

# Ambiguity, Monetary Policy and Trend Inflation

Riccardo M. Masolo and Francesca Monti

Bank of England and Centre for Macroeconomics

Cleveland Fed

29-30 September 2016

**Disclaimer:** Any views expressed are solely those of the authors and so cannot be taken to represent those of the Bank of England, of any of its policy committees or to state Bank of England policy

# Motivation

Masolo Monti

Intro

Model

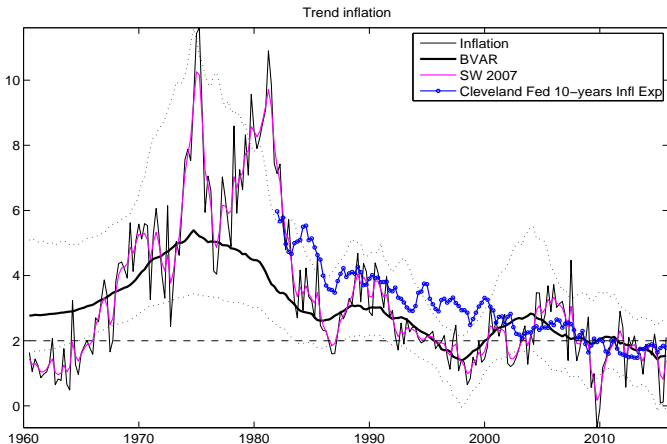
Results

Conclusions

- Inflation exhibits low-frequency variations: **inflation trend**
- Low-frequency inflation movements matter: they drive dynamics (Stock and Watson, 2007) and persistence of inflation (Cogley and Sbordone, 2008)
- We hardly have any theory about it:
  - Ascari and Sbordone (2014) show it has big effects on the static and dynamic properties of a model
  - most models ignore it (log-linearization around zero inflation or full steady-state indexation)
  - or treat variations in the inflation **trend** as variations in the inflation **target**, e.g. Del Negro, Giannoni and Schorfheide (2015).

# Trend inflation

Measures of trend inflation: TVP-VAR *à la* Cogley and Sargent (2002) and Cogley and Sbordone (2008), UC model *à la* Stock and Watson (2007), 10 years ahead inflation expectations



# A time-varying inflation target?

The Fed announced an 2% PCE inflation target in 2012. But before then:

- Blue Book simulations have been done with a 1.5%-2% target at least since 2000.
- As early as 1996, numerous FOMC members indicated preferences for 2% inflation target (Lindsey, 2003)
- *Chairman Greenspan testified in 1989 in favor of a qualitative zero inflation objective...* (Goodfriend, 2003)
- Orphanides (2002) suggests that low and stable inflation has been an objective since at least the end of WWII

# An alternative explanation for trend inflation

- In our model **trend inflation** stems from the agents' **ambiguity** regarding the conduct of monetary policy.
- Without resorting to changes in the target or changes in the policy's responsiveness to inflation, our model can explain:
  - the evolution of trend inflation in the US since the 1981
  - explain the below-target trend inflation since 2009/2010
  - explain the shift from indeterminacy to determinacy in the early 1980s (Coibion and Gorodnichenko, 2011)
  - Paul Volcker's apparent excessive tightening in 1982

# A alternative explanation for trend inflation

Masolo Monti

Intro

Model

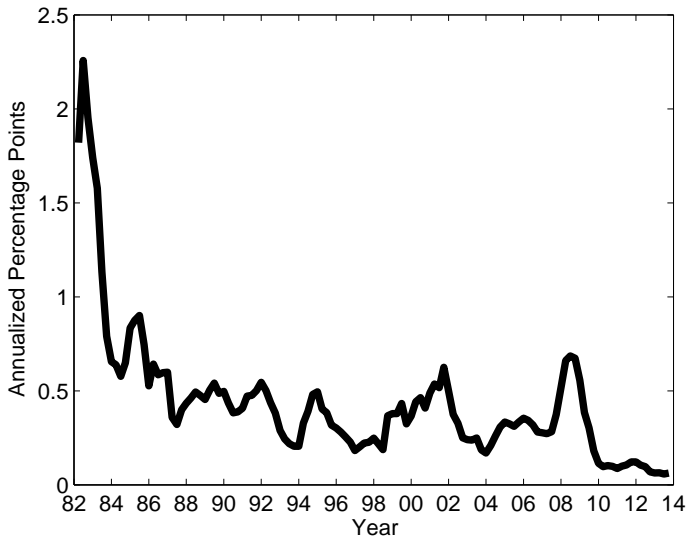
Results

Conclusions

- **Ambiguity**: situation in which there is uncertainty around the probability distribution of states of the world.
  - Agents entertain as possible not one but a set of beliefs,
  - and they are unable to assign probabilities to them.
- We assume agents in the model are ambiguity averse. Camerer and Weber (1992), Dimmock et al. (2016)
- This means they will make their decisions based on the worst case scenario. Gilboa and Schmeidler (1989)
- We use a measure of **forecaster disagreement** about the policy rate as a proxy for ambiguity about policy Drechsler (2013), Ilut and Schneider (2014)

## The data

We put our theory to a quantitative test, using data on the **interdecile dispersion of SPF nowcasts of 3 month TBILL.**



# Private sector confidence and transparency

- There is consensus that transparency increased from the late 1979s onwards, e.g. Lindsey (2003), Bernanke (2013)
- There is evidence that transparency translates into reduction in private sector's uncertainty
  - Swanson (2006): since the late 1980s private sector forecasters have been better at forecasting the Fed Funds rate, their cross-section dispersion shrank. Provides evidence that it is linked to transparency.
  - Ehrmann et al. (2012) also find that increased transparency lowers disagreement.
  - Boyarchenko et al. (2016) show how Fed announcements affect market confidence lowering the risk premium.



# The model

Masolo Monti

Intro

Model

Results

Conclusions

- Standard small New Keynesian Model (similar to Galí, 2008):
  - No capital
  - Sticky prices (Calvo 1983)
  - Competitive labor market
- *The private sector is not fully confident about its understanding of the monetary policy rule*
- *Agents dislike this uncertainty.*
- Gilboa and Schmeidler (1998), Epstein and Schneider (2003) and Ilut and Schneider (2014)

▶ More on ambiguity

▶ Literature

# Monetary policy

Masolo Monti

Intro

Model

Results

Conclusions

The Central Bank follows a very simple reaction function:

$$R_t = R_t^n \Pi_t^\phi$$

where  $R_t^n = \mathbb{E}_t \frac{A_{t+1}}{\beta A_t}$  is the natural rate of interest

- it is *dynamically* optimal: stabilizes inflation and the output gap
- together with the subsidy it is *statically* optimal as well: it implements first best
- we isolate what can go wrong despite the best intentions

# Monetary policy according to households

Masolo Monti

Intro

Model

Results

Conclusions

The households are uncertain about the conduct of monetary policy

$$\mathbb{E}_t^\mu R_t = R_t^n \Pi_t^\phi e^{\mu_t}$$

where  $R_t^n = \mathbb{E}_t \frac{A_{t+1}}{\beta A_t}$  is the natural rate of interest and  $\mu_t \in [\underline{\mu}_t, \bar{\mu}_t]$

Households base their consumption-savings decision on a **distorted belief** of the prevailing interest rate.

# Households' problem

Masolo Monti

Intro

Model

Results

Conclusions

The households solve this problem, which reflect their aversion to ambiguity:

$$U_t(\vec{C}; s^t) = \min_{\mu_t \in [\underline{\mu}_t, \bar{\mu}_t]} \mathbb{E}^{\mu} \left[ u(\vec{C}_t) + \beta U_{t+1}(\vec{C}; s_t, s_{t+1}) \right]$$

$$P_t C_t + B_{t+1} = R_{t-1} B_t + W_t N_t + T_t$$

where their felicity is described by:

$$u(\vec{C}_t) = \log[C_t] - \frac{N_t^{1+\psi}}{1+\psi}$$

# Households' first order conditions

$$\frac{1}{C_t} = \mathbb{E}_t^\mu \left[ \frac{\beta R_t}{C_{t+1} \Pi_{t+1}} \right]$$

$$N_t^\sigma C_t = \frac{W_t}{P_t}$$

$$\mathbb{E}_t^\mu \left[ \frac{\beta R_t}{C_{t+1} \Pi_{t+1}} \right] \equiv \mathbb{E}_t \left[ \frac{\beta \tilde{R}_t}{C_{t+1} \Pi_{t+1}} \right]$$

Hence the intertemporal Euler equation becomes:

$$\frac{1}{C_t} = \mathbb{E}_t \left[ \frac{\beta \tilde{R}_t}{C_{t+1} \Pi_{t+1}} \right]$$

## Steady state analysis

The interest rate used for decision-making purposes is not the one set by the CB



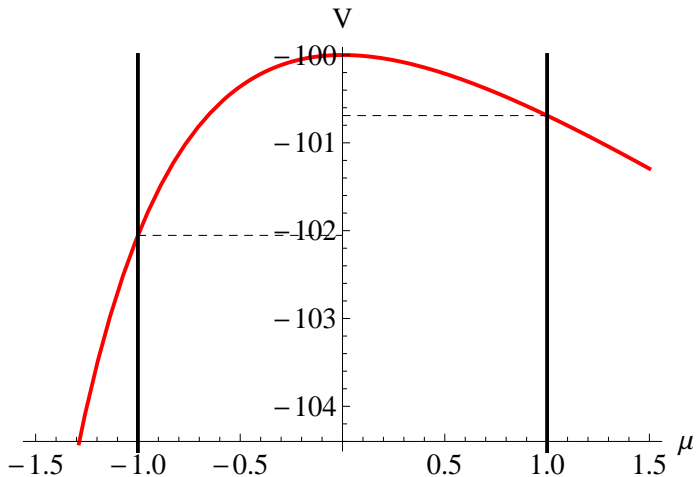
Inflation will not hit the first-best level

$$\bar{\pi} = \pi^* - \frac{\mu}{\phi - 1}$$



- Price dispersion emerges
- Labor productivity and ultimately welfare fall
- *This effect arises both when inflation is inefficiently high or low*
- There is an endogenous “amplification” of ambiguity (Unlike Ilut and Schneider, 2014)

# Steady-state welfare as a function of $\mu$



► calibration

► role of  $\phi$

# Steady-state welfare as a function of $\mu$

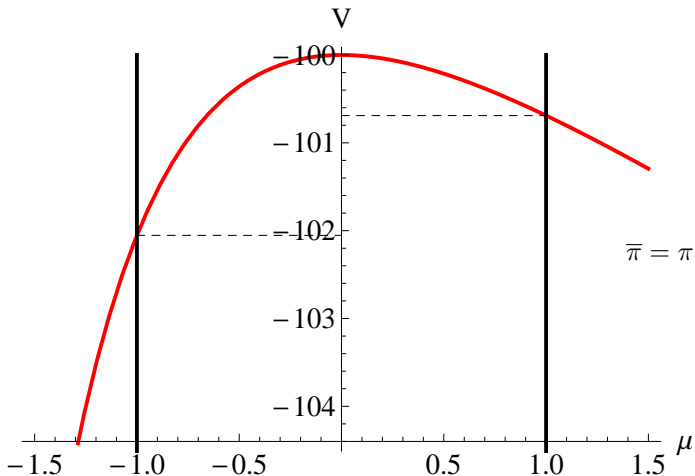
Masolo Monti

Intro

Model

Results

Conclusions



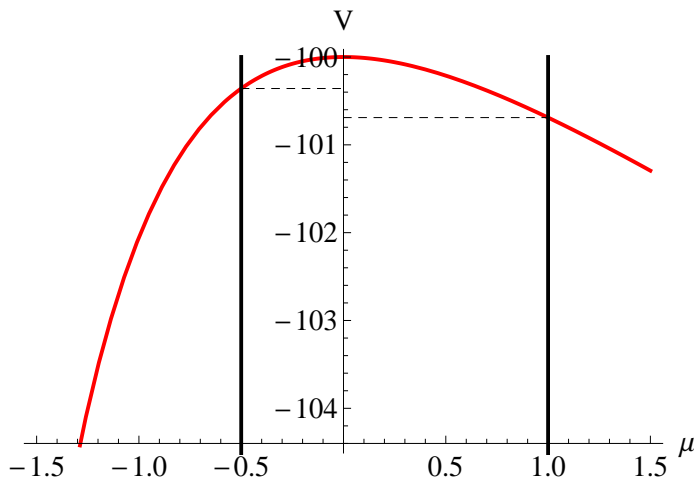
$$\bar{\pi} = \pi^* - \frac{\mu}{\phi - 1}$$

► calibration

► role of  $\phi$



# Steady-state welfare as a function of $\mu$



► calibration

► role of  $\phi$

# Steady-state welfare as a function of $\mu$

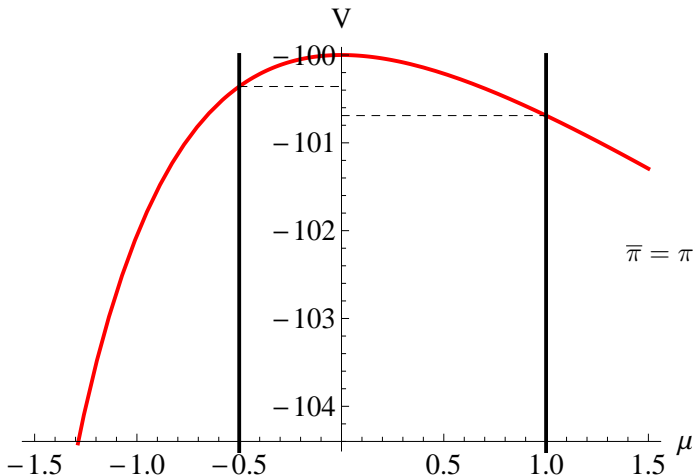
Masolo Monti

Intro

Model

Results

Conclusions



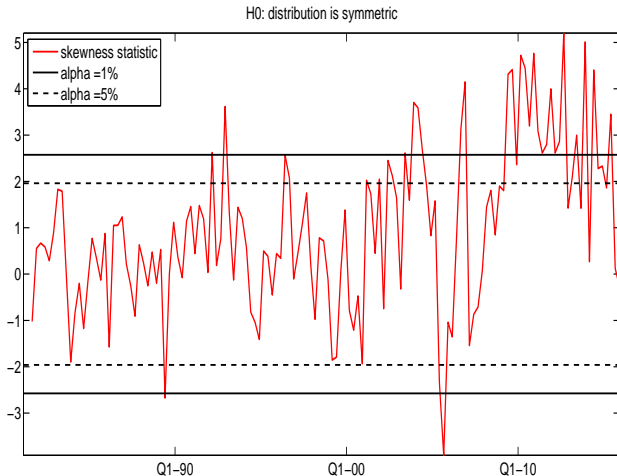
$$\bar{\pi} = \pi^* - \frac{\bar{\mu}}{\phi - 1}$$

► calibration

► role of  $\phi$

# Putting Symmetry to the Test

- Symmetric bounds imply  $\bar{\pi} \geq \pi^*$
- The ZLB is an obvious candidate for asymmetric bounds

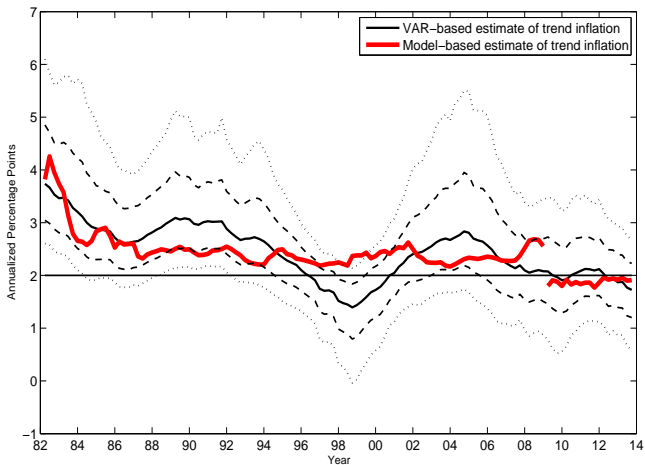


... hence the switching

# Ambiguity and Trend Inflation

Masolo Monti

$$\bar{\pi} = \pi^* - \frac{\mu}{\phi - 1} \quad \pi^* = 2 \quad \phi = 1.5 \quad \mu = \pm \bar{\mu} \geq 0$$



Intro

Model

Results

Conclusions

# Evidence from the SPF 2007Q4

Questions that were included in the 2007Q4 SPF Survey

- Do you think the Fed follows a numerical target for long-run inflation ?
- If so, what value?
- Respondents also provided their expectations for inflation over the next 10 years

Table: 2007 Q4 SPF Special Survey

	Targeters	Non-Targeters
Percentage of Responders	48	46
Average Target	1.74	n.a.
10-yr PCE Inflation Expectation	2.12	2.25
Short-rate Dispersion	.49	.61

# Optimal monetary policy: overview

- Absent ambiguity our monetary policy rule is optimal (implements first best)
- Is it still the case when agents are not entirely sure about the policy rule? Yes & No

We show that:

- If agents fear that policy is too loose, it is optimal for the policymaker to implement a tighter policy than implied by the rule.
- If agents fear that policy is too tight, it is optimal for the policymaker to implement a looser policy than implied by the rule.

# Optimal monetary policy

## Proposition

*Given our model economy, a small  $\bar{\mu} > 0$  and restricting  $\underline{\phi}(-\bar{\mu}, \cdot) < \phi \leq \bar{\phi}$ , the following rule is statically and dynamically optimal in its class:*

$$R_t = R_t^* \Pi_t^{\bar{\phi}} \quad (1)$$

where

$$R_t^* = R_t^n e^{\delta^*(\bar{\mu}, \bar{\phi}, \cdot)} \quad (2)$$

and

$$0 < \delta^*(\bar{\mu}, \bar{\phi}; \cdot) < \bar{\mu} \quad (3)$$

is implicitly defined by

$$\mathbb{V}(-\bar{\mu} + \delta^*(\bar{\mu}, \bar{\phi}; \cdot), \cdot) = \mathbb{V}(\bar{\mu} + \delta^*(\bar{\mu}, \bar{\phi}; \cdot), \cdot).$$

# Optimal policy

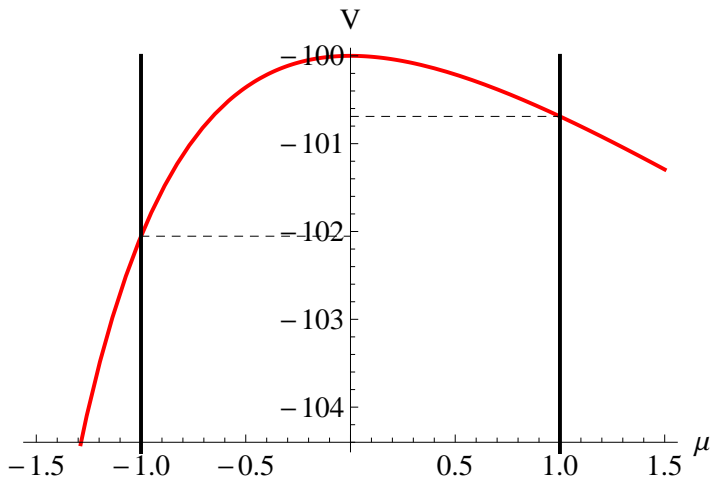


Figure: Steady-state welfare as a function of  $\mu$  (measured in annualized percentage points).



# Optimal policy

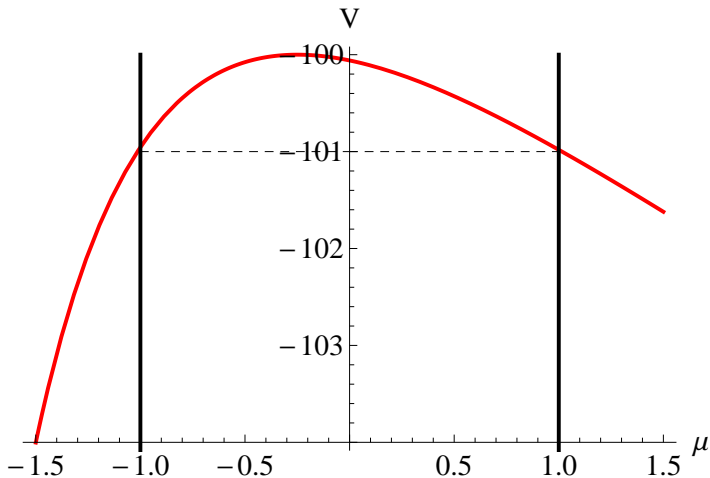


Figure: Steady-state welfare as a function of  $\mu$  (measured in annualized percentage points).

# Conclusions

- Without resorting to exogenous shifts in the target or the parameter of the Taylor rule our model can:
  - ① explain trend inflation dynamics in the US before *and after* the crisis
  - ② Capture the switch from indeterminacy to determinacy in the early 1980s without changes in the responsiveness to inflation
- Our model's policy implications:
  - The less credible a policymaker is, the more hawkish it needs to be
  - If agents fear that policy is too tight, it is optimal to implement looser policy than implied by the rule

# Ambiguity in macro models

Mainly, two alternative preferences specifications used for representing ambiguity aversion in macro:

- ① **Multiple priors:** Gilboa and Schmeidler, 1998 and Epstein and Schneider, 2003.
  - Multiple priors utility is not smooth when belief sets differ in means.
  - → Effects of ambiguity show up in a first order approximation  
Ilut and Schneider (2014)
- ② **Multiplier preferences:** Hansen and Sargent, 2001.
  - Fear of misspecification: statistical perturbation around an approximating model.
  - Smooth utility function

# Literature

- I. Optimal MP design in small NK models. An incomplete list includes:
  - King and Wolman 1996,
  - Schmitt-Grohé and Uribe, 2007
  - Ascari and Ropele, 2007
  - Yun, 2005
  
- II. Ambiguity:
  - Ilut and Schneider, 2014 (first-order effects of ambiguity)
  - Gilboa and Schmeidler, 1998
  
- III. Ambiguity and Monetary Policy:
  - Cogley, Colacito, Hansen and Sargent, 2008
  - Adams and Woodford, 2012
  - Benigno and Paciello, 2014

# Firm's problem

Firms:

- operate a linear production function:  $Y_t = A_t N_t$
- receive a cost subsidy  $\tau = 1/\epsilon$
- maximize expected profits subject to Calvo frictions:

$$\max_{P_t^*} E_t \left[ \sum_{s=0}^{\infty} \theta^s Q_{t+s} \left( \left( \frac{P_t^*}{P_{t+s}} \right)^{1-\epsilon} Y_{t+s} - \Psi \left( \left( \frac{P_t^*}{P_{t+s}} \right)^{-\epsilon} Y_{t+s} \right) \right) \right]$$

Which result in the following standard first-order conditions:

$$\frac{P_t^*(i)}{P_t} = \frac{E_t \sum_{j=0}^{\infty} \theta^j Q_{t+j} \left( \frac{P_{t+j}}{P_t} \right)^{\epsilon} \frac{\epsilon}{\epsilon-1} MC_{t+j}}{E_t \sum_{j=0}^{\infty} \theta^j Q_{t+j} \left( \frac{P_{t+j}}{P_t} \right)^{\epsilon-1}}$$

$$\frac{P_t^*(i)}{P_t} = \left( \frac{1 - \theta \Pi_t^{\epsilon-1}}{1 - \theta} \right)^{\frac{1}{1-\epsilon}}$$

The government taxes to finance the subsidy. We lump the profits together with the tax, which results in the following:

$$\begin{aligned} T_t &= P_t \left( -\tau \frac{W_t}{P_t} N_t + Y_t \left( 1 - (1 - \tau) \frac{W_t \Delta_t}{P_t A_t} \right) \right) \\ &= P_t Y_t \left( 1 - \frac{W_t \Delta_t}{P_t A_t} \right) \end{aligned}$$

[▶ Back](#)

# Calibration

Masolo Monti

Intro

Model

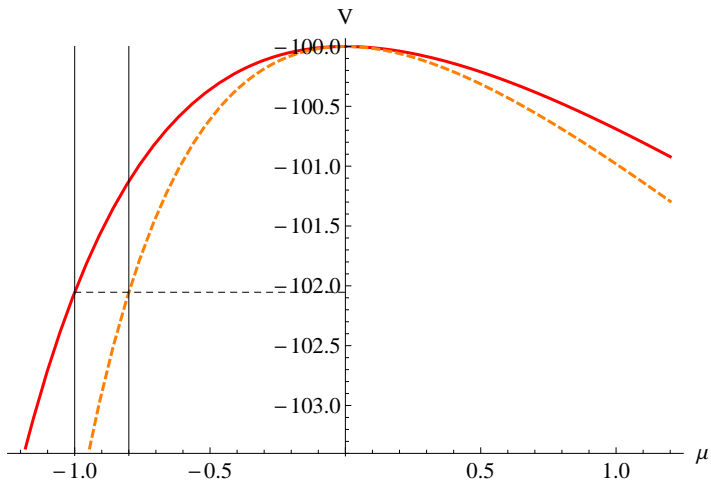
Results

Conclusions

$\beta$	Subjective Discount	.995
$\psi$	Inverse Frish Elasticity	1
$\phi$	Inflation Responsiveness	1.5
$\epsilon$	Demand elasticity	15
$\theta$	Calvo probability	.83

▶ Back

# A simple equivalence: Illustration



**Figure:** Welfare function for  $\phi = 1.5$  (solid red line) and  $\phi = 1.4$  (orange dashed line).



# Quadratic loss function

We follow Coibion, Gorodnychenko and Wieland (2011) to derive the *policy-independent* quadratic loss function in the presence of trend inflation:

$$\mathcal{L}_t = \sum_{j=0}^{\infty} \beta^j \left( \Theta_0(\bar{\mu}, \cdot) + \frac{1+\psi}{2} \text{var}(\tilde{y}_{t+j}) + \Theta_2(\bar{\mu}, \cdot) \text{var}(\pi_{t+j}) \right)$$

Where  $\Theta_2$  is an *increasing* function of  $\bar{\mu}$ . [▶ Back](#)

## What if there are other shocks?

The dynamic properties of the policy functions would have to be worked out numerically (e.g. Schmitt-Grohe' and Uribe 2004) but we can say that reducing ambiguity would:

- 1 reduce the negative welfare consequences of any of those shocks since:

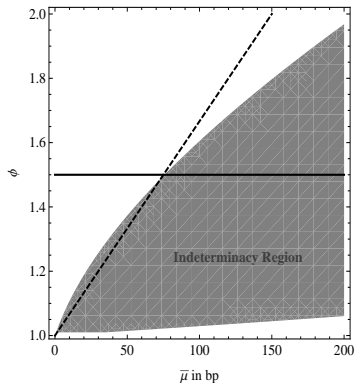
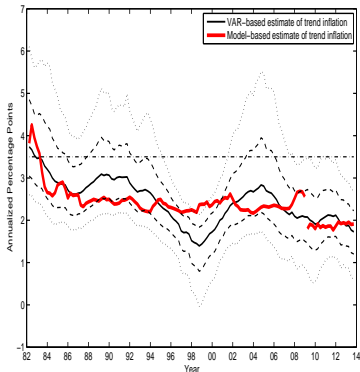
$$\frac{\partial \Theta_2(\bar{\mu}, \cdot)}{\partial \bar{\mu}} = \frac{\partial \Theta_2(\bar{\mu}, \cdot)}{\partial \Pi_w(\bar{\mu})} \frac{\partial \Pi_w(\bar{\mu})}{\partial \bar{\mu}} > 0 \quad (4)$$

- 2 reduce the inflation-output gap stabilization tradeoff (since the coefficient on the output gap variance does not depend on steady state inflation)

The less credible, the more hawkish a CB needs to be.

# Indeterminacy

We find a determinacy region that is consistent with the findings in Coibion and Gorodnichenko (2011)



▶ back

# The model's dynamics

Masolo Monti

Intro

Model

Results

Conclusions

$$\begin{aligned}\tilde{y}_t &= \mathbb{E}_t \tilde{y}_{t+1} - (\phi \pi_t + \hat{\mu}_t - \mathbb{E}_t \pi_{t+1}) \\ \pi_t &= \kappa_0(-\bar{\mu}, \cdot) \left( (1 + \psi) \tilde{y}_t + \psi \hat{\Delta}_t \right) + \kappa_1(-\bar{\mu}, \cdot) \mathbb{E}_t \widehat{F2}_{t+1} \\ &\quad + \kappa_2(-\bar{\mu}, \cdot) \mathbb{E}_t \pi_{t+1} \\ \hat{\Delta}_t &= \kappa_3(-\bar{\mu}, \cdot) \hat{\Delta}_{t-1} + \kappa_4(-\bar{\mu}, \cdot) \pi_t \\ \widehat{F2}_t &= \mathbb{E}_t \left( \kappa_5(-\bar{\mu}, \cdot) \pi_{t+1} + \kappa_6(-\bar{\mu}, \cdot) \widehat{F2}_{t+1} \right)\end{aligned}$$

- The coefficients  $\kappa$ 's depend on the degree of steady state uncertainty:
  - the slope of the Phillips curve:  $\bar{\mu} \uparrow \rightarrow \kappa_0 \downarrow$
  - the policy trade-off worsens

► loss function