Transition Risk Uncertainty and Robust Optimal Monetary Policy

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Introduction

- Climate change has become one of the most prominent concerns globally
- IMF: greenhouse gas emissions $\downarrow$ 40% $\Rightarrow$ warming $< 2^{\circ}$C
- IEA: The goal of a zero-net emission economy by 2050

Questions:

- *What is the economic cost to achieve environmental targets through carbon price policies? How much does it differ between models?*
- *How should the Central Bank conduct its optimal policy during the transition?*

Our Approach

Transition risk uncertainty:

- Include environmental aspect in 29 NK-DSGE models
- Implement carbon price increase in all models to:
  - 40% emission reduction
  - Zero-net emission economy
- Pre-announcement of carbon price path for -40% emissions scenario

Optimal model-robust monetary policy in 3 scenarios:

- Over the business cycle
- During transition risk
- In cooperation with the government

(Dis-) advantage of the model-robust rule in terms of CB loss / IRFs

Preview of results

Transition risk uncertainty:

- -40% $\Rightarrow$ Output $\downarrow$ 0.7% to 4% Inflation -0.5 to 1.5 pp
- -100% $\Rightarrow$ Output $\downarrow$ 2% to 6% Inflation -0.5 to -0.1 pp
- Pre-announcement affects inflation but not the rest of the economy

Optimal model-robust monetary policy:

- The CB should react less due to model uncertainty
- The CB should be (slightly!) more cautious during the transition (model uncertainty effect only for EA)
- In cooperation with the government it should react
  - less to inflation
  - more to output growth

  CB reacts more due to model uncertainty.

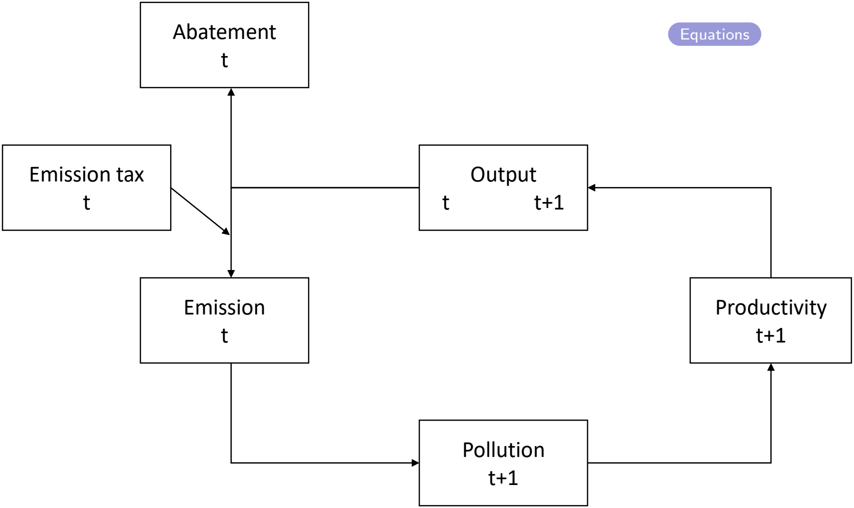
Literature

Climate models: Annicchiarico and Di Dio (2015), Fischer and Springborn (2011), Heutel (2012), Nordhaus (1977), ...

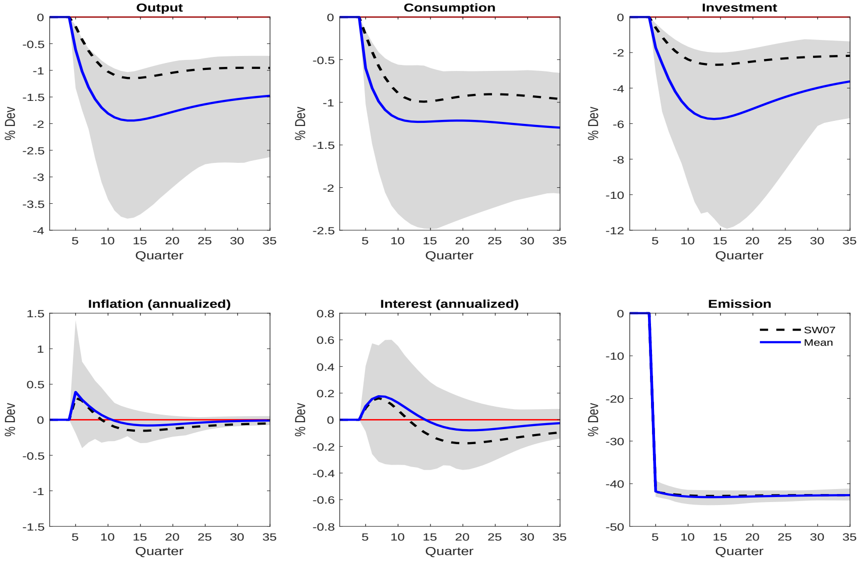
Transition risk: Benmir and Roman (2020), Carattini et al. (2021) , Ferrari and Landi (2021) , Le (2023), ...

Model uncertainty: Onatski and Williams (2003), Kuester and Wieland (2010), Levin et al. (2003), Orphanides and Wieland (2013), ...

Environmental DSGE Models - Overview

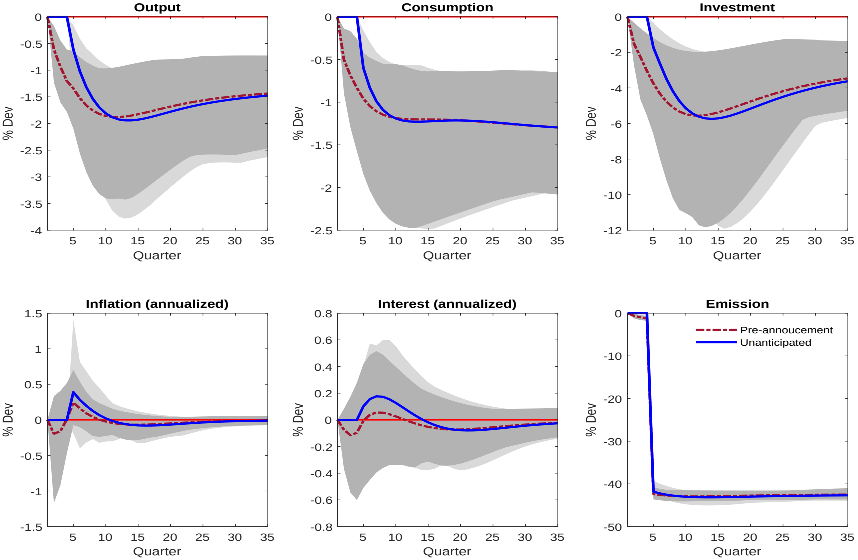


Unanticipated carbon price shock after 5 quarters



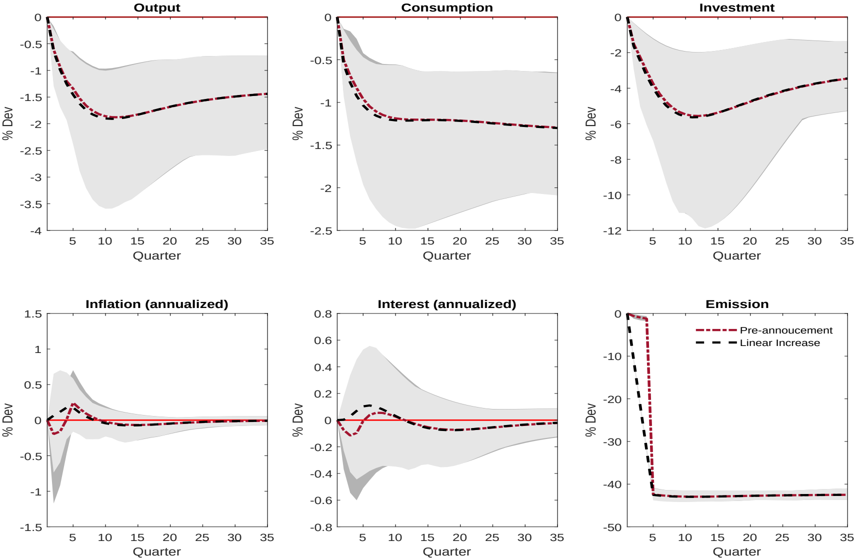
Notes. Grey shaded area is 90% credible set across models

Anticipated carbon price shock after 5 quarters



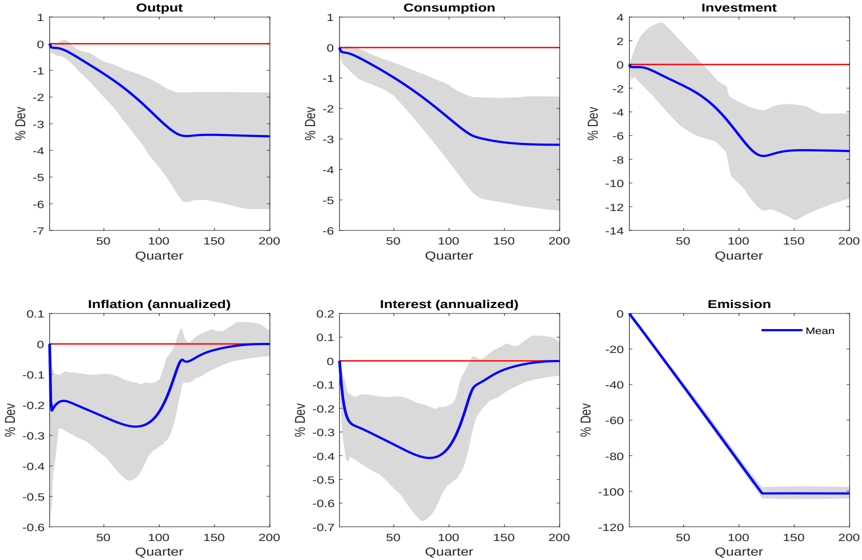
Notes. Light (dark) grey shaded areas are 90% credible set unanticipated (anticipated)

Anticipated carbon price shock - linear increase



Notes. Light (dark) grey shaded areas are for anticipated linear increase (one-time)

Anticipated carbon price shock - Linear - Zero Emissions



Notes. Grey shaded area is 90% credible set across models

Optimal Model-robust Monetary Policy (only CB)

$$\min_{\{\rho,\alpha_\pi,\alpha_y\}} \quad \left[\ Var\left(\tilde{\pi}^q\right) + \lambda_y\ Var\left(\Delta\tilde{Y}\right) + \lambda_R\ Var\left(\Delta\tilde{R}\right)\ \right]$$

$s.t.$

$$\mathbf{E}_t\left[f\left(x_t, x_{t+1}, x_{t-1}, z_t, \Theta\right)\right] = 0$$

Optimal Model-robust Monetary Policy (only CB)

$$\min_{\{\rho,\alpha_\pi,\alpha_y\}} \quad \sum_{m=1}^{M} \omega_m \left[\; Var_m\left(\tilde{\pi}^q\right) + \lambda_y \; Var_m\left(\Delta\tilde{Y}\right) + \lambda_R \; Var_m\left(\Delta\tilde{R}\right) \; \right]$$

$$\begin{aligned} s.t. \qquad \tilde{R}_t \; &= \; \rho \; \tilde{R}_{t-1} + (1-\rho) \; \left(\alpha_\pi \; \mathbf{E}_t\left[\tilde{\pi}^q_{t+h}\right] + \alpha_y \; \Delta\tilde{Y}_t\right) \\ \tilde{\tau}^e_t \; &= \; \rho^e \; \tilde{\tau}^e_{t-1} + \sigma^e \epsilon^e_t \qquad\qquad \epsilon^e_t \sim \mathcal{N}(0,1) \\ & \mathbf{E}_t\left[f_m\left(x^m_t, x^m_{t+1}, x^m_{t-1}, z_t, \Theta^m\right)\right] = 0 \qquad \forall m \in M \end{aligned}$$

Optimal Model-robust Monetary Policy (only CB)

$$\min_{\{\rho,\alpha_\pi,\alpha_y\}} \quad \sum_{m=1}^{M} \omega_m \left[Var_m\left(\tilde{\pi}^q\right) + \lambda_y \, Var_m\left(\Delta\tilde{Y}\right) + \lambda_R \, Var_m\left(\Delta\tilde{R}\right) \right]$$

$$s.t. \quad \tilde{R}_t = \rho \, \tilde{R}_{t-1} + (1-\rho) \left(\alpha_\pi \, \mathbf{E}_t\left[\tilde{\pi}^q_{t+h}\right] + \alpha_y \, \Delta\tilde{Y}_t\right)$$

$$\tilde{\tau}^e_t = \rho^e \, \tilde{\tau}^e_{t-1} + \sigma^e \epsilon^e_t \qquad \epsilon^e_t \sim \mathcal{N}(0,1)$$

$$\mathbf{E}_t\left[f_m\left(x^m_t, x^m_{t+1}, x^m_{t-1}, z_t, \Theta^m\right)\right] = 0 \qquad \forall m \in M$$

- Over business cycle: All transitory shocks
- During transition risk: Permanent carbon price shock

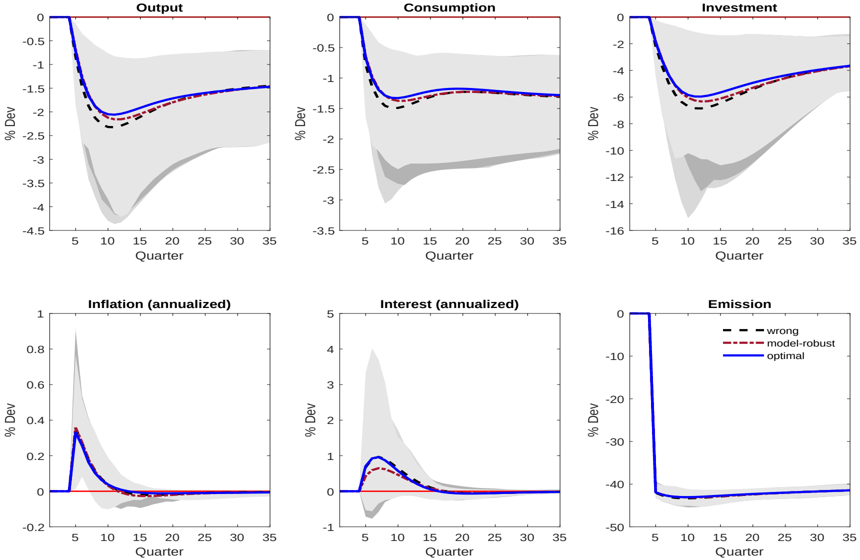
Optimal Model-robust Monetary Policy (cooperation)

$$\min_{\{\rho,\alpha_\pi,\alpha_y,\theta^e\}} \quad \sum_{m=1}^{M} \omega_m \left[L_m^{CB} + \lambda_e \ Var_m\left(\tilde{e}\right) + \lambda_{\tau^e} \ Var_m\left(\tilde{\tau}^e\right) \right]$$

$$\begin{aligned} s.t. \qquad \tilde{R}_t \ &= \ \rho \ \tilde{R}_{t-1} + \alpha_\pi \ \mathbf{E}_t \left[\tilde{\pi}^q_{t+h} \right] + \alpha_y \ \Delta \tilde{Y}_t \\ \tilde{\tau}^e_t \ &= \ \theta^e \ \tilde{e}_t \\ \mathbf{E}_t \left[f_m \left(x^m_t, x^m_{t+1}, x^m_{t-1}, z_t, \Theta^m \right) \right] &= 0 \qquad \forall m \in M \end{aligned}$$

- TFP shock (persistence: 0.9)

Evaluation of Model-robust Rules - IRF (unanticipated shock)



Advantages are larger than disadvantages, larger for consumption and investment. (Very) small influence on inflation. Evaluation CB loss

Concluding Remarks

1) Transition Risk Uncertainty:

- Implement environmental aspect in 29 NK-DSGE models
- Carbon price increase causes for -40% emissions
  - 0.7% - 4% output loss
  - Pre-announcement affects inflation but not rest of economy

2) Optimal model-robust monetary policy:

- The CB should react less to inflation due to model uncertainty
- The CB should be (slightly!) more restrained during the transition
- In cooperation with the government it should react
  - less to inflation
  - more to output growth
- Other model-specific rules have 3-4 times higher CB loss increases (compared to own rule) than model-robust rules

Extra Slides

List of Models

Model acronym	Reference
EA_CKL09	Christoffel et al. (2009)
EA_SW03	Smets and Wouters (2003)
EA_SWW14	Smets et al. (2014)
EA_VI16bgg	Villa (2016)
NK_BGG99	Bernanke et al. (1999)
NK_CKL09	Christoffel et al. (2009)
NK_GK09lin	Gertler and Karadi (2011)
NK_KM16	Krause and Moyen (2016)
US_ACELm	Altig et al. (2005)
US_ACELswm	Altig et al. (2005)
US_BKM12	Bils et al. (2012)
US_CD08	Christensen and Dib (2008)
US_CFOP14	Carlstrom et al. (2014)
US_DG08	De Graeve (2008)
US_DNGS15	Del Negro et al. (2015)
US_DNGS15_SW	Del Negro et al. (2015)
US_DNGS15_SWpi	Del Negro et al. (2015)
US_DNGS15_SWSP	Del Negro et al. (2015)
US_FMS13	Fève et al. (2013)
US_FU19	Fratto and Uhlig (2020)
US_JPT11	Justiniano et al. (2011)
US_KK14	Kliem and Kriwoluzky (2014)
US_KS15	Kriwoluzky and Stoltenberg (2015)
US_LTW17gz	Leeper et al. (2017)
US_LTW17nu	Leeper et al. (2017)
US_LWY13	Leeper et al. (2013)
US_RA07	Rabanal (2007)

Environmental DSGE Models - Details

- Production function

$$Y_t = A_t^{env} \ (K_{t-1})^{\alpha} \ (H_t)^{1-\alpha}$$

- Pollution damages productivity

$$A_t^{env} = \left(1 - \left(d_0 + d_1 \ X_t + d_2 \ X_t^2\right)\right) \ A_t$$

- Stock of pollution

$$X_t = \nu \ X_{t-1} + e_t + e_t^{row}$$

- Emissions from production

$$e_t = \gamma_1 \ (1 - \mu_t) \ Y_t$$

- Abatement level (μ) with costs (z)

$$z_t = \theta_1 \ \mu_t^{\theta_2} \ Y_t$$

Environmental DSGE Models - Details

- Abatement costs and emission price enter cost of firms, FOCs become

$$W_t \; H_t \; = \; (1-\alpha) \; \Psi_t \; Y_t$$

$$R_t^k \; K_{t-1} \; = \; \alpha \; \Psi_t \; Y_t$$

$$\mu_t \; = \; \left(\frac{\gamma_1 \; \tau_t^e}{\theta_1 \; \theta_2} \right)^{\frac{1}{\theta_2 - 1}}$$

Ψ is MC w/o environment, price on emissions τ^e

Environmental DSGE Models - Details

- Marginal costs with (MC) and w/o environment (Ψ) become

$$\Psi_t \;=\; \frac{1}{\alpha^{\alpha}\;(1-\alpha)^{(1-\alpha)}\;A_t^{env}}\,W_t^{(1-\alpha)}\;\left(R_t^k\right)^{\alpha}$$

$$MC_t = \Psi_t + \gamma_1\,(1-\mu_t)\,\tau_t^e + \theta_1\mu_t^{\theta_2}$$

- Abatement costs enter resource constraint

$$Y_t \;=\; C_t + I_t + G_t + \theta_1\;\mu_t^{\theta_2}\;Y_t$$

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Optimal Monetary Policy Rules by Region

	Relative weights				Euro Area							
					Individual models				Model-robust rule			
Scenario	λ_y	λ_R	λ_e	λ_{τ^e}	$\bar{\rho}$	$\bar{\alpha}_\pi$	$\bar{\alpha}_y$	$\bar{\theta}^e$	ρ_r	$\alpha_{\pi,r}$	$\alpha_{y,r}$	θ_r^e
Business cycle	1	0.5			0.9	8.2	7.8		0.9	8	8	
Transition risk	1	0.5			0.9	5.6	2.8		0.9	4	1	
Cooperation	1	0.5	0.5	0.1	0.9	4	15.8	0.2	0.9	2	18	0.2
					United States							
Business cycle	1	0.5			0.9	10.7	5.8		0.9	8	4	
Transition risk	1	0.5			0.88	7	4		0.9	7	5	
Cooperation	1	0.5	0.5	0.1	0.87	5.3	12.9	0.23	0.9	5	16	0.2

Results:

- EA models imply (mostly) more aggressive reaction to output growth and very cautious transition
- US models more aggressive reaction to inflation

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Evaluation of Model-robust Rules

1. Model-specific rule in own model

$$L^i = \frac{1}{M} \sum_{m=1}^{M} L_m | \left(\rho_m, \alpha_{\pi,m}, \alpha_{y,m}\right)$$

2. Model-robust rule in all model

$$L^r = \frac{1}{M} \sum_{m=1}^{M} L_m | \left(\rho_r, \alpha_{\pi,r}, \alpha_{y,r}\right)$$

3. Model-specific rule in other models

$$L^w = \frac{1}{M} \sum_{p=1}^{M} \left[\frac{1}{M} \sum_{m=1}^{M} L_m | \left(\rho_p, \alpha_{\pi,p}, \alpha_{y,p}\right) \right]$$

Evaluation of Model-robust Rules - Results

Scenario \ Loss	$100\ \frac{L^r - L^i}{L^i}$	$100\ \frac{L^r - L^w}{L^w}$	$100\ \frac{L^w - L^i}{L^i}$
Business cycle	4 %	-11 %	16 %
Transition risk	7 %	-17 %	28 %
Cooperation	20 %	-23 %	56 %

- Model-robust rule has (on average)
  - slightly higher CB loss than own model-specific rule
  - smaller CB loss than other model-specific rules
- Other model-specific rules have 3-4 higher CB loss <u>increases</u> (compared to own rule) than model-robust rules

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