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Monetary Policy and the Uncovered Interest Rate Parity Puzzle

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Abstract

High interest rate currencies tend to appreciate. This is the *uncovered interest rate parity (UIP) puzzle*. It is primarily a statement about *short-term* interest rates and how they are related to exchange rates. Short-term interest rates are strongly affected by monetary policy. We represent monetary policy as foreign and domestic Taylor rules. We use a statistical pricing-kernel model to map these Taylor rules into an exchange rate process and ask if the model can account for the UIP puzzle. We find that if the foreign Taylor rule responds to variations in the nominal exchange rate, but the domestic Taylor rule does not, then there are parameterizations of the model for which the well-known UIP regression coefficient is negative. An economic interpretation of our results is that the excess returns to currency speculation that are inherent in deviations from UIP represent the costs that central banks incur for implementing Taylor rule type policies.

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1 Introduction

The uncovered interest rate parity (UIP) relation states that high interest rate currencies ought to tend to depreciate against low interest rate currencies. For many currency pairs and time periods we seem to see the opposite. This is puzzling in that it has proven difficult to write down a model that can explain why UIP is at odds with data.

The UIP evidence is primarily about *short-term* interest rates and currency depreciation rates. Monetary policy exerts substantial influence over short-term interest rates. Therefore, the UIP puzzle can be synonymously stated in terms of monetary policy; why do countries with high interest rate policies have currencies which tend to appreciate against those with low interest rate policies? This is the question that we ask. We represent foreign and domestic monetary policies as Taylor rules, develop a statistical pricing-kernel model which maps the Taylor rules into an exchange rate process, and then ask if the model can account for the UIP evidence.

We are not the first to examine the link between UIP deviations and monetary policy.[1] What distinguishes our paper is how monetary policy is represented. Many existing papers include a specific model of money, most commonly some sort of cash-in-advance constraint. We take a short-cut. Monetary policy takes the form of an Taylor rule, an interest rate equation of the form

$$i_t = \tau + \tau_1 \pi_t + \tau_2 z_t \quad , \tag{1}$$

where i_t is the short rate, π_t is the inflation rate and z_t is a "policy shock." We also require that the interest rate satisfy the standard (nominal) pricing kernel equation,

$$i_t = -\log E_t \, n_{t+1} e^{-\pi_{t+1}} \quad , \tag{2}$$

where n_{t+1} is the (real) marginal rate of substitution. How can both equations hold? We use the framework developed in Gallmeyer, Hollifield, Palomino, and Zin (2007) (GHPZ). Their approach is to solve for an inflation process such that equations (1) and (2) are both satisfied. This captures the essence of the new-Keynesian paradigm; the notion that inflation π_t is an endogenous process, reflecting both policy responses and household responses to the same underlying shocks. What results is what GHPZ call a 'monetary policy consistent pricing kernel:' a nominal pricing kernel which depends on the Taylor-rule parameters τ, τ_1 and τ_2. We build

[1] Previous work includes Alvarez, Atkeson, and Kehoe (2007), Backus, Gregory, and Telmer (1993), Bekaert (1994), Burnside, Eichenbaum, Kleshchelski, and Rebelo (2006), Canova and Marrinan (1993), Dutton (1993), Grilli and Roubini (1992), Lucas (1982), Macklem (1991), Marshall (1992), McCallum (1994) and Schlagenhauf and Wrase (1995).

on their work by specifying such pricing kernels for both domestic and foreign-currency denominated payoffs and then using results from Backus, Foresi, and Telmer (2001) to derive the implications for exchange rates and the UIP puzzle.

An important precursor to our paper is McCallum (1994) who also derived implications for UIP as the solution to a linear rational expectations model characterized by a policy-type interest rate rule. Our contribution is to explicitly incorporate the pricing kernel approach in equation (2), which we think is helpful for the identification of shocks.

2 Model

We begin with a terse treatment of existing results in order to fix notation. The core of our approach is the standard pricing-kernel equation,

$$b_t^{n+1} = E_t\, m_{t+1} b_{t+1}^n \quad , \tag{3}$$

where b_t^n is the U.S. dollar (USD) price of a nominal n-period zero-coupon bond at date t and m_t is the pricing kernel. We will work mostly with the short rate, the yield on the shortest maturity bond, defined as $i_t = -\log b_t^1$. An equation analogous to (3) applies for foreign-currency denominated bonds, say in units of British pounds (GBP). GBP-denominated variables, m_t^*, i_t^*, etc., will be denoted with asterisks. Fama's (1984) well-known decomposition of the interest-rate differential, $i_t - i_t^*$, into the expected rate of depreciation of USD, q_t, and the excess expected return to currency speculation, p_t, — so that $i_t - i_t^* = p_t + q_t$ — can be expressed as,

$$\begin{aligned} i_t - i_t^* &= \log E_t\, m_{t+1}^* - \log E_t\, m_{t+1} && (4)\\ q_t &= E_t \log m_{t+1}^* - E_t \log m_{t+1} && (5)\\ p_t &= \big(\log E_t\, m_{t+1}^* - E_t \log m_{t+1}^*\big) - (\log E_t\, m_{t+1} - E_t \log m_{t+1}) && (6)\\ &= Var_t(\log m_{t+1}^*)/2 - Var_t(\log m_{t+1})/2 \quad , && (7) \end{aligned}$$

where equation (7) is only valid for the case of conditional lognormality. The rate of USD currency depreciation is denoted $d_{t+1} = S_{t+1}/S_t$, so that $q_t = E_t \log d_{t+1}$, where S_t is the nominal exchange rate, USD per unit GBP. See Backus, Foresi, and Telmer (2001) for a less-terse development of these results.

The population regression coefficient from the well-known regression of the depreciation rate on the interest-rate differential,

$$\log\, d_{t+1} = c + b\big(i_t - i_t^*\big) + \text{residuals}$$

is

$$b = \frac{Cov(q_t, p_t + q_t)}{Var(p_t + q_t)} \quad . \tag{8}$$

UIP implies that $b = 1$. Our objective is to write down a model that fits the empirical facts, $b < 0$. It is important to note that a necessary condition for this is that p_t vary over time. The implies that, at least for the lognormal case, we *must* have stochastic volatility in the log kernels.

2.1 Taylor Rules and the UIP Regression

We represent monetary policy with a Taylor rule of the form

$$i_t = \tau + \tau_1 \pi_t + \tau_2 z_t \quad . \tag{9}$$

where i_t and π_t are the continuously-compounded short nominal interest rate and inflation rate, respectively, and z_t is a "policy shock." There are many alternative specifications for Taylor rules. A good discussion related to asset pricing is Ang, Dong, and Piazzesi (2007). We begin with this relatively simple specification for reasons of tractability and clarity. Cochrane (2007) uses a similar specification to address issues related to price-level determinacy and the identification of the parameters in equation (9).

The process for z_t is a AR(1) with stochastic volatility:

$$z_t = \varphi_z z_{t-1} + v_{t-1}^{1/2} \varepsilon_t \tag{10}$$

$$v_t = \theta_v (1 - \varphi_v) + \varphi_v v_{t-1} + \sigma_v w_t \tag{11}$$

where ε_t and w_t are *i.i.d.* standard normal. Recall that stochastic volatility is not an option. It is a requirement. The only issue is where it comes from. Since our goal is to emphasize monetary policy we specify the source of the stochastic volatility as the "policy shock."

Turning to asset pricing, define the continuously-compounded inflation rate as $\pi_{t+1} = \log(P_{t+1}/P_t)$. The nominal pricing kernel, $m_{t+1} = n_{t+1} P_t / P_{t+1}$, is comprised of a real piece n_{t+1} and an inflation piece, P_{t+1}/P_t. The short rate is $i_t = -\log E_t \, m_{t+1}$. Given this structure, we have the following result:

Result 1:

> Suppose that foreign and domestic Taylor rules are both of the form (9), with identical coefficients and shocks which are not perfectly correlated. If the real part of the pricing kernel is constant, $n_{t+1} = n$, and the policy shocks are not autocorrelated, $\varphi_z = 0$, then the UIP regression coefficient is
>
> $$b = \frac{\rho_v}{\tau_1} \quad .$$
>
> Derivations are provided in Appendix 1.

Common wisdom is that $\tau_1 > 1$, so $b < 1$. Therefore, b isn't negative unless volatility is negatively autocorrelated which is implausible. Nevertheless, the UIP regression coefficient can be significantly less than unity and the joint distribution of exchange rates and interest rates will admit positive expected excess returns to suitably-defined trading strategy.

Why set n_{t+1} to a constant? This implies that investors are risk-neutral over real-valued consumption gambles. We do this in order to achieve a combination of tractability and clarity. Tractability is obvious from Result 1. There seems to be a clear relation between the UIP regression parameter and the all-important τ_1 parameter that is the focus of attention in the new-Keynesian monetary theory literature. By clarity we mean the following. There is much debate about the empirical relation between consumption and excess returns from currency speculation (see Lustig and Verdehlan (2007a), the associated critique by Burnside (2007), and the response in Lustig and Verdehlan (2007b)). By omitting consumption-based risk completely, when the magnitude of which is perhaps small in any case, we hope to more sharply focus on our topic of interest: monetary policy.

2.2 Asymmetric Taylor Rules

The series of examples outlined in Backus, Foresi, and Telmer (2001) suggest that asymmetries between the foreign and domestic pricing kernels are likely to play a critical role in achieving $b < 0$. Their approach is purely statistical in nature. There are many parameters and few sources of guidance for which asymmetries are plausible and which are not. Our approach offers more guidance. The Taylor rules (9) are a sensible, and arguably observable, source of asymmetry. It seems plausible the Fed policy depends less on Bank of England policy than the converse.

The following result shows that if the domestic Taylor rule is of the form (9), but the foreign Taylor rule depends on the depreciation rate, $\log(S_{t+1}/S_t)$, then $b < 0$ is possible. This has much the flavor of the specification of McCallum (1994).

Result 2:

> Suppose that the domestic Taylor rule is of the form (9). The foreign Taylor rule is of the form
>
> $$i_t^* = \tau^* + \tau_3^* \log(S_t/S_{t-1}) \ . \tag{12}$$
>
> If the real part of the pricing kernel is constant, $n_{t+1} = n$, and the policy shocks are not autocorrelated, $\varphi_z = 0$, then the sign of the UIP regression coefficient depends on the sign of the following term, which

can be negative depending on parameter values:

$$Cov(i_t - i_t^*, q_t) = (a_2 - a_2^*)\varphi_v \left((a_2 - a_2^*)\varphi_v - (a_1^2 - a_1^{*2})/2\right) \frac{\sigma_v^2}{1 - \varphi_v^2} \quad (13)$$

where,

$$a_1^* = \frac{\tau_3^* \tau_2}{(\varphi_z - \tau_1)(\varphi_z + \tau_3^*)} \quad (14)$$

$$a_2^* = \frac{1}{\varphi_v + \tau_3^*} \left(\frac{a_1^{*2}}{2} + \frac{\tau_3^* \tau_2^2}{2(\varphi_z - \tau_1)^2(\varphi_v - \tau_1)} \right) \quad (15)$$

Derivations are provided in Appendix 2.

From Federico's email: In particular, if $a_2 > a_2^*$, we need $(a_2 - a_2^*)\varphi_v < (a_1^2 - a_1^{*2})/2$ and viceversa.

3 Conclusions

Work-in-progress

Appendix 1

The short rate must satisfy both the Euler equation and the Taylor rule:

$$i_t = -\log E_t\, m_{t+1} \tag{16}$$
$$i_t = \tau + \tau_1 \pi_t + \tau_2 z_t \ , \tag{17}$$

where the processes for z_t and its volatility v_t are

$$z_t = \varphi_z z_{t-1} + v_{t-1}^{1/2} \varepsilon_t \tag{18}$$
$$v_t = \theta_v (1-\varphi_v) + \varphi_v v_{t-1} + \sigma_v w_t \tag{19}$$

where ε_t and w_t are *i.i.d.* standard normal. Given that $m_{t+1} = n_{t+1} P_t / P_{t+1}$ and $\pi_{t+1} = \log(P_{t+1}/P_t)$, set the real pricing kernel to a constant and guess that the solution for endogenous inflation is:

$$\pi_t = a + a_1 z_t + a_2 v_t \ , \tag{20}$$

Substitute equation (20) into the pricing kernel and compute the expectation in equation (16):

$$i_t = C + a_1 \varphi_z z_t + (a_2 \varphi_v - a_1^2/2) v_t \ , \tag{21}$$

where

$$C \equiv -n + a + a_2 \theta_v (1-\varphi_v) - (a_2 \sigma_v)^2/2 \tag{22}$$

Match-up the coefficients with the Taylor rule and solve for the a_i parameters:

$$a = \frac{C-\tau}{\tau_1} \tag{23}$$
$$a_1 = \frac{\tau_2}{\varphi_z - \tau_1} \tag{24}$$
$$a_2 = \frac{\tau_2^2}{2(\varphi_z-\tau_1)^2(\varphi_v-\tau_1)} \tag{25}$$

It's useful to note that

$$a_2 = \frac{a_1^2}{2(\varphi_v - \tau_1)}$$

Inflation and the short rate are:

$$\pi_t = \frac{C-\tau}{\tau_1} + \frac{\tau_2}{\varphi_z-\tau_1} z_t + \frac{\tau_2^2}{2(\varphi_z-\tau_1)^2(\varphi_v-\tau_1)} v_t \tag{26}$$
$$i_t = C + \frac{\varphi_z \tau_2}{\varphi_z - \tau_1} z_t + \frac{\tau_1 \tau_2^2}{2(\varphi_z-\tau_1)^2(\varphi_v-\tau_1)} v_t \tag{27}$$
$$= C + \varphi_z a_1 z_t + \tau_1 a_2 v_t \tag{28}$$

The pricing kernel is

$$
\begin{aligned}
-\log m_{t+1} &= C + (\sigma_v a_2)^2/2 + a_1\varphi_z z_t + a_2\varphi_v v_t + a_1 v_t^{1/2}\varepsilon_{t+1} + \sigma_v a_2 w_{t+1} \\
&= D + \frac{\tau_2}{\varphi_z - \tau_1}\varphi_z z_t + \frac{\varphi_v \tau_2^2}{2(\varphi_z - \tau_1)^2(\varphi_v - \tau_1)} v_t \\
&\quad + \frac{\tau_2}{\varphi_z - \tau_1} v_t^{1/2}\varepsilon_{t+1} + \frac{\sigma_v \tau_2^2}{2(\varphi_z - \tau_1)^2(\varphi_v - \tau_1)} w_{t+1}
\end{aligned} \tag{29}
$$

where

$$
D \equiv C + (\sigma_v a_2)^2/2 \tag{30}
$$

The GBP-denominated kernel and variables are denoted with asterisks. The interest-rate differential, the expected depreciation rate, q_t, and the risk premium, p_t, are:

$$
i_t - i_t^* = \varphi_z a_1 z_t - \varphi_z^* a_1^* z_t^* + \tau_1 a_2 v_t - \tau_1^* a_2^* v_t^* \tag{31}
$$

$$
q_t = D - D^* + a_1\varphi_z z_t - a_1^*\varphi_z^* z_t^* + a_2\varphi_v v_t - a_2^*\varphi_v^* v_t^* \tag{32}
$$

$$
p_t = -\frac{1}{2}\left(a_1^2 v_t - a_1^{*2} v_t^* + \sigma_v^2 a_2^2 - \sigma_v^{*2} a_2^{*2}\right) \tag{33}
$$

It is easily verified that $p_t + q_t = i_t - i_t^*$.

If we assume that all foreign and domestic parameter values are the same (*i.e.*, $\tau = \tau^*$) and if we set $\varphi_z = 0$, then the regression parameter is:

$$
\begin{aligned}
b &= \frac{Cov(i_t - i_t^*\,,\, q_t)}{Var(i_t - i_t^*)} \\
&= \frac{\varphi_v}{\tau_1}
\end{aligned}
$$

Appendix 2

Let the foreign Taylor rule be

$$i_t^* = \tau^* + \tau_3^*(\pi_t - \pi_t^*) \quad . \tag{34}$$

Guess that the solution for foreign inflation is:

$$\pi_t^* = a^* + a_1^* z_t + a_2^* v_t \quad , \tag{35}$$

Similarly to Appendix 1, substitute equation (35) into the pricing kernel and compute the expectation in equation (16):

$$i_t^* = C^* + a_1^* \varphi_z z_t + (a_2^* \varphi_v - a_1^{*2}/2) v_t \quad , \tag{36}$$

where

$$C^* \equiv -n^* + a^* + a_2^* \theta_v (1 - \varphi_v) - (a_2^* \sigma_v)^2/2 \tag{37}$$

Match-up the coefficients with the Taylor rule and solve for the a_i^* parameters:

$$a^* = a - \frac{C - \tau^*}{\tau_3^*} \tag{38}$$

$$a_1^* = \frac{\tau_3^* \tau_2}{(\varphi_z - \tau_1)(\varphi_z + \tau_3^*)} \tag{39}$$

$$a_2^* = \frac{1}{\varphi_v + \tau_3^*} \left(\frac{a_1^{*2}}{2} + \frac{\tau_3^* \tau_2^2}{2(\varphi_z - \tau_1)^2 (\varphi_v - \tau_1)} \right) \tag{40}$$

The interest-rate differential, the expected depreciation rate, q_t, and the risk premium, p_t, are:

$$i_t - i_t^* = C - C^* + (a_1 - a_1^*)\varphi_z z_t + \left((a_2 - a_2^*)\varphi_v - (a_1^2 - a_1^{*2})/2 \right) v_t \tag{41}$$

$$q_t = D - D^* + (a_1 - a_1^*)\varphi_z z_t + (a_2 - a_2^*)\varphi_v v_t \tag{42}$$

$$p_t = -\frac{1}{2} \left((a_1^2 - a_1^{*2}) v_t + (a_2^2 - a_2^{*2}) \sigma_v^2 \right) \tag{43}$$

It is easily verified that $p_t + q_t = i_t - i_t^*$.

Moments

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