Robust Real Rate Rules

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

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 with trend growth + 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.

- Easy to implement in practice, with bonds of any maturity.
  - Using perpetuities answers Cochrane (2011) critique.
  - Also solves all ZLB determinacy and steady-state multiplicity issues.

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, they do not need to care 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 interest on reserves 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:

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

- 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! Always locally unique.
    - Approximately globally unique under weak assumptions: there exists $\overline{Z} \geq 1$ such that for all sufficiently high ϕ, $1 \leq \frac{\Pi}{\Pi_t} \leq \overline{Z}^{\frac{1}{\phi - 1}} \to 1$ as $\phi \to \infty$. So, for large ϕ, $\Pi_t \approx \Pi$.
    - Under slightly stronger restrictions on the SDF, $\Pi_t = \Pi$ is globally unique solution for all sufficiently high ϕ.

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 $\mathrm{AR}(1)$ 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.
  - 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 $\mathrm{IMA}(1{,}1)$ model beats Phillips curve based forecasts (both conditionally and unconditionally).
  - One theoretical explanation: McLeay & Tenreyro (2019).

- Also: Miranda-Agrippino & Ricco (2021):
  - Contractionary monetary policy shock causes immediate fall in the price level.
  - Delayed impact on unemployment.

- All supportive of models in which causation in PC 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), n_t exogenous natural rate ($\delta = 1$, $\varsigma = \mathrm{EIS}$ recovers standard Euler equation):

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

- 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 nor 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 effect of monetary shocks 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 $\kappa > 0$, $\phi_x \geq 0$ 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 real rates.

- 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 parameters 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 $\alpha \neq 0$ (as in data!), then $e_t = 0$ is unique stationary soln, so $\eta_t = \pi_t = \alpha\varepsilon_{\zeta,t} + \nu_t$. Stable! Determinate!
  - 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! ↑ bubble in debt price balanced by ↓ quantity. Initial debt price jumps.
  - With passive MP this implies multiplicity, so FTPL does not guarantee 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:

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

- CB uses the rule:

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

- Combining implies:

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

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

$$\pi_t = \pi^*_t + \mathbb{E}_t \sum_{j=0}^{\infty} A_j \left(\bar{\nu}_{t+j} - \nu_{t+j}\right), \qquad A_0 = -\frac{1}{\phi}, \qquad A_j = \mathrm{O}\left(\phi^{-\frac{j}{T+L}}\right) \text{ as } j \to \infty$$

Practical implementation: Discussion

- CB's inflation error $\pi_t - \pi_t^*$ is stationary as long as $\bar{\nu}_{t+j} - \nu_{t+j}$ 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) and problems of ZLB

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

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

  - Monetary rule, (with $\phi > \Xi^{-1}$ has opposite response to inflation than conventional):

$$\hat{Q}_{I,t} = \hat{Q}_{R,t} \left(\frac{\Pi}{\Pi_t}\right)^{-\frac{\phi}{\Xi\phi-1}}, \qquad \hat{Q}_{I,t} := \frac{Q_{I,t}}{\Pi^t}, \qquad \hat{Q}_{R,t} := \frac{Q_{R,t}}{P_t}.$$

  - Log-linearization:

$$\phi\pi_t = \mathbb{E}_t\pi_{t+1}, \qquad \hat{q}_{R,t} - \hat{q}_{I,t} = \Xi\mathbb{E}_t[\hat{q}_{R,t+1} - \hat{q}_{I,t+1}] + \mathbb{E}_t[\pi_{t+1}].$$

  - With $\phi > \Xi^{-1}$, then exploding inflation is inconsistent with finite nominal perpetuity price.

- Targeting perpetuity prices also removes all ZLB problems, as no ZUB on perpetuity prices.
  - Intuition for unconventional sign: Suppose at ZLB for ever, then $\hat{Q}_{I,t} = \infty$. CB selling perpetuities rules this out.

Conclusion

- The Taylor principle does not guarantee determinacy with standard monetary rules.
- Real rate rules guarantee determinacy no matter the rest of the economy. Easy to implement.

- 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 policy is not necessarily explosive.
  - Real rate rules on perpetuities give global uniqueness even with the ZLB, 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:
  - $\mathrm{MA}(0)$, $\mathrm{MA}(1)$ and $\mathrm{ARMA}(1{,}1)$ 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 $\mathrm{ARMA}(1{,}2)$ 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:

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

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

- Optimal policy must have an $\mathrm{MA}(\infty)$ representation ($\theta_1, \theta_2, \ldots$ TBD):

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

  - Implies objective is:

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

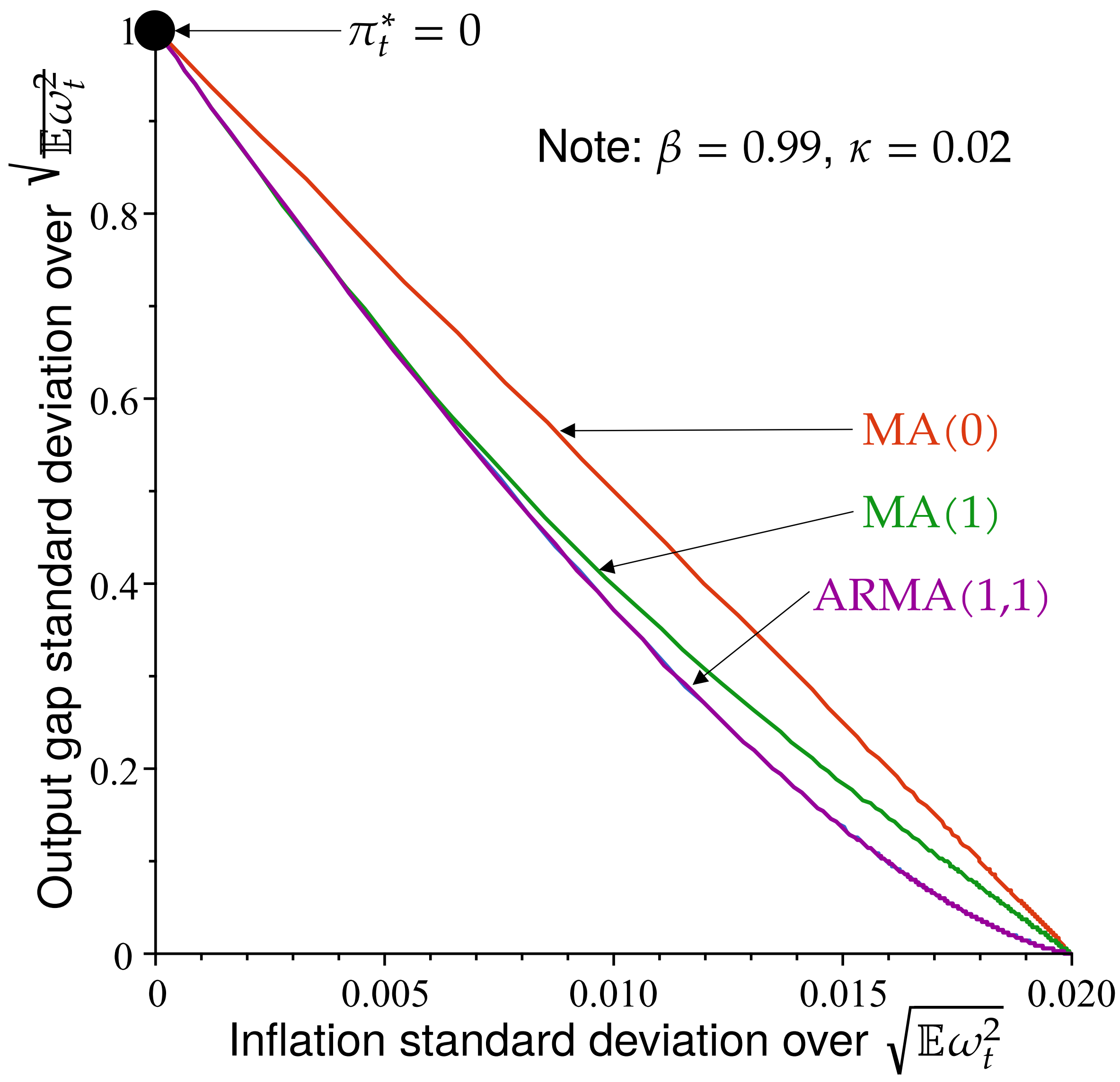
Welfare of real rate rules in a simple model

- Optimising subject to $\pi_t = \pi_t^*$ being $\mathrm{MA}(0)$ gives the discretionary optimum with $\pi_t = \kappa \frac{\lambda}{\lambda+\kappa^2} \omega_t$ and $\pi_t + \frac{\lambda}{\kappa} x_t = 0$.

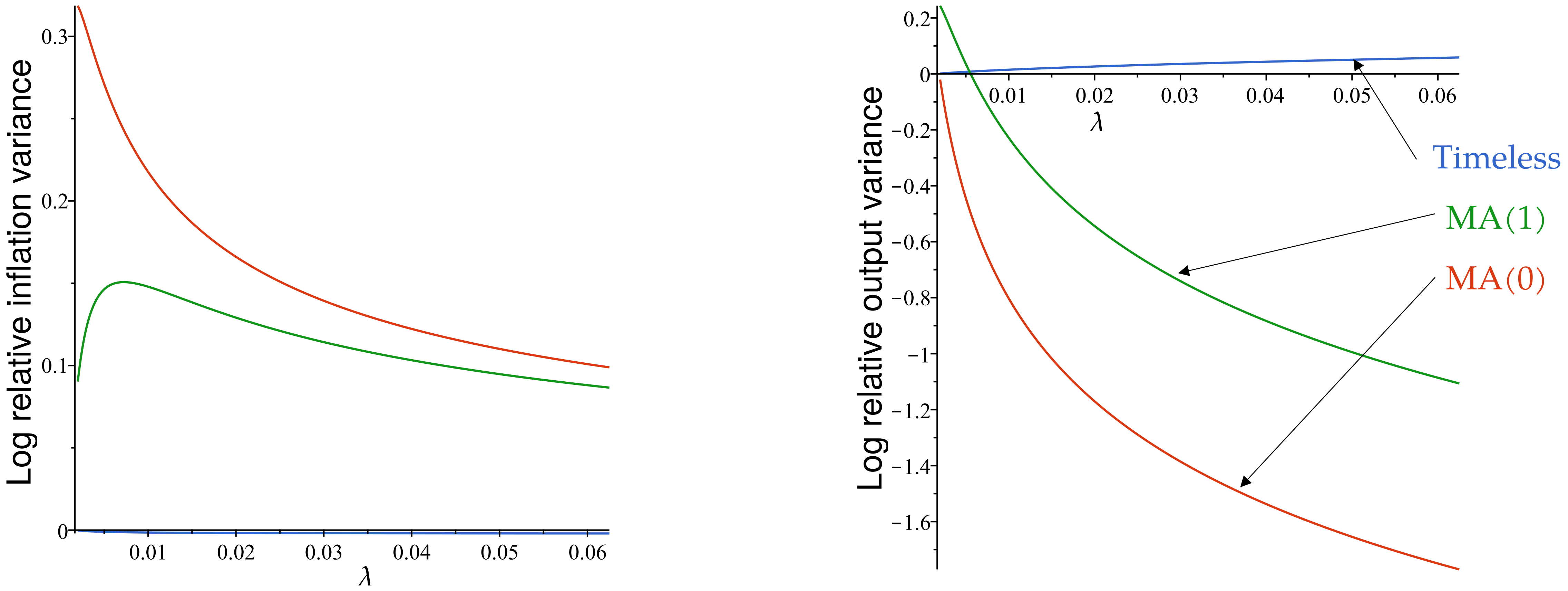
- Optimising subject to $\pi_t = \pi_t^*$ being an $\mathrm{MA}(1)$ gives a solution with $\pi_t = \kappa\theta_0\omega_t + \kappa\theta_1\omega_{t-1}$ where $\theta_0 \geq 0$ and $\theta_1 \leq 0$.
  - Thus ω_t increases π_t while reducing $\mathbb{E}_t\pi_{t+1}$, lessening output gap movements.

- Optimising subject to $\pi_t = \pi_t^*$ being an $\mathrm{ARMA}(1{,}1)$ 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 $\mathrm{IMA}(1{,}1)$ processes estimated by Dotsey, Fujita & Stark (2018) for the post-1984 period.

Policy frontiers (varying λ)



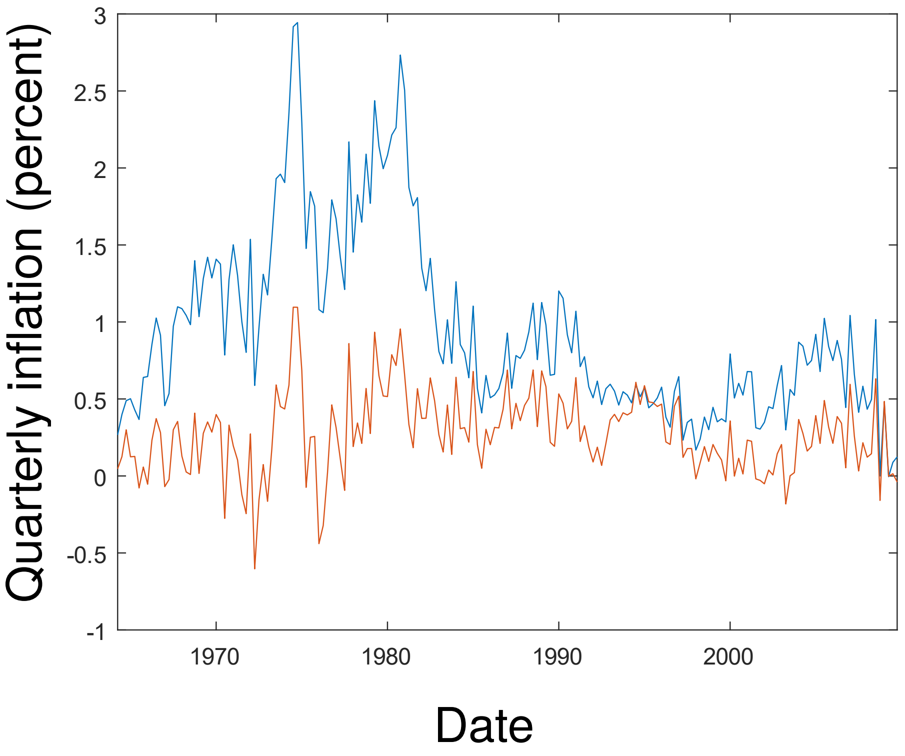
Log relative variances to $\mathrm{ARMA}(1,1)$ policy

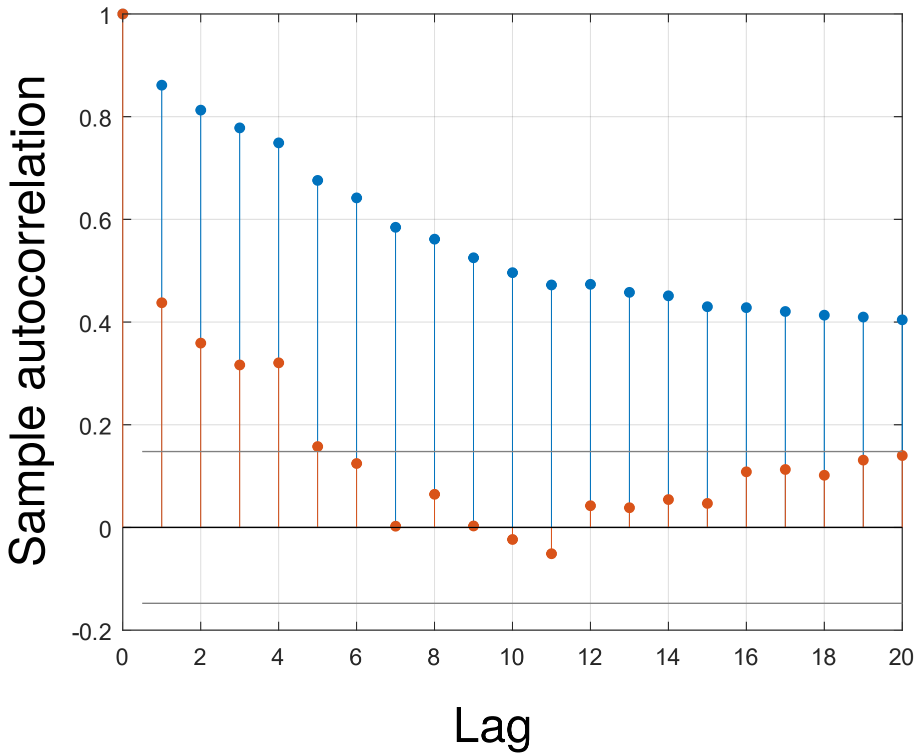


Note: $\beta = 0.99$, $\kappa = 0.02$.

$\mathrm{MA}(0)$ and $\mathrm{MA}(1)$ 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, $\mathrm{ARMA}(1,\infty)$ representation:

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

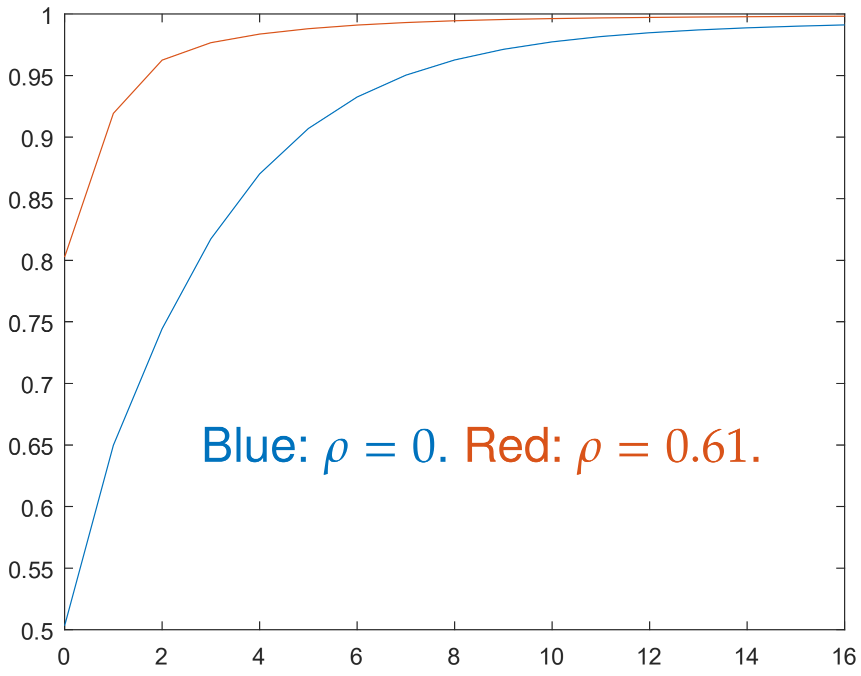
  - $\varepsilon_{1,t}, \dots, \varepsilon_{N,t}$ are the model's structural shocks.

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

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

- Henceforth: "multiple shock ARMA" = "MSARMA".

Simple approximation to optimal policy 2/2



Number of MA lags

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

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

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