Revisiting the Exchange Rate Pass Through: A General Equilibrium Perspective

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*The views and conclusions presented in this paper are exclusively those of the authors and do not necessarily reflect the position of the Central Bank of Chile or of its Board members.

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- Large literature estimating the ERPT using reduced-form models: single equation, VAR.
- The estimated ERPTs vary significantly across countries, types of baskets of goods, and time $\rightarrow$ different explanations.

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  - Response NER and prices to shocks depends on expected MP.
  - MP rule in empirical models?/Alternative MP reactions

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Related Literature

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- **Preview of results: Differences are significant!**
  - Effect predicted by empirical ERPT is "almost surely" always wrong.
  - Effect of monetary policy on ERPT depends significantly on shock hitting the economy.

Rest of the Talk

- The empirical approach vs. DSGE models
- Brief description of the model and the parametrization strategy
- Main drivers of the nominal exchange rate
- Conditional and unconditional ERPT
- Alternative MP and ERPT*
- Conclusions

The empirical approach
vs.
DSGE models

ERPT: VAR vs. DSGE

- VAR-based ERPT: $x_t = \Gamma + \Phi_1 x_{t-1} + ... + \Phi_p x_{t-p} + u_t$.
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  - ERPT h periods ahead: $ERPT^V(h) \equiv \frac{CIRF^V_{\pi^j,\pi^S}(h)}{CIRF^V_{\pi^S,\pi^S}(h)}$.

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  - $UERPT^{PV}(h)$: obtained applying the VAR methodology to an infinite sample generated by the DSGE model.

A Quantitative DSGE Model

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- Bayesian estimation with 22 variables, both aggregate and sectorial.

Details Data Shocks Calibration Estimation Goodness of fit

Main drivers of the NER in the model

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  - Difference: $\downarrow F^*$ tends to decrease CPI inflation by its impact on import prices. IRFs

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Variance Decomposition

Var.	R	R^W	$EMBI$	UIP	F^*	Sum.
π^S	3	6	2	**14**	**71**	95
π	3	13	5	**13**	**10**	44
π^T	3	17	7	**19**	**14**	59
π^N	2	15	6	**10**	**9**	43
R	13	19	7	**14**	**11**	64
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  - F^* is much more relevant than UIP for the NER, but for other variables they have a similar influence.

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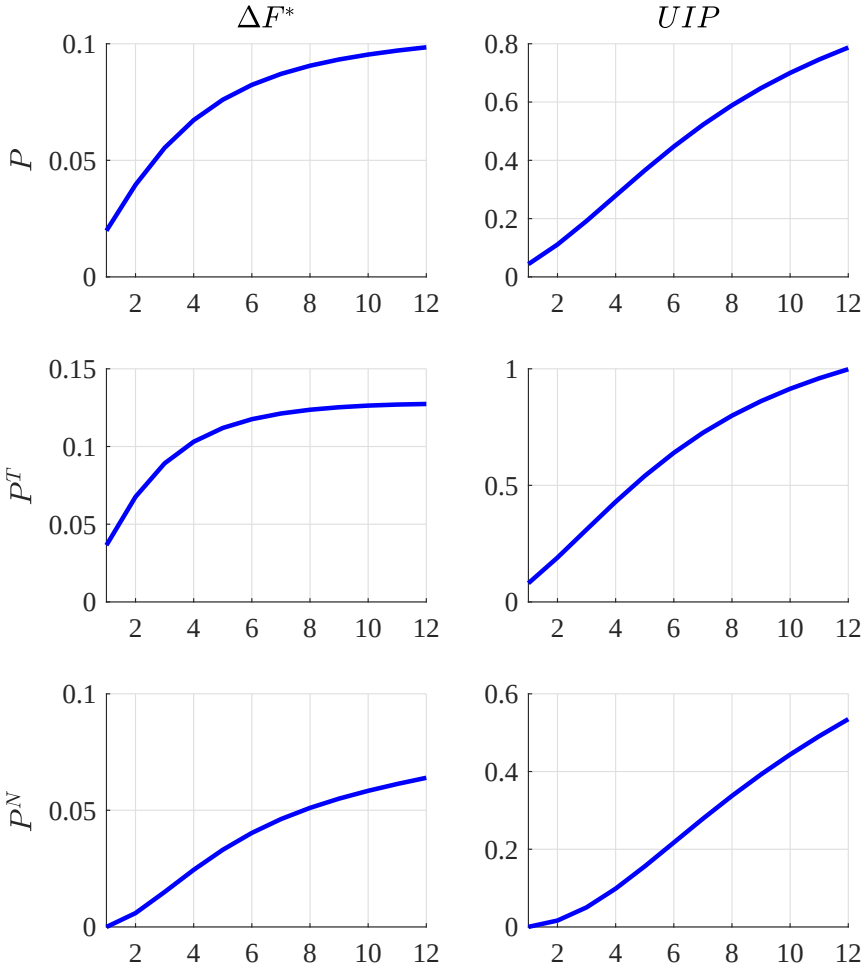

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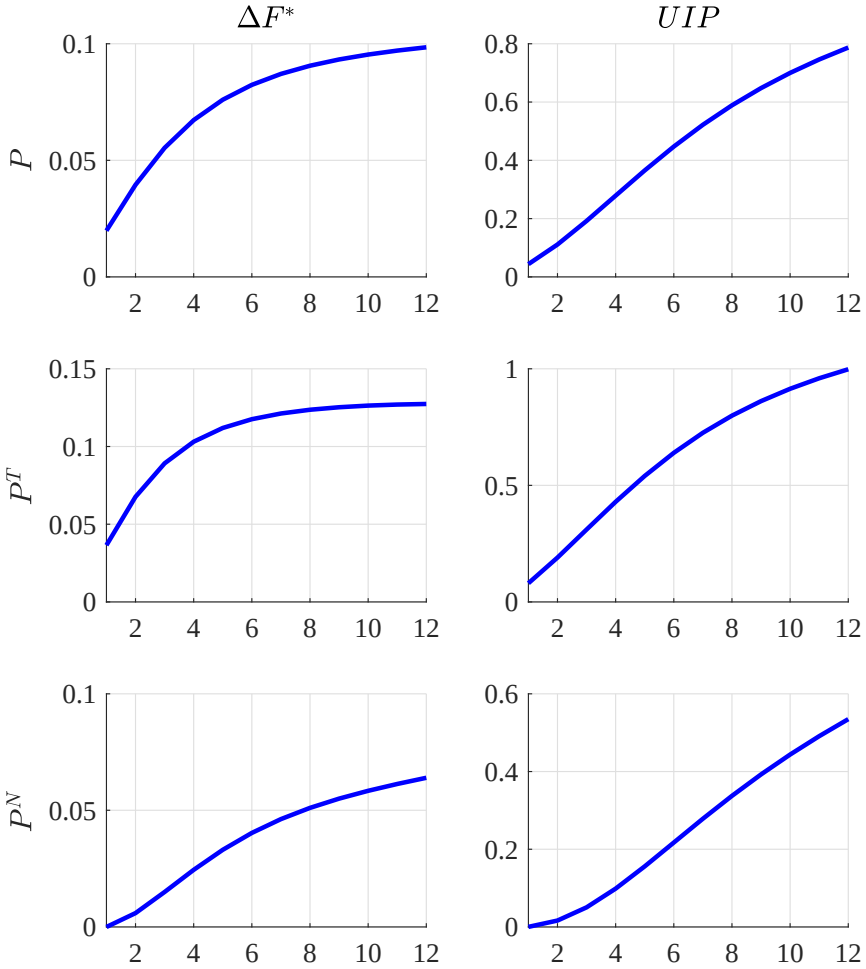

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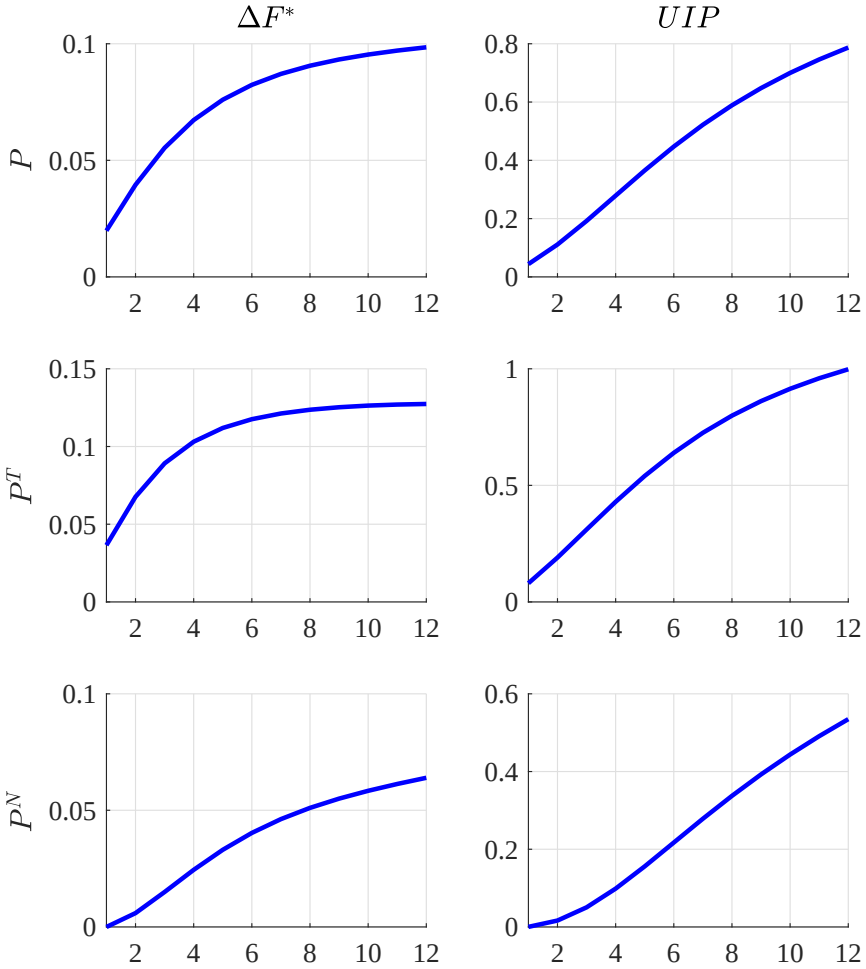

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- For both, the pass-through is higher for T than for N.

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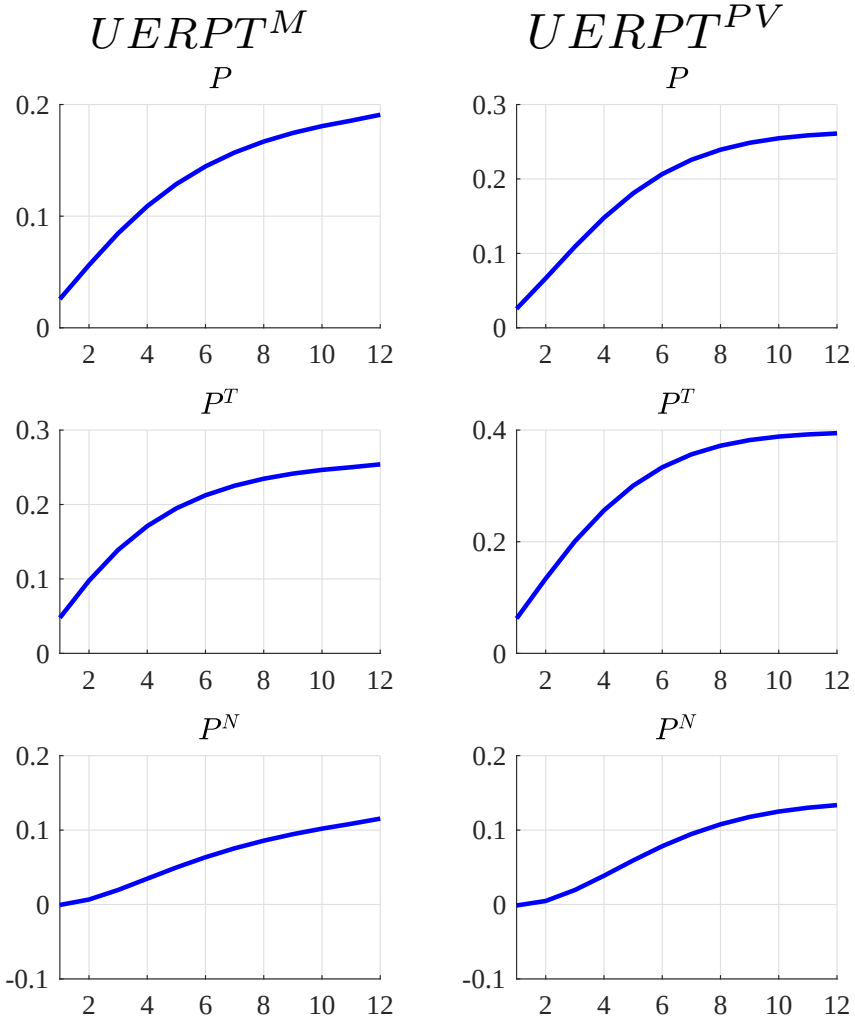

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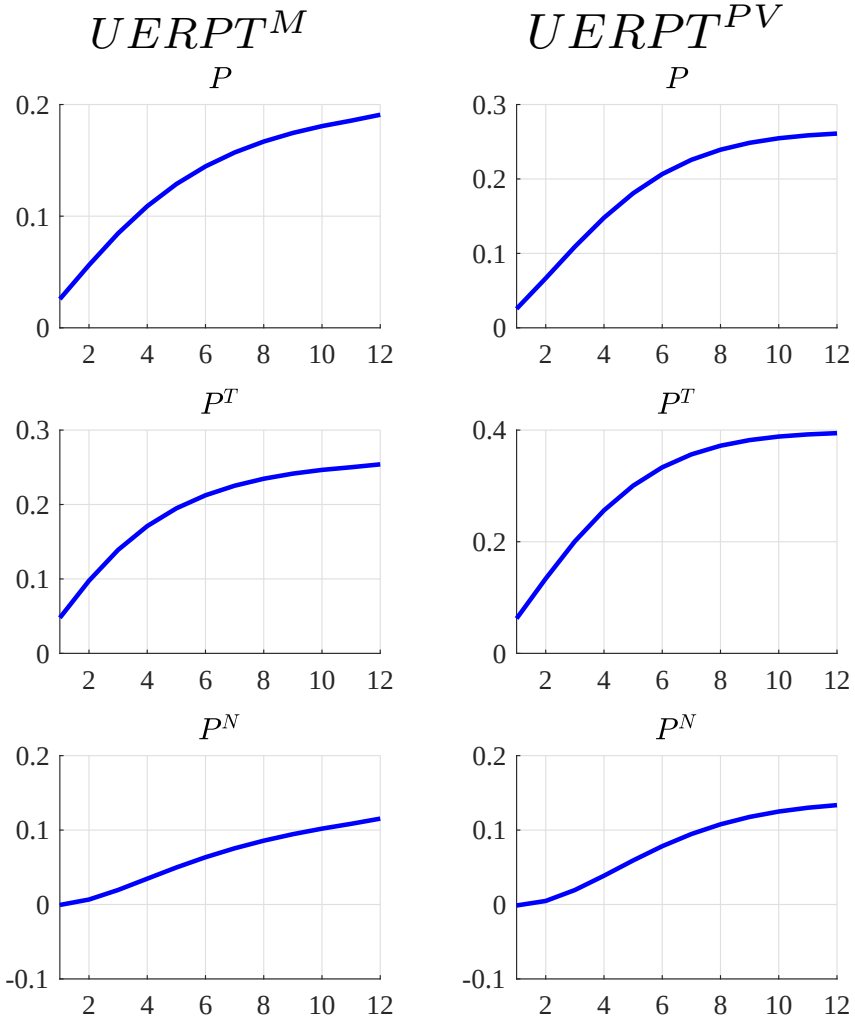

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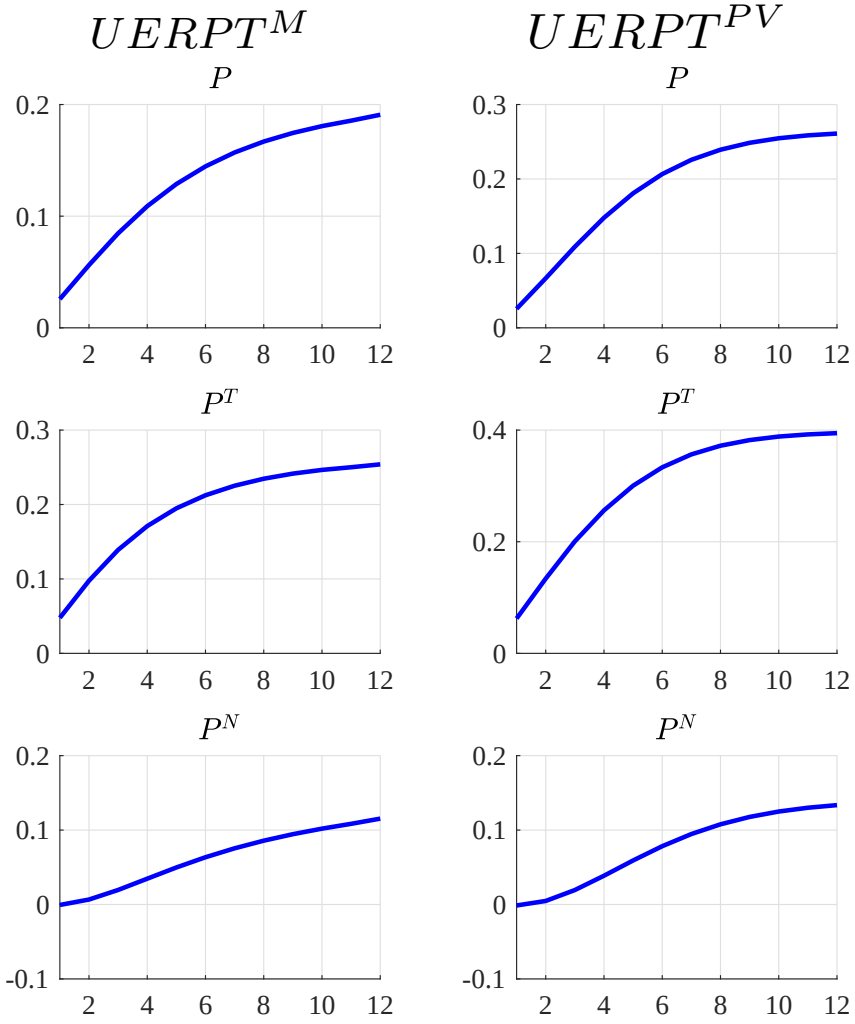

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- Comparable with VAR literature.
- Implications:
  - Whenever there is only one shock, unconditional EPRT predicts the movement in prices wrongly.
  - If both shocks hit the economy, the prediction will be correct **only** if the relative importance of each shock in that moment equals the one implicit in the unconditional ERPT.

Monetary Policy and ERPT

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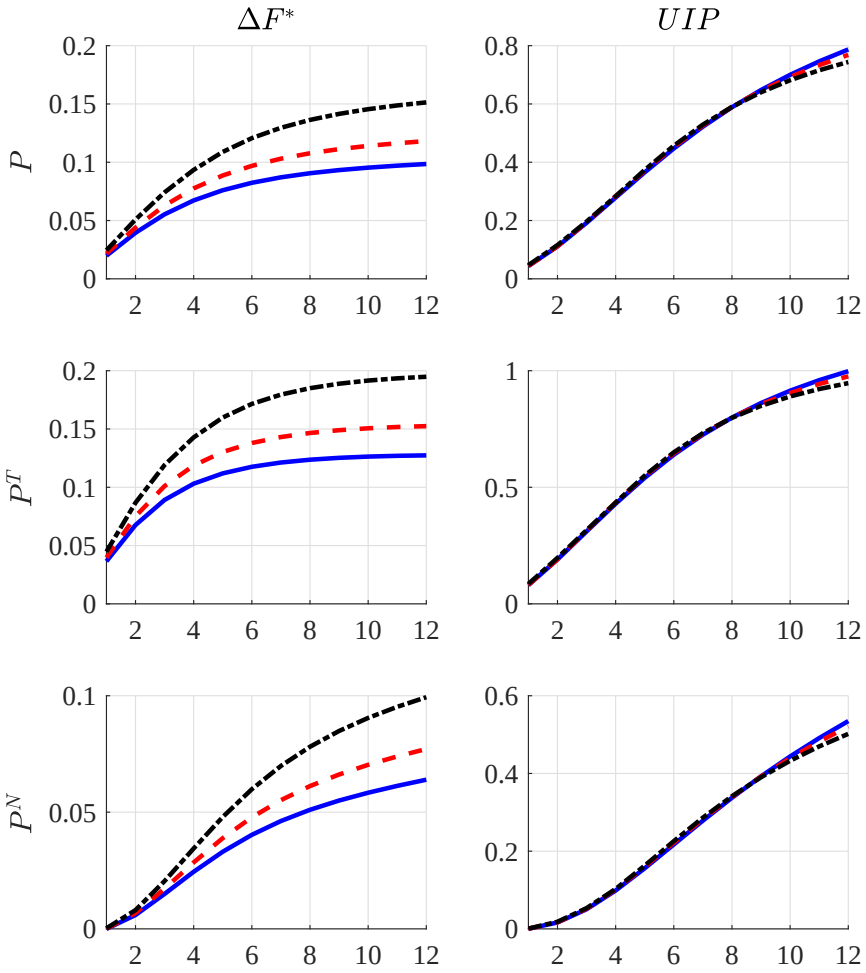
- Not clear ex-ante: a more expansionary policy will tend to increase both inflation and the NER. IRF

Expected Monetary Policy and ERPT

Conditional ERPT



Solid blue: Baseline. Dashed red: $T^* = 2$.
Dashed-dotted black: $T^* = 4$.

- After a shock to F^* a more expansionary policy path increases the ERPT.
  - Delaying the tightening by a year rises the ERPT after 2 years by almost 50% for all prices.

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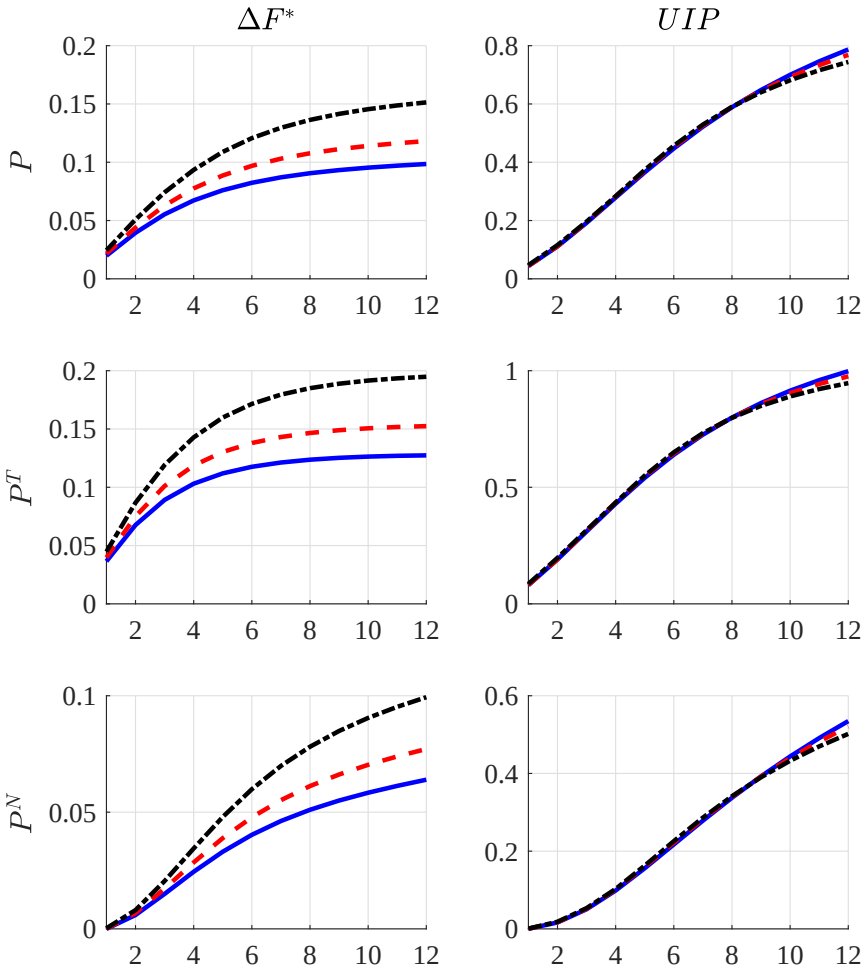

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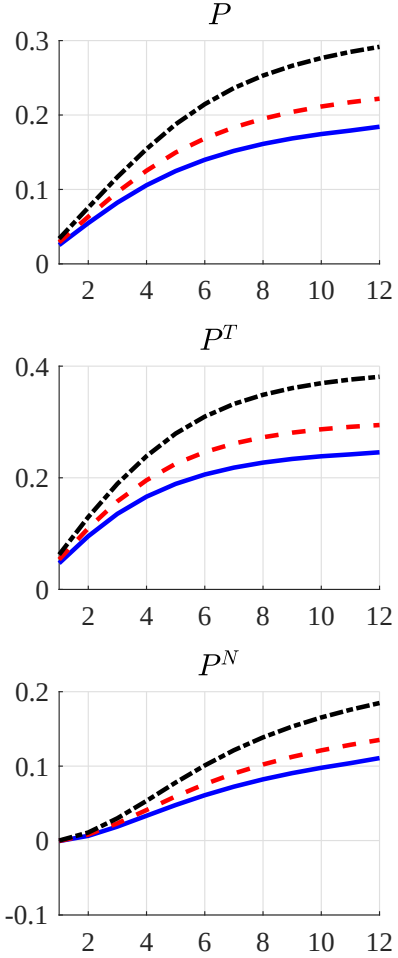
- After a UIP shock (R^W,$EMBI$), alternative policy paths do not affect the ERPT.

Expected Monetary Policy and ERPT

Unconditional ERPT
$(UERPT^M)$



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- Unconditional ERPT also affected.
- Distinguishing conditional and unconditional ERPT is also relevant from this perspective.

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- The ERPT (Conditional or Unconditional) is different under alternative expected paths of the policy rate.
  - VAR silent about this.

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- Conditional and Unconditional ERPT are quite different.
  - Unprecise (wrong) predictions of effect on prices.
- The ERPT (Conditional or Unconditional) is different under alternative expected paths of the policy rate.
  - VAR silent about this.
  - Under the shock, just differences in what the monetary policy is expected to do can bring important differences.

Thank you!

EXTRAS

Related Literature

- Conditional vs. Unconditional ERPT.
  - Shambaugh (2008) and Forbes et al (2016) identify general shocks (supply, demand, etc.) in VAR models, obtaining different conditional ERPT for each shock.
    - They do not show how the unconditional measures are related to the conditional ones and the importance of the bias generated.
    - Identified shocks are too general (sign or long run restrictons).
  - Bouakez and Rebei (2008) use an estimated DSGE model for Canada.
    - Our model includes a richer sectoral structure (TNT).
    - Our measure of unconditional ERPT is comparable to the empirical literature.
  - Corsetti et al. (2008) explores the connection between DSGE models and regression-based estimates.

- Relationship MP and ERPT
  - Effect MP on ERPT (Taylor, 2000; Gagnon and Ihrig, 2004; Devereux et al., 2004)
  - Effect ERPT on MP (Deveraux et al ,2006; Devereux and Yetman, 2014; Engel, 2009; Corsetti et al, 2010)

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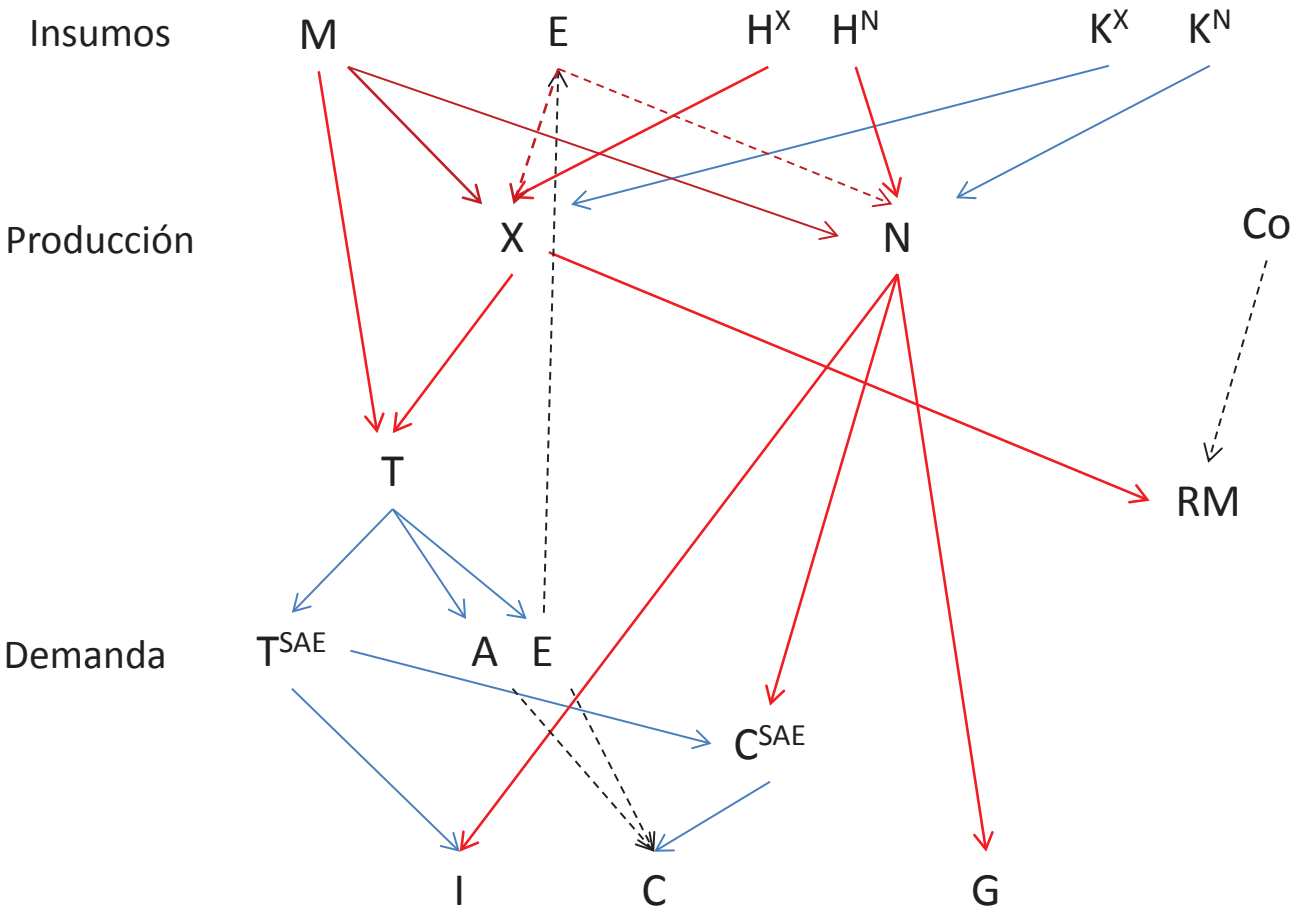
Description of the model



Note: Solid-red lines indicate sticky prices. Dotted-black lines are exogenous relative prices. Solid-blue lines are competitive prices.

Households

Representative Household maximizes:

$$\max E_0 \sum_{t=0}^{\infty} \beta^t \xi_t^{\beta} \left\{ \frac{\left(C_t - \phi_c \tilde{C}_{t-1}\right)^{1-\sigma}}{1-\sigma} - \kappa_t \left(\xi_t^{h,X} \frac{h_t^{X\,1+\varphi}}{1+\varphi} + \xi_t^{h,N} \frac{h_t^{N\,1+\varphi}}{1+\varphi} \right) \right\}$$

$\tilde{C}_t$ aggregate consumption, $\kappa_t = (\tilde{C}_t - \tilde{C}_{t-1})^{-\sigma}$ and ξ_t^{β}

$$P_t C_t + S_t B_t^* + B_t + P_t^I I_t^N + P_t^I I_t^X =$$
$$h_t^{X,d} \int_0^1 W_t^X(j) \left(\frac{W_t^X(j)}{W_t^X} \right)^{-\epsilon_W} dj + h_t^{N,d} \int_0^1 W_t^N(j) \left(\frac{W_t^N(j)}{W_t^N} \right)^{-\epsilon_W} dj$$
$$+ S_t R_{t-1}^* B_{t-1}^* + R_{t-1} B_{t-1} + P_t^N R_t^N K_{t-1}^N + P_t^X R_t^X K_{t-1}^X + T_t + \Pi_t$$

Labor unions choose wages a la Calvo and when not chosen optimally, the wage is updated by:

$$\pi_{t-1}^{\zeta_{WJ}} \bar{\pi}^{1-\zeta_{WJ}}$$

Back

Households

C_t is composite of C_t^{NFE}, C_t^F and C_t^E. The price is:

$$P_t = (P_t^{NFE})^{1-\gamma_{FC}-\gamma_{EC}}(P_t^F)^{\gamma_{FC}}(P_t^E)^{\gamma_{EC}}$$

$$\begin{aligned} C_t^{NFE} &= \left[\gamma^{1/\rho}(C_t^N)^{\frac{\varrho-1}{\varrho}} + (1-\gamma)^{1/\varrho}(C_t^T)^{\frac{\varrho-1}{\varrho}}\right]^{\frac{\varrho}{\varrho-1}} \\ C_t^T &= \left[\gamma_T^{1/\varrho_T}(C_t^X)^{\frac{\varrho_T-1}{\varrho_T}} + (1-\gamma_T)^{1/\varrho_T}(C_t^M)^{\frac{\varrho_T-1}{\varrho_T}}\right]^{\frac{\varrho_T}{\varrho_T-1}} \end{aligned}$$

$$C_t^J = \int_0^1 G(C_t^J(i))di$$

We assume G features constant elasticity of substitution $\epsilon_J > 1$.

Back

Capital and Investment Goods

In sector $J = \{X, N\}$:

$$K_t^J = \left[1 - \Gamma\left(\frac{I_t^J}{I_{t-1}^J}\right)\right] u_t I_t^J + (1-\delta) K_{t-1}^J$$

with $\Gamma'(.) > 0$, $\Gamma''(.) > 0$, u_t shock to the marginal efficiency of investment.

Supply of investment: competitive firms with technology

$$I_t = \left[\gamma_I^{1/\varrho_I} (\tilde{I}_t^N)^{\frac{\varrho_I - 1}{\varrho_I}} + (1-\gamma_I)^{1/\varrho_I} (\tilde{I}_t^T)^{\frac{\varrho_I - 1}{\varrho_I}}\right]^{\frac{\varrho_I}{\varrho_I - 1}}$$

$$\tilde{I}_t^T = \left[\gamma_{T,I}^{1/\varrho_{T,I}} (\tilde{I}_t^X)^{\frac{\varrho_{T,I} - 1}{\varrho_{T,I}}} + (1-\gamma_{T,I})^{1/\varrho_{T,I}} (\tilde{I}_t^M)^{\frac{\varrho_{T,I} - 1}{\varrho_{T,I}}}\right]^{\frac{\varrho_{T,I}}{\varrho_{T,I} - 1}}$$

Back

Firms

- $X\&N$ **Sectors**: Each firm $j \in J = \{X, N\}$:

$$Y_t^J(j) = (V_t^J(j))^{\gamma_J}(M_t^J(j))^{1-\gamma_J}$$

with:

$$V_t^J(j) = z_t^J \left[K_{t-1}^J(j)\right]^{\alpha_J} \left[A_t^J h_t^J(j)\right]^{1-\alpha_J}$$

with z_t^J is stationary, A_t^J is a non-stationary. $A_t^N/A_{t-1}^N = a_t$ is stationary and

$$A_t^X = (A_{t-1}^X)^{1-\Gamma_X}(A_t^N)^{\Gamma_X}$$

M_t^j is a combination of the one sold by sector M and energy. The price of the importable input is:

$$P_t^{ME} = (P_t^M)^{1-\gamma_{EM}}(P_t^E)^{\gamma_{EM}}$$

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Firms

- **Sector** M: Differentiate an homogeneous good using:

$$Y_t^M(j) = M_t(j)$$

Price of their input is $P_{m,t} = S_t P_t^{M,*}$.

All firms set prices a la Calvo. When not choosing optimally, their price is updated according to:

$$\left[(\pi_{t-1}^J)^{\varrho_J} \pi_{t-1}^{1-\varrho_J} \right]^{\zeta_J} \bar{\pi}^{1-\zeta_J}$$

for $J = \{X, M, N\}$.

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Commodity and Foreign Sector

- **Commodity**: endowment, has its own trend A_t^{Co}:

$$A_t^{Co} = (A_{t-1}^{Co})^{1-\Gamma_{Co}} (A_t^{Co})^{\Gamma_{Co}}$$

Completely exported and sold at the international price P_t^{Co*}

- **Foreign Sector**:
  - Demand for exportable:

$$C_t^{X,*} = \left(\frac{P_t^X}{S_t P_t^*} \right)^{-\epsilon^*} Y_t^* \xi_t^{X,*}$$

  - External interest rate/closing device:

$$R_t^* = R_t^W \exp\left\{ \phi_B \left(\bar{b} - \frac{S_t B_t^*}{P_t^Y GDP_t} \right) \right\} \xi_t^{R1} \xi_t^{R2}$$

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Fiscal and Monetary Policy

- **Fiscal Policy**: G_t exogenous and spent in N. BC;

$$\vartheta S_t P_t^{Co*} Y_t^{Co} + R_{t-1} B_{t-1}^G = P_t^N G_t + T_t + B_t^G$$

- **Monetary Policy**: Taylor type rule:

$$\left(\frac{R_t}{R}\right) = \left(\frac{R_{t-1}}{R}\right)^{\varrho_R} \left[\left(\frac{(\pi_t^{NFE})^{\alpha_\pi^{NFE}} \pi_t^{1-\alpha_\pi^{NFE}}}{\bar{\pi}}\right)^{\alpha_\pi} \left(\frac{GDP_t/GDP_{t-1}}{a}\right)^{\alpha_y}\right]^{1-\varrho_R} e_t^m$$

π_t^{NFE} is core inflation. Variables without t are steady state values.

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Driving Forces

- *Domestic* (12): consumption preferences (ξ_t^{β}), labor supply ($\xi_t^{h,X}, \xi_t^{h,N}$), relative price of food and energy (p_t^F, p_t^E), efficiency of investment (u_t), stationary productivity (z_t^X, z_t^N), growth rate long run trend (a_t), government consumption (g_t) and monetary policy (ϵ_t^m).
- *Foreign* (8): World interest rate (R_t^W), foreign risk premium (ξ_t^{R1}, ξ_t^{R2}), international price of commodities (P_t^{Co*}), imported goods (P_t^{M*}) and CPI trade partners (P_t^*), demand for exports ($\xi_t^{X,*}$) and foreign aggregate demand (Y_t^*).

Foreign prices cointegrate and we have the following model for $j = \{Co*, M*, *\}$:

$$P_t^j = (\pi^* P_{t-1}^j)^{\Gamma_j} (F_t^*)^{1-\Gamma_j} u_t^j, \qquad \text{with } \Gamma_j \in [0,1)$$

$$\Delta F_t^* \equiv \frac{F_t^*}{F_{t-1}^*}, \qquad \frac{\Delta F_t^*}{\pi^*} = \left(\frac{\Delta F_{t-1}^*}{\pi^*}\right)^{\rho_{F*}} \exp(\epsilon_t^{F*}), \qquad \text{with } \rho_{F*} \in (-1,1)$$

where $\epsilon_t^{F^*}$ is an i.i.d. shock and u_t^j are independent shocks.

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Data

Quarterly frequency from 2001.Q3 to 2016.Q3:[1]

- Real growth rate of: GDP, GDP^X (Agriculture, Fishing, Industry, Utilities, Transportation), GDP^N (Construction, Retail, Services), GDP^{Co} (Mining), C, I, G.
- TB/GDP.
- π^N (services, excluding Food and Energy), π^T (goods. ex. Food and Energy), π^M (imported goods, ex. Food and Energy), π^F (Food) and π^E (Energy).
- π^{WX}, π^{WN}: cost per unit of labor (the CMO index).
- π^S, R.
- External: R^W (LIBOR), EMBI Chile, π^* (inflation commercial partners, IPE Index), π^{Co*} (Copper price), π^{M*} (inflation imported goods, IVUM index), Y^* (GDP commercial partners).

All domestic variables assumed to have measurement error of 10%.

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[1] Source: Central Bank of Chile. Seasonally adjusted (X-11 filter), expressed in logs, multiplied by 100, and demeaned. All growth rates are changes from two consecutive quarters.

Calibration

Para.	Descrip.	Value	Source
σ	Risk Aversion	1	Medina & Soto (2007)
φ	Inv. Frish elast.	1	Medina & Soto (2007)
δ	Capital depreciation	0.01	Medina & Soto (2007)
ϵ^j	Elast. of Subst. Var.	11	Medina & Soto (2007)
γ	Share C^N in C^{NFE}	0.62	I-O Matrix, av. 08-13
γ_T	Share C^X in C^T	0.23	I-O Matrix, av. 08-13
γ_I	Share I^N in I	0.62	I-O Matrix, av. 08-13
γ_{TI}	Share I^X in I^T	0.02	I-O Matrix, av. 08-13
γ_{EC}	Share C^E in C	0.09	I-O Matrix, av. 08-13
γ_{FC}	Share C^F in C	0.19	I-O Matrix, av. 08-13
α_X	Capital in V.A. X	0.66	I-O Matrix, av. 08-13
α_N	Capital in V.A N	0.49	I-O Matrix, av. 08-13
$1-\gamma_X$	M in Prod. X	0.2	I-O Matrix, av. 08-13
$1-\gamma_N$	M in Prod. M	0.08	I-O Matrix, av. 08-13
γ_{EM}	Share E in Interm. M	0.09	I-O Matrix, av. 08-13

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Calibration

Para.	Descrip.	Value	Source
s^{TB}	Ratio of TB to PIB	0.05	Av. 01-15
s^{PIB_N}	Ratio of PIB^N to PIB	0.6	Av. 01-15
s^{PIB_N}	Ratio of PIB^N to PIB	0.6	Av. 01-15
s^{Co}	Ratio of Co to GDP	0.1	Av. 01-15
s^{G}	Ratio of G to GDP	0.12	Av. 01-15
ξ^{R1}	EMBI Chile (annual)	1.015	Av. 01-15
π	Inflation (annual)	1.03	Av. 01-15
a	Long-run growth (annual)	1.016	Av. 01-15
R^W	World Int. Rate (annual)	1.045	Av. 01-15
R	MP Rate (annual)	1.058	Av. 01-15

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Estimated Parameters

Para.	Description	Dist.	Prior Mean	Prior St.D.	Posterior Mode	Posterior St.D.
ϕ_C	Habits C	β	0.65	0.2	0.892	0.030
ϕ_I	Inv. Adj. Costs	$\mathcal{N}^+$	4	1	4.247	0.802
θ_{WX}	Calvo W^X	β	0.65	0.2	0.940	0.013
θ_{WN}	Calvo W^N	β	0.65	0.2	0.974	0.005
ζ_{WX}	Din. Index. W^X	β	0.5	0.27	0.155	0.182
ζ_{WN}	Din. Index. W^N	β	0.5	0.27	0.150	0.088
ϱ	Sust. C^T,C^N	$\mathcal{N}^+$	1.1	0.6	0.900	0.533
ϱ_I	Sust. I^T,I^N	$\mathcal{N}^+$	1.1	1.5	1.113	0.886
ρ_R	Smoothing	β	0.8	0.05	0.772	0.030
α_π	Reaction to π	$\mathcal{N}^+$	1.7	0.1	1.580	0.098
α_π^{SAE}	Reaction to π^{NFE}	β	0.5	0.2	0.385	0.182
α_y	Reaction to y	$\mathcal{N}^+$	0.125	0.05	0.175	0.047
η^*	Elast. Ext. Dem.	$\mathcal{N}^+$	0.3	0.15	0.028	0.082
ϕ_B	Elast. Country Prem.	IG	0.001	∞	0.002	0.001

The standard deviation of the posterior is approximated by the inverse Hessian evaluated at the posterior mode.

Estimated Parameters

			Prior		Posterior	
Para.	Description	Dist.	Mean	St.D.	Mode	St.D.
θ_X	Calvo X	β	0.5	0.27	0.546	0.085
θ_M	Calvo M	β	0.5	0.27	0.853	0.014
θ_N	Calvo N	β	0.5	0.27	0.979	0.004
ζ_X	Din. Index. X	β	0.5	0.27	0.058	0.130
ζ_M	Din. Index. M	β	0.5	0.27	0.548	0.310
ζ_N	Din. Index. N	β	0.5	0.27	0.633	0.052
ϱ_X	Index. Sector X	β	0.5	0.27	0.761	0.472
ϱ_M	Index. Sector M	β	0.5	0.27	0.498	0.177
ϱ_N	Index. Sector N	β	0.5	0.27	0.827	0.065
Γ_X	Adj. Trend X	β	0.65	0.2	0.772	0.247
Γ_{Co}	Adj. Trend Co	β	0.65	0.2	0.772	0.241

Note: The standard deviation of the posterior is approximated by the inverse Hessian evaluated at the posterior mode.

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Estimated Parameters, Exogenous Processes

		Prior		Posterior	
Para.	Dist.	Mean	St.D.	Mode	St.D.
ρ_{ξ^β}	β	0.65	0.2	0.792	0.079
ρ_a	β	0.35	0.15	0.278	0.155
ρ_u	β	0.65	0.2	0.620	0.117
ρ_{zX}	β	0.5	0.23	0.847	0.084
ρ_{zN}	β	0.5	0.23	0.944	0.028
$\rho_{\xi X*}$	β	0.65	0.2	0.860	0.061
$\rho_{\xi R1}$	β	0.65	0.2	0.937	0.051
$\rho_{\xi R2}$	β	0.65	0.2	0.851	0.065
$\rho_{\xi hX}$	β	0.65	0.2	0.811	0.076
$\rho_{\xi hN}$	β	0.65	0.2	0.897	0.051
ρ_{yCo}	β	0.55	0.2	0.873	0.069

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Estimated Parameters, Exogenous Processes

		Prior		Posterior	
Para.	Dist.	Mean	St.D.	Mode	St.D.
ρ_{p^A}	β	0.65	0.2	0.974	0.016
ρ_{p^E}	β	0.65	0.2	0.903	0.054
Γ_*	$\mathcal{U}$	0.5	0.2886	0.323	0.115
Γ_{M*}	$\mathcal{U}$	0.5	0.2886	0.505	0.082
Γ_{Co*}	$\mathcal{U}$	0.5	0.2886	0.117	0.120
ρ_*	$\mathcal{U}$	0	0.5773	0.770	0.152
ρ_{M*}	$\mathcal{U}$	0	0.5773	0.478	0.123
ρ_{Co*}	$\mathcal{U}$	0	0.5773	0.918	0.045
ρ_{F*}	$\mathcal{U}$	0	0.5773	0.234	0.121

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Estimated Parameters, Standard Deviations Exogenous shocks

		Prior		Posterior	
Para.	Dist.	Mean	St.D.	Mode	St.D.
$\sigma^{\xi^{\beta}}$	$\mathcal{N}^{+}$	0.03	0.03	0.047	0.013
σ^{a}	IG	0.01	∞	0.004	0.001
σ^{u}	$\mathcal{N}^{+}$	0.03	0.03	0.062	0.017
$\sigma^{z^{X}}$	$\mathcal{N}^{+}$	0.01	0.03	0.013	0.002
$\sigma^{z^{N}}$	$\mathcal{N}^{+}$	0.005	0.03	0.047	0.006
$\sigma^{e^{m}}$	$\mathcal{N}^{+}$	0.01	0.01	0.002	0.000
$\sigma^{\xi^{X*}}$	$\mathcal{N}^{+}$	0.01	0.01	0.018	0.002
$\sigma^{\xi^{R1}}$	$\mathcal{N}^{+}$	0.01	0.01	0.001	0.000
$\sigma^{\xi^{R2}}$	$\mathcal{N}^{+}$	0.01	0.01	0.004	0.002

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Estimated Parameters, Standard Deviations Exogenous shocks

		Prior		Posterior	
Para.	Dist.	Mean	St.D.	Mode	St.D.
$\sigma^{\xi^{hX}}$	$\mathcal{N}^+$	0.1	0.15	0.252	0.102
$\sigma^{\xi^{hN}}$	$\mathcal{N}^+$	0.1	0.15	0.234	0.093
σ^{yCo}	$\mathcal{N}^+$	0.02	0.02	0.021	0.002
σ^{p^E}	$\mathcal{N}^+$	0.04	0.04	0.024	0.003
σ^{p^A}	$\mathcal{N}^+$	0.02	0.02	0.012	0.001
σ^*	$\mathcal{U}$	0.25	0.1443	0.013	0.002
σ^{M*}	$\mathcal{U}$	0.25	0.1443	0.014	0.002
σ^{Co*}	$\mathcal{U}$	0.25	0.1443	0.117	0.011
σ^{F*}	$\mathcal{U}$	0.25	0.1443	0.031	0.006

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Goodness of Fit

Variable	St. Dev. (%) Data		Model	AC(1) Data		Model
ΔGDP	0.9	(0.1)	1.1	0.5	(0.2)	0.5
$\Delta CONS$	1.0	(0.1)	0.8	0.7	(0.2)	0.7
ΔINV	3.9	(0.4)	4.4	0.3	(0.2)	0.7
ΔGDP^X	1.5	(0.1)	1.5	0.2	(0.1)	-0.1
ΔGDP^N	0.8	(0.1)	1.6	0.7	(0.1)	0.6
TB/GDP	5.5	(0.5)	5.2	0.8	(0.1)	0.9
π	0.7	(0.1)	0.6	0.6	(0.2)	0.7
π^T	0.7	(0.1)	0.8	0.6	(0.2)	0.8
π^N	0.4	(0.1)	0.4	0.7	(0.2)	0.9
π^M	0.8	(0.1)	0.8	0.7	(0.2)	0.8
π^{WX}	0.6	(0.1)	0.7	0.7	(0.1)	0.8
π^{WN}	0.4	(0.0)	0.4	0.8	(0.2)	0.9
R	0.4	(0.0)	0.6	0.9	(0.2)	0.9
π^S	5.2	(0.8)	5.7	0.2	(0.2)	0.0
rer	5.0	(0.4)	8.7	0.8	(0.1)	0.9

Note: For each moment, the three columns are: point estimate in the data, GMM standard error in the data, unconditional moment in the model at the posterior mode.

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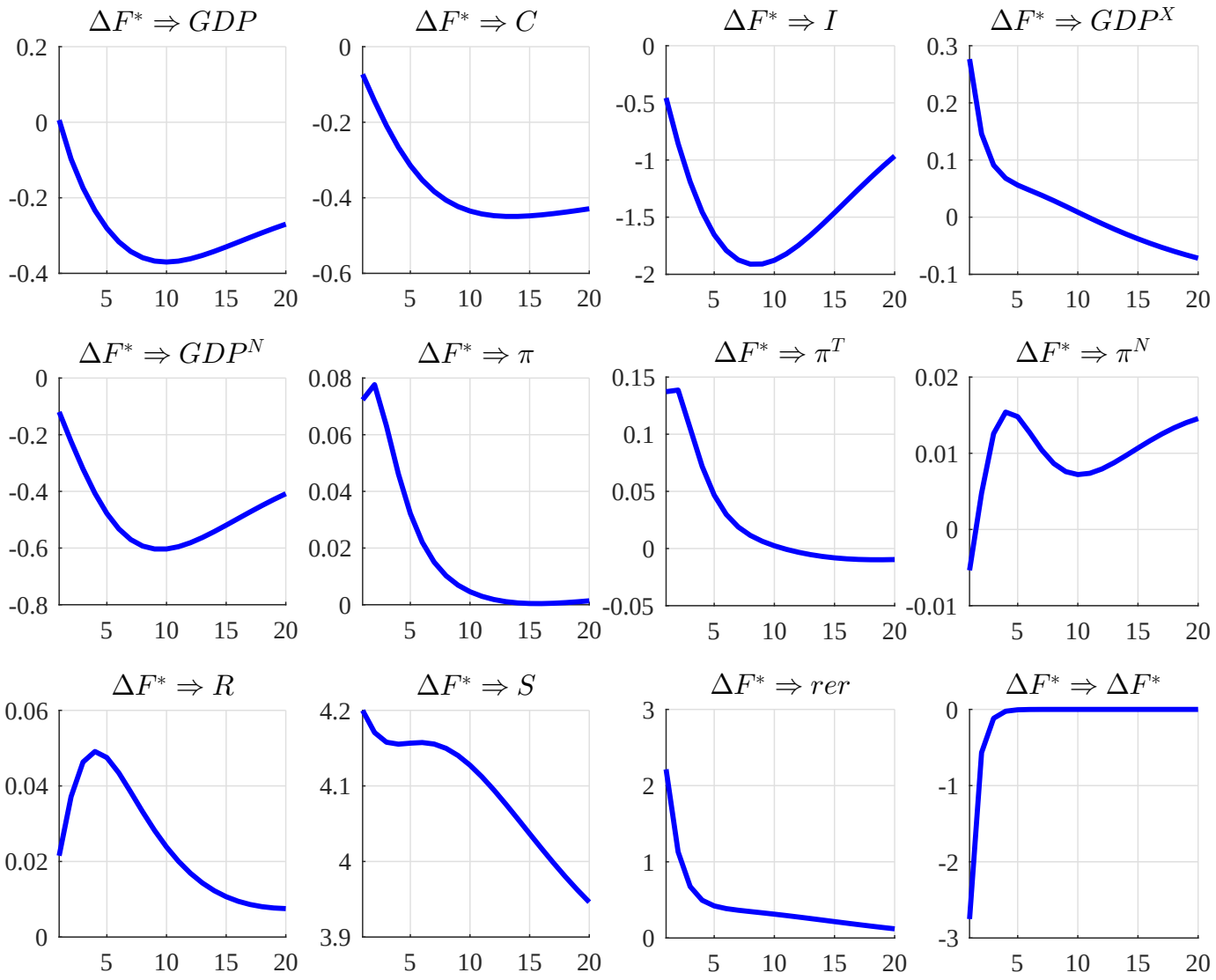
Determinants of the NER, Shocks to F_t^*



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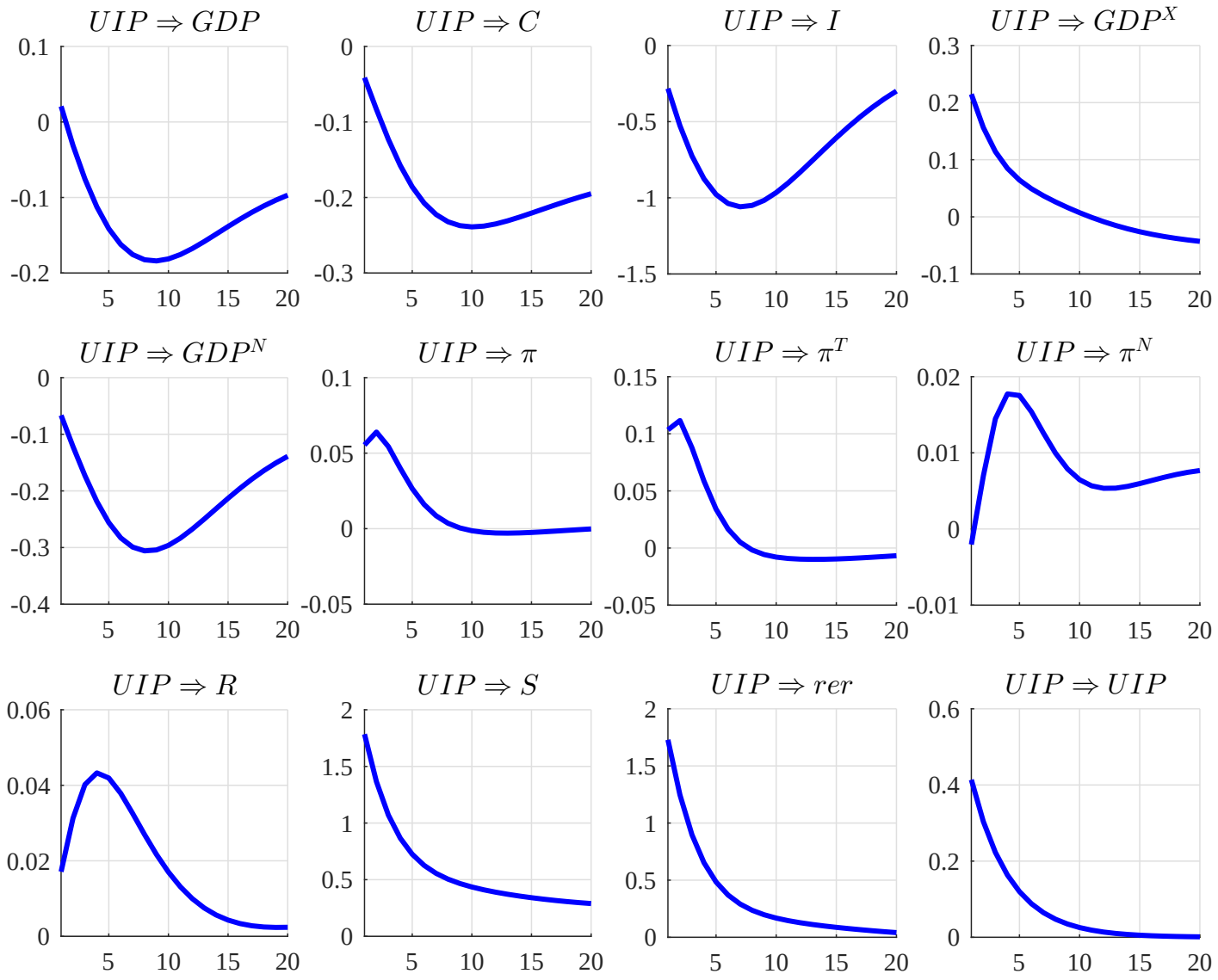
Determinants of the NER, Shocks to UIP



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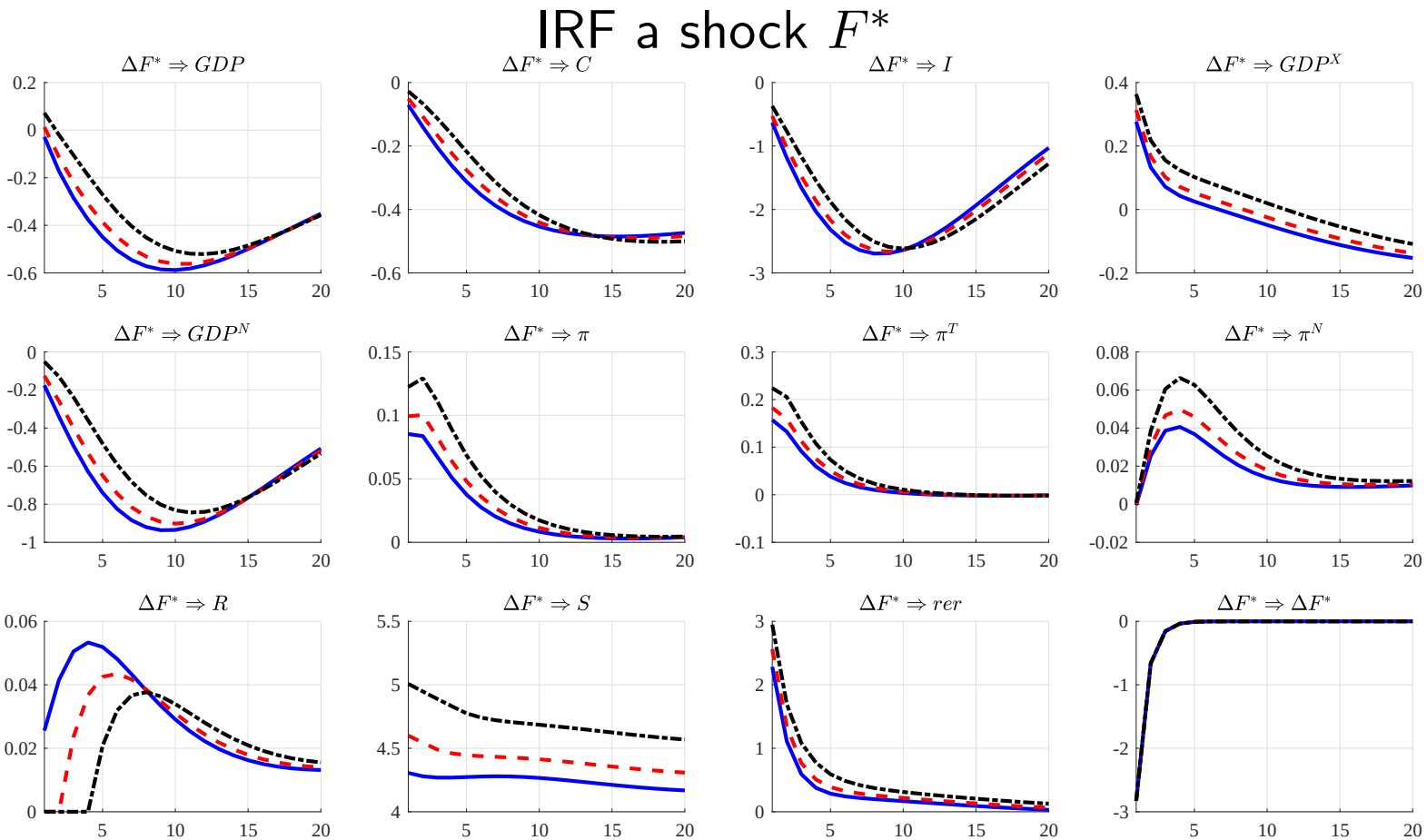
IRF with alternative policy paths



Línea sólida azul: Base. Línea de rayas roja: $T^* = 2$. Línea de rayas y puntos negra: $T^* = 4$

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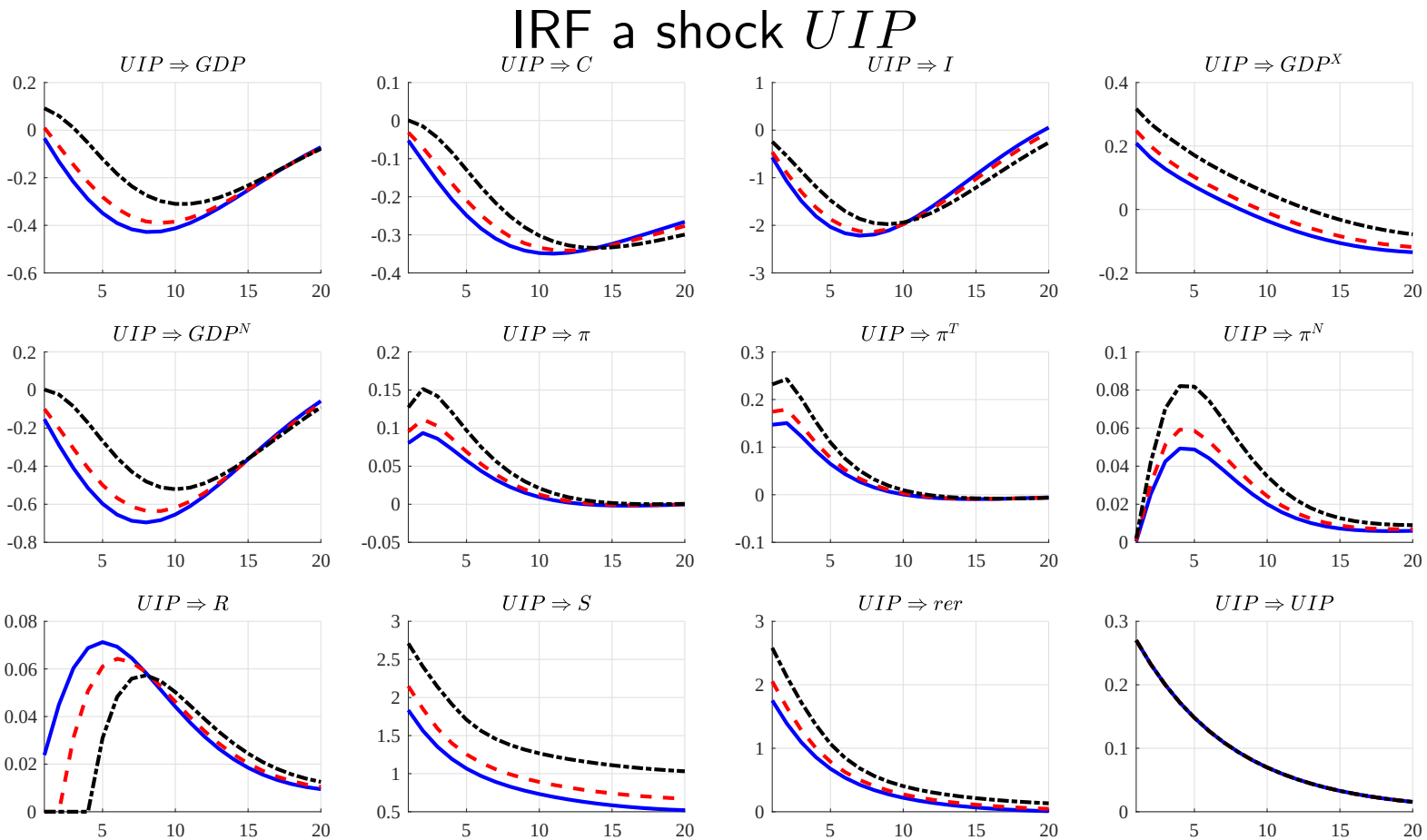
IRF with alternative policy paths



Línea sólida azul: Base. Línea de rayas roja: $T^* = 2$. Línea de rayas y puntos negra: $T^* = 4$

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