

Robust Real Rate Rules

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Paper and slides available on <https://www.tholden.org/>.

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Motivation: Fragility of the Taylor principle

- The Taylor principle requires the response of nominal rates to inflation to be greater than one. Sufficient for determinacy in simple models. (Guarantees no sunspots.)
- Insufficient if there is e.g.:
 - A fraction of hand-to-mouth households (Gali, Lopez-Salido & Valles 2004).
 - Firm-specific capital (Sveen & Weinke 2005).
 - High government spending (Natvik 2009).
 - A positive inflation target (Ascari & Ropele 2009), particularly in the presence of trend growth and sticky wages (Khan, Phaneuf & Victor 2019).
- Inverts if there are e.g.:
 - Enough hand-to-mouth households (Bilbiie 2008).
 - Certain financial frictions (Manea 2019).
 - Non-rational expectations (Branch & McGough 2010; 2018).
 - Active fiscal policy (Leeper & Leith 2016; Cochrane 2022).

This paper

- Monetary rules with a unit response to real rates guarantee determinate inflation under the weakest possible assumptions on the rest of the economy.
 - Robust to household heterogeneity, non-rational households/firms, active fiscal policy, missing transversality conditions, existence/slope of the Phillips curve, etc.
 - Fisher equation is key for monetary transmission.
- Enable the determinate robust implementation of an arbitrary path for inflation.
 - So can match observed inflation dynamics, or any model's optimal policy.
 - Will suggest a reversed interpretation of the Phillips curve.
- Easy to implement in practice, with bonds of any maturity.
 - Using perpetuities or also targeting inflation swaps answers Cochrane (2011).

A first example

- Nominal bond: \$1 bond purchased at t returns $\$(1 + i_t)$ at $t + 1$.
- Real bond (e.g. TIPS): \$1 bond purchased at t returns $\$(1 + r_t + \pi_{t+1})$ at $t + 1$.
 - π_{t+1} is realized inflation between t and $t + 1$.
- Arbitrage between these two implies the Fisher equation:

$$i_t = r_t + \mathbb{E}_t \pi_{t+1}$$

- Abstracting from inflation risk / term / liquidity premia for now.
- Central bank uses the “real rate rule”:

$$i_t = r_t + \phi \pi_t$$

- With $\phi > 1$. Then:

$$\mathbb{E}_t \pi_{t+1} = \phi \pi_t$$

- Unique non-explosive solution, $\pi_t = 0$. Determinate inflation!

Why is this robust? No need for Euler!

- Does not require an aggregate Euler equation to hold.
 - Robust to heterogeneous households and hand-to-mouth agents.
 - Robust to non-rational household expectations.
- For the Fisher equation to hold just need either:
 - Two deep pocketed, fully informed, rational agents in the economy, OR
 - A large market of rational agents with dispersed information. (Hellwig 1980; Lou et al. 2019)
- Much more likely financial market participants have RE than households.
 - Can even partially relax the RE requirement for financial market participants.

Why is this robust? No need for Phillips!

- Does not require an aggregate Phillips curve to hold.
 - Robust to slope of the Phillips curve (if it exists).
 - Robust to forward/backward looking degree of Phillips curve equation.
 - Robust to non-rational firm expectations.
- If CB is unconcerned with output and unemployment then they do not need to care at all about the Phillips curve or its slope.
 - Under this monetary rule, the Phillips curve is irrelevant for inflation dynamics.
 - The Phillips curve (if it exists) determines the output gap, given inflation.
- Only require that at least some prices are adjusted each period using current information.

Real rate rules elsewhere in the literature

- Papers with rules responding to real rates, for analytic convenience e.g.:
 - Adão, Correia & Teles (2011), Holden (2019), Lubik, Matthes & Mertens (2019).
- Closest prior work: Cochrane (2017; 2018; 2022) on spread targeting.
 - Cochrane briefly considers a rule of the form $i_t = r_t + \phi\pi_t$ before setting $\phi = 0$.
 - Determinacy in Cochrane's world comes from the Fiscal Theory of the Price Level.
- Other related work:
 - Hetzel (1990) proposes using nominal bond, real bond spread to guide policy.
 - Dowd (1994) proposes targeting the price of price level futures contracts.
 - Hall & Reis (2016) propose making IOR a function of price level deviations from target, e.g. nominal return from \$1 of $\$(1 + r_t) \frac{p_{t+1}}{p_t^*}$ or $\$(1 + i_t) \frac{p_t}{p_t^*}$.
- Large literature on rules tracking efficient (“natural”) real interest rate.
 - E.g., Cúrdia et al. (2015). Very different idea.

Real rate rules in non-linear models

- Nominal and real bond pricing:

$$I_t \mathbb{E}_t \frac{\Xi_{t+1}}{\Pi_{t+1}} = 1, \quad R_t \mathbb{E}_t \Xi_{t+1} = 1$$

- Non-linear real rate rule:

$$I_t = R_t \Pi \left(\frac{\Pi_t}{\Pi} \right)^\phi$$

- So:

$$\mathbb{E}_t \frac{\Xi_{t+1}}{\mathbb{E}_t \Xi_{t+1}} \frac{\Pi}{\Pi_{t+1}} = \left(\frac{\Pi}{\Pi_t} \right)^\phi$$

- $\Pi_t = \Pi$ is always one solution of this equation! Locally unique!
 - Globally unique at least when Ξ_{t+1} is uncorrelated with Π_{t+1}^{-1} .
 - Global multiplicity unlikely without extremely implausible SDF dynamics.
 - Always global uniqueness if inflation target is $\frac{\Pi}{\Xi} \Xi_t$ or if also target inflation swaps!

Monetary policy shocks

- Suppose the CB uses the rule:

$$i_t = r_t + \phi\pi_t + \zeta_t$$

- with $\phi > 1$, and ζ_t drawn from an AR(1) process with persistence ρ .

- Then from the Fisher equation:

$$\mathbb{E}_t\pi_{t+1} = \phi\pi_t + \zeta_t$$

- Unique solution: $\pi_t = -\frac{1}{\phi-\rho}\zeta_t$.
 - Contractionary (positive) monetary policy shocks reduce inflation.
 - If the CB is more aggressive (ϕ is larger) inflation is less volatile.
 - Can understand inflation dynamics without knowing the rest of the economy.

Explaining observed inflation dynamics

- Large literature finds no role for the Phillips curve in forecasting inflation.
 - Data: Atkeson & Ohanian (2001), Ang, Bekaert & Wei (2007), Stock & Watson (2009), Dotsey, Fujita & Stark (2018).
 - E.g., in post-1984 period, Dotsey, Fujita & Stark (2018) find that an IMA(1,1) model beats Phillips curve based forecasts (both conditionally and unconditionally).
 - One theoretical explanation: McLeay & Tenreyro (2019).
- Also: Miranda-Agrippino & Ricco (2021): a contractionary monetary policy shock causes an immediate fall in the price level, with delayed impact on unemployment.
- All supportive of models in which the causation in the Phillips curve only runs in one direction: *from inflation to the output gap*. As here!

Output dynamics in a simple model

- As before, CB sets $i_t = r_t + \phi\pi_t + \zeta_t$, so $\pi_t = -\frac{1}{\phi-\rho}\zeta_t$.

- Rest of model 1: Phillips curve (PC), with mark-up shock ω_t :

$$\pi_t = \beta\mathbb{E}_t\pi_{t+1} + \kappa x_t + \kappa\omega_t$$

- Rest of model 2: Discounted/compounded Euler equation (EE) (Bilbiie 2019), with n_t exogenous natural rate ($\delta = 1$, $\varsigma = \text{EIS}$ recovers standard Euler equation):

$$x_t = \delta\mathbb{E}_tx_{t+1} - \varsigma(r_t - n_t)$$

- PC implies: $x_t = -\frac{1}{\kappa}\frac{1-\beta\rho}{\phi-\rho}\zeta_t - \omega_t$. x_t does not help forecast inflation as $\mathbb{E}_t\pi_{t+1} = \rho\pi_t$.
 - Once you know π_t , there is no extra useful information in x_t .

Real rate dynamics in a simple model

- In the model of the last slide, if ω_t is IID, EE implies:

$$r_t = n_t + \frac{1}{\varsigma} \left[\frac{1}{\kappa} \frac{(1 - \beta\rho)(1 - \delta\rho)}{\phi - \rho} \zeta_t + \omega_t \right]$$

- Derived without solving EE forward!
 - Implies degree of discounting/compounding (δ) has no impact on determinacy.
 - Also implies robustness to missing transversality conditions.
 - Contrasts with Bilbiie (2019): if $\varsigma > 0$ and $\beta \leq 1$, with a standard Taylor rule, $\phi > 1$ is only sufficient for determinacy if $\delta \leq 1$.
 - Contrasts with Bilbiie (2008): if $\delta = 1$ and $\varsigma < 0$, with a standard Taylor rule, $\phi > 1$ is neither necessary or sufficient for determinacy.
- Under real rate rule, $\phi > 1$ is always necessary and sufficient! (Given $\phi \geq 0$.)
 - Robust to lags in EE and PC. (PC lag may reduce persistence of ME on x_t !)

Responding to other endogenous vars

- In the model:

$$i_t = r_t + \phi\pi_t + \phi_x x_t + \zeta_t$$

$$\pi_t = \tilde{\beta}(1 - \varrho_\pi)\mathbb{E}_t\pi_{t+1} + \tilde{\beta}\varrho_\pi\pi_{t-1} + \kappa x_t + \kappa\omega_t$$

$$x_t = \tilde{\delta}(1 - \varrho_x)\mathbb{E}_t x_{t+1} + \tilde{\delta}\varrho_x x_{t-1} - \varsigma(r_t - n_t)$$

- If $\kappa > 0$, $\phi_x > 0$ and $\tilde{\beta} \in [0,1]$, then $\phi_\pi > 1$ is sufficient for determinacy!
- Real rate rule still helps robustness as it disconnects EE from prices.
- More generally, $\phi_\pi > 1$ always sufficient for determinacy providing responses to other endogenous variables are small enough (in any model).
 - Implies robustness to non-unit responses to real rates. Other vars may proxy RR.
- For greater robustness, replace other endogenous vars in rule with structural shocks.
 - If structural shocks (e.g., ω_t) not observed can infer from structural equations.
 - If equation params not known, can learn in real time, still with determinacy!

Implementing arbitrary inflation dynamics

- Suppose CB uses the rule:

$$i_t = r_t + \mathbb{E}_t \pi_{t+1}^* + \phi(\pi_t - \pi_t^*)$$

- π_t^* : an exogenous stochastic process, possibly a function of economy's other shocks.
- So, from the Fisher equation: $\mathbb{E}_t(\pi_{t+1} - \pi_{t+1}^*) = \phi(\pi_t - \pi_t^*)$.
- With $\phi > 1$, unique, determinate solution: $\pi_t = \pi_t^*$.
- The CB can hit an arbitrary path for inflation!
 - E.g., optimal policy. So real rate rules can attain highest possible welfare.
 - And real rate rules can explain any observed inflation dynamics.
- Related literature on implementation of optimal policy: Svensson & Woodford (2003), Dotsey & Hornstein (2006), Evans & Honkapohja (2006), Evans & McGough (2010).

Avoiding “over determinacy”

- If price level is determinate independent of MP, then $\phi > 1$ can mean explosive π_t .
 - E.g., true if fiscal policy is active (real surpluses do not respond to debt).
 - With one period debt, active fiscal, flex. prices: $\pi_t - \mathbb{E}_{t-1}\pi_t = -\varepsilon_{s,t}$.
 - So, with real rate rule: $\pi_t = \phi\pi_{t-1} + \varepsilon_{\zeta,t-1} - \varepsilon_{s,t}$. Explosive!
- This is a knife edge result.
 - In any model: $\eta_t := \pi_t - \mathbb{E}_{t-1}\pi_t = \alpha\varepsilon_{\zeta,t} + \nu_t$, where $\mathbb{E}_{t-1}\nu_t\varepsilon_{\zeta,t} = 0$ and $\mathbb{E}_{t-1}\nu_t = 0$.
 - From RRR and Fisher: $\alpha\phi e_t = \alpha\mathbb{E}_t e_{t+1}$, where $e_t := \mathbb{E}_t\pi_{t+1}$.
 - If $\alpha \neq 0$ (data!), then $e_t = 0$ is unique stationary soln, so $\eta_t = \pi_t = \alpha\varepsilon_{\zeta,t} + \nu_t$. Stable!
 - Explosions only unavoidable if MP shock has no contemporaneous impact on π_t !
- With active fiscal policy, geometric coupon debt gives a stable π_t solution with $\phi > 1$.
 - Still consistent with transversality! \uparrow bubble in debt price balanced by \downarrow quantity.
 - Initial debt price jumps. With passive MP implies multiplicity, so FTPL \neq uniqueness.

Practical implementation: Setup

- Markets in short maturity inflation protected securities may be illiquid or unavailable.
 - Suppose instead they instead target five-year returns.
 - Long maturities may have substantial risk/term/liquidity premia.
 - Extra complication: Inflation may be observed with a lag. One month for US CPI.
- Notation:
 - i_t : nominal yield per period on a five-year sovereign (nominal) bond at t .
 - r_t : real yield per period on a five-year sovereign inflation protected bond at t .
 - T : number of periods in five years. E.g., if t is measured in months, $T = 60$.
 - L : information lag. Market participants use the $t - L$ information set in period t .
 - ν_{t-L} risk (etc.) premia on five-year nominal bonds relative to five-year real bonds at t . (Lagged subscript as participants use $t - L$ date variables at t .)
 - $\bar{\nu}_{t-L}$ central bank's period t belief about level of ν_{t-L} (possibly correlated with ν_{t-L}).

Practical implementation: Maths

- Fisher equation:

$$i_t - r_t = v_{t-L} + \mathbb{E}_{t-L} \frac{1}{T} \sum_{k=1}^T \pi_{t+k}$$

- CB uses the rule:

$$i_t - r_t = \bar{v}_{t-L} + \mathbb{E}_{t-L} \frac{1}{T} \sum_{k=1}^T \pi_{t+k}^* + \phi(\pi_{t-L} - \pi_{t-L}^*)$$

- Combining implies:

$$\mathbb{E}_t \frac{1}{T} \sum_{k=1}^T (\pi_{t+k+L} - \pi_{t+k+L}^*) = (\bar{v}_t - v_t) + \phi(\pi_t - \pi_t^*)$$

- With $\phi > 1$ this has a unique solution of the form:

$$\pi_t = \pi_t^* + \mathbb{E}_t \sum_{j=0}^{\infty} A_j (\bar{v}_{t+j} - v_{t+j}), \quad A_0 = -\frac{1}{\phi}, \quad A_j = O\left(\phi^{-\frac{j}{T+L}}\right) \text{ as } j \rightarrow \infty$$

Practical implementation: Discussion

- CB's inflation error $\pi_t - \pi_t^*$ is stationary as long as $\bar{v}_{t+j} - v_{t+j}$ is stationary.
- If ϕ is large enough, $\pi_t \approx \pi_t^*$. If aggressive enough, limited knowledge of risk premia and information lags make no difference to CB's ability to hit $\pi_t = \pi_t^*$.
- Note: CB's trading desk should hold $i_t - r_t$ constant between meetings.
 - This requires i_t to move between meetings, in response to observed changes in r_t .
 - No reason this should be significantly harder than holding i_t fixed.
- CB could also offer to exchange \$1 face value of real debt for $\$(1 + i_t - r_t)$ face value of nominal, as proposed by Cochrane (2017; 2018).
- Or to buy/sell portfolios with \$1 nominal debt, $-\$1$ real debt for $\$(i_t - r_t)$.
- Or trade inflation swaps (which pay $\Pi_{t+1} - K_t$ at $t + 1$, with no payments at t).

Responses to Cochrane (2011)

- Cochrane (2011) argues no reason to rule out explosive NK equilibrium.
- Using a type of nominal and real perpetuities gives one resolution. Pricing:

$$Q_{I,t} = \mathbb{E}_t \frac{\Xi_{t+1}}{\Pi_{t+1}} [Q_{I,t+1} + \Pi^{t+1}], \quad Q_{R,t} = \mathbb{E}_t \frac{\Xi_{t+1}}{\Pi_{t+1}} [Q_{R,t+1} + P_{t+1}]$$

- Monetary rule: $\hat{Q}_{I,t} = \hat{Q}_{R,t} \left(\frac{\Pi}{\Pi_t} \right)^{-\frac{\phi}{\Xi\phi-1}}$, in terms of detrended: $\hat{Q}_{I,t} := \frac{Q_{I,t}}{\Pi^t}$, $\hat{Q}_{R,t} := \frac{Q_{R,t}}{P_t}$.
 - Log-linearization: $\phi\pi_t = \mathbb{E}_t \pi_{t+1}$, $\hat{q}_{R,t} - \hat{q}_{I,t} = \Xi \mathbb{E}_t [\hat{q}_{R,t+1} - \hat{q}_{I,t+1}] + \mathbb{E}_t [\pi_{t+1}]$
 - If $\phi > \Xi$, then exploding inflation is inconsistent with finite nominal perpetuity price.
- Targeting perpetuity prices also removes all ZLB problems, as no ZUB on perpetuity.
- Another option is to simultaneously intervene in both nominal bond and inflation swap markets. Allows to set $\mathbb{E}_t \frac{\Xi_{t+1}}{\Xi_t \Xi_{t+1}} \Pi_{t+1} = \Pi_t^* = \left[\mathbb{E}_t \frac{\Xi_{t+1}}{\Xi_t \Xi_{t+1}} \Pi_{t+1}^{-1} \right]^{-1}$ so $\Pi_{t+1} = \Pi_t^*$.
 - No need for Taylor principle, or any equilibrium selection via stationarity.

Conclusion

- The Taylor principle does not guarantee determinacy with standard monetary rules.
- Real rate rules guarantee determinacy no matter the rest of the economy.
- Classic determinacy results may be reinterpreted as defining “sufficiently close to a real rate rule”.
- Real rate rules enable the determinate implementation of arbitrary inflation dynamics.
- As such, they can attain high welfare and explain observed dynamics.
- Also established:
 - FTPL does not give uniqueness, and active-active is not necessarily explosive.
 - Modified real rate rules give uniqueness without imposing stationarity.

Extra slides

- But don't price setters determine inflation?
- Welfare with simple real rate rules.
- References

But don't price setters determine inflation?

- Suppose all firms doubled their price today. What would happen?
- The CB observes high inflation, so (e.g.) offers a deposit facility paying $i_t = r_t + \phi\pi_t > r_t$ (continuously adjusting i_t as r_t moves).
- Financial market participants still expect zero future inflation, so they are happy to deposit and receive $i_t > r_t$.
- The entirety of the money stock ends up being transferred to this deposit facility (and r_t almost certainly rises).
- Consumers have no cash \Rightarrow at least some goods are not sold \Rightarrow goods markets do not clear.
- At least some firms reduce their price until markets clear.
 - This will only occur when $\pi_t = 0$.

Welfare

- Recap: Real rate rules can determinately implement an arbitrary path for inflation, including optimal policy. Automatic that they can attain high welfare!
- Makes sense to limit to “simple” real rate rules though.
 - “Simple” here means simple dynamics of targeted inflation.
 - Claim: Looking for optimal simple inflation dynamics is a useful approach to policy.
- Two exercises follow:
 - MA(0), MA(1) and ARMA(1,1) inflation policy in a simple NK model. Latter is sufficient to attain unconditional optimal.
 - Examination of optimal policy in the Justiniano, Primiceri & Tambalotti (2013) model. Multiple shock ARMA(1,2) inflation policy is very close to fully optimal.

A simple NK model for policy analysis

- Look at welfare in a simple model with the Phillips curve (ω_t IID):

$$\pi_t = \beta \mathbb{E}_t \pi_{t+1} + \kappa x_t + \kappa \omega_t$$

- And the policy objective to minimise:

$$(1 - \beta) \mathbb{E} \sum_{k=0}^{\infty} \beta^k (\pi_{t+k}^2 + \lambda x_{t+k}^2) = \mathbb{E} (\pi_t^2 + \lambda x_t^2)$$

- Equality under the constraint that policy must be time-invariant.

- Optimal policy must have an MA(∞) representation ($\theta_1, \theta_2, \dots$ TBD):

$$\pi_t = \kappa \sum_{k=0}^{\infty} \theta_k \omega_{t-k}$$

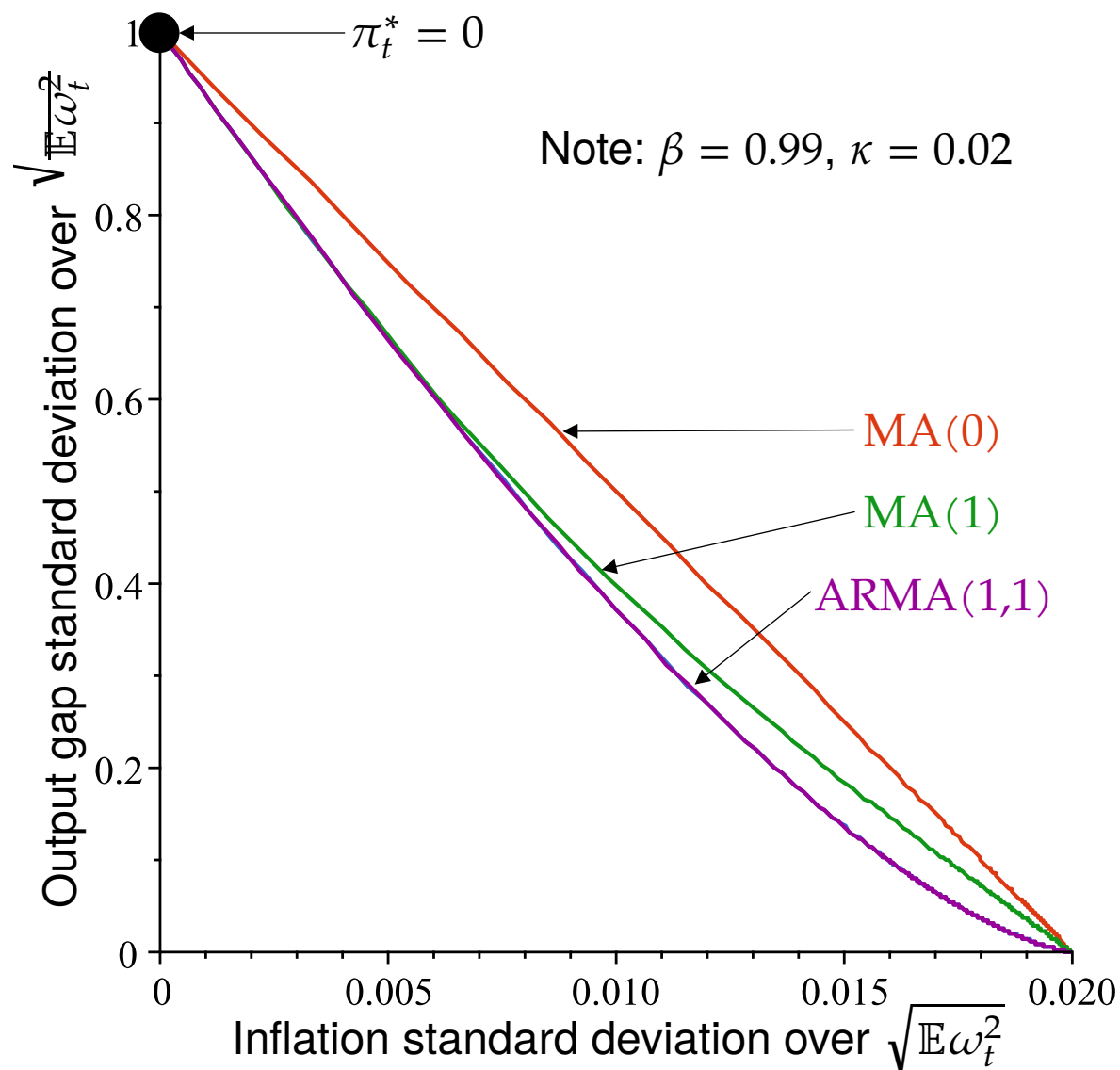
- Implies objective is:

$$\mathbb{E} (\pi_t^2 + \lambda x_t^2) = \mathbb{E} [\omega_t^2] \sum_{k=0}^{\infty} [\kappa^2 \theta_k^2 + \lambda (\theta_k - \beta \theta_{k+1} - \mathbb{1}[k=0])^2]$$

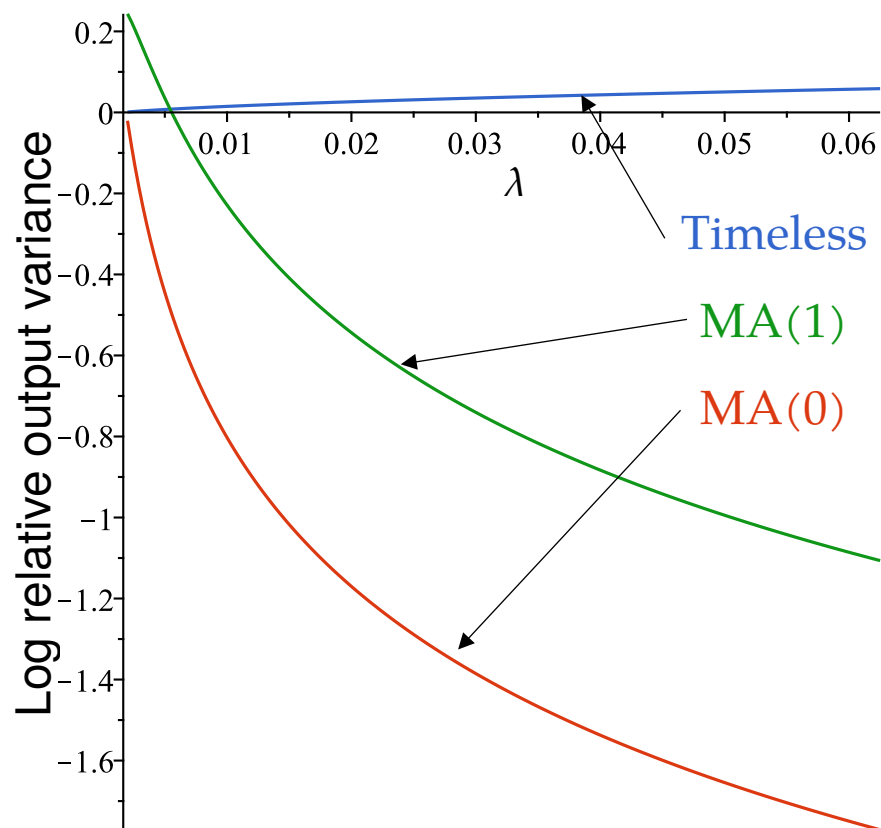
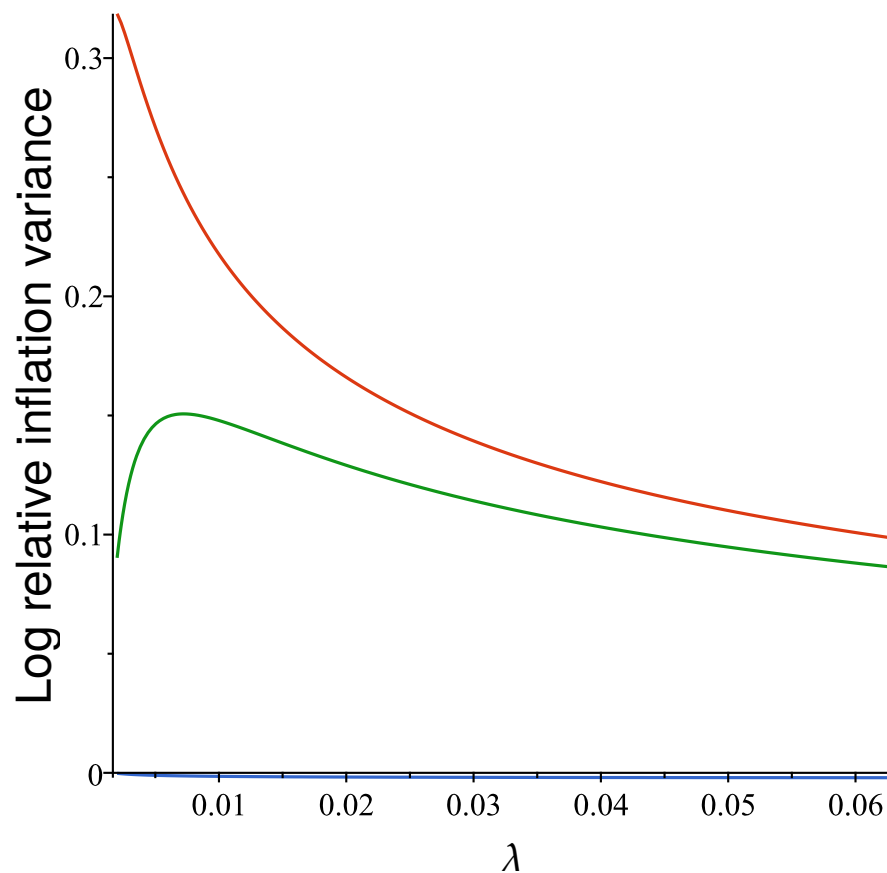
Welfare of real rate rules in a simple model

- Optimising subject to $\pi_t = \pi_t^*$ being an MA(0) gives the discretionary optimum with $\pi_t = \kappa \frac{\lambda}{\lambda + \kappa^2} \omega_t$ and $\pi_t + \frac{\lambda}{\kappa} x_t = 0$.
- Optimising subject to $\pi_t = \pi_t^*$ being an MA(1) gives a solution with $\pi_t = \kappa \theta_0 \omega_t + \kappa \theta_1 \omega_{t-1}$ where $\theta_0 \geq 0$ and $\theta_1 \leq 0$.
 - Thus ω_t increases π_t while reducing $\mathbb{E}_t \pi_{t+1}$, lessening output gap movements.
- Optimising subject to $\pi_t = \pi_t^*$ being an ARMA(1,1) give the unconditionally optimal solution from the prior literature (e.g. Damjanovic, Damjanovic & Nolan (2008)) with $\pi_t + \frac{\lambda}{\kappa} (x_t - \beta x_{t-1}) = 0$.
 - Optimal MA coefficient equals $-\beta \approx -0.99$. Close to the IMA(1,1) processes estimated by Dotsey, Fujita & Stark (2018) for the post-1984 period.

Policy frontiers (varying λ)



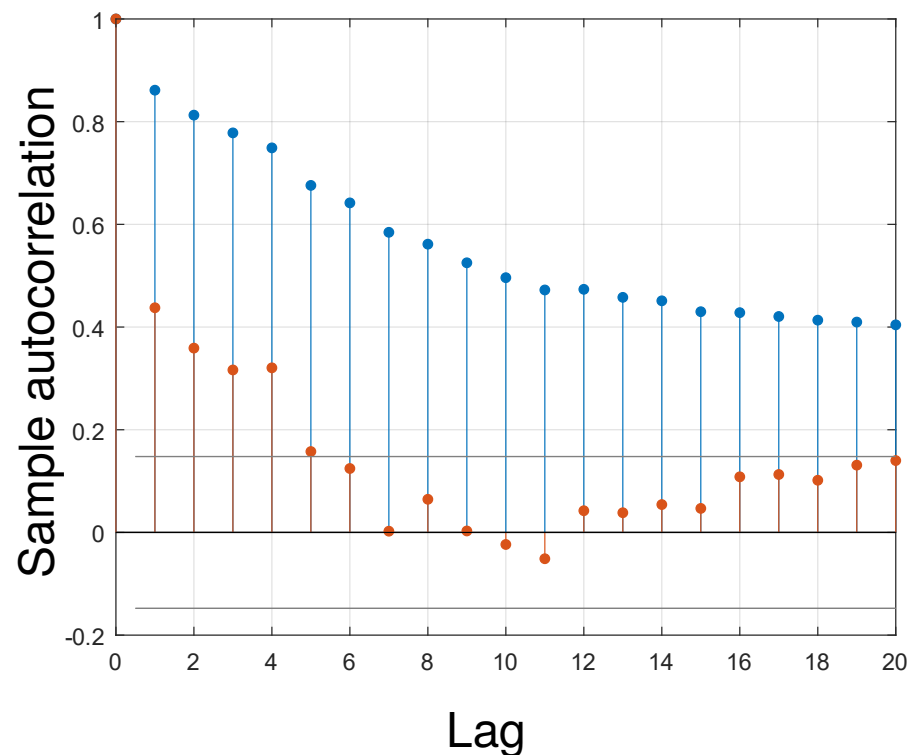
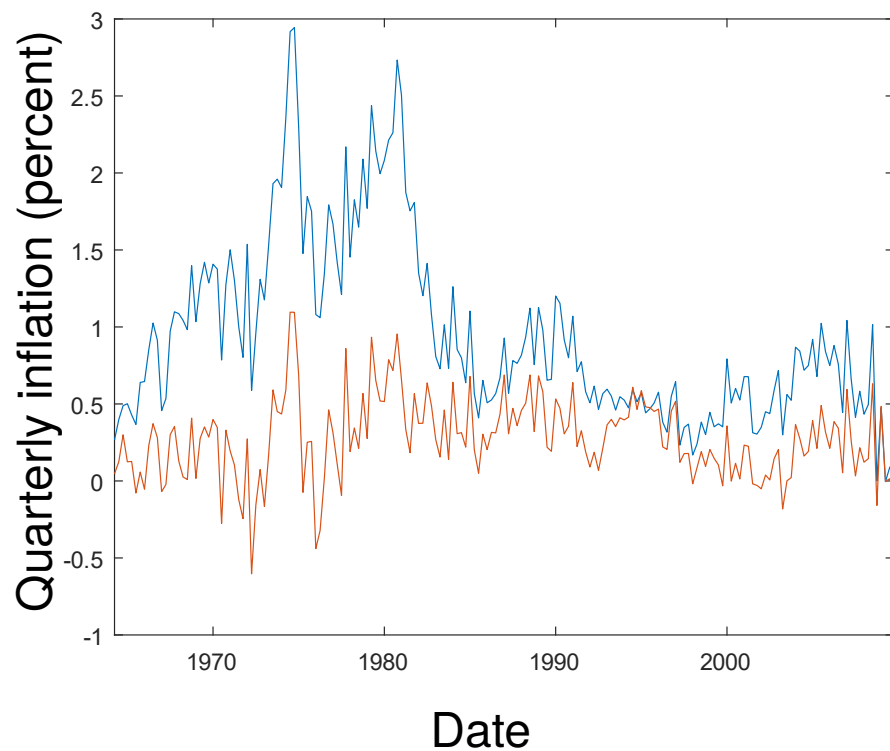
Log relative variances to ARMA(1,1) policy



Note: $\beta = 0.99$, $\kappa = 0.02$.

MA(0) and MA(1) policies generate too much inflation variance.

Optimal inflation dynamics in a richer model



Using the Justiniano, Primiceri & Tambalotti (2013) model and replication files.

Blue: actual US inflation dynamics.

Red: inflation dynamics under optimal policy and US historical shocks. Less persistent!

Simple approximation to optimal policy 1/2

- For any $\rho \in (-1, 1)$, the solution for optimal inflation has a multiple shock, ARMA(1, ∞) representation:

$$\pi_t - \pi = \rho(\pi_{t-1} - \pi) + \sum_{k=0}^{\infty} \sum_{n=1}^N \theta_{n,k}^{(\rho)} \varepsilon_{n,t-k}$$

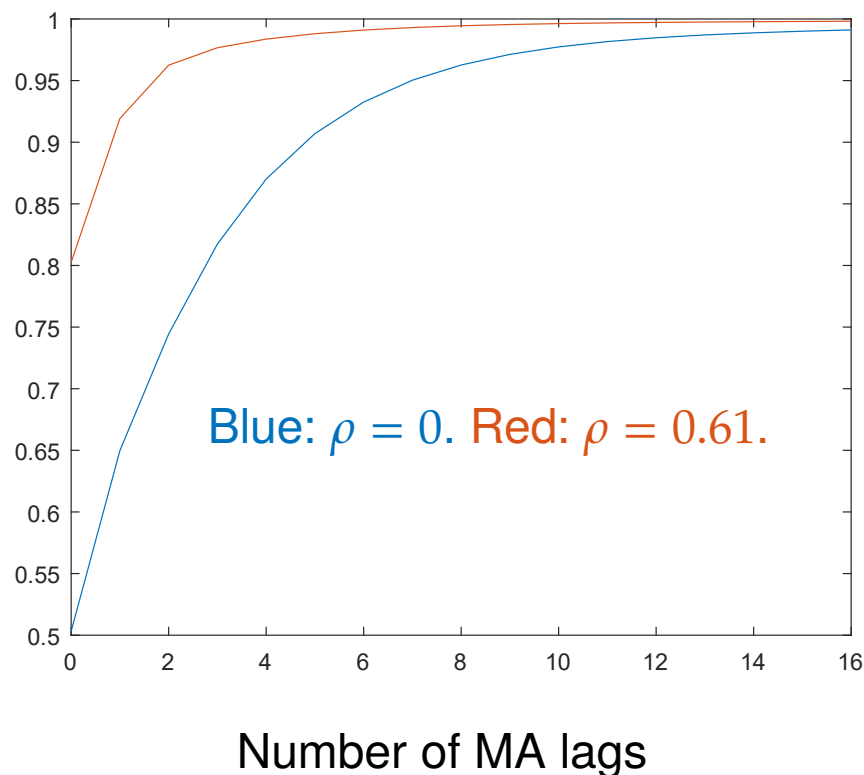
○ $\varepsilon_{1,t}, \dots, \varepsilon_{N,t}$ are the model's structural shocks.

- Approximate by truncating MA terms at some point: E.g. multiple shock ARMA(1, K):

$$\pi_t^{(K)} - \pi = \rho(\pi_{t-1}^{(K)} - \pi) + \sum_{k=0}^K \sum_{n=1}^N \theta_{n,k}^{(\rho)} \varepsilon_{n,t-k}$$

- Henceforth: “multiple shock ARMA” = “MSARMA”.

Simple approximation to optimal policy 2/2



Proportion of the variance of optimal inflation in the Justiniano, Primiceri & Tambalotti (2013) model explained by truncating the number of MA lags.

MSARMA(1,1) explains $> 90\%$ of optimal inflation variance, MSARMA(1,2) $> 95\%$!

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