Inflation Formation Processes, Monetary Policy, and Shock Volatilities in Brazil, Chile, Colombia, Mexico and Peru

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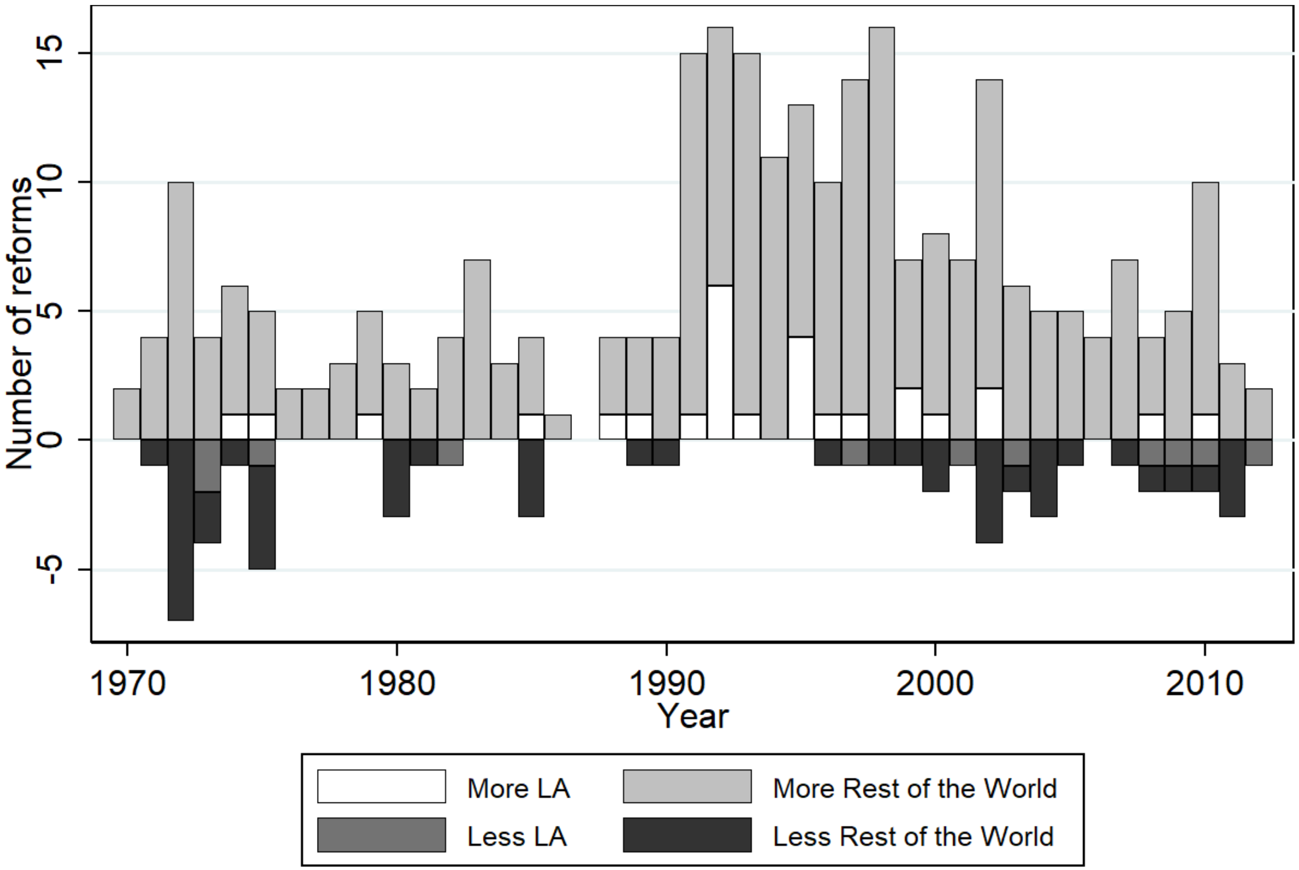
Reforms to the independence of central banks around the world (Garriga (2016))



According to Garriga (2016), since 1970, countries that took **positive** reforms towards independence were the following: Venezuela in 1974; Chile in 1975; Haiti in 1979; Mexico in 1985; Brazil in 1988; Chile in 1989; El Salvador in 1991; Argentina, Colombia, Ecuador, Nicaragua, Peru, and Venezuela in 1992; Mexico in 1993; Bolivia, Costa Rica, Paraguay, and Uruguay in 1995; Honduras in 1996; Cuba in 1997; Nicaragua and Venezuela in 1999; El Salvador in 2000; Guatemala and the Dominican Republic in 2002; and Uruguay in 2008 and 2010. Meanwhile, **negative** reforms hindering Central Bank independence include the following: Argentina and El Salvador in 1973, Panama in 1975, El Salvador in 1982, Uruguay in 1997, Venezuela in 2001, Argentina in 2003, Ecuador in 2008, Venezuela in 2009, Nicaragua in 2010, and Argentina in 2012.

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

Average inflation	1980-1989	1990-1999	2000-2009	2010-2017	Positive reforms towards 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

Looking for the disinflation culprits

- **Goal:** explore the role played by the evolution of monetary policy, price rigidities and structural shocks in these disinflationary episodes.
- **Challenge:** the analysis of the policy stance and inflation process is complex as they are jointly determined with other macroeconomic variables.
- **Strategy:** estimate Markov-Switching open-economy DSGE models with monetary factors to:
  - Measure monetary policies, inflation determinants, and shocks.
  - Perform counterfactuals under different monetary policies, price rigidities and shocks volatilities.

A Monetary Small Open Economy Markov-Switching Dynamic General Equilibrium Model

- Open-economy IS curve:

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

- Open-economy Phillips curve:

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

- Interest rate rule:

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

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

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

Model: External Sector and Technology

- AR(1) process for the terms of trade $\left(\frac{P^{exports}}{P^{imports}}\right)$:

$$\Delta q_t = \rho_q \Delta q_{t-1} + \sigma_{q,\xi_t^{vol}} \varepsilon_{q,t}$$

- Evolution of foreign output

$$y_t^* = \rho_{y^*} y_{t-1}^* + \sigma_{y^*,\xi_t^{vol}} \varepsilon_{y^*,t}$$

- Evolution of foreign inflation

$$\pi_t^* = \rho_{\pi^*} \pi_{t-1}^* + \sigma_{\pi^*,\xi_t^{vol}} \varepsilon_{\pi^*,t}$$

- Evolution of technology

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

Empirical strategy

- We estimate the previous model using macroeconomic data on inflation, interest rates, output growth, nominal exchange rate depreciation and changes in terms of trade from Brazil, Chile, Colombia, Mexico and Peru.

- We allow for endogenous structural breaks and classify regimes according to (1) the relative weight of inflation in an interest rate reaction function, (2) the relative slope of the Phillips curve, and (3) the shock volatility of technology.

Observable	Measurement Equation	Shocks
Output growth	$y_t - y_{t-1} + a_t$	$\varepsilon_{a,t}$
Inflation	$4\pi_t$	$\varepsilon_{y^*,t}$
Nominal interest rate	$4r_t$	$\varepsilon_{r,t}$
Nominal exchange rate depreciation	Δe_t	$\varepsilon_{\pi^*,t}$
Changes in terms of trade	Δq_t	$\varepsilon_{q,t}$

Solving the MS-DSGE model

- Given that the traditional stability concepts for constant DSGE models do not hold for the Markov-switching case, to solve the linear version of the model we use the solution method proposed by Maih (2015), which uses the minimum state variable (MSV) concept to present the solution of the system in the following form:

$$X_t(s_t, s_{t-1}) = T\left(\xi_t^{sp}, \theta_t^{sp}\right)X_{t-1}(s_{t-1}, s_{t-2}) + R\left(\xi_t^{vo}, \theta_t^{sp}\right)\varepsilon_t$$

where T and R matrices contains the model's parameters θ_t^{sp}. X_t stands for the $(n \times 1)$ vector of endogenous variables that is a function of the current and past states of the system, s_t and s_{t-1}, respectively. ε_t is the $(k \times 1)$ vector of exogenous processes.

- We introduce the possibility of regime change for two structural parameters (sp) and for shock volatilities (vo) through three independent Markov chains: $\xi_t^{mp}, \xi_t^{pc}\ and\ \xi_t^{vol}$, that are assumed to follow first-order processes with the following transition matrices:

$$H^i = \begin{pmatrix} H_{11} & H_{12} \\ H_{21} & H_{22} \end{pmatrix} \qquad \text{for } i = mp, pc, vol$$

- 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 that average across states.

Estimating the MS-DSGE model

- This paper uses the Bayesian approach to estimate the model with the following procedure:

1. We compute the solution of the system using the algorithm proposed in Maih (2015), and employing a modified version of the Kim and Nelson (1999) filter to compute the likelihood with the prior distribution of the parameters.

2. Construct the posterior kernel result from stochastic search optimization routines.

3. We use the mode of the posterior distribution as the initial value for a Metropolis Hasting algorithm, with 100,000 iterations, to construct the full posterior distribution.

4. Utilizing mean and variance of the last 50,000 iterations we compute moments.

Summary of the parameter estimates

Interest rate rule:

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

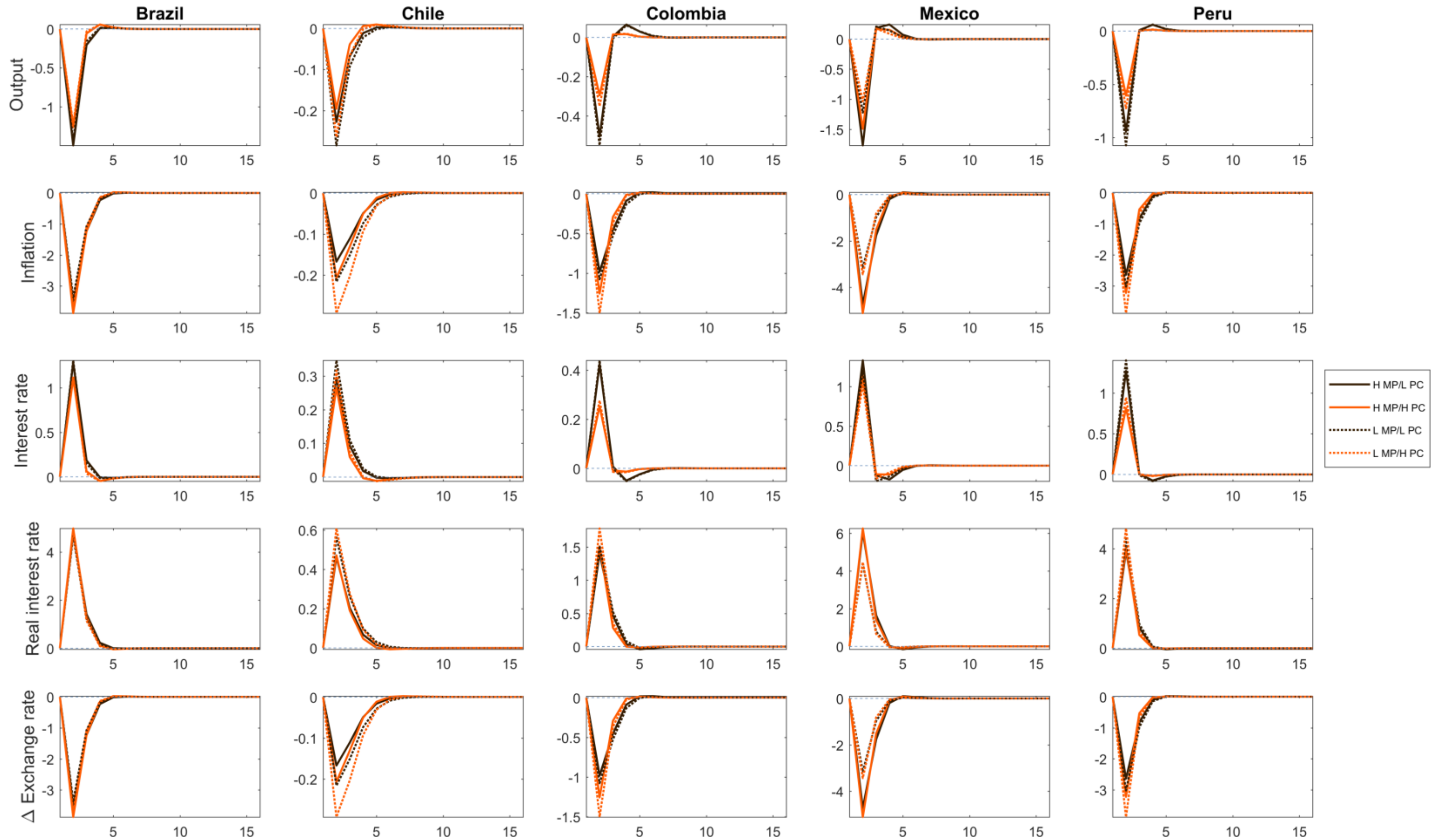
High / Low: $r_\pi \xi_t^{sp}$	ρ_r	r_π	r_y	$r_{\Delta e}$
Brazil	0.76 / 0.64	2.31 / 1.27	0.30 / 0.50	0.30 / 0.43
Chile	0.67 / 0.54	2.50 / 0.81	0.25 / 0.42	0.17 / 0.12
Colombia	0.75 / 0.61	2.51 / 0.91	0.30 / 0.67	0.20 / 0.38
Mexico	0.68 / 0.48	1.70 / 0.91	0.28 / 0.56	0.13 / 0.74
Peru	0.58 / 0.46	1.94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

Open-economy Phillips curve:

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

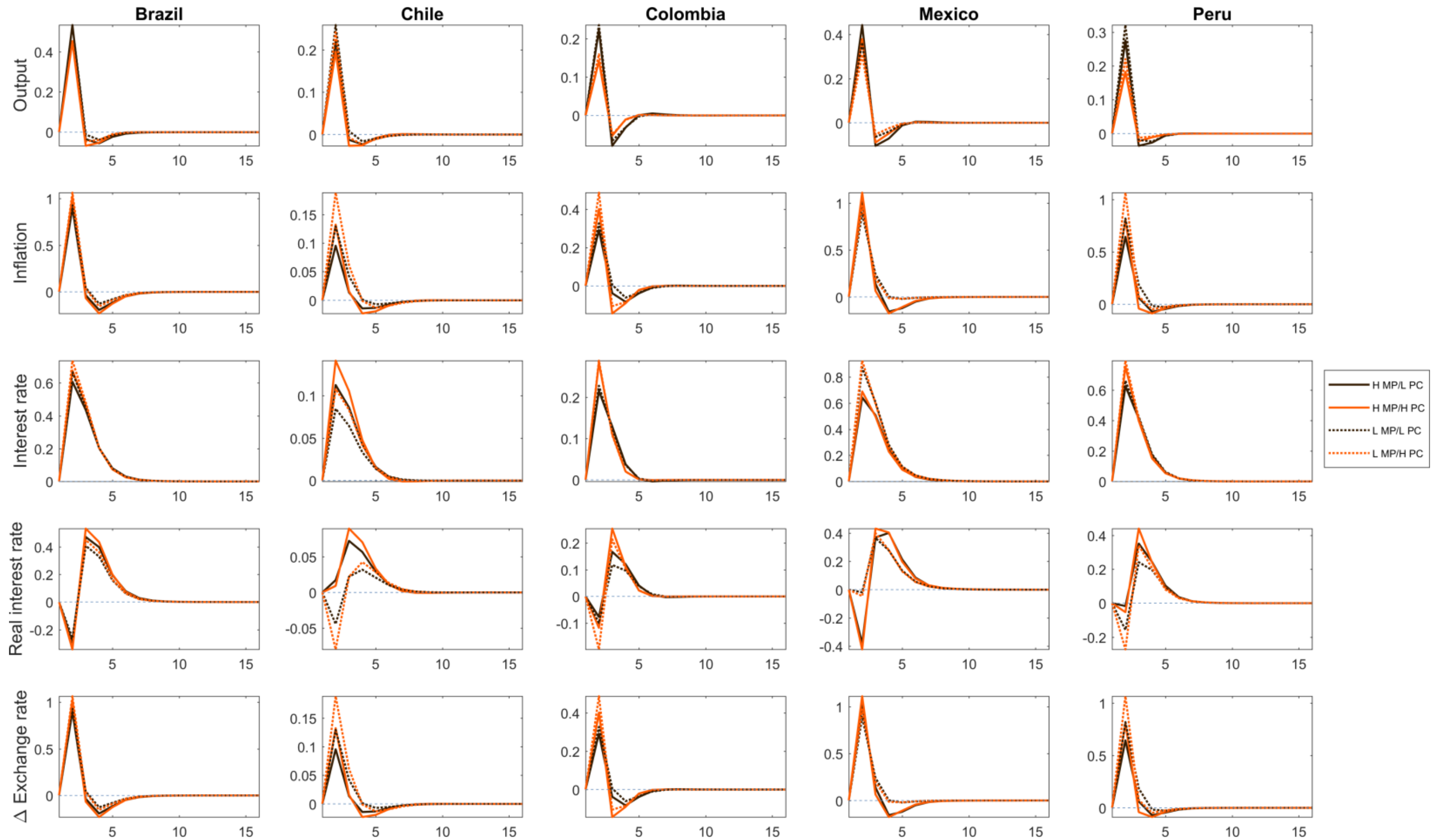
High / Low: $\kappa \xi_t^{sp}$	$E_t\{\pi_{t+1}\}$	π_{t-1}	$E_t\{\Delta q_{t+1}\}$	$(y_t - \bar{y}_t)$
Brazil	0.74 / 0.80	0.25 / 0.19	-0.09	2.35 / 1.72
Chile	0.64 / 0.70	0.35 / 0.30	-0.11	0.62 / 0.39
Colombia	0.73 / 0.58	0.26 / 0.42	-0.18	3.47 / 1.42
Mexico	0.62 / 0.56	0.37 / 0.44	-0.16	2.80 / 2.17
Peru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

Monetary policy shock



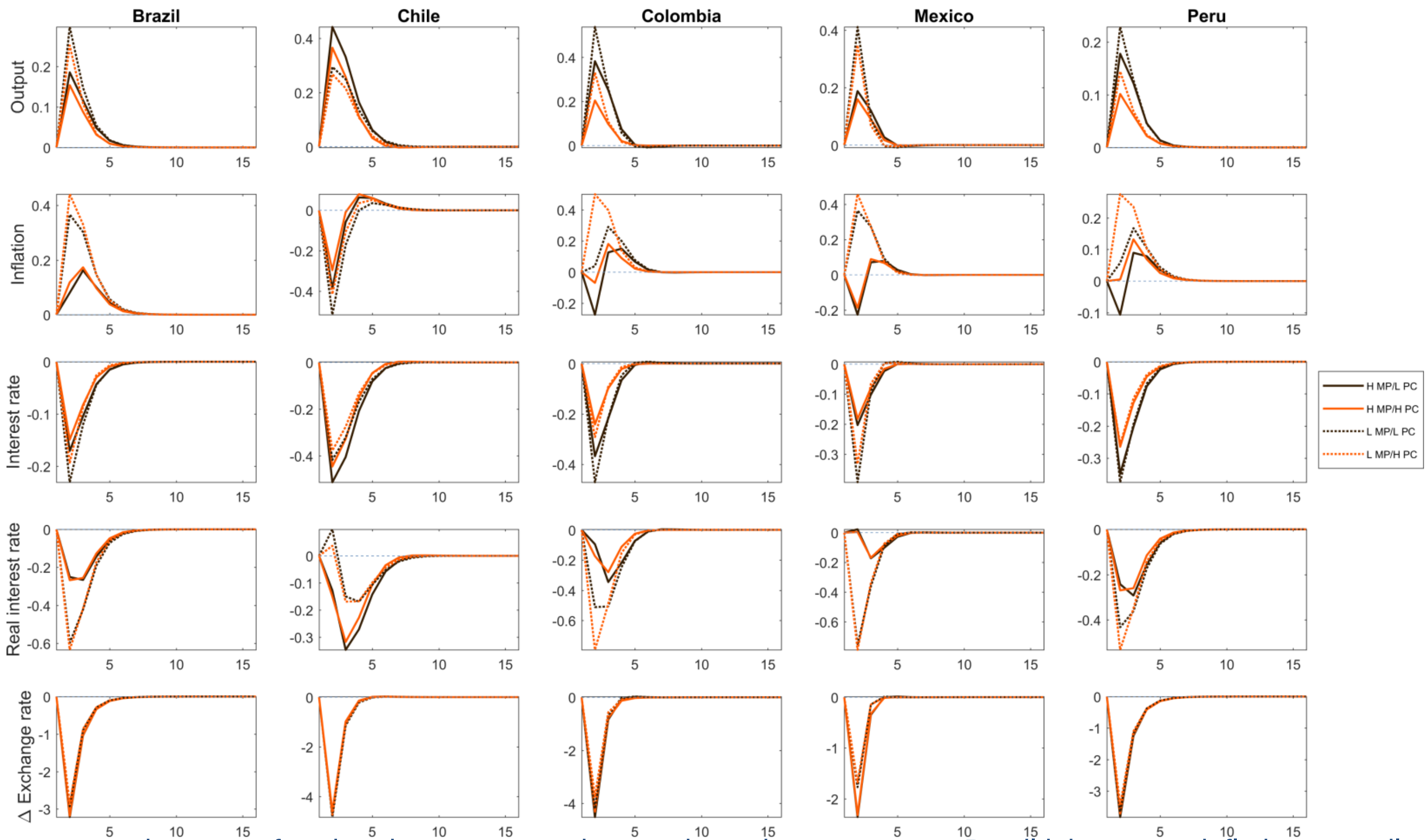
An unexpected increase in interest rates appreciates the currency, while it lowers inflation and output. Under the high policy response regime (solid), appreciations are larger in Mexico where real interest rates increase by more and inflation and output drops are larger; meanwhile appreciations are smaller in Chile, Colombia and Peru where real interest rates increase by less and the reduction in inflation is smaller. Under the low slope of the Phillips curve regime (brown), exchange rate appreciations are smaller in Chile, Colombia and Peru, where inflation reductions are also relatively smaller.

Technology shock



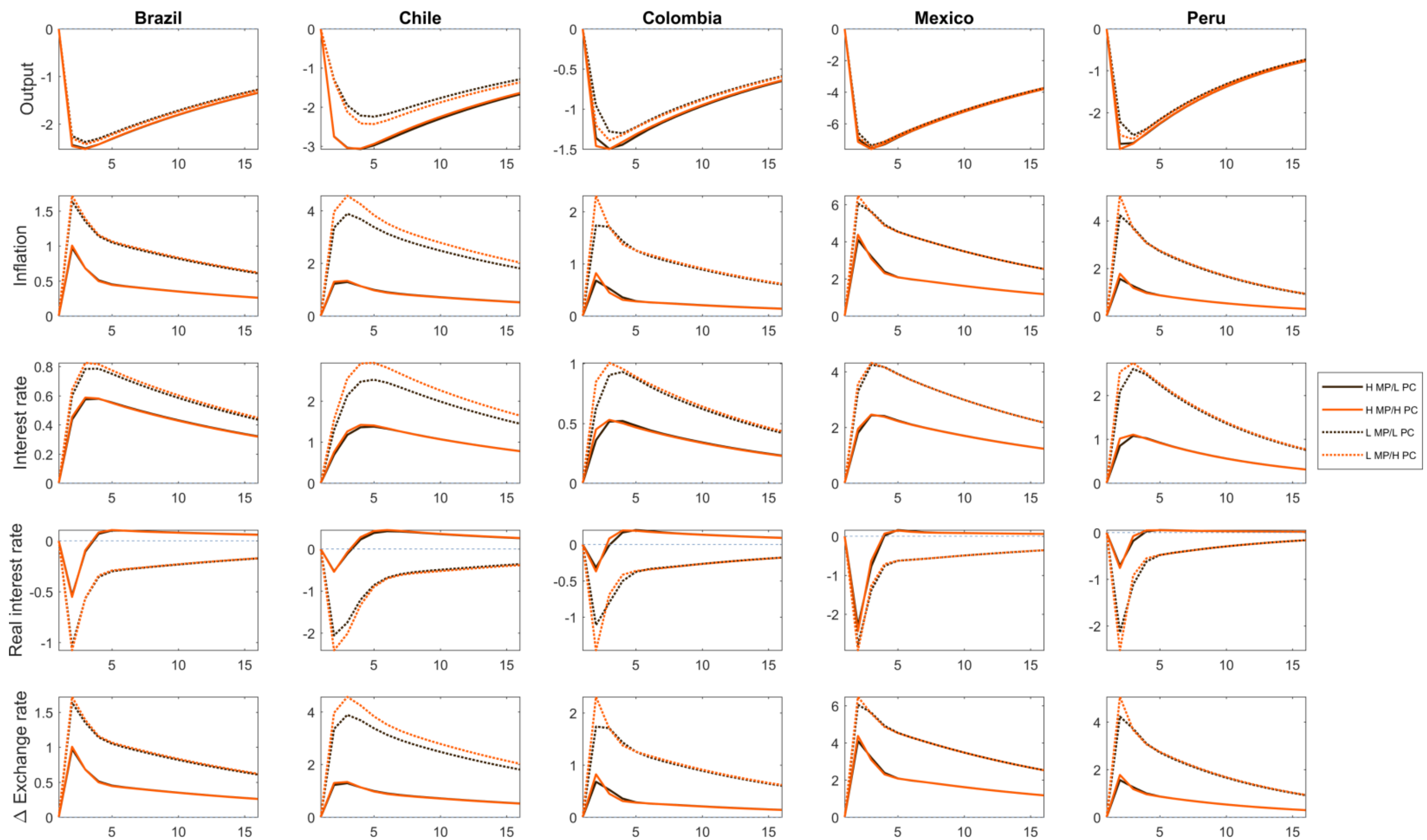
Technology is assumed to be difference stationary, so innovations in productivity have permanent effects on output. On average, output increases, inflation is positive, and currency depreciates. These movements are slightly smaller under the high policy response regime (solid). Output increases less and inflation more under a high Phillips curve slope (orange).

Terms of trade shock



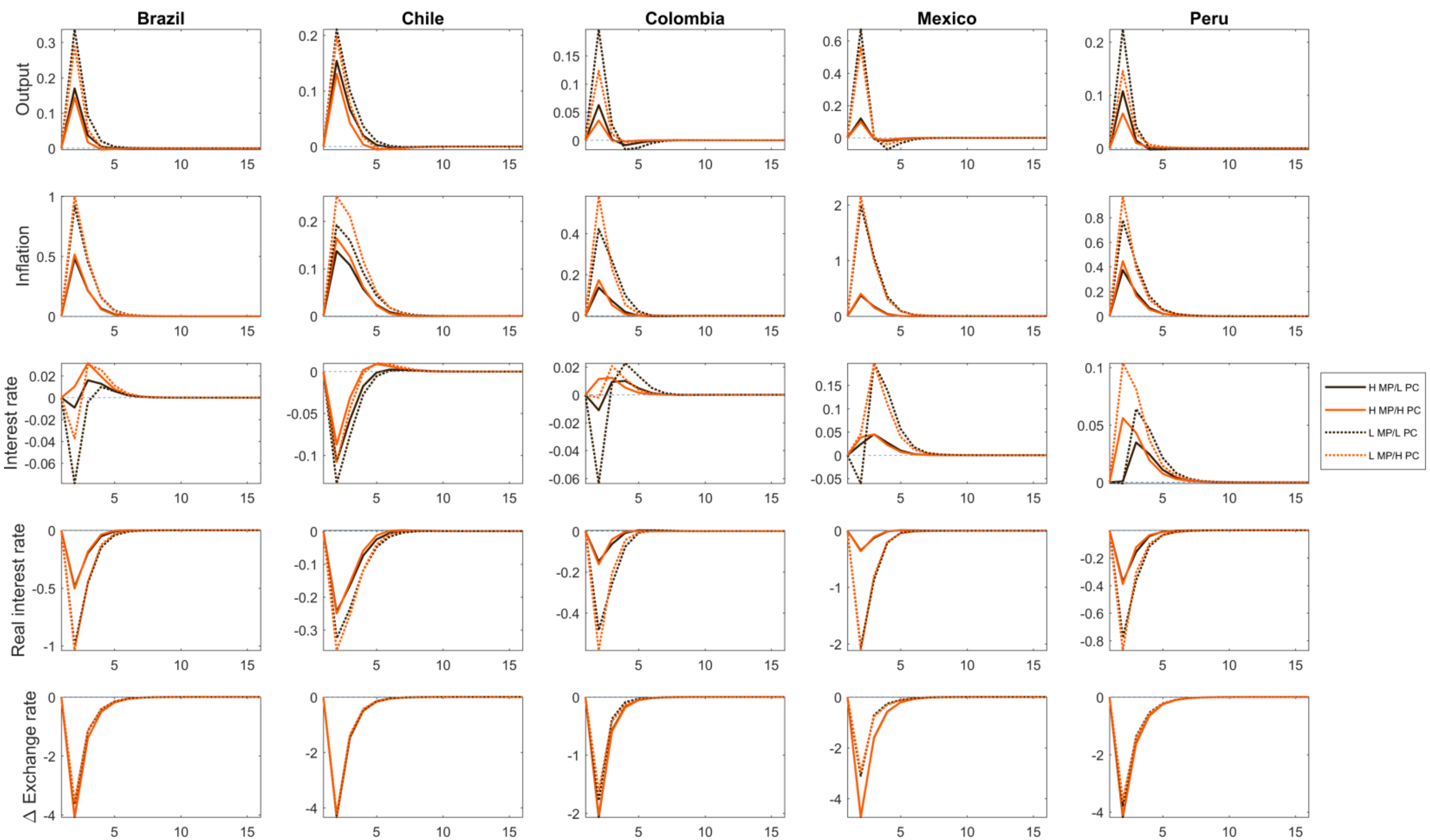
An unexpected improvement in terms of trade raises output and appreciates the currency. In Brazil it increases inflation regardless of the slope of the Phillips curve with higher increases if the interest rate response is low (dashed) and/or the slope of the Phillips curve is high (orange). In Chile inflation drops, with larger effects if interest rate response is low (dashed) and/or the Phillips curve slope is low (brown). In Colombia, Mexico and Peru, inflation drops if monetary policy response is high (solid) with larger drop if the Phillips curve coefficient is low (solid brown), and raises if interest rate response is low (dashed), with larger increase if the Phillips curve slope is high (dashed orange). The output increases are larger under low monetary policy response (dashed) in Brazil, Colombia, Mexico and Peru, where interest rates drop more, while in Chile the output increase and the interest rate cut are larger under high policy response (solid). On average, appreciations are of similar magnitude under both policy response regimes and both slopes of the Phillips curve.

World output shock



World demand shocks lower domestic output, increase inflation, and cause an exchange rate depreciation. These results arises because, under the estimated elasticities of intertemporal substitution, world output shocks lower domestic potential output in all countries. Despite the fact that nominal interest rates increase, real interest rates decrease. Under high policy response regimes (solid) output contractions are larger, inflation increases less, nominal exchange rate depreciation is smaller, and the central banks cut real interest rates by less. In general, a high slope of the Phillips curve (orange) magnifies the responses.

World inflation shock



Shocks to import price inflation appreciate the currency, but raise inflation because, in addition to the inherent foreign price inflation, the central bank reacts to movements in the exchange rate, and lowers real interest rates. Under high policy response regimes (solid) output and inflation increases by less, and the nominal exchange rate depreciation is of similar magnitude, except for Mexico where it is larger under high response. The high slope of the Phillips curve regime (orange) magnifies the inflationary and appreciating currency effects, while it dampens output expansions.

Brazil: switching parameters and shocks estimates and regime probabilities

High interest rate response	Low interest rate response
$r_t = 0.76 r_{t-1} + (1-0.76)(2.31 + 0.30 y_t + 0.30 \Delta e_t)$	$r_t = 0.64 r_{t-1} + (1-0.64)(1.27 \pi_t + 0.50 y_t + 0.43 \Delta e_t)$
High Phillips curve	**Low Phillips curve**
$\pi_t = 0.74 E_t\{\pi_{t+1}\} + 0.25 \pi_{t-1} - 0.09 \Delta q_t + 2.35(y_t - \bar{y}_{t-1})$	$\pi_t = 0.80 E_t\{\pi_{t+1}\} + 0.19 \pi_{t-1} - 0.09 \Delta q_t + 1.72(y_t - \bar{y}_{t-1})$
High shocks volatility	**Low shocks volatility**
$\sigma_{a,\xi_t^{vol=h}} = 4.76$	$\sigma_{a,\xi_t^{vol=l}} = 4.46$

$H_{h,l}^{mp} = 0.12$

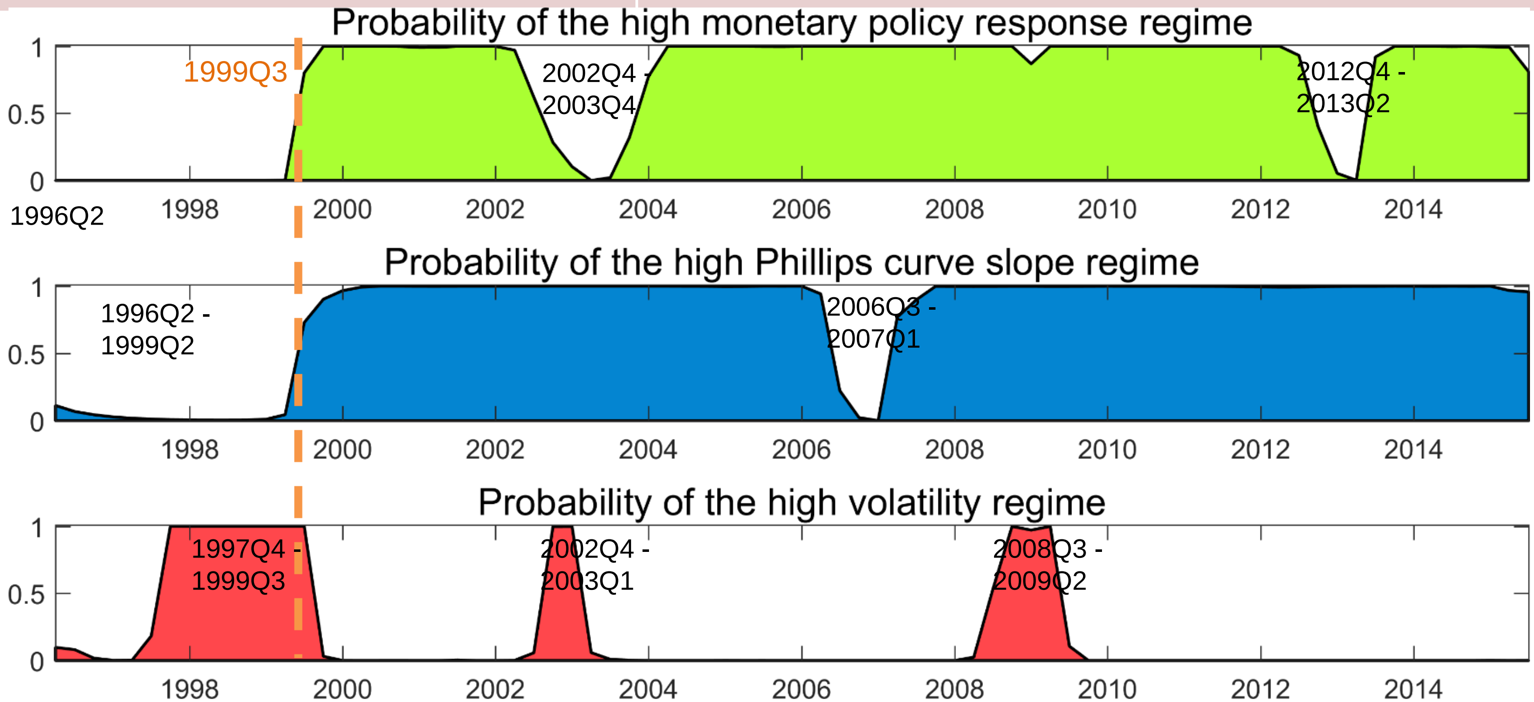
$H_{l,h}^{mp} = 0.22$

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

$H_{l,h}^{pc} = 0.15$

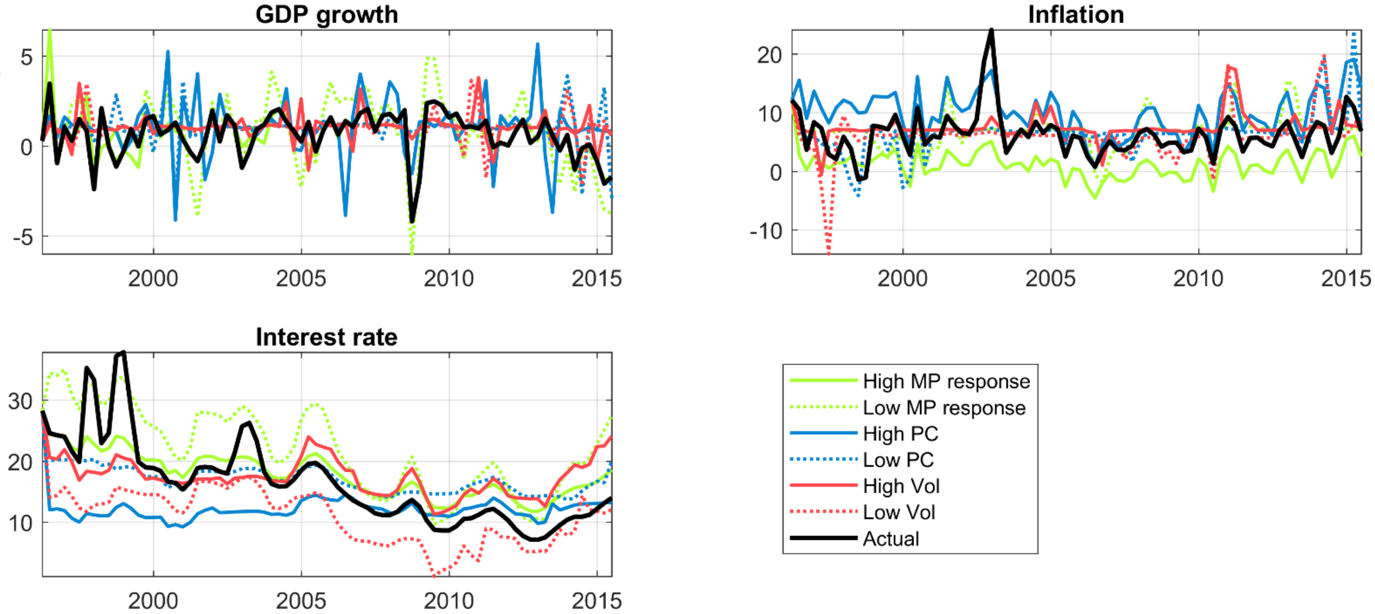
$H_{h,l}^{vol} = 0.17$

$H_{l,h}^{vol} = 0.30$



Brazil: counterfactuals

In Brazil, regime switch to H_MP and L_Vol help to explain the observed reduction of inflation and its volatility despite the regime switch to H_PC.



	Output Growth		Inflation		Interest Rate	
	M	SD	M	SD	M	SD
High MP	0.67	1.37	1.23	2.45	17.87	3.69
Low MP	0.76	2.03	9.98	3.87	22.03	7.04
High PC	1.06	1.63	7.06	2.95	12.16	2.19
Low PC	1.04	1.07	6.43	3.71	17.02	2.36
High Vol	1.05	0.80	7.54	2.33	17.48	3.09
Low Vol	1.04	0.77	5.88	3.80	11.01	4.73
Actual	0.64	1.26	6.31	3.72	16.49	7.00

Chile: switching parameters and shocks estimates and regime probabilities

High interest rate response	Low interest rate response
$r_t = 0.67 r_{t-1} + (1-0.67)(2.50\pi_t + 0.25 y_t + 0.17\Delta e_t)$	$r_t = 0.54 r_{t-1} + (1-0.54)(0.81\pi_t + 0.42 y_t + 0.12\Delta e_t)$
High Phillips curve	**Low Phillips curve**
$\pi_t = 0.64 E_t\{\pi_{t+1}\} + 0.35\pi_{t-1} - 0.11\Delta q_t + 0.62(y_t - \bar{y}_{t-1})$	$\pi_t = 0.70 E_t\{\pi_{t+1}\} + 0.30\pi_{t-1} - 0.11\Delta q_t + 0.39(y_t - \bar{y}_{t-1})$
High shocks volatility	**Low shocks volatility**
$\sigma_{a,\xi_t^{vol=h}} = 5.21$	$\sigma_{a,\xi_t^{vol=l}} = 3.77$

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

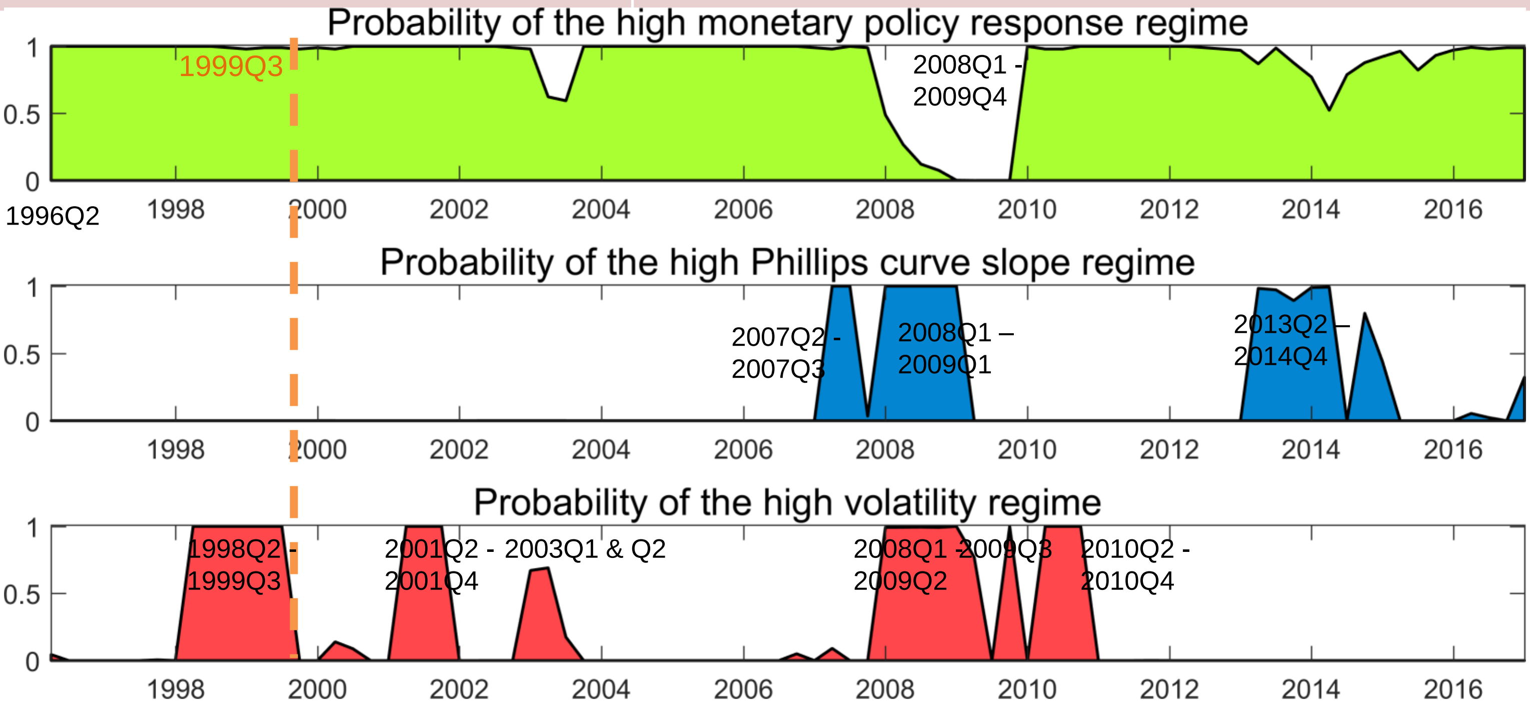
$H_{l,h}^{mp} = 0.07$

$H_{h,l}^{pc} = 0.03$

$H_{l,h}^{pc} = 0.03$

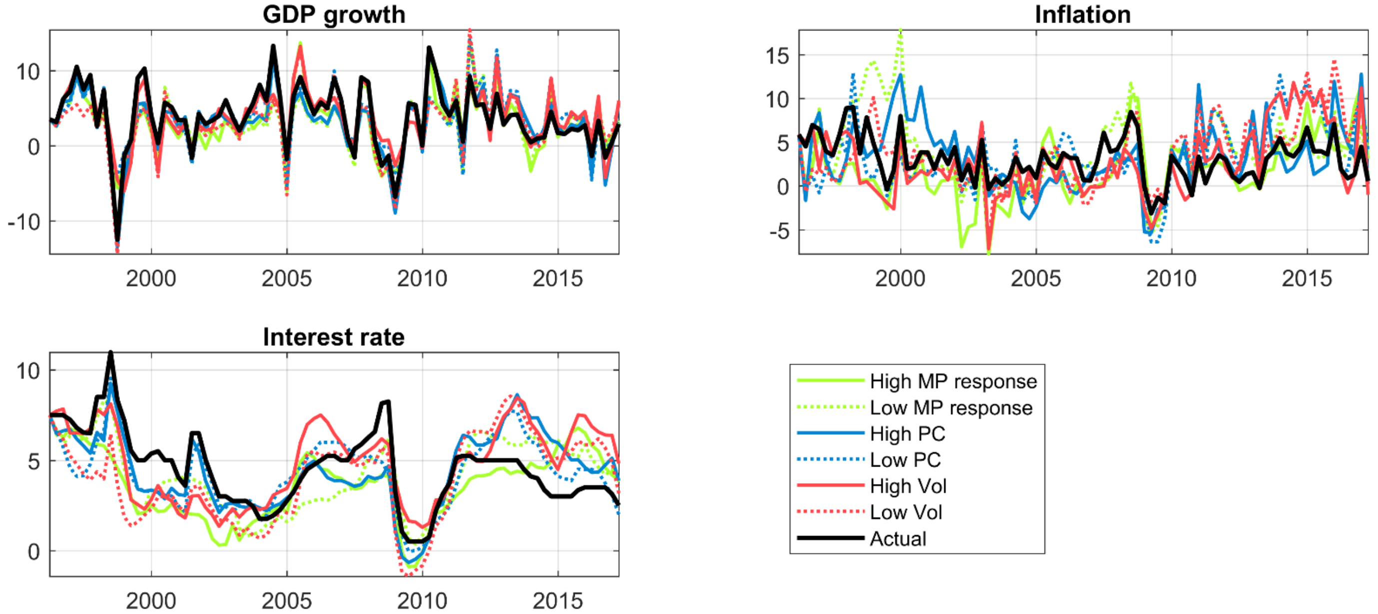
$H_{h,l}^{vol} = 0.22$

$H_{l,h}^{vol} = 0.05$



Chile: counterfactuals

In Chile, H_MP kept inflation low without implying higher interest rates, neither lower or more volatile output.



	Output Growth		Inflation		Interest Rate	
	M	SD	M	SD	M	SD
High MP	2.96	3.76	1.74	3.64	3.59	1.93
Low MP	2.82	4.03	4.06	4.31	4.15	1.96
High PC	3.22	4.25	3.30	3.88	4.43	2.08
Low PC	3.66	3.76	3.34	3.85	4.33	1.93
High Vol	3.97	3.84	2.70	3.91	4.87	2.13
Low Vol	3.10	4.31	3.56	3.90	3.97	2.36
Actual	3.80	4.16	3.03	2.51	4.54	2.06

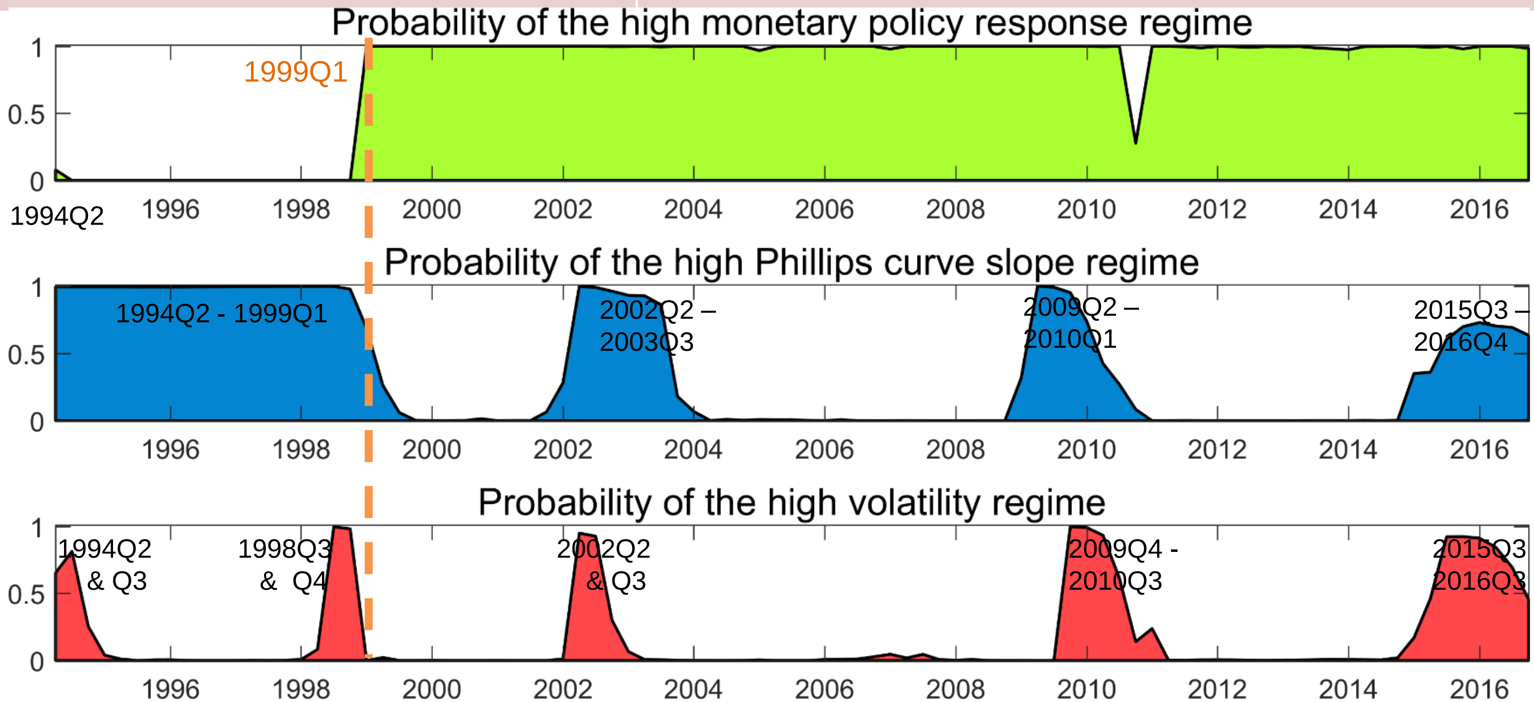
Colombia: switching parameters and shocks estimates and regime probabilities

High interest rate response	Low interest rate response
$r_t = 0.75 r_{t-1} + (1-0.75)(2.51\pi_t + 0.30 y_t + 0.20\Delta e_t)$	$r_t = 0.61 r_{t-1} + (1-0.61)(0.91\pi_t + 0.67 y_t + 0.38\Delta e_t)$
High Phillips curve	**Low Phillips curve**
$\pi_t = 0.73 E_t\{\pi_{t+1}\} + 0.26\pi_{t-1} - 0.18\Delta q_t + 3.47(y_t - \bar{y}_{t-1})$	$\pi_t = 0.58 E_t\{\pi_{t+1}\} + 0.42\pi_{t-1} - 0.18\Delta q_t + 1.42(y_t - \bar{y}_{t-1})$
High shocks volatility	**Low shocks volatility**
$\sigma_{a,\xi_t^{vol=h}} = 5.97$	$\sigma_{a,\xi_t^{vol=l}} = 4.64$

$H_{h,l}^{mp} = 0.13$
$H_{l,h}^{mp} = 0.18$

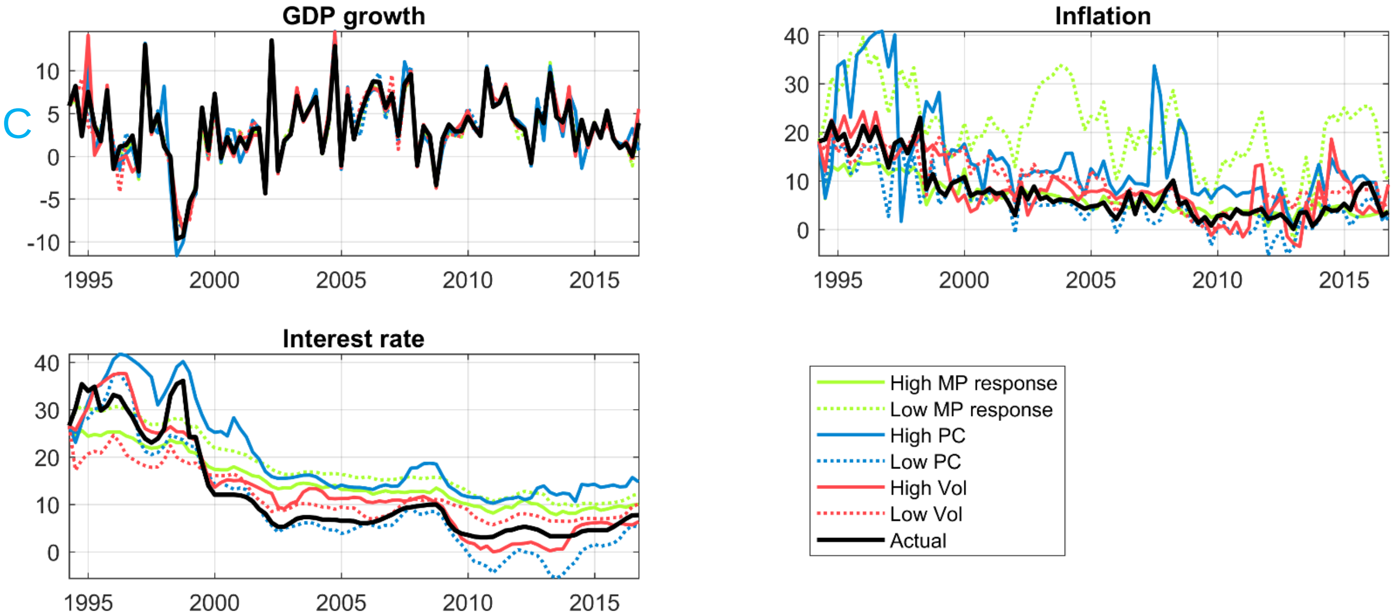
$H_{h,l}^{pc} = 0.14$
$H_{l,h}^{pc} = 0.09$

$H_{h,l}^{vol} = 0.16$
$H_{l,h}^{vol} = 0.12$



Colombia: counterfactuals

In Colombia, regime switch to H_MP and L_PC 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	3.19	3.84	6.60	3.59	14.77	5.58
Low MP	3.20	3.99	20.95	8.20	17.94	6.74
High PC	3.26	4.42	14.21	9.71	20.08	9.64
Low PC	3.46	4.18	5.49	5.49	9.58	11.06
High Vol	3.38	4.22	8.90	6.47	13.08	10.31
Low Vol	3.28	4.13	9.68	5.22	11.86	5.40
Actual	3.35	4.14	7.74	5.77	12.06	10.24

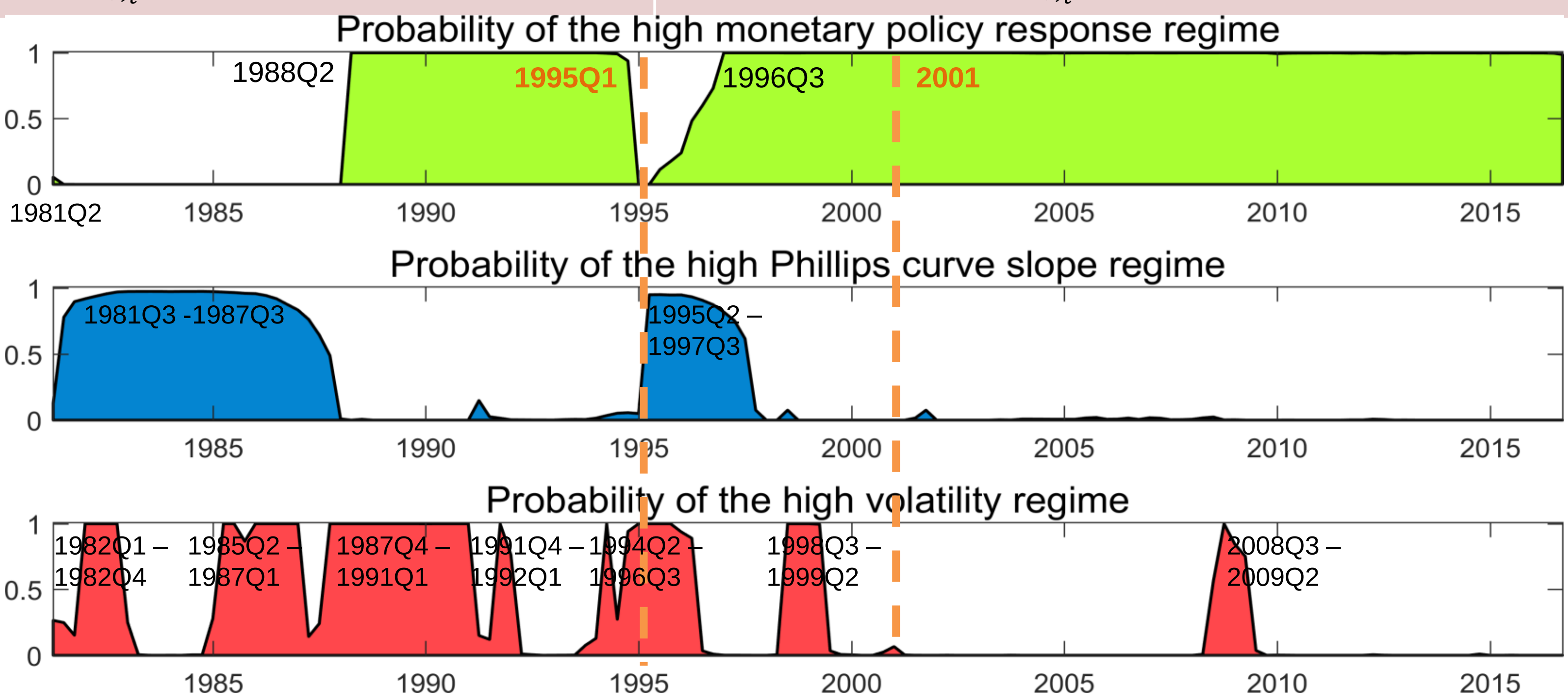
Mexico: switching parameters and shocks estimates and regime probabilities

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**
$\sigma_{a,\xi_t^{vol=h}} = 7.51$	$\sigma_{a,\xi_t^{vol=l}} = 3.03$

$H_{h,l}^{mp} = 0.06$
$H_{l,h}^{mp} = 0.09$

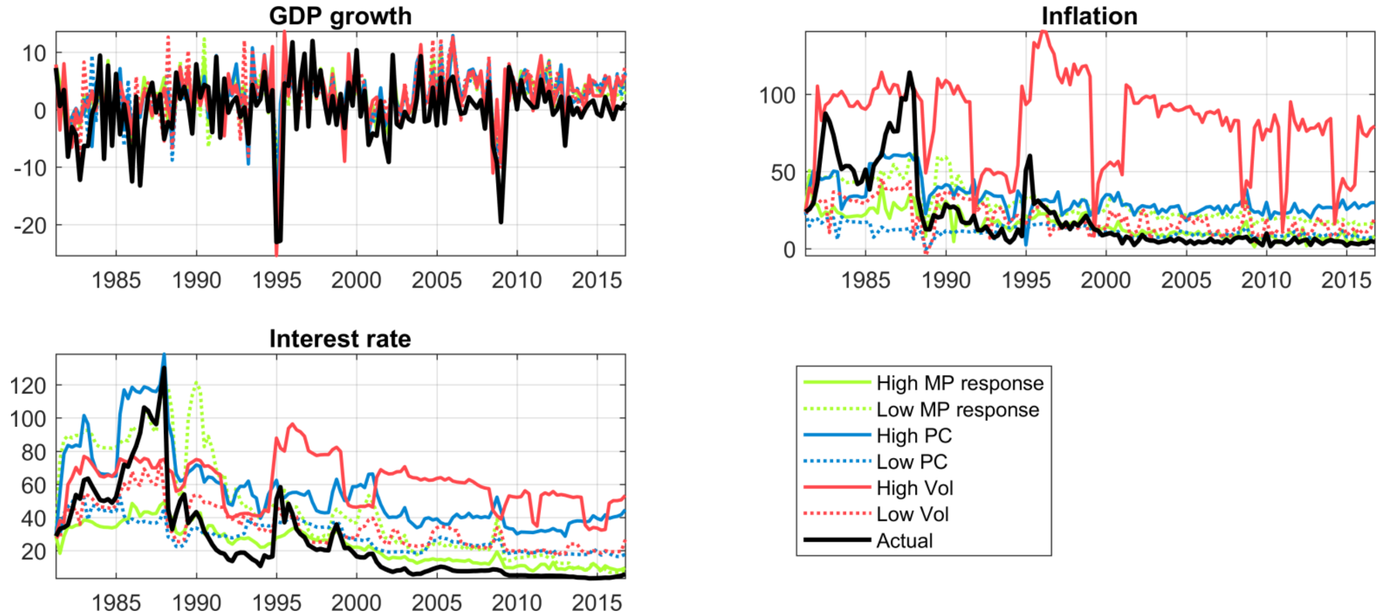
$H_{h,l}^{pc} = 0.14$
$H_{l,h}^{pc} = 0.09$

$H_{h,l}^{vol} = 0.10$
$H_{l,h}^{vol} = 0.19$



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

Peru: switching parameters and shocks estimates and regime probabilities

High interest rate response	Low interest rate response
$r_t = 0.58 r_{t-1} + (1-0.58)(1.94\pi_t + 0.47 y_t + 0.19\Delta e_t)$	$r_t = 0.46 r_{t-1} + (1-0.46)(1.01\pi_t + 0.64 y_t + 0.25\Delta e_t)$
High Phillips curve	**Low Phillips curve**
$\pi_t = 0.83 E_t\{\pi_{t+1}\} + 0.16\pi_{t-1} - 0.12\Delta q_t + 4.54(y_t - \bar{y}_{t-1})$	$\pi_t = 0.70 E_t\{\pi_{t+1}\} + 0.30\pi_{t-1} - 0.12\Delta q_t + 2.18(y_t - \bar{y}_{t-1})$
High shocks volatility	**Low shocks volatility**
$\sigma_{a,\xi_t^{vol=h}} = 5.53$	$\sigma_{a,\xi_t^{vol=l}} = 3.38$

$H_{h,l}^{mp} = 0.04$

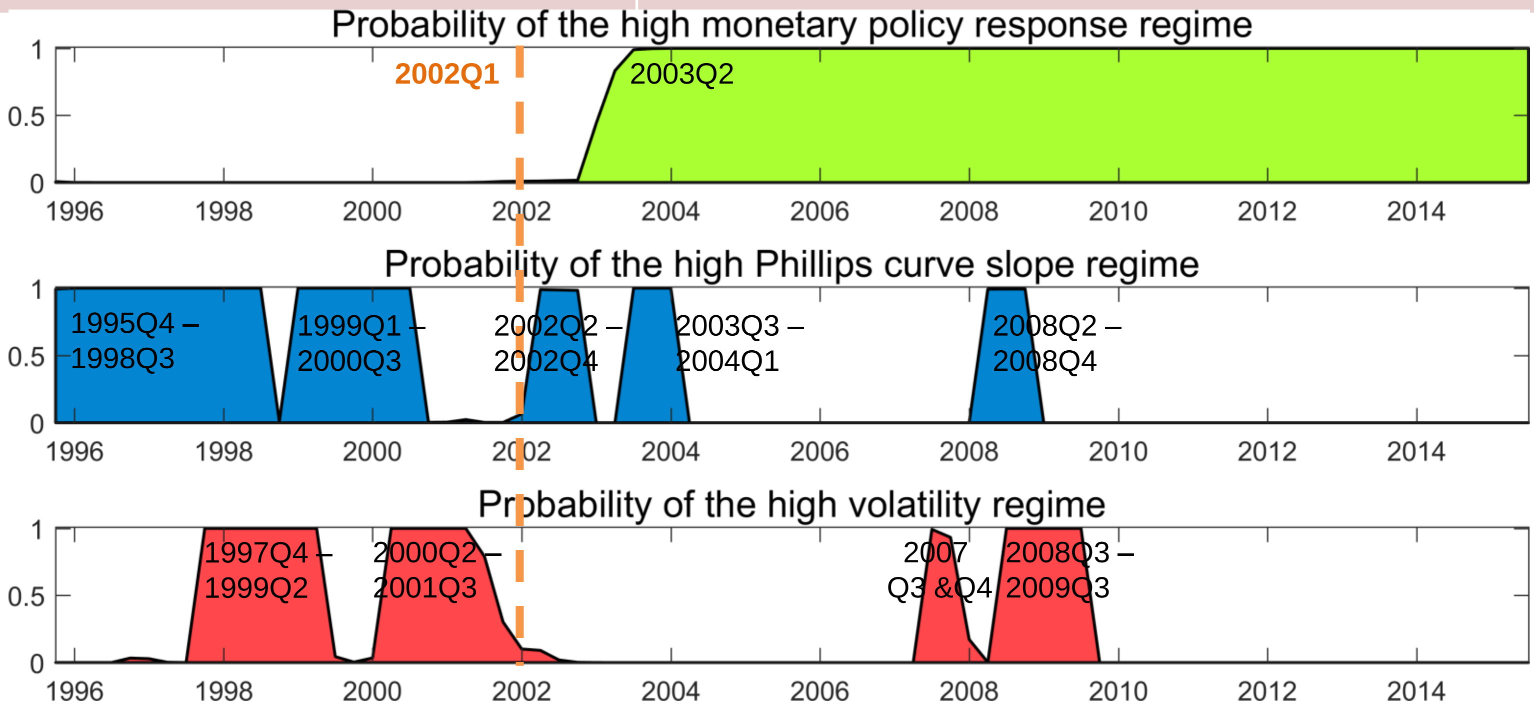
$H_{l,h}^{mp} = 0.07$

$H_{h,l}^{pc} = 0.13$

$H_{l,h}^{pc} = 0.11$

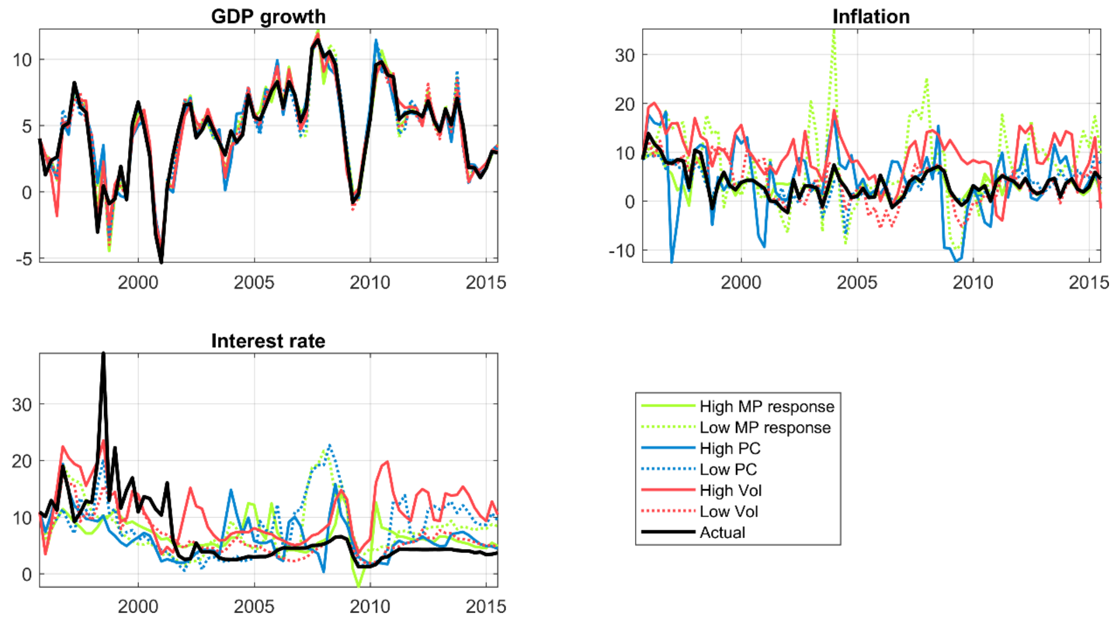
$H_{h,l}^{vol} = 0.15$

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



Peru: counterfactuals

In Peru, regime switch to H_MP, L_PC and 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	4.64	3.36	3.32	2.43	6.79	2.86
Low MP	4.61	3.40	7.29	8.08	8.04	4.66
High PC	4.64	3.31	4.33	6.89	6.46	3.67
Low PC	4.62	3.36	3.50	3.00	8.31	5.24
High Vol	4.59	3.35	9.43	5.05	10.80	4.82
Low Vol	4.64	3.43	3.79	4.33	6.58	3.62
Actual	4.65	3.31	3.62	3.18	6.91	6.03

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