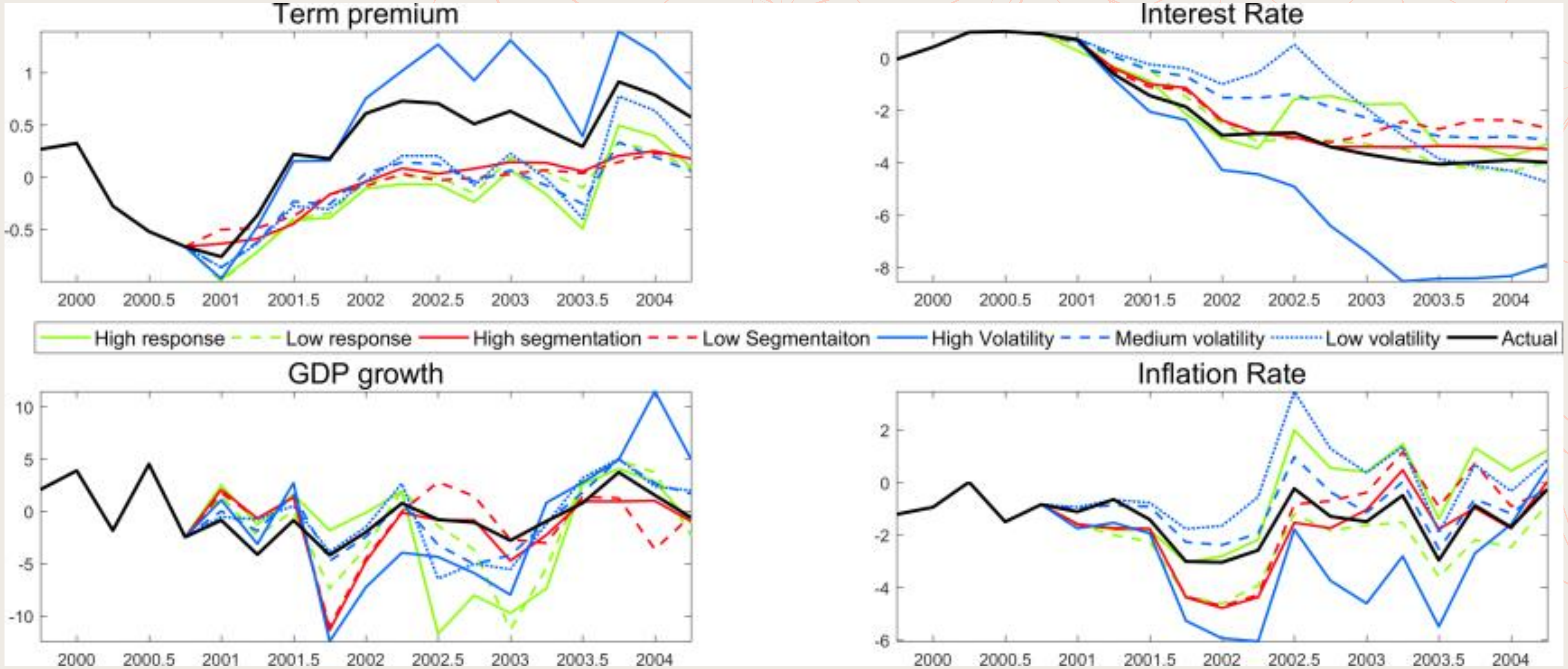
1990q2 – 1993q4 (15q): 7 HF, 4 MS, 15 HM



	Term premium	Interest rate	GDP growth	Inflation rate
If HF ___	Increase less	Decrease more	Stronger recovery	Lower
If HS ___	Higher	Decrease more	Higher contraction	Deep deflation
If LS . . .	Lower	Decrease less	Smaller contraction	Closer to data
If HM ___	Lower	Earlier but smaller decrease	Mitigate contraction	Closer to data
If LM _ _ _	Higher	Sharper decrease	Longer and deeper contraction	Deep deflation

High monetary policy response to financial factors served to mitigate economic contraction.

2000q4 – 2004q2 (15q): 5 HF, 8 MS, 0 HM



	Term premium	Interest rate	GDP growth	Inflation rate
If LF _ _ _				
If HS ___	Much larger	Much lower	Deeper and longer contraction	Prolonged deflation
If HM _____	Lower	Earlier decrease	Delayed contraction to 2002q3 but deeper	Higher

If the monetary authority had responded more aggressively, it could have delayed the GDP contraction to 2002q3, but this would have been deeper and inflation larger.

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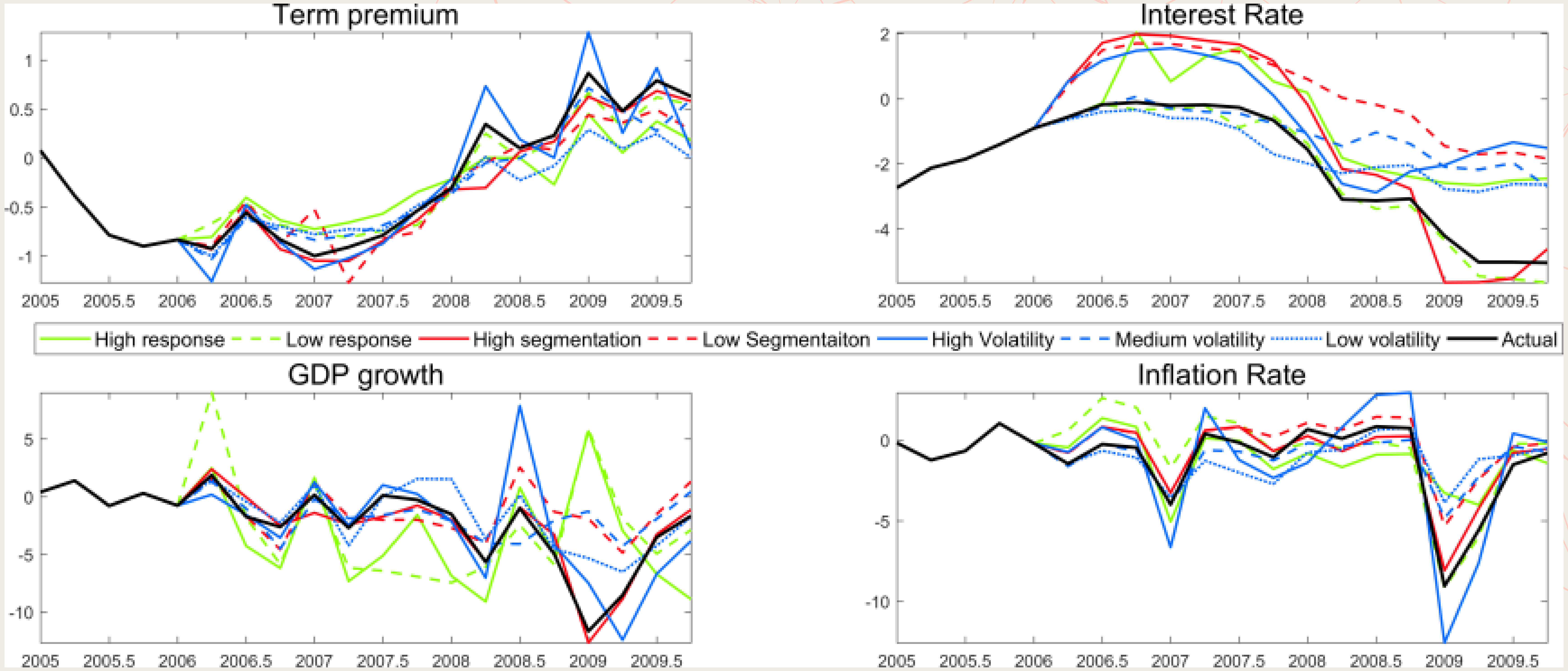
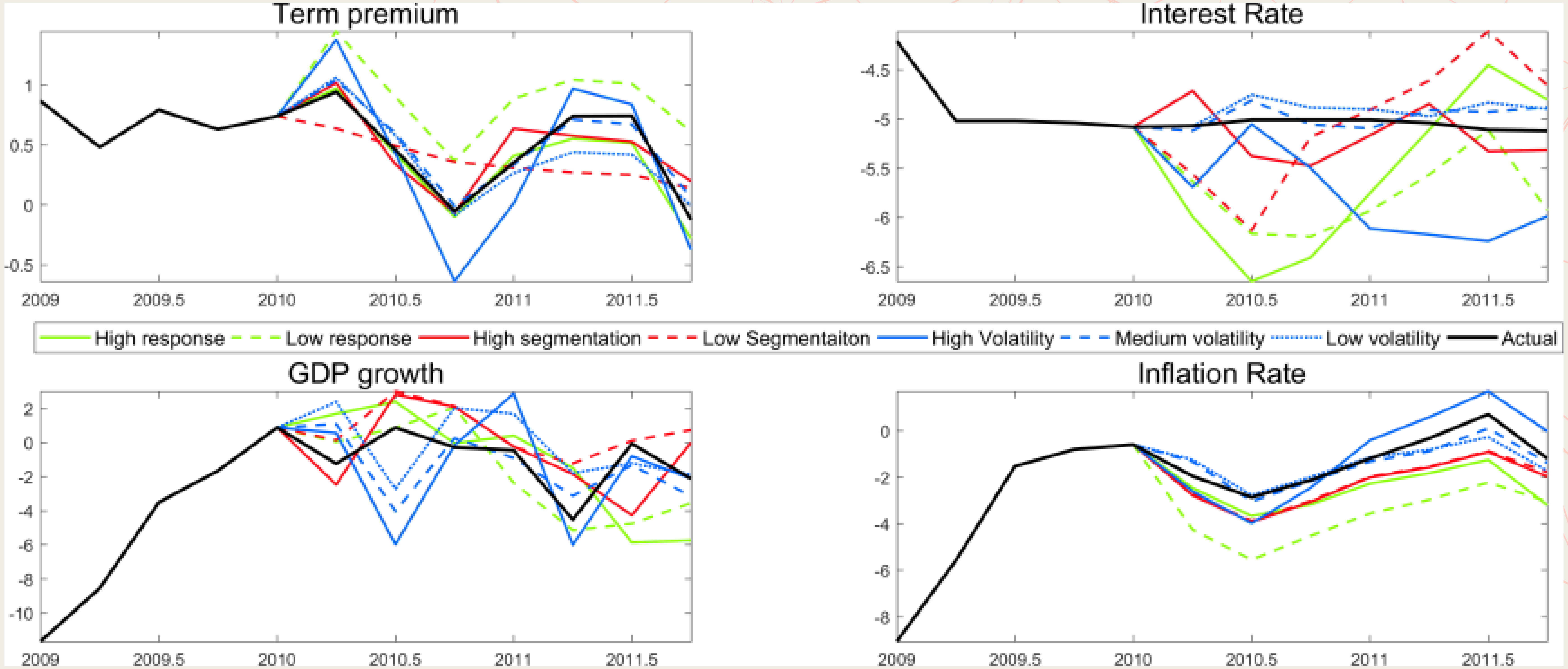
2006q1 – 2009q4 (16q): 13 HF, 1 HS 3 MS, 0 HM



	Term premium	Interest rate	GDP growth	Inflation rate
If LF _ _ _		Smaller cut in 2008 - 2009	Mild contraction	Higher
If HS ___	First lower and then higher	Higher	Deeper contraction in 2009q1 & q2	Prolonged deflation
If LM _ _ _		Closer to data	Boom and bust	Higher
If HM _____		Increase + 2%	Strong contraction	Lower

If the monetary authority had responded more aggressively, it might had precipitated the GDP contraction.

2010q1 – 2011q4 (8q): 2 HF, 4 MS, 8 HM



	Term premium	Interest rate	GDP growth	Inflation rate
If LF _ _ _	Steady reduction	First lower, then higher	Faster recovery	
If HS ___	More volatile	Lower	More volatile	First lower, then higher
If LM _ _ _	Higher	Low in line with Wu and Xia shadow	Slower recovery	Lower

High monetary policy response to financial factors served to mitigate economic contraction.

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Conclusions

- Based on a model fit criteria, the introduction of Markov switching in parameters and variances improves the fit of a macroeconomic VAR model with financial variables, with the best fit in an unrestricted model with two switches in coefficients and three switches in variances (2c3v).
- The introduction of Markov switching in parameters and specially in variances, also greatly improves the fit of a DSGE macroeconomic model with financial frictions in long-term debt instruments developed by Carlstrom, Fuerst and Paustian (2S2R3V).
- To fit the data, an estimated time-invariant DSGE produces larger shocks relative to a DSGE model with Markov-switching in parameters.
- An estimated DSGE without Markov-switching in parameters misinterprets structural regime switches as large shocks events.
- Meanwhile, an estimated DSGE without Markov-switching in shocks overestimates the high coefficients regimes.
- The IRFs are markedly different depending on the regime the economy is under.

Conclusions cont.

- In the used DSGE model, when allowing for switching in the parameters capturing financial frictions and monetary policy and switching in shocks volatilities there are different, well defined, regimes of high and low financial frictions, high and low monetary policy response to the term premium and high, medium, and low credit shock volatilities regimes.
- Using the estimated model, we perform counterfactual analysis on six episodes with presence of high financial frictions and/or medium and high shocks volatility.
- In three of them there was a high monetary policy response to financial factors: 1978q4 - 1983q4 which helped to mitigate inflation at the cost of economic activity, and the 1990q2 - 1993q4 and 2010q1 - 2011q4 episodes in which the high response served to mitigate economic contractions.
- Meanwhile, in the three episodes where low response to financial factors is observed, if the monetary authority had responded more aggressively, from 1971q1 - 1978q3 it could have attained lower inflation at the cost of lower GDP, from 2000q4 - 2004q4 it could have delayed the GDP contraction to 2002q3, but this would have been deeper and inflation larger, and in 2006q1 - 2009q4 it might had precipitated the GDP contraction.
- The presence of high financial frictions and high shock volatility makes recessions deeper and recoveries more sluggish showing the importance of the financial-macroeconomic nexus.

Annex

Credit shock

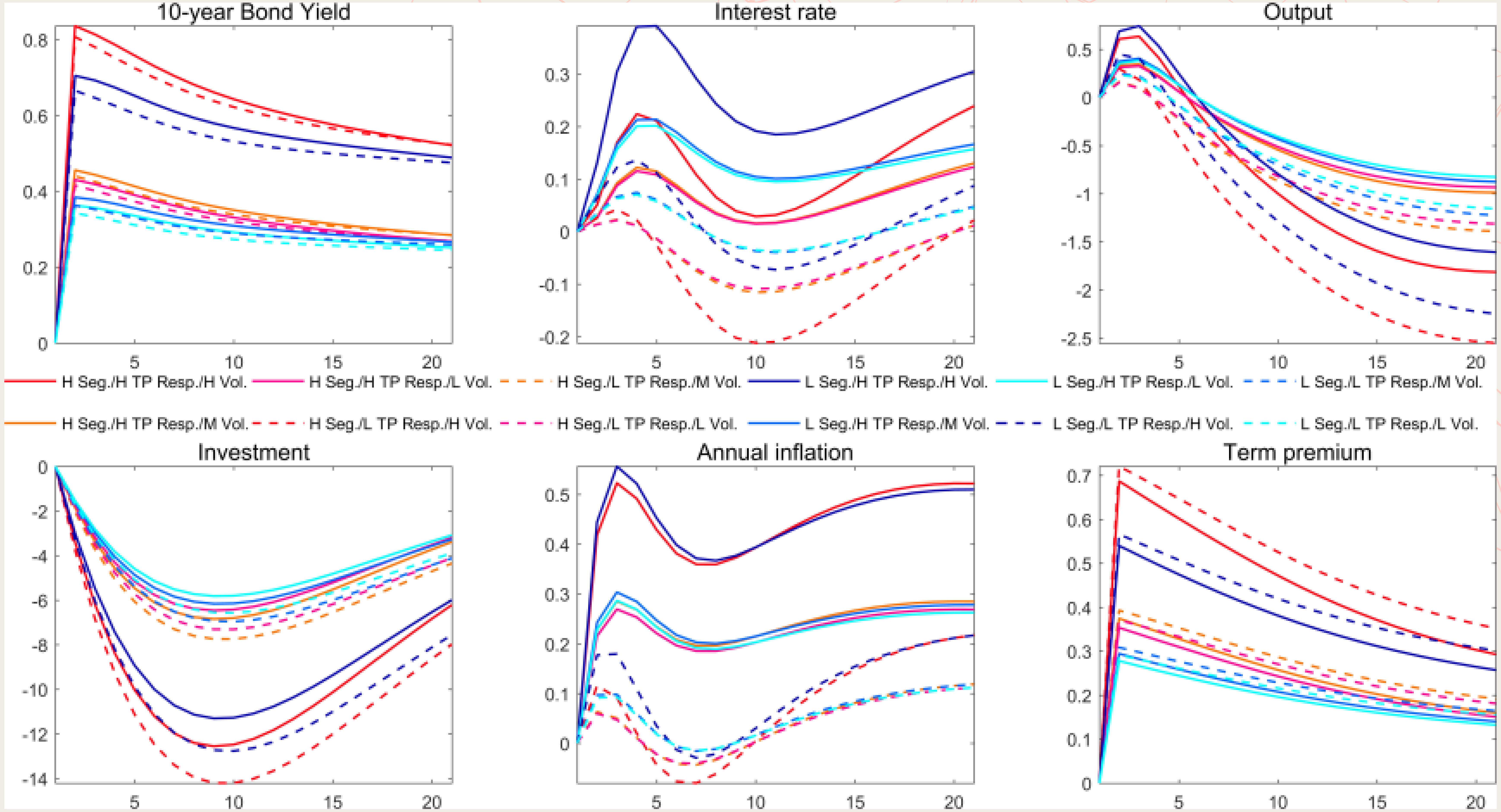


Figure: IRFs of the MS-DSGE model to a one standard deviation credit shock under alternative regimes for financial frictions, monetary policy and volatility. High financial frictions regimes are presented in red-like colors, while low ones are presented in blue-like colors. High monetary policy response regimes are presented in solid lines, while low ones are presented in dashed lines. High volatility regimes have the darkest colors, medium mild tones, and low ones are in the lightest tones.

Monetary policy shock

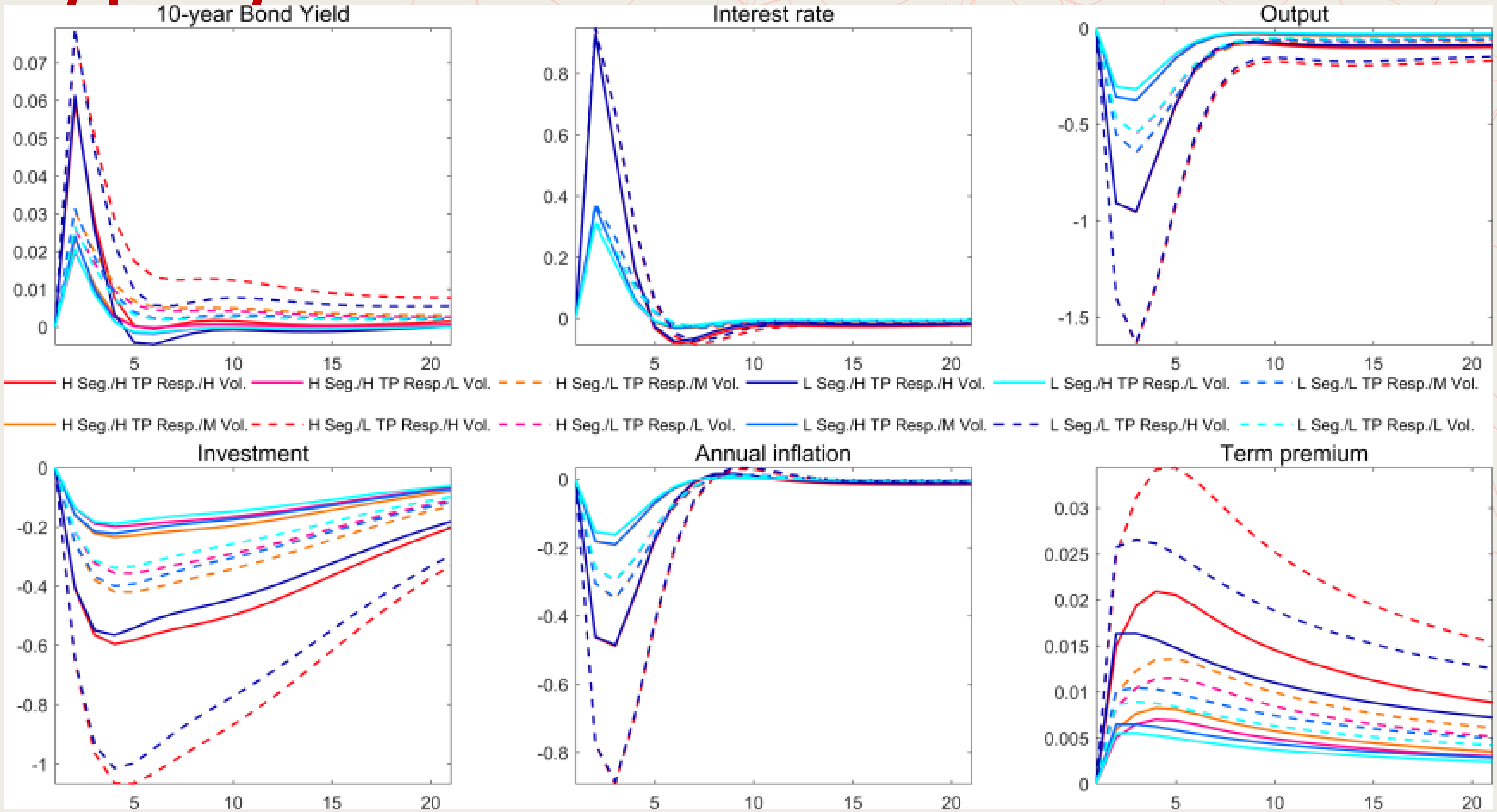
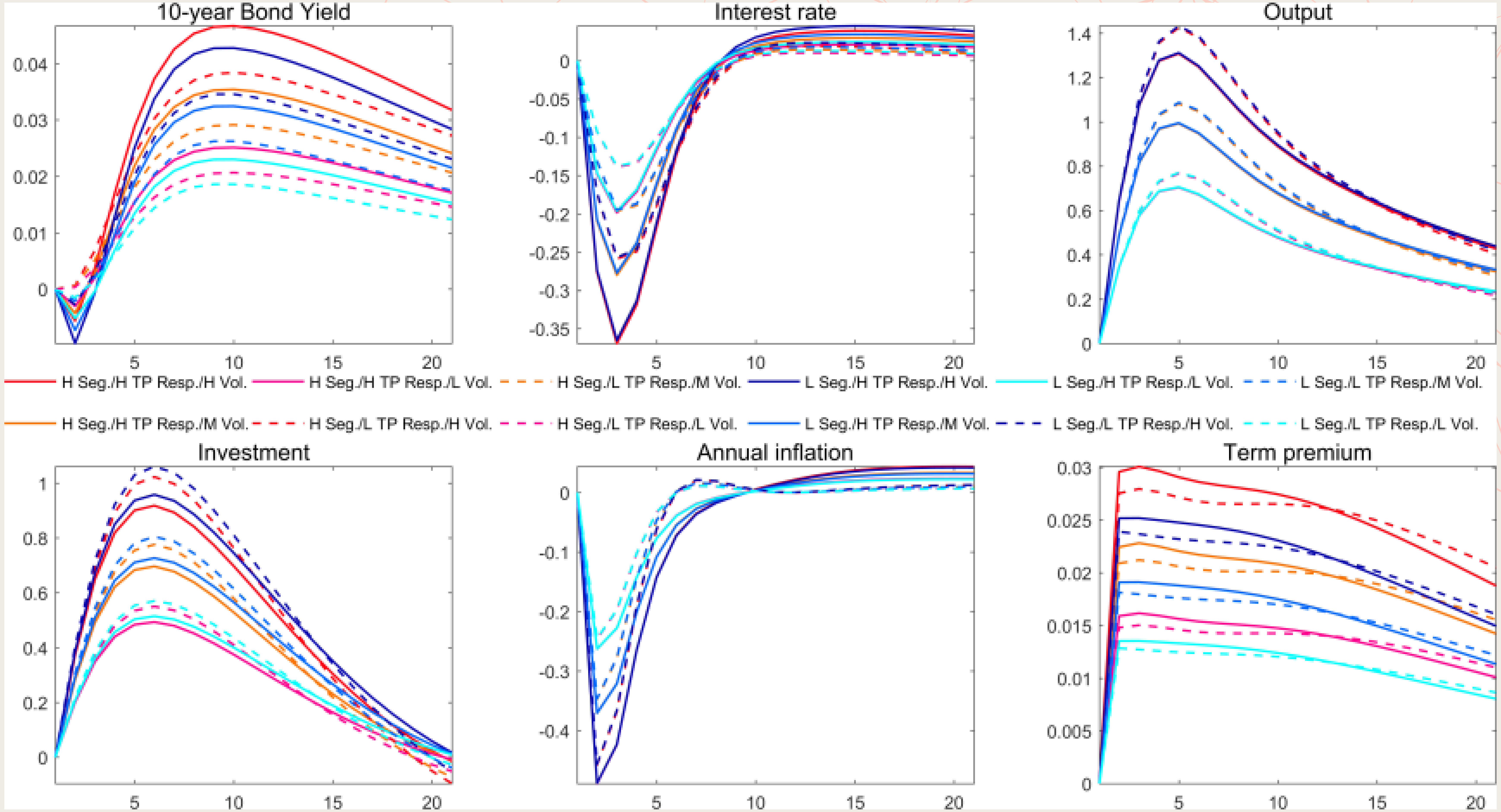


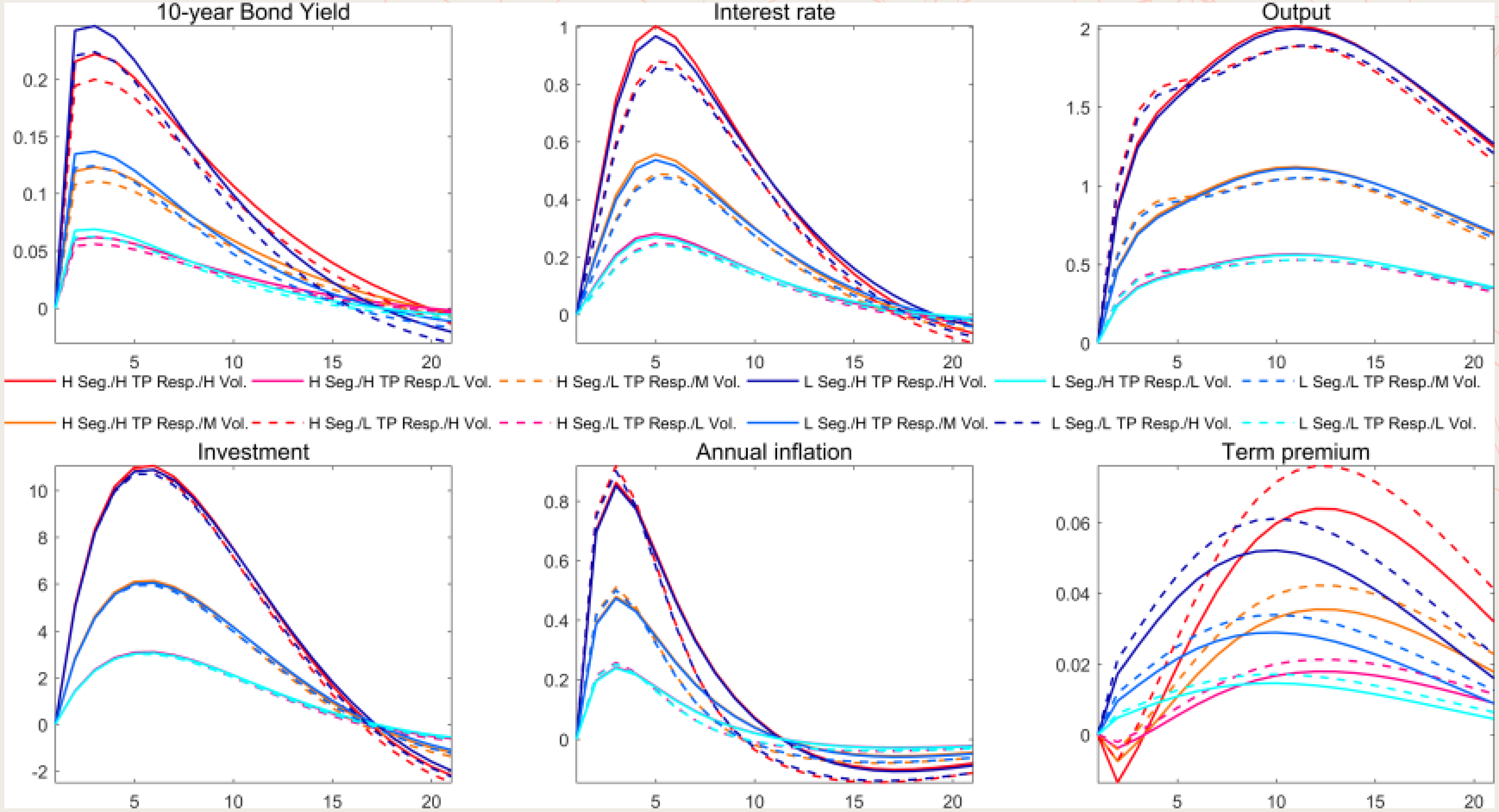
Figure: IRFs of the MS-DSGE model to a one standard deviation monetary policy shock under alternative regimes for financial frictions, monetary policy and volatility. High financial frictions regimes are presented in red-like colors, while low ones are presented in blue-like colors. High monetary policy response regimes are presented in solid lines, while low ones are presented in dashed lines. High volatility regimes have the darkest colors, medium mild tones, and low ones are in the lightest tones

Technology

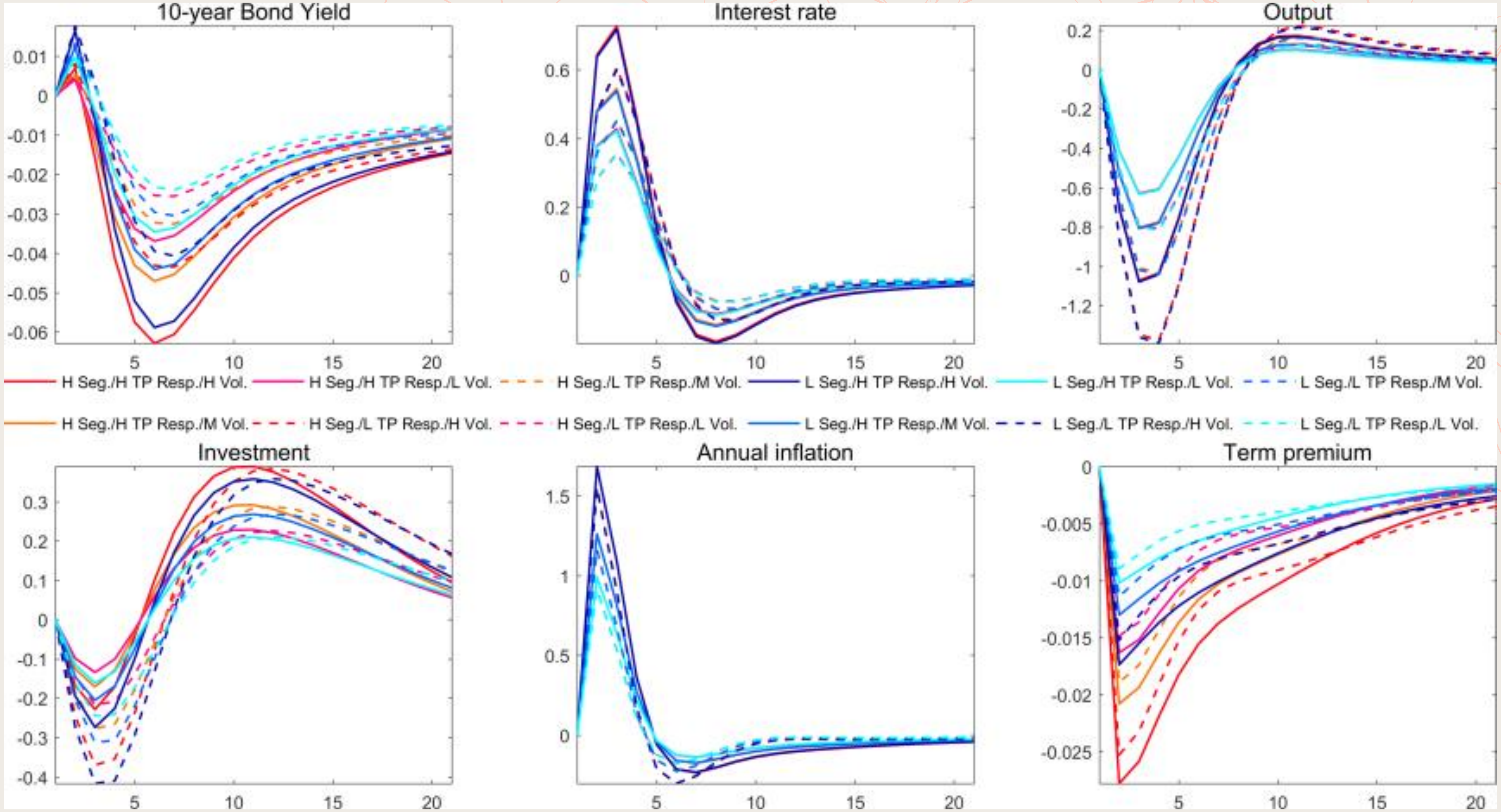


10-year Bond Yield
Interest rate
Output
Investment
Annual inflation
Term premium
H Seg./H TP Resp./H Vol.
H Seg./H TP Resp./L Vol.
H Seg./L TP Resp./M Vol.
L Seg./H TP Resp./H Vol.
L Seg./H TP Resp./L Vol.
L Seg./L TP Resp./M Vol.
H Seg./H TP Resp./M Vol.
H Seg./L TP Resp./H Vol.
H Seg./L TP Resp./L Vol.
L Seg./H TP Resp./M Vol.
L Seg./L TP Resp./H Vol.
L Seg./L TP Resp./L Vol.

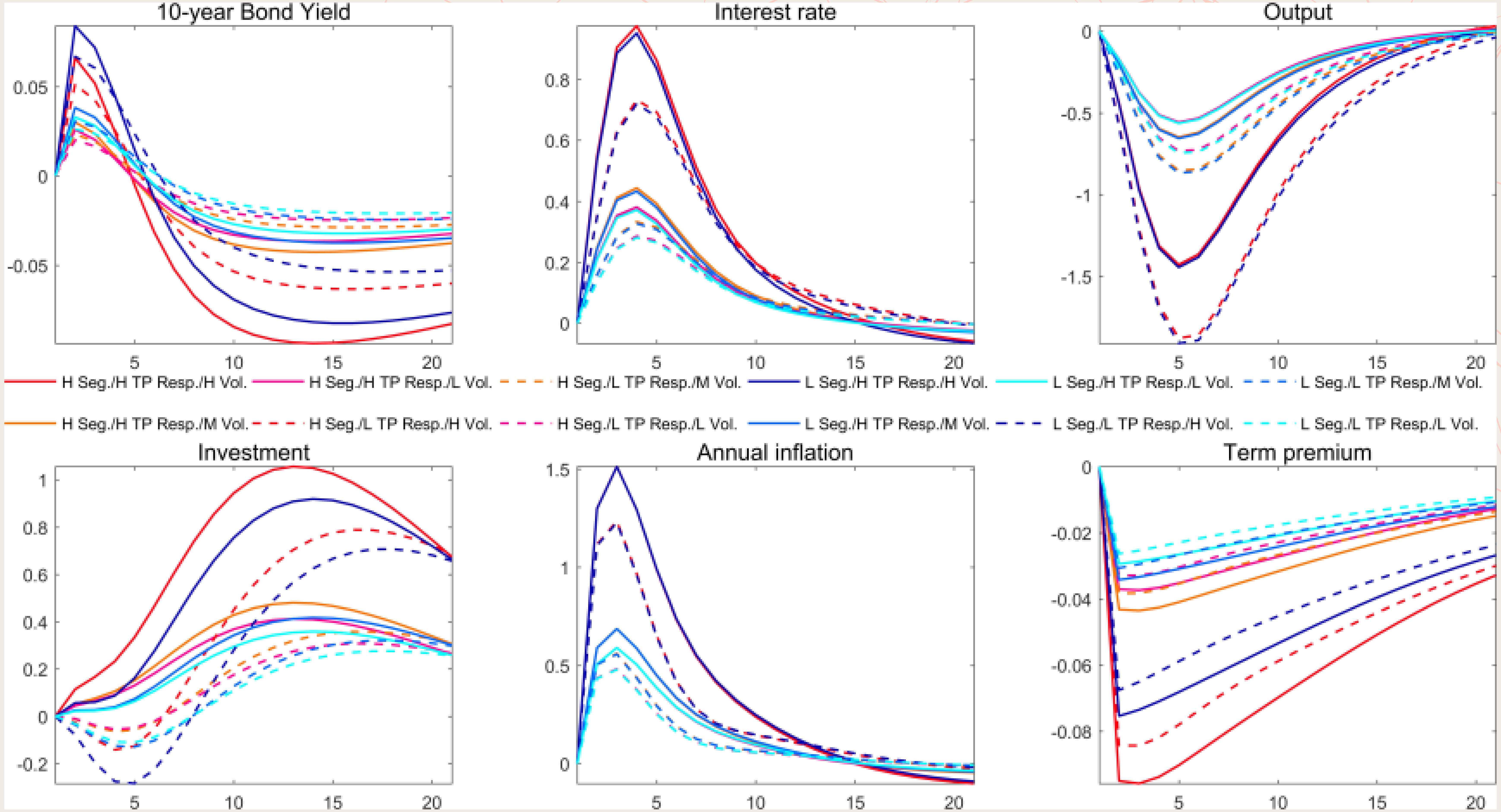
Investment-specific



Price mark-up

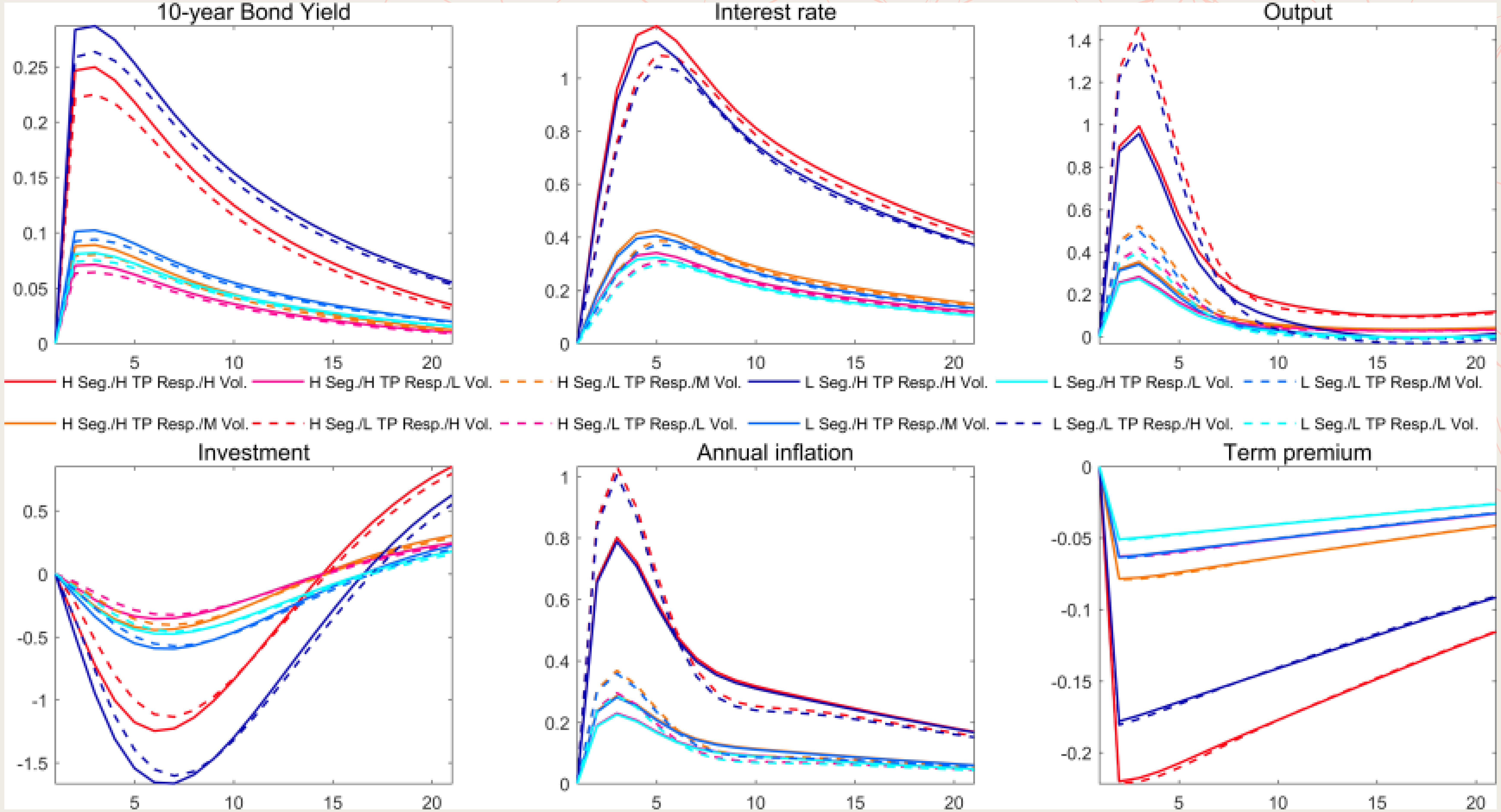


Wage mark-up



10-year Bond Yield
Interest rate
Output
Investment
Annual inflation
Term premium
H Seg./H TP Resp./H Vol.
H Seg./H TP Resp./L Vol.
H Seg./L TP Resp./M Vol.
L Seg./H TP Resp./H Vol.
L Seg./H TP Resp./L Vol.
L Seg./L TP Resp./M Vol.
H Seg./H TP Resp./M Vol.
H Seg./L TP Resp./H Vol.
H Seg./L TP Resp./L Vol.
L Seg./H TP Resp./M Vol.
L Seg./L TP Resp./H Vol.
L Seg./L TP Resp./L Vol.

Discount rate



Regime probabilities: MS-VAR stress variance and MS-DSGE credit shocks volatility

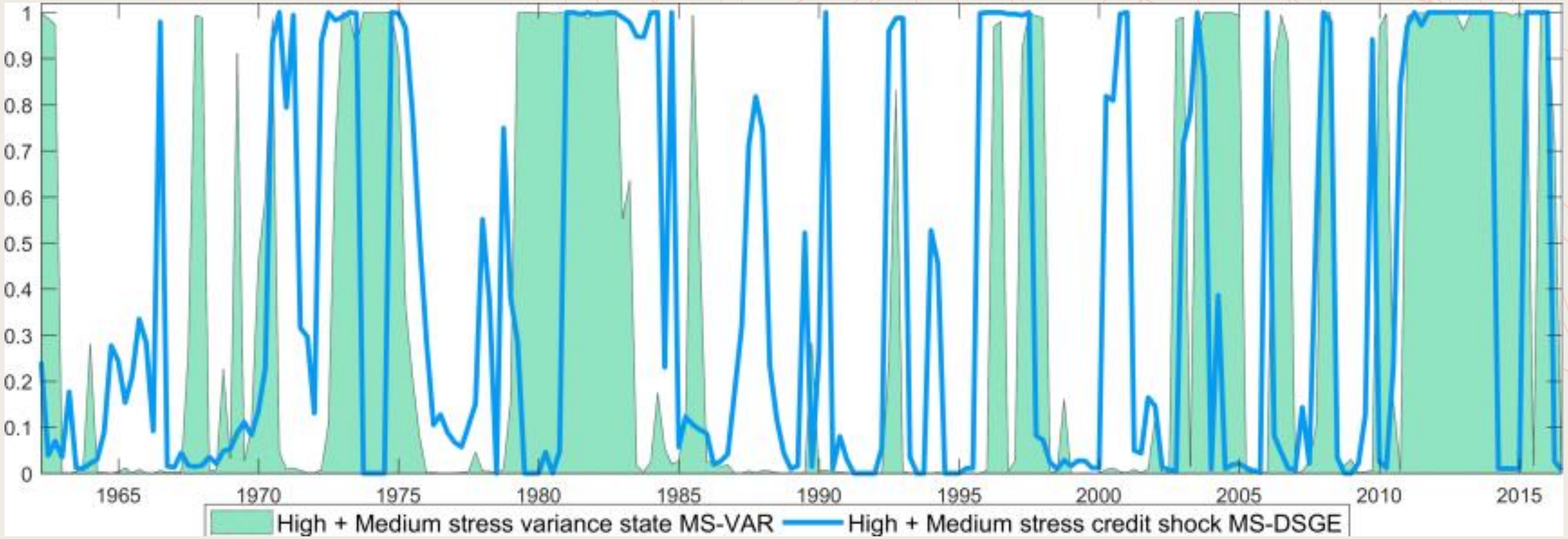
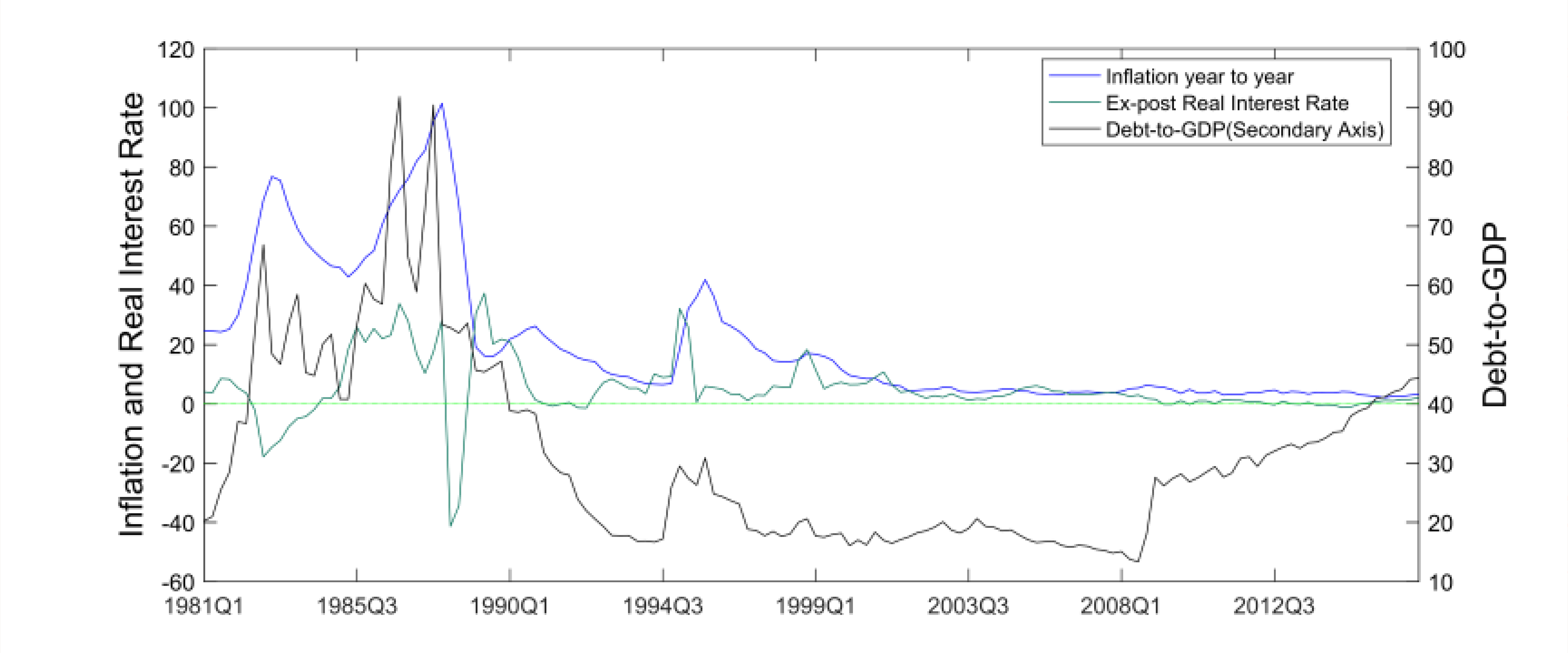


Figure: Comparison of MS-VAR high and medium frictions states, and MS-DSGE high and medium credit shock volatilities. The green area reports the probabilities of the High and Medium stress regime variance (as a sum) for the MS-VAR model. The blue solid line reports the probabilities of the High and Medium stress regime variance (as a sum) for the MS-DSGE model.

Monetary and Fiscal Policies Interactions in Mexico: 1981 – 2016

Sebastián Cadavid Sánchez André C. Martínez Fritscher Alberto Ortiz Bolaños

Inflation, ex-post real interest rates and debt to GDP in Mexico: 1981 - 2016



Fiscal (FP) and monetary policies (MP) stances may determine the evolution of macroeconomic variables such as debt and inflation and affect other policy objectives.

FP may influence the achievement of inflation control by MP: expansionary FP may lead to higher inflation.

MP may influence public balance and debt path: Central Bank transfers, real value of debt and real interest rates.

Monetary and Fiscal Policies Interactions in Mexico: 1981 – 2016, Model summary

- IS Curve

$$\left(1+\frac{\Phi}{\gamma}\right)(y_t - g_t) = E_t\{y_{t+1} - g_{t+1} + a_{t+1}\} + \frac{\Phi}{\gamma}(y_{t-1} - g_{t-1} - a_t) - \left(1-\frac{\Phi}{\gamma}\right)(R_t - E_t\{\pi_{t+1} + d_{t+1} - d_t\})$$

- Phillips Curve

$$(1+\varsigma\beta)\pi_t = \beta E_t\{\pi_{t+1}\} + \varsigma\pi_{t-1} + \frac{\kappa}{\left(1+\frac{\Phi}{\gamma}\right)}\left[\left(1+\frac{\alpha}{1-\alpha}\left(1-\frac{\Phi}{\gamma}\right)\right)y_t - g_t - \frac{\Phi}{\gamma}(y_{t-1} - g_{t-1} - a_t)\right] + \mu_t$$

- Monetary Policy Rule

$$R_t = \rho_{R,\xi_t^{sp}} R_{t-1} + \left(1-\rho_{R,\xi_t^{sp}}\right)\left[\psi_{\pi,\xi_t^{sp}}\pi_t + \psi_{y,\xi_t^{sp}}(y_t - y_t^n)\right] + \sigma_{R,\xi_t^{vo}}\epsilon_{R,t}$$

- Fiscal Rule

$$\tilde{\tau}_t^{tax} = \rho_{\tau^{tax},\xi_t^{sp}}\tilde{\tau}_{t-1}^{tax} + \left(1-\rho_{\tau^{tax},\xi_t^{sp}}\right)\left[\delta_{b,\xi_t^{sp}}\tilde{b}_{t-1} + \delta_e(e\tilde{x}p_t) + \delta_y(\hat{y}_t - \hat{y}_t^*)\right] + \sigma_{\tau,\xi_t^{vo}}\epsilon_{\tau,t}$$

- Debt

$$\tilde{b}_t = \beta^{-1}\tilde{b}_{t-1} + \beta^{-1}(\tilde{R}_{t-1}^m - \tilde{y}_t + \tilde{y}_{t-1} - \tilde{a}_t - \tilde{\pi}) - \frac{\tau^{tax}}{b}\tilde{\tau}_t^{tax} - \frac{\tau^{non-tax}}{b}\tilde{\tau}_t^{non-tax} + \frac{exp}{b}e\tilde{x}p_t + \frac{tp}{b}\widetilde{tp}_t$$

$$\tilde{b}_t = \left(\beta^{-1} - \frac{\tau^{tax}}{b}\left(1-\rho_{\tau^{tax},\xi_t^{sp}}\right)\delta_{b,\xi_t^{sp}}\right)\tilde{b}_{t-1} + \cdots$$

Estimation

In the estimation, we allow for two possible values for every relevant policy parameter:

For fiscal policy, we obtain the high (PF) and low (AF) tax rate response to debt.

- Passive

$$\tilde{\tau}_t^{tax} = 0.79\tilde{\tau}_{t-1}^{tax} + (1-0.79)\left[0.0624\tilde{b}_{t-1} + 0.09(e\tilde{x}p_t) + 0.15(\hat{y}_t - \hat{y}_t^*)\right]$$

- Active

$$\tilde{\tau}_t^{tax} = 0.73\tilde{\tau}_{t-1}^{tax} + (1-0.73)\left[0.0003\tilde{b}_{t-1} + 0.09(e\tilde{x}p_t) + 0.15(\hat{y}_t - \hat{y}_t^*)\right]$$

For monetary policy, we estimate the low (PM) and high (AM) interest rate sensitivity to inflation.

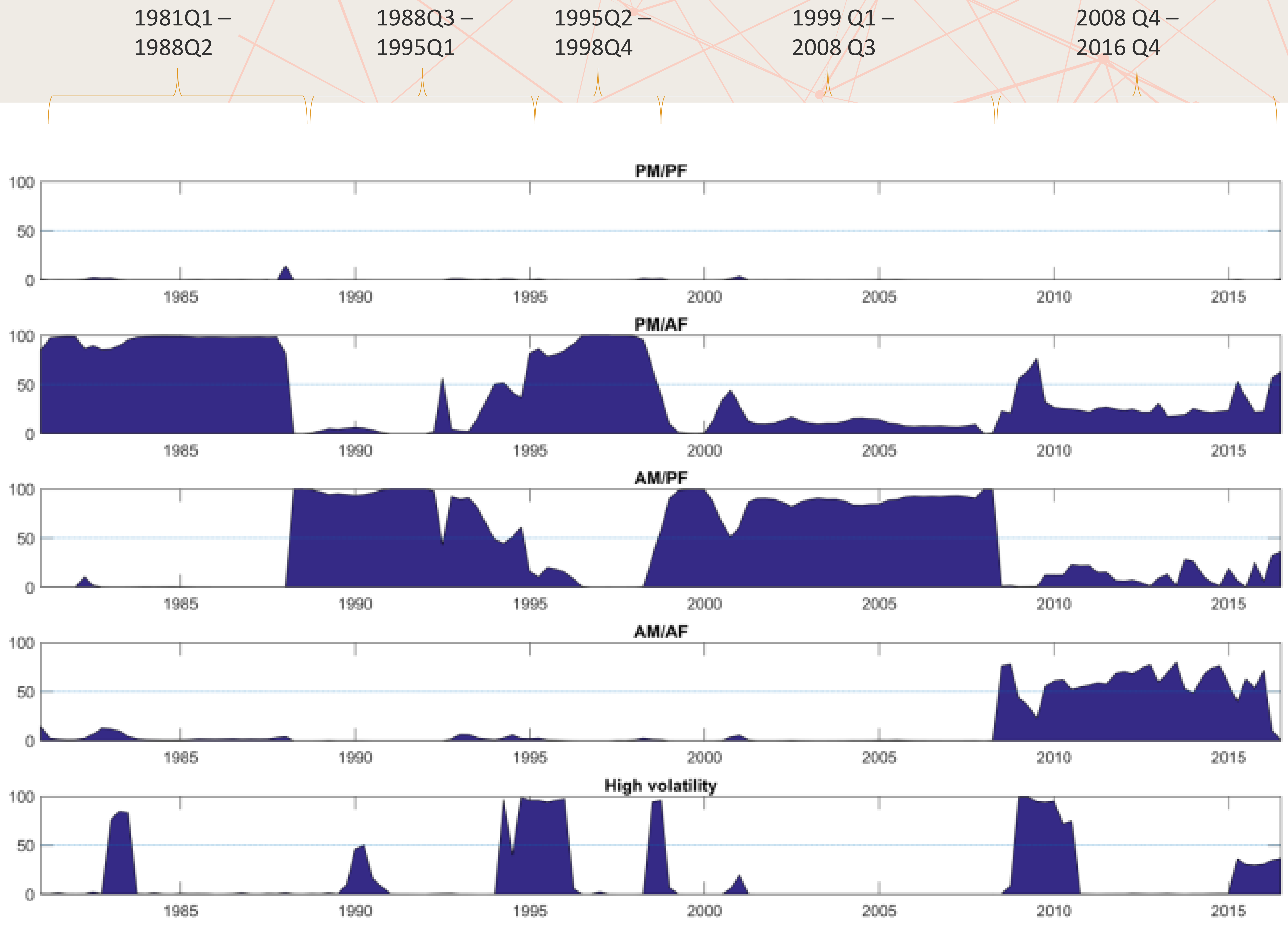
- Passive

$$R_t = 0.58R_{t-1} + (1-0.58)[0.79\pi_t + 0.66(y_t - y_t^n)]$$

- Active

$$R_t = 0.55R_{t-1} + (1-0.55)[1.81\pi_t + 0.94(y_t - y_t^n)]$$

Smoothed probabilities



Counterfactuals

- We run two counterfactuals that allow us to understand better the role of expectations, policy mix and shocks in the evolution of the macroeconomic variables. We suppose what it would have happened if:

1. Fiscal and monetary policy regime had stayed within a single regime in the whole sample, 1981 - 2016.

2. *Around each regime switch, 1988Q3, 1995Q2, 1999Q1 and 2008Q4:*
   a) *The regime changed and there was full credibility (100% probability of remaining in the new regime).*
   b) *The regime had not changed remaining in the status-quo (100% probability of remaining in the previous regime).*
   c) *The regime changed but there was no credibility (0% probability of remaining in the new regime).*

Summary of results: counterfactuals averages

1981 – 2016	Inflation	Debt
Data	**20.4**	**31.2**
Monetary dominance (AM / PF)	13.2	-57.1
Fiscal dominance (PM / AF)	42.0	154.0
Both active (AM / AF)	15.4	201.7
Both passive (PM / PF)	49.4	-62.1

		Inflation				Debt			
Period	**Regime**	Fully credible	Non credible	Status Quo	**Actual**	Fully credible	Non credible	Status Quo	**Actual**
1988Q3-2016Q4	**AM / PF**	13.0	42.5	41.5	**12.8**	1.6	138.3	118.6	**26.5**
1995Q2-2016Q4	**PM / AF**	19.2	6.4	8.4	**8.4**	64.8	16.7	17.2	**23.9**
1999Q1-2016Q4	**AM / PF**	4.9	12.9	11.2	**5.2**	20.6	80.9	187.0	**24.1**
2008Q4-2016Q4	**AM / AF**	4.8	3.3	3.5	**3.8**	47.5	26.2	26.4	**32.1**