Real interest rate and monetary policy in the post Bretton Woods United States.

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Outline

1. Introduction
   - Motivation
   - Research questions
   - Literature review
2. Theoretical model
3. Data
4. Empirical investigation
   - Pre-estimation tests
   - ARDL Model
   - Post-estimation diagnostic tests
5. Conclusion

In a nutshell

What we do:

- We derive a relationship between the real interest rate and its determinants through a long-forgotten general equilibrium growth model of heterogeneous capital introducing monetary policy instruments in the model.
- We estimate this relationship using time series data for the United States using an Autoregressive Distributed Lag Model (ARDL).
- We employ the estimated relationship to highlight the short- and long-run dynamics given counterfactual shocks related and unrated to monetary policy.

In a nutshell

Preliminary results:

- We find the existence of a long-run relationship between the real interest rate and its determinants.
- The coefficients of the long-term effects are all statistically significant at conventional levels of confidence and their signs are consistent with those expected from theory.
- We show that after some disturbance the interest rate returns to equilibrium.
- Among other results, we show that the deviations from the expected rate of inflation, while neutral in the long-run, in the short run they affect inversely the real interest rate.

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Fed's goals

Authorized by the U.S. Congress to handle all issues of the money, Fed is mandated to pursue:

- Price stability
- Maximum employment
- Economic growth consistent with the economy's productive potential
- Low long-term interest rate

Fed's policy instruments

- The quantity of money supply (up to 1990's)
- The discount rate or Federal Funds Rate (FFR)

Fed's actions

- Price stability at an inflation rate around 2% (target rate)
- Combining with an estimate of growth rate analogous to economy's productive potential and maximum employment, Fed estimates the **natural or neutral** interest rate r^*.
- Departures from r^* for some markets arise policy interventions (injecting or withdrawing stimulus).
- Fed does **not** remain indifferent to its mandate for a low r^* in the long run.

Our viewpoint of Fed's actions

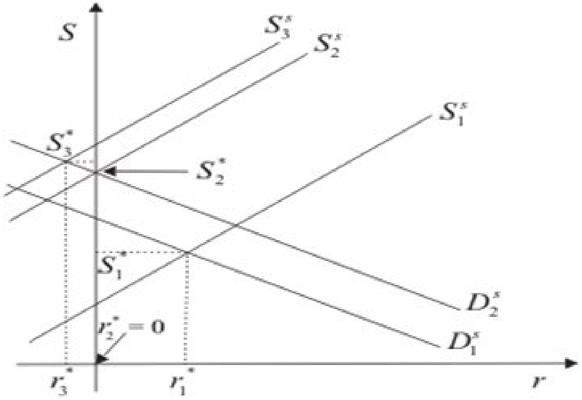

Figure 1: Supply and demand for "savings"

S_3^s, this is Fed's policies in the 1970's, and less so in the late 2010s, which pushed r^* even to negative levels as depicted by r_3^*.

Research question

What are the determinants of the real interest rate? How are these determinants responsible for the negative real interest rates?

Related Literature

As we described in Figure 1, Fed's policies in the 1970's and in the late 2010's pushed r^* even to negative levels as depicted by r_3^*.

- Brand et al. (2019) argue that responsible are (1) the slowdown in the growth rates of the labor force, (2) the TFP, (3) the decline in the labor participation rate, (4) the population age, (5) the inequality, (6) the flight to safe assets, (7) the global saving-investment imbalances
- Bernanke (2005) and Rachel and Smith (2015) argue it is attributed to a global glut of savings
- Bitros (2018) suggests that FED cannot be absolved from all responsibility for the decline of labor share in the US

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Heterogeneous capital model

The demand for loanable funds:

$$r_d = \mu + \lambda \frac{\gamma_0}{\gamma_1} - \frac{(1 + \gamma_1) \times S(t)}{\alpha \times N(t) - \gamma_0 \times S(t)} \tag{1}$$

The supply for loanable funds in the presence of central bank:

$$r_f^s = \mu + n - \gamma_1 + \frac{[\gamma_0 \times (\theta - \mu + \gamma_1) - 1] \times w \times S(t)}{M(t) \times V(t) - \gamma_0 \times w \times S(t)} \tag{2}$$

The theoretical model of the interest rate

Equations (1) and (2) give respectively the demand and supply functions in the market for loans. For equilibrium in this market, it must hold that:

$$r^d = r_f^s \tag{3}$$

If we could solve analytically using equations (1), (2) and (3) and deflate the nominal variables we would derive the following equilibrium function:

$$r^* = h(s^*(t), m(t), V(t); \mu, n, w, \alpha; \lambda, \gamma_0, \gamma_1) \tag{4}$$

where $r^* = r_f^* - \theta$ and the symbols $s^*(t)$ and $m(t)$ are expressed in real money terms.

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Data

- Time period: 1973-2019
- Country: United States
- Public available data
- Sources: World Bank (WB), International Monetary Fund (IMF), Federal Reserve Bank of St. Louis (FED), AMECO

Data

Symbol	Definition	Derivation	Source
θ	Observed rate of inflation (Consumer Price Index)	$\frac{P(t)-P(t-1)}{P(t-1)}$	IMF
r_f	Nominal interest rate	Government's bond (FIGB_PA)	IMF
$s(t)$	Real gross investment	Gross capital formation (NE.GDI.TOTL.KD)	WB
$y(t)$	Real gross domestic product	NY.GDP.MKTP.KD	WB
$m(t)$	Real money supply	Broad money (IFS line 35L.ZK)	WB
g	Economic growth rate	$\frac{y(t)-y(t-1)}{y(t-1)}$	WB
w	Index of labor cost	Real unit labour costs (QLCD)	AMECO
μ	Rate of technological progress	$\frac{y(t)}{\text{total labor force}}$	FRED
n	Rate of population change	$\frac{N(t)-N(t-1)}{N(t-1)}$	WB
α	Labor force participation rate	Civilian labor force level, $\geq$16years (CLF16OV)	FRED
$V(t)$	Velocity of money at time t	$\frac{y(t)}{m(t)}$	
$\hat{\epsilon_\theta}$	Unexpected inflation	$\hat{\epsilon_\theta} = \theta - \hat{\theta}$ $= \theta - (\hat{\beta_0} + \hat{\beta_1} \times t)$	

All variables are expressed in 2015 constant prices. The real unit labour cost is the ratio of compensation per employee to nominal GDP per person employed.

Table 1: Definition and measurement of variables

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Empirical strategy

- Unit root tests for examining the order of integration.
- ARDL estimation in ECM form
- Bound test for cointegration
- Post-estimation diagnostic tests

Unit-root tests

- $r \sim I(1)$
- $\mathbf{X} \sim$ a mix of $I(0)$ & $I(1)$
- Two structural breaks; one in 1980s and the other in 2008s.
- None of the variables is integrated of order greater than 1.

Unit roots

	r	$s(t)$	$m(t)$	$V(t)$	w	g	μ	n	$\hat{\epsilon_\theta}$
Panel A: Levels									
AFD	-2.34	-0.86	0.07	-1.06	-0.99	-5.27^{***}	-3.72^{***}	0.11	-2.08
ADF with t	-2.47	-0.252	-1.99	-1.15	-2.17	-5.28^{***}	-5.46^{***}	-0.82	-3.35^{*}
PP	-2.35	-0.85	-0.09	-1.47	-1.04	-5.29^{***}	-3.66***	-0.49	-1.99
PP with t	-2.41	-2.73	-2.56	-1.52	-2.37	-5.27^{***}	-5.42^{***}	-1.21	-3.25^{*}
KPSS	0.19^{**}	0.13^{*}	0.07	0.20^{**}	0.19^{**}	0.07	0.13^{**}	0.25^{***}	0.15^{**}
Panel B: First differences									
ADF	-6.92^{***}	-5.85^{***}	-4.44^{***}	-5.36^{***}	-6.36^{***}	-9.05^{***}	-9.51^{***}	-4.43^{***}	-6.7^{***}
PP	-6.94^{***}	-5.81^{***}	-4.45^{***}	-5.41^{***}	-6.37^{***}	-10.05^{***}	-11.48^{***}	-4.42^{***}	-6.8^{***}
KPSS	0.05	0.04	0.04	0.07	0.05	0.04	0.04	0.05	0.05

Notes: $s(t)$ and $m(t)$ are in logarithmic form. The null hypothesis for ADF and PP unit root tests is that the time series is non-stationary. $Z(t)$-statistics are presented for both tests. The null hypothesis for KPSS unit root test is that the time series is trend stationary. The *LM*-statistics are reported. The maximum lag for KPSS is 3 and has been chosen by Schwarz criterion. ***, **, * declares the rejection of null hypothesis for $\alpha = 1, 5, \&\ 10\%$, respectively.

Table 2: Unit root tests

Real interest rate plot

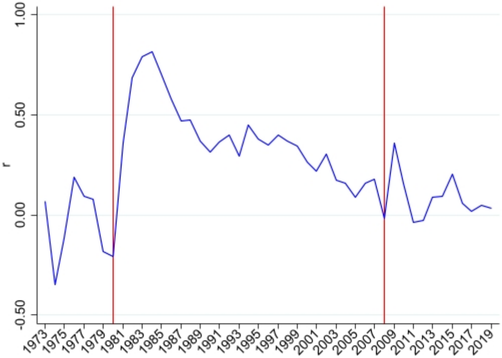


Figure 2: Real interest rate plot

ARDL Model

We estimate the following ARDL model in error correction form. We follow the work of Kripfganz and Schneider (2018):

$$\Delta r_t = b_0 + b_1 t - \gamma(r_{t-1} - \delta' \mathbf{X_{t-1}}) + \sum_{i=1}^{p-1} \psi_{ri} \Delta r_{t-1} + \sum_{j=0}^{q_x-1} \psi'_{xj} \Delta \mathbf{X_{t-j}} + e_t \quad (5)$$

where δ is a vector of long-run coefficients, ψ_r and ψ_x are the short-run coefficients and γ is the speed of adjustment.

Long-run estimates and speed of adjustment

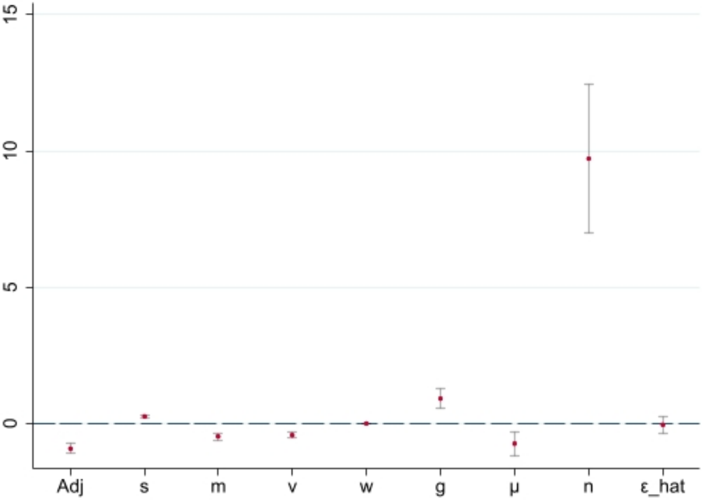


Figure 3: Long-run effects

Long-run estimates

	Variable	Coefficients	T-ratio
Long-run effects	s_{t-1}	0.28^{***}	7.61
	m_{t-1}	-0.53^{***}	-7.43
	V_{t-1}	-0.48^{***}	-8.76
	w_{t-1}	-0.003^{***}	-2.84
	g_{t-1}	0.98^{***}	5.54
	μ_{t-1}	-0.82^{***}	-3.28
	n_{t-1}	10.54^{***}	7.64
	$\hat{\epsilon}_{\theta,t-1}$	-0.05	-0.32
ECT	Adj	-0.92^{***}	-11.22

The optimal lag length is chosen by the Schwarz information criterion.
***, **, * denote the rejection of null hypothesis that the coefficients are equal to zero for $\alpha = 1, 5, \& 10\%$, respectively.

Table 3: Estimates

Short-run effects

	Variable	Coefficients	T-ratio
Short-run effects	Δs_t	0.06	1.43
	Δm_t	-0.68^{***}	-9.40
	Δm_{t-1}	-0.068^{**}	-2.34
	ΔV_t	-0.44^{***}	-9.07
	Δw_t	-0.005^{***}	-5.10
	Δg_t	0.90^{***}	5.20
	Δmu_t	-0.28^{***}	-1.81
	Δmu_{t-1}	0.317^{***}	5.37
	Δn_t	7.30^{***}	6.80
	Δn_{t-1}	-7.58^{***}	-5.85
	Δn_{t-2}	-6.35^{***}	-4.95
	$\Delta \hat{\epsilon}_{\theta,t}$	-0.68^{***}	-8.45
	$\Delta \hat{\epsilon}_{\theta,t-1}$	-0.27^{***}	-4.64
	$\Delta \hat{\epsilon}_{\theta,t-2}$	-0.16^{***}	-3.68
Exogenous variables	$I_1 = [t \geq 1980]_t$	0.030^{***}	7.24
	$I_2 = [t \geq 2008]_t$	-0.014^{**}	-2.34
	t	0.006^{***}	5.55
	b_0	0.796^{***}	6.43
ARDL(1,1,2,0,2,0,2,3,3)	Number of observations	47	
	R^2	0.985	
	$\bar{R}^2$	0.967	
	$\sqrt{MSE}$	0.003	

The optimal lag length is chosen by the Schwarz information criterion.
***, **, * denote the rejection of null hypothesis that the coefficients are equal to zero for $\alpha = 1, 5, \& 10\%$, respectively.

Table 4: Estimates

Bound test

		10%		5%		1%	
	K	I(0)	I(1)	I(0)	I(1)	I(0)	I(1)
F	15.51	2.37	3.45	2.69	3.83	3.34	4.63
t	-4.83	-3.13	-4.53	-3.41	-4.85	-3.96	-5.49

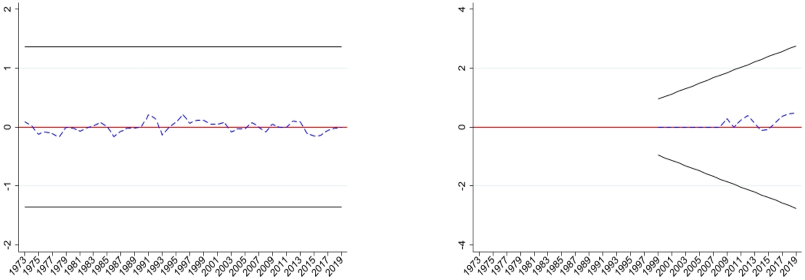
Table 5: PSS Bound testing

Post-estimation diagnostic tests

Type	Diagnostic Test	Test statistics	p-value
Heteroskedasticity	Cameron-Trivedi IM, White test	47.00	0.43
	Breusch-Pagan/Cook–Weisberg test	0	0.95
Serial Correlation/Autocorrelation	Durbin's alternative test	2.15	0.16
	Breusch–Godfrey LM test	4.56	0.05
	LM test for ARCH	0.18	0.68
Misspecification	Ramsey RESET test	1.91	0.16
Normality	Skewness and kurtosis tests	0.15	0.93
	Jarque-Bera test	0.02	0.99

Table 6: Diagnostic tests

Parameter Stability



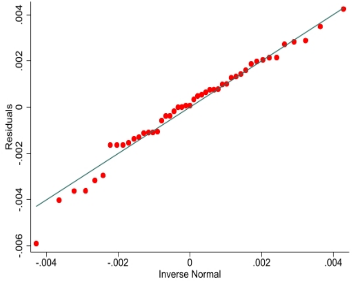
(a) OLS

(b) Recursive residuals

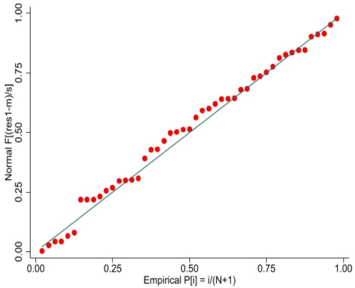
Notes: CUSUM test for parameter stability. Black lines show the 95% confidence interval around the null hypothesis of non-existence of structural break. Recursive residuals are used.

Figure 4: CUSUM test

Further tests for normality of the residuals



(a) Quantiles of residuals against quantiles of normal distribution



(b) Standardized normal distribution

Figure 5: Distribution of the residuals

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Conclusion

Our objective in this paper was to shed some light on the nature of possible distortions that may spring from monetary policies based on the pricing of the funds that central banks provide to the economy. For this purpose, we adopted a research strategy based on three tasks:

- To derive a relationship between the real interest rate and its determinants, including possible influences from the country's central bank. We obtained onet by embedding monetary policy in a long-forgotten general equilibrium growth model of heterogeneous capital.
- To estimate this relationship using time series data for United States
- To employ the estimated relationship to highlight the short- and the long-term dynamics of the real interest rate, given arbitrary shocks, related and unrelated to monetary policy.

Conclusion

- We find that by injecting (withdrawing) "artificial savings", the central bank influences the real interest rate negatively (positively) through direct and indirect channels; one direct being, for example, the quantity of money, whereas another indirect being the velocity of circulation.
- The deviations from the expected rate of inflation, while neutral in the long-run as we expected, in the short run they affect inversely the real interest rate. By implication, economic agents do not appear to suffer from "interest rate illusion", and hence, monetary authorities should not rest assured that policy induced changes in the interest rate may escape unnoticed and without real consequences for the economy.

Next steps

- Income inequality, exchange rate
- Counterfactual shocks (work in progress)
- Panel framework

Thank you!!

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