Title:
FORWARD BIAS, UNCOVERED INTEREST PARITY AND RELATED PUZZLES: THE ROLE OF MONETARY POLICY

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The Forward-Bias Puzzle, failure of uncovered interest parity and related puzzles suggest that there is a fundamental failure in international financial markets. Many theories attempt to explain this bias and failure. But none of them has been widely accepted; at least partly because they are not consistent with the related puzzles. The model of monetary policy in Table 6 explains the Forward-Bias Puzzle and UIP failure without appealing to information failures. It also explains, or is at least consistent with, the related puzzles. Finally it suggests that we need to change the way we think about UIP.

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Key words: exchange rates; interest rates; risk premia; rational expectations; uncovered and covered interest parity; forward bias; speculation; arbitrage.

JEL: E43, E44, F30, F31, G14, G15.
1. Introduction.

Several puzzles are closely related to the forward-bias puzzle and failure of uncovered interest parity (UIP). They include: (1) the Carry Trade Puzzle; (2) the Commodity Puzzle; (3) the Development Puzzle; (4) the Inflation and Outlier Puzzle, (5) the Levels versus Differences Puzzle; (6) the Maturity Puzzle and (7) the Time Dependency Puzzle. Section 2 discusses all these puzzles.

There have been many attempts to explain the forward-bias puzzle and failure of UIP. But none of them are widely accepted; at least partly because they do not explain the related puzzles. The two most widely cited explanations are risk premiums and the failure of rational expectations. For a discussion of these two alternatives see Sarno (2005,678). Less frequently cited alternatives include the following: nonlinearities [Sarno et al (2006)], peso problems and fads [Sercu and Vinaimont (2006)], perpetual learning [Chakraborty and Evans (2008)], adverse selection [Burnside et al (2009)], career risk [Liu and Sercu (2009)], deep habits [Moore and Roche (2010)], infrequent portfolio decisions [Bacchetta and van Wincoop (2010)], carry and momentum trading [Baillie and Chang (2011)], and over confidence [Burnside et al (2011)]. A recent book, Miller (2014), uses an inter-temporal version of UIP with systematic errors in expectations to explain the failure of UIP.

These puzzles suggest that there may be a fundamental failure in international financial markets and they pose a serious challenge to open economy macroeconomics. I suggest a relatively simple explanation for all these puzzles that does not rely on risk premiums, less than Rational Expectations or fundamental failures like "deep habits". The puzzles are the result of routine monetary policies.

I build on the monetary policy explanation for the failure of UIP first suggested by McCallum (1994) and then extended by Chinn and Meredith (2004) to explain the Maturity Puzzle. Other related work includes Anker (1999), Kirkos (2002) and Lafuente and Ruiz (2006).

2. The puzzles.

I begin with the two primary puzzles: the failure of UIP and forward bias.
2.1. Uncovered Interest Parity.

Eq. (1) describes UIP. The expected change in the exchange rate should equal the appropriate interest rate differential.

\[ E(\Delta s_{t+k} | I_t) = i_t \square i^* \] (1)

Where \( s_t \) is the log of the domestic price of foreign exchange, \( E(x_{t+k} | I_t) \) is the conditional expectation of \( x_{t+k} \) based on the information set \( I_t \) available at \( t \) while \( i_t \) and \( i^* \) are risk-free domestic and foreign interest rates with the same maturity as \( s_{t+k} \).

One approach to UIP uses covered interest parity (CIP) and assumes that speculation equates \( E(s_{t+k} | I_t) \) and the log of the appropriate current forward rate denoted \( f_t \). Together they imply eq. (1). Since there is a large body of evidence supporting CIP, when UIP fails, it is natural to question the assumption that \( E(s_{t+k} | I_t) \) equals \( f_t \). That question appears to be the source of the idea that risk premiums cause UIP to fail.

Another approach uses the Fisher equation, an expectations version of purchasing power parity (EPPP) and the assumption that real interest rates are equal. When nominal interest rates equal real rates plus expected rates of inflation, then \( i_t \square i^* \) equals the appropriate difference in expected rates of inflation plus the difference in real interest rates. With the real differential zero, the Fisher equation and EPPP also imply eq. (1). When UIP fails, this approach suggests that it fails because the Fisher equation fails, EPPP fails, or real rates are not equal.

As pointed out in Section 5, both approaches ignore some important implications of CIP and the liquidity effects of the open market operations that produce the inflation that lies at the heart of UIP.

In either case, eq. (2) is the standard test equation where estimates of \( b \) should equal 1.0

\[ \Delta s_{t+k} = a + b(i_t \square i^*) + e_{t+k} \] (2)

But estimates of \( b \) denoted \( ^\wedge \) are often negative. For recent examples see Tables 1 and 4 below, and Aslan and Korap (2010).

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1 This is the approach used in the New Palgrave Dictionary of Economics, Vol. 1 (2008, 451).
If expectations are rational, $e_{t+k}$ has a zero mean, is uncorrelated and is orthogonal to $i_t - i^*$. Since the failure of rational expectations implies that $e_{t+k}$ and $i_t - i^*$ can be correlated, the failure of rational expectations provides another explanation for why $\hat{\beta}$ might not equal 1.0. But that failure does not by itself explain why $\hat{\beta}$ are often negative and significant.

### 2.2. Forward-Bias.

The modern forward-bias puzzle begins with Fama (1984) who splits $f_t$ into $E(s_{t+1}|I_t)$ and a "premium" denoted $p_t$.

$$f_t = E(s_{t+1}|I_t) + p_t$$

(3)

Although subsequent literature almost universally calls $p_t$ a risk premium, Fama (1984) does not. He first mentions $p_t$ in his Abstract.

There is less agreement on whether forward rates contain time varying premiums. Conditional on the hypothesis that the forward market is efficient or rational, this paper finds that both components of forward rates vary through time. Moreover, most of the variation in forward rates is variation in premiums, and the premium and expected future spot rate components of forward rates are negatively correlated.

The term "risk premium" never appears in the Abstract.

On the next page, Fama points out that eq. (3) is "no more than a particular definition of the premium component of the forward rate. To give this equation economic content, a model that describes the determination of $p_t$ is required." Table 6 provides such a model.

Contrary to previous work, from this point on I interpret $p_t$ as the expected return to speculation, not as a risk premium. I have several reasons for doing so: First, eq. (3) in effect defines $p_t$ as $f_t - E(s_{t+1}|I_t)$, which is the expected return to speculation. If $E(s_{t+1}|I_t)$ is greater than $f_t$, a speculator expects to earn $E(s_{t+1}|I_t)$ minus $f_t$ by buying the foreign currency forward and then selling it later for $E(s_{t+1}|I_t)$. If $f_t - E(s_{t+1}|I_t)$ is positive, speculators expect to make a profit by selling the foreign currency forward and covering the sale by buying the currency at the lower $E(s_{t+1}|I_t)$. I discuss speculation in terms of
forward contracts to simplify the exposition. Speculators who do not cover an equivalent CIP position expect to earn $|f_t - E(s_{t+1} | I_t)|$. So the expected speculative return is the same either way.

Second equality is not equivalence. Ignoring transaction costs, equilibrium implies that expected returns equal risk premiums. But equilibrium does not imply that $p_t$ is a risk premium. Equilibrium only implies that the arithmetic value of $p_t$ equals the arithmetic value of the risk premium.

A third reason I interpret $p_t$ as the expected return to speculation is that expected speculative returns provide a better explanation of the forward bias than risk premiums. Consider an initial equilibrium where expected returns to speculation and risk premia are both zero. There is no forward bias, UIP holds and speculators hold no forward contracts. An exogenous increase in the expected speculative return $f_t \cdot E(s_{t+1} | I_t)$ causes UIP to fail and induces speculators to sell the foreign currency forward. That forward position creates a risk premium for risk adverse speculators. That risk premium is the result, not the cause, of the forward bias.

Unless an exogenous increase in risk can somehow create an expected speculative return, it cannot create a forward bias or cause UIP to fail. Starting in the same equilibrium, an exogenous increase in risk or risk aversion would discourage speculators from taking any position. Expected returns remain zero, there is no forward bias and UIP continues to hold. Anyone who claims that risk premiums are the "cause" of forward bias rather than the effect needs to explain how that can be.

A fourth reason I interpret $p_t$ as the expected return to speculation is that expected speculative returns explain the Carry Trade better than risk premiums. Only risk neutral speculators would borrow where rates are low and lend where they are high if risk premiums fully offset the expected profit. For the Carry Trade to be so popular expected profits for at least intra-marginal trades must exceed risk premiums. But how can risk premiums create expected profits greater than themselves?

Whatever the interpretation of $p_t$, eq. (3) implies eq. (4).
\[ f_t \cdot s_t = E(\Delta s_{t+1} | I_t) + p_t \]  \hspace{1cm} (4)

Assuming rational expectations and rearranging eq. (4) produces eq. (5).

\[ \Delta s_{t+1} = (f_t \cdot s_t) \cdot p_t + \varepsilon_{t+1} \]  \hspace{1cm} (5)

Omitting \( p_t \) produces the "Fama equation".

\[ \Delta s_{t+1} = \alpha + \beta(f_t \cdot s_t) + \varepsilon_{t+1} \]  \hspace{1cm} (6)

The Forward-Bias Puzzle is that, over a wide variety of time periods during the current float, \( \hat{\varepsilon} \) for short maturities between developed countries are often negative and significant.

2.3. Carry Trade.

The "carry trade" refers to borrowing where international interest rates are "low" and lending where they are "high", which appears to produce profit with little risk. For some recent articles on the carry trade see Burnside et al (2008), Hochradl and Wagner (2010) and Baillie and Chang (2011). I call this apparent economic profit the Carry Trade Puzzle. As pointed out above, I do not see how risk premiums could produce the carry trade. I also do not see how the carry trade could prosper if expectations were seriously and systematically biased.

2.4. Commodity Puzzle.

One would expect Fama’s premium to be as valid for commodity markets as for foreign-exchange markets. The premium \( f_t \cdot E(s_{t+1} | I_t) \) can refer to the domestic price of wool as well as the domestic price of foreign exchange. Eq. (5) would appear to be as relevant for wool, or any other commodity with forward markets, as it is for foreign-exchange markets.

Given the importance of the bias in foreign-exchange markets, looking for the same puzzle in commodity markets would seem an obvious and important thing to do. To the best of my knowledge there have been only two attempts to do so: Fama and French (1987) and Kearns (2007). Using futures indexes, Kearns finds positive \( \hat{\varepsilon} \) for commodities. Using individual futures prices, Fama and French
find mostly positive ^ for commodities. Frequent negative ^ for flexible exchange rates and mostly positive ^ for commodities is the Commodity Puzzle.

2.5. Development Puzzle.

Apparently Bansal and Dahlquist (2000) were the first to suggest that the forward-bias puzzle is confined largely to developed countries. Later Frankel and Poonawala (2010) estimated eq. (6) between the U.S. and 21 developed countries and 14 developing countries. The average ^ between developed countries and the U.S. is □4.3. The average ^ between developing countries and the U.S. is 0.003. The difference between □4.3 and 0.003 illustrates the Development Puzzle.

2.6. Levels versus Differences Puzzle.

The issue of levels versus differences is one of the oldest puzzles associated with the forward-bias puzzle. Researchers initially regressed \( s_{t+1} \) against \( f_t \) and often found coefficients close to one. Then the issue of spurious regressions arose. To avoid that problem, researchers regressed \( s_{t+1} - s_t \) against \( f_t - s_t \). They found coefficients that were routinely negative and almost never close to one. Those different results are the Levels versus Differences Puzzle.

2.6. Maturity puzzle.

Using developed countries, Alexius (2001), Chinn and Meredith (2004) and Chinn (2006) find that ^ are usually negative for maturities of one year or less but that ^ are usually positive for over one year. More recently Lothian and Wu (2011) find the same pattern using over 200 years of data. Negative ^ for short maturities and positive ^ for long maturities is the conventional Maturity Puzzle.

Miller (2014, 11) suggests changing the maturity puzzle because UIP tends to hold when both long and short maturity changes in exchange rates are regressed against long-maturity interest rate differentials:

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2 Since both articles use interest rate differentials rather than forward premiums for developing countries, their ^ probably should be interpreted as ^.

3 For a survey of the early literature see Levich (1979).

4 The frequency domain tests for short maturity ^ in Table 2 suggest that it is not negative in either the very short or long run.

5 See Miller (2014, 11) for the relevant references.
Now it becomes "why does the UIP puzzle disappear when variations in the spot rate (either high frequency or low frequency) are regressed against a long-term ID. (Italics and bold both in the original.)

2.7. Time Dependency Puzzle.

Both $\hat{\Delta}$ and $\hat{\gamma}$ vary widely over time. For an example of the time dependency of $\hat{\Delta}$, see Baillie (2011). For examples of the time dependency of $\hat{\gamma}$, see Han (2004) and Lothian and Wu (2011). Table 4 below shows that, as implied by CIP, $\hat{\gamma}$ and $\hat{\Delta}$ move together over time. Those time dependent results are the Time Dependency Puzzle.

2.8. Miller's Puzzles.

All the above puzzles were included in drafts of this paper written before Miller (2014) was published. Miller (2014, 3) lists ten puzzling facts and anomalies about foreign exchange markets with the forward bias puzzle and failure of UIP considered one puzzle. Five like delayed overshooting are not directly related to the forward bias puzzle and failure of UIP. I ignore them. His list omits the Carry Trade, Commodity and Levels versus Differences Puzzles. But he includes two puzzles that I omitted: (1) The Inflation Puzzle (He includes the Development Puzzle in this puzzle.): $\hat{\Delta}$ increases with inflation. (2) The Extreme Support Puzzle: Positive (negative) $\hat{\gamma}$ with outlier (non-outlier) interest rate differentials and/or forward premiums.

I treat these two as one puzzle and discuss them later with the Development Puzzle because inflation plays an important role in all three.

3.0. CIP.

Covered interest parity is one of the few theories in open economy macroeconomics for which there is impressive empirical support. Given that empirical support, any explanation for the forward bias or failure of UIP that is not consistent with CIP is suspect. As Section 5 shows, CIP has important implications for the failure of UIP and the forward bias.

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6 See Miller (2014) for the details and relevant references.
Akram et al (2008) probably provide the best available analysis of covered interest parity.\footnote{For additional work on CIP see Fong et al (2010) and the work cited there.}

Overall, the evidence is consistent with the Grossman-Stiglitz view of financial markets where efficiency is not interpreted as a statement about prices being correct at each point in time but the notion that in efficiently-functioning financial markets very short-term arbitrage opportunities can arise and invite traders to exploit them, which makes it worthwhile to watch the relevant markets. This is the arbitrage mechanism that restores the arbitrage-free prices we observe on average. Nevertheless, the lack of predictability of arbitrage and the fast speed at which arbitrage opportunities are exploited and eliminated imply that a typical researcher in international macro-finance using data at the daily or lower frequency can safely assume that CIP holds. Akram et al (2008, 238)

Akram et al make it clear that CIP is not an identity or anything like an identity. Identities hold in every possible state of the world. They describe occasional CIP failures. Indeed, as they point out, the success of the theory depends on those occasional failures.

Akram et al (2008) also say that one can safely assume that CIP holds for daily and lower frequency data. They do not distinguish between developed and developing countries nor between short and long maturities. Since they use maturities of one year or less from developed countries, strictly speaking their conclusions only hold under those conditions. Whether or not arbitrage is as effective in developing markets and for longer maturities remains an issue that needs to be resolved.

Eq. (7) describes the theory of covered interest parity.

\[ f_t \times s_t \times (i_t \times i^*) = d_t \]  \hspace{1cm} (7)

Where forward premiums and interest rate differentials have the same maturity. For good data the deviation \( d \), should reflect primarily transaction costs, particularly bid-ask spreads.

For now I ignore \( d \), and assume that covered interest parity holds exactly because that simplifies the discussion. I return to \( d \) later.

CIP implies that the failure of UIP and the forward bias are two sides of the same coin. With \( d \) zero, eq. (7) implies (8).

\[ f_t = s_t + (i_t \times i^*) \]  \hspace{1cm} (8)

Subtracting the appropriate \( E(s_{t+1}|I_t) \) from both sides of eq. (8) produces eq. (9).
\[ f_t \cdot E(s_{t+1}|I_t) = (i_t \cdot i^*) \cdot [E(s_{t+1}|I_t) \cdot s_t] \]  \hspace{1cm} (9)

CIP implies that the forward bias \( f_t \cdot E(s_{t+1}|I_t) \) equals the deviation from UIP \((i_t \cdot i^*) \cdot [E(s_{t+1}|I_t) \cdot s_t]\).

As long as “informed” participants know that CIP holds and their expectations are logically consistent, CIP imposes restrictions on UIP. It would be logically inconsistent to know that CIP holds and at the same time ignore that fact when forming expectations about the future.

Eq. (8) implies eq. (10).

\[ s_t = f_t \cdot (i_t \cdot i^*) \]  \hspace{1cm} (10)

With informed and consistent expectations, eq. (10) implies eq. (11).

\[ E(s_{t+1}|I_t) = E(f_{t+1}|I_t) \cdot E[(i_{t+1} \cdot i^*_{t+1})|I_t] \]  \hspace{1cm} (11)

Eq. (11) minus eq. (10) produces eq. (12), which implies eq. (13).

\[ E(s_{t+1}|I_t) \cdot s_t = [E(f_{t+1}|I_t) \cdot f_t] \cdot \{E[(i_{t+1} \cdot i^*_{t+1})|I_t] \cdot (i_t \cdot i^*)\} \]  \hspace{1cm} (12)

\[ [E(s_{t+1}|I_t) \cdot s_t] \cdot (i_t \cdot i^*) = [E(f_{t+1}|I_t) \cdot f_t] \cdot E[(i_{t+1} \cdot i^*_{t+1})|I_t] \]  \hspace{1cm} (13)

When CIP holds, UIP holds if and only if the expected change in the forward rate equals the expected interest rate differential. Any explanation of the failure of UIP that assumes informed and consistent expectations and does not meet that condition is inconsistent with CIP.

4.0. Some New Evidence.

This section reconfirms and extends some of the relevant evidence concerning \( \wedge \) and \( \wedge \).

4.1. Data.

My data cover four intervals: (1) weekly data from the Federal Reserve Bulletin for the 1960s between the U.S. and Canada when rates were pegged, (2) similar weekly data for the early 1970s when rates were flexible, (3) daily data from Balke and Wohar (1998) for 1977 to 1993 between the
U.S. and U.K. when rates were flexible and (4) weekly data from Einzig (1937) for the early 1920s between the U.S. and U.K. when rates were flexible.\(^8\)

Quality differs. The best are from Balke and Wohar (1998). The Einzig data are not quite as good. On page 1253 the *Federal Reserve Bulletin* for October 1964 warns that "...the interest arbitrage incentives shown in these tables provide only an approximate indication of the covered differentials in treasury bill yields in the specified markets."

4.2. Forward Bias and UIP.

All ( and ( in Table 1 use RATS with Robusterrors. Durbin-Watson statistics are low due to multi-period overlapping horizons. All ( are negative and two are significant at 1%. All but one ( is negative with one significant at 5% and two at 1%.

| Table 1 |
|----------|
| Forward bias and UIP |
| \(s_{t+1} = a + b(i_t - i^*) + e_{t+1}\) | \(s_{t+1} = \alpha + \beta(f_t - s_t) + \epsilon_{t+1}\) |
| U.S.-U.K.: 1922-1925 (Flexible) | U.S.-U.K.: 1922-1925 (Flexible) |
| ( ) | ( ) |
| \(-2/\text{DW}\) | \(-2/\text{DW}\) |
| 2.18** | 1.80** |
| (0.20) | (0.25) |
| U.S.-U.K.: 1977-1993 (Flexible) | |
| ( ) | ( ) |
| \(-2/\text{DW}\) | \(-2/\text{DW}\) |
| 0.61** | 0.59** |
| (0.06) | (0.06) |
| U.S.-U.K.: 1977-1993 (Flexible) | U.S.-U.K.: 1977-1993 (Flexible) |
| ( ) | ( ) |
| \(-2/\text{DW}\) | \(-2/\text{DW}\) |
| 0.26** | 0.25** |
| (0.04) | (0.05) |
| U.S.-U.K.: 1922-1925 (Flexible) | U.S.-U.K.: 1922-1925 (Flexible) |
| ( ) | ( ) |
| \(-2/\text{DW}\) | \(-2/\text{DW}\) |
| 0.274 | 0.74 |
| (0.60) | (0.74) |

Standard errors in parentheses. * Significant at 5%. ** Significant at 1%.

Estimates of ( and ( are 'static'. Cross spectra from \(i_t i^*\) to \(\Delta s_{t+1}\) show the dynamic interaction between \(i_t i^*\) and \(\Delta s_{t+1}\). Table 2 shows that cross spectrum using the Balke-Wohar data.\(^9\)

| Table 2 |
|----------|
| Cross Spectrum: Interest Rate Differential to Future Change in Spot Rate: U.S.-U.K. 1977-1993 |
| Cycles/Month | Coherency Squared | Gain | Phase | Cycles/Month | Coherency Squared | Gain | Phase |
| 0 | 0.1069 | 1.52828 | 0.5584 | 0.263 | 0.1244 | 16.1140 | 0.5809 |
| 0.026 | 0.1586 | 2.0745 | 0.5806 | 0.289 | 0.1579 | 19.3720 | 0.5414 |

\(^8\) In Einzig (1937) and the *Bulletin* rates are three month. For information on Canadian data see the *Federal Reserve Bulletin* for October 1964. In Balke and Wohar (1998) rates are one month. See Balke and Wohar for more information. All data are available on request.

\(^9\) I convert their daily data into 'monthly' data using a month of 22 business days.
A negative ^ corresponds to a phase angle of 0.5. For cycles less than one year (0.08
cycles/month) and greater than 19 months (0.053 cycles/month) coherence squared and gain are both
insignificant. Phase angles are also not significantly different from zero (1.0). Between one year and
19 months both coherence squared and gain are significant and the phase angle is significantly
different from zero, but not significantly different from 0.5, which is consistent with a negative ^.

Table 2 suggests that negative ^ disappear in both the long run and short run.

### Table 3
Levels

|                | s_{t+1} = a + Bf_t + e_{t+1} |
|----------------|-----------------------------|
|               |                            | -r/DW | ( )  | ( )  | -r/DW |
| U.S.-U.K.: 1922-1925 (Flexible) | U.S.-Canada: 1970-1973 (Flexible) |        |      |      |      |
| 2.55**         | 0.58**                      | 0.293  | 2.18** | 0.70** | 0.794 |
| (0.30)         | (0.05)                      | (0.30) | (0.04) | (0.30) | (0.04) |
| U.S.-Canada: 1961-1969 (Pegged) | U.S.-U.K.: 1977-1993 (Flexible) |        |      |      |      |
| 2.18**         | 0.70**                      | 0.794  | -1.47** | 0.98** | 0.952 |
| (0.30)         | (0.04)                      | (0.23) | (0.00) | (0.23) | (0.00) |

Standard errors in parentheses. * Significant at 5%. ** Significant at 1%.

4.3. Levels versus differences.

Table 1 shows the results when using differences. Table 3 reports the results of regressing s_{t+1}
against f_t. All ( are significantly greater than zero. For the best data, ( is close to one.

4.4. Time Dependency.

Table 4 uses daily Balke-Wohar data to illustrate the time dependency of ( and ( over the same
intervals. I believe that this is the first time that has been done. The first interval uses the first 1,000
observations to obtain (1 and (1. The second interval uses observations 101 to 1,100 to obtain (2 and (2.
The third interval uses observation 201 to 1,200 to obtain \( \ell_3 \) and \( \ell_3 \) and so on. As implied by CIP and low transaction costs, \( \ell \) and \( \ell \) move together over time.

### Table 4
Time Dependency of \( \ell \) and \( \ell \)

| Int. | \( \ell \) | \( \ell \) | Int. | \( \ell \) | \( \ell \) | Int. | \( \ell \) | \( \ell \) | Int. | \( \ell \) | \( \ell \) |
|------|--------|--------|------|--------|--------|------|--------|--------|------|--------|--------|
| 1    | 0.64   | 0.65   | 10   | -2.60  | -2.67  | 19   | -7.89  | -8.48  | 27   | -5.30  | -5.87  |
| 2    | -1.20  | -1.25  | 11   | -2.51  | -2.57  | 20   | -8.93  | -9.75  | 28   | -3.39  | -3.25  |
| 3    | -3.47  | -3.62  | 12   | -2.90  | -3.02  | 21   | -11.00 | -12.40 | 29   | -2.59  | -2.42  |
| 4    | -3.47  | -3.62  | 13   | -5.30  | -5.32  | 22   | -10.48 | -12.35 | 30   | -4.73  | -4.73  |
| 5    | -3.20  | -3.33  | 14   | -7.60  | -8.02  | 23   | -5.99  | -10.36 | 31   | -3.86  | -3.55  |
| 6    | -3.08  | -3.20  | 15   | -7.80  | -8.19  | 23   | -5.00  | -7.60  | 32   | -4.99  | -4.83  |
| 7    | -2.76  | -2.85  | 16   | -8.01  | -8.49  | 24   | -4.87  | -6.47  | 33   | -6.49  | -4.71  |
| 8    | -2.57  | -2.65  | 17   | -7.00  | -7.49  | 25   | -4.19  | -4.71  | 34   | -6.49  | -4.71  |
| 9    | -2.41  | -2.50  | 18   | -7.60  | -8.13  | 26   | -7.89  | -8.48  |

4.5. Transaction costs.

With the exception of Balke and Wohar (1998) and Paya et al (2010), most of the relevant empirical literature ignores the effects of transaction costs.

Using U.S.-U.K. data for the early 1920s from Einzig (1937) and the non-linear model described by eq. (14), Paya et al (2010) find that deviations from CIP bias \( \ell \) toward zero.

\[
s_{t+1} = A + B(f_t - s_t)e^{k|d_t|} + e_{t+1}
\]  

(14)

They summarize their results as follows:

We examined data for the interwar period for the dollar-sterling exchange rate and found that the degree of bias in the standard Fama regression varies significantly with the deviation from covered interest parity. When deviations are large, the degree of bias is much smaller than implied by the standard Fama regression. Paya et al (2010, 57)

I replicate their results in Table 5 using my data and eqs. (15) and (16) \(^{10}\)

\[
\Delta s_{t+1} = a_1 + b_1(i_t \Box i^*)e^{k|d_t|} + v_{t+1}
\]  

(15)

\[
\Delta s_{t+1} = \alpha_1 + \beta_1(f_t \Box s_t)e^{k|d_t|} + v_{t+1}
\]  

(16)

Where \( |d_t| \) is the absolute value of \( d_t \) rather than \( d_t \), squared as in Paya et al (2010).  

### Table 5
Effects of Transaction Costs

\(^{10}\) They use the forward premium from Einzig to calculate deviations from CIP. I use the same premia and Einzig’s spot rates to retrieve forward rates.
\[ \Delta s_{t+1} = a_1 + b_1(i_t - i^*) e^{k_1(d_t)} + v_{t+1} \]

\[ \Delta s_{t+1} = \alpha + \beta(i_t - s_t) e^{k_2(d_t)} + \nu_{t+1} \]

|                  | \( \Delta s_{t+1} \) | \( \Delta s_{t+1} \) |
|------------------|-----------------------|-----------------------|
|                  | \( (i_t - i^*) e^{k_1(d_t)} \) | \( (i_t - s_t) e^{k_2(d_t)} \) |
| U.S.-U.K.: 1922-1925 (Flexible) | 2.16** (-9.07)** | 1.928** 6.68** |
|                  | (0.20) (1.38)        | (0.236) (2.04)        |
| U.S.-Canada: 1961-1969 (Pegged) | 0.26** (-2.24)** | 0.28** 10.70** |
|                  | (0.04) (0.81)        | (0.05) (5.30)         |
| U.S.-Canada: 1970-1973 (Flexible) | -0.23 0.67        | 0.19 0.19 |
|                  | (0.12) (1.26)        | (0.10) (13.41)        |
| U.S.-U.K.: 1977-1993 (Flexible) | 0.68** (-3.68)** | 0.68** 15.83** |
|                  | (0.06) (0.36)        | (0.06) (4.56)         |

Standard errors in parentheses. * Significant at 5%. ** Significant at 1%.

Five of the eight \( \Delta s_{t+1} \) in Table 5 are negative and significant. The one positive \( \Delta s_{t+1} \) is insignificant. \( \Delta s_{t+1} \) represent what \( \Delta s_{t+1} \) would be if \( d_t \) were zero. Three of the four \( \Delta s_{t+1} \) in Table 1 are closer to zero than corresponding \( \Delta s_{t+1} \). \( \Delta s_{t+1} \) represent what \( \Delta s_{t+1} \) would be if \( d_t \) were zero. All \( \Delta s_{t+1} \) in Table 1 are closer to zero than corresponding \( \Delta s_{t+1} \). Deviations from CIP appear to bias \( \Delta s_{t+1} \) and \( \Delta s_{t+1} \) toward zero. For the Balke-Wohar data, \( d_t \) represent primarily transaction costs. For that data, \( \Delta s_{t+1} \) and \( \Delta s_{t+1} \) are both significant at 1%.

5. Monetary Policy.

McCallum (1994, 123) was the first to suggest that monetary policy explains the forward bias and failure of UIP. He uses a simple model to show how a combination of stabilizing interest rates and leaning against the wind produces negative \( \Delta s_{t+1} \). Chinn and Meredith (2004, 420-23) follow up on McCallum’s work with a "richer" model that explains the Maturity Puzzle. Other work suggesting that monetary policy is relevant includes Anker (1999), Kirkos (2002) and Lafuente and Ruiz (2006) while Mark and Moh (2007) show that intervention intensifies the forward premium.

A substantial empirical literature uses vector auto-regression to analyze how monetary shocks affect UIP. It includes Eichenbaum and Evans (1995), Grilli and Roubini (1996), Cushman and Zha (1997), Kim and Roubini (2000), Faust and Rogers (2003), Scholl and Uhlig (2008), Bjørnland (2009),
Bouakez and Normandin (2010) and Heinlein and Krolzig (2012). Most find that monetary shocks create at least temporary deviations from UIP.

The model in Table 6 extends earlier theoretical work on the effects of monetary policy in several ways: (1) It shows, I believe for the first time, how conventional open market operations produce forward bias and cause UIP to fail. (2) Unlike earlier work, it does not assume that UIP holds. (3) For the first time it shows how CIP affects forward bias and the failure of UIP. (4) For the first time it points out the importance of monetary regimes and liquidity effects. (5) For the first time it takes into account how central banks intervene in foreign exchange markets and the effects of sterilization. (6) For the first time it explains how monetary policy creates the expectations associated with forward bias and the failure of UIP. (7) For the first time it provides an explanation that, unlike almost all alternative explanations, explains, or is at least consistent with, all the related puzzles discussed in Section 3 and (8) It suggests that we need to reconsider the theory behind UIP.

5.1. The Model.

Like any useful theory, the model in Table 6 is not realistic. It is a caricature designed to show how monetary policy affects ( and ^ when expectations are rational.

Table 6
A Simple Model of the Effects of Monetary Policy

| Expression | Description |
|------------|-------------|
| ft st = i t i* = (t | Covered interest parity. (I) |
| st = (λ1)(t + (t ZX st | Spot rate assuming CIP, PPP and intervention. (II) |
| ft = λ(t + (t ZX st | Forward rate assuming CIP, PPP and intervention. (III) |
| et = B(t + Du t FX st + vt | Monetary policy. (IV) |
| t = E((t+1|Ce) + (t λ e HX st | Interest rate differential. (V) |
| E((t+1|Ce) = C(B(t + Du t FX st + vt) | Expected inflation. (VI) |
| Δ(t+1 = C(B(t + Du t FX st + vt + xt+1 | Actual inflation. (VII) |

Definitions:
| t | Price level differential. |
| t | Real interest rate differential. |
| t | Nominal interest rate differential used to estimate (t. |
Actual rate of unemployment minus natural rate.

Shocks:
\[ v_t = Vv_{t-1} + \nu_t \quad 0 \leq V < 1 \]
\[ u_t = Uu_{t-1} + w_t \quad 0 \leq U < 1 \]
\[ r_t = Rr_{t-1} + y_t \quad 0 \leq R < 1 \]

\( C, B, D, \Lambda, \alpha \) and \( h \) are all \( \geq 0 \). Random variables \( w_t, x_t, y_t, \) and \( \nu_t \) have zero means, are uncorrelated and orthogonal. \( 1 \leq F \leq 0, Z = \alpha(1+F)X \) and \( H = h(1-F) \).

I do not assume rational expectations because I believe that individuals have Rational Expectations. I do not! I do so for three reasons: First, so far there is no theory of expectations that explains the behavior of exchange rates better than Rational Expectations. Second, Rational Expectations simplify the math. Third, while less than rational expectations may be able to explain negative \( ( \) and \( ^{^\wedge} \), see for example Miller (2014), my objective is to show how monetary policy affects \( ( \) and \( ^{^\wedge} \) without appealing to less than Rational Expectations. Whether less than rational expectations and monetary policy are complimentary or competing explanations for negative \( ( \) is an empirical issue beyond the objectives of this paper.

Purely for purposes of exposition, I interpret the U.S. as the home country and the exchange rate as the dollar price of sterling. Although foreign central banks do almost all the intervention, to simplify the exposition I assume that the Fed intervenes in the market for U.S. dollars.

Like McCallum (1994) and Chinn and Meredith (2004), for simplicity I assume that there is just one short-term interest rate in each country when there should be at least two: one associated with monetary policy, e.g., the Fed funds rate, and the other used to estimate \( ( \), e.g., one month Euro rates. "Liquidity effects" are crucial for how monetary policies affect \( ( \). Liquidity effects dominate when reducing the Fed funds rate reduces the interest rate differential \( ( \), used to estimate \( ( \).

Eq. (I) describes CIP. Like the rest of the model it ignores transaction costs. Equations (II) and (III) describe the foreign exchange markets. They are implications of CIP. When CIP holds, subtracting the equation that describes the spot rate from the one that describes the forward rate must produce CIP. Eqs (II) and (III) assume nothing about the link between exchange rates and \( ( \). Since
spot markets are much larger than individual forward markets, there is a strong presumption that \( \lambda \) is closer to one than to zero.

Central banks often intervene directly in spot exchange markets. \( ZX\Delta s_t \) in eqs. (II) and (III) captures the most common form of intervention, leaning against the wind. Neely (2001, 4-6) reports that almost 90% percent of central banks sometimes or always lean against the wind and that 40% fully sterilize while only 30% never sterilize.

McCallum (1994) and Chinn and Meredith (2004) both ignore intervention and sterilization. Table 6 incorporates intervention and sterilization. \( X \) describes the response to a given \( \Delta s_t \). The Fed leans against the wind by selling sterling (buying dollars) as its price rises. \( Z \) describes how that intervention affects \( s_t \). A positive \( Z \) implies that a positive \( \Delta s_t \) tends to produce a positive \( \Delta s_{t+1} \).

Both \( Z \) and the resulting change in the monetary base depend on sterilization. The Fed sterilizes by selling (buying) assets like U.S. T bills as it buys (sells) sterling. With complete sterilization, intervention does not affect the monetary base and \( F \) in eq. (IV) is zero. With no sterilization, \( F \) is one and each dollar's worth of sterling that the Fed sells reduces the monetary base by one dollar. There is a general consensus that sterilization reduces \( Z \). There is a less general consensus that \( Z \) is positive even when sterilization is complete.\(^{11}\) Table 6 assumes that \( Z \) is positive even when \( F \) is zero.

Selling (buying) sterling as exchange rates rise reduces (increases) the Fed's holdings of sterling deposits at the Bank of England. To restore those deposits to their desired level, the Fed sells (buys) U.K. assets like T bills.

\( \epsilon_t \) describes the relative price levels and captures purchasing power parity. There are several versions of purchasing power parity, but the most common is based on arbitrage and the law of one price (LOP).\(^{12}\) If one takes the role of arbitrage and the LOP seriously, then the prices in \( \epsilon_t \) should not

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\(^{11}\) Phillips and Pippenger (1993) find evidence of a temporary effect for sterilized intervention. Although she attributes it to a signaling effect, in her early review of the literature Edison (1993, 54) refers to a temporary effect. In their review of the later literature, Beine et al (2003, 892) also mention a temporary effect. More recently Fatum (2008) finds evidence of a temporary effect. Pippenger and Phillips (1973) probably provide the best estimate of \( Z \) because they are able to avoid simultaneity by assuming that, in the absence of intervention, the exchange rate is a random walk; an assumption that Pippenger (2008a) supports.

\(^{12}\) See Rogoff (1996).
be retail because arbitrage is not possible at the retail level. If one grocery store sells seedless red grapes at $0.99 per pound and a store across the street sells them for $2.00 a pound, an arbitrager cannot buy them at $0.99 and sell them for $2.00. Arbitrage also is not possible in most wholesale markets. Brand names and marketing contracts usually prevent arbitrage. But there are exceptions like wholesale markets for fresh fish and fresh flowers. It is possible to buy live lobsters at the wholesale market in Boston on Monday and simultaneously contract to sell them in LA later that week. But that is not true for frozen lobster where there are brand names and no similar wholesale markets.

I call the version of purchasing power parity that takes arbitrage and the law of one price seriously the arbitrage version of purchasing power parity or APPP. In APPP all prices are from markets where true arbitrage is possible. Although the number of commodity markets where arbitrage is possible is small relative to the number of retail or wholesale markets, the absolute number is still large. It includes a wide range of petroleum products, metals and agricultural products. Of course, if you prefer to interpret (t) as describing conventional PPP, you can do so.

If both central banks target their price level, they stabilize (t), and the exchange rate. If either central bank targets inflation, (t) has a unit root because at least one central bank allows changes in the price level to accumulate. Since Taylor rules target inflation, they would imply that (t) has a unit root.

Eq. (IV) describes monetary policy. A positive B implies interest stabilization. The Fed buys (sells) short-term assets when (t) is positive (negative), which reduces the variance of the interest rate differential denoted σ. A positive D implies macro-stabilization. The Fed lowers the Fed funds rate (buys short-term assets) when unemployment is above the natural rate and raises the Fed funds rate (sells short-term assets) when unemployment is below the natural rate. A positive X implies intervention. With full sterilization, intervention does not affect the monetary base; otherwise selling (buying) sterling reduces (increases) the monetary base.

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13 For evidence that arbitrage is effective in such markets see Pippenger and Phillips (2008) and Pippenger (2008b).
Eq. (V) describes the nominal interest rate differential used to obtain $\hat{\iota}$. As long as $B$, $D$ and $X$ are all zero, $\iota$ equals the difference in expected inflation plus the real differential. $C$ describes the inflationary effects of open market operations. $\Lambda$ describes the liquidity effects. When $C \square \Lambda$ is negative, liquidity effects dominate and lowering the Fed funds rate lowers $\iota$.

Liquidity effects decline and inflationary effects increase as maturity increases. Lowering the Fed funds rate normally reduces other U.S. short-term interest rates, but the effect on say 5 year rates is much smaller and can be positive. In stable monetary regimes, liquidity effects dominate in the short run. In unstable regimes with high and variable rates of inflation liquidity effects tend to disappear and $C \square \Lambda$ can become positive. There is also a time dimension. Liquidity effects disappear over time as banks, households and firms adjust their portfolios and commodity prices change.

Eq. (VI) describes actual future inflation denoted $\Delta(t+1)$. It depends on changes in the monetary base and $x_{t+1}$, which is white noise because expectations are rational. How strongly $\Delta(t+1)$ responds to changes in the monetary base depends on the inflationary effects of open market operations $C$.

$C$ depends on the time horizon and monetary regime. The shorter the time horizon the smaller is $C$. A substantial increase in the monetary base today would not cause much of a price increase tomorrow, but it would within a couple of years. In a highly stable monetary regime like most of post WWII Germany $C$ is relatively small. In an inflationary regime like Germany in the early 1920s $C$ would be relatively large. In other words $C$ tends to be relatively large when $\Lambda$ is relatively small and the reverse. For now the implicit assumption is that the monetary regime is stable.

Eq. (VII) describes expected inflation. Expected inflation equals actual inflation without $x_{t+1}$, as required by the simplifying assumption of Rational Expectations.

5.2. Effects.

$(C \square \Lambda)$ plays a crucial role in how monetary policy affects $\hat{\iota}$. There is a strong presumption that in stable monetary regimes it is negative for short maturities. In other words, for short maturities an
expansionary monetary policy, e.g., reducing the Fed funds rate, reduces other short-term interest rates. There is also a strong presumption that \((C\Lambda)\) increases with the maturity of \(\tau\), and that it is larger, and even positive for short maturities in unstable regimes.

The Appendix shows the solution for \(^\wedge\) implied by the model in Table 6. It is complex. Most of that complexity is the result of two things that, to the best of my knowledge, most other attempts to explain the forward bias and/or failure of UIP ignore: (1) covered interest parity and (2) the possibility that the “shocks” to the model might not be white noise. For example both McCallum (1994) and Chinn and Meredith (2004) ignore the implications of CIP and both assume that the shocks to their model are white noise. To remove some of the complexity, and hopefully reveal more of the economics, when analyzing how monetary policy affects \(^\wedge\) I first ignore the implications of CIP and assume that all shocks are white noise.

5.2.1. \(B, D\) and \(X = 0\): \(B, D\) and \(X\) all zero does not mean the absence of monetary policy. Monetary policy in the form of \(v_t\) still drives the inflation differential. Eq. (17) describes the deviations from UIP when \(B, D\) and \(X\) are all zero.

\[
E(\Delta s_{t+1}|I_t) = f_t + \Lambda v_t + E(x_{t+1}|I_t) + (\lambda_1)E(\Delta v_{t+1}|I_t) + (\lambda_1)(C\Lambda)E(\Delta v_{t+1}|I_t)
\]

(17)

Structured errors do not affect the deviations from UIP but CIP does.

The right-hand side of eq.(17), and similar equations below, provide the economic content required for Fama's \(p_t\). Using CIP to replace \(\tau\) with \(f_t\), \(s_t\) implies that the left-hand side of eq. (17) equals \(E(s_{t+1}|I_t) \neq f_t\).

The standard interpretations of UIP in Section 2.1 are incomplete. They ignore some implications of CIP and the liquidity effects produced by the open market operations behind the inflation differential. If we ignore those effects \([\Lambda=\lambda=0]\) and assume that \(\tau\) is zero as in Section 2.1, then eq. (17) implies that UIP holds because \(E(x_{t+1}|I_t)\) is zero.
To highlight the role of monetary policy eq. (18) describes \( \hat{\omega} \) when \( D, B \) and \( X \) are all zero, random terms are white noise and \( (\lambda \square 1) \) is zero.

\[
\hat{\omega} = C(C \square \Lambda)\sigma^2/[\sigma + (C \square \Lambda)^2\sigma^2] \quad (18)
\]

Liquidity effects determine the sign of \( \hat{\omega} \). If \( (C \square \Lambda) \) is positive, then \( \hat{\omega} \) is positive. If \( \Lambda \) is zero, which would be the case at long maturities, then \( \hat{\omega} \) goes to 1.0 as \( \sigma \) goes to zero. If \( (C \square \Lambda) \) is negative, then \( \hat{\omega} \) is negative.

Contrary to the impression left by the conventional discussion of UIP in Section 2.1, eq. (18) suggests that, as long as \( \ell \) is short term and the monetary regime is stable, \( \hat{\omega} \) is unlikely to equal one but likely to be negative.

To see the economics, start in a steady state with \( \Delta s_{t-1} \) and \( \ell_{t-1} \) zero. With a stable monetary regime liquidity effects dominate. The open market operation associated with a positive \( \nu_t \) creates a negative \( \ell_t \). As long as \( C \) is not zero, that open market operation also produces a positive \( \Delta s_{t+1} \).

Eq. (19) describes \( \hat{\omega} \) when \( (\lambda \square 1), R, U \) and \( V \) are not zero. Structured error terms do not affect \( \hat{\omega} \) unless CIP holds.

\[
\hat{\omega} = [C(C \square \Lambda)\sigma^2 + (\lambda \square 1)(R \square 1)\sigma + (\lambda \square 1)(C \square \Lambda)^2(V \square 1)\sigma^2]/[\sigma + (C \square \Lambda)^2\sigma^2] \quad (19)
\]

Regardless of the sign of \( (C \square \Lambda) \), CIP increases \( \hat{\omega} \) because all the terms in eq. (19) that contain \( (\lambda \square 1) \) are in the numerator and are positive. CIP can cause \( \hat{\omega} \) to be positive even when \( (C \square \Lambda) \) is negative. But \( \hat{\omega} \) is negative as long as \( \sigma \) is zero, \( (C \square \Lambda) \) is negative and \( C \) is greater than \( |(\lambda \square 1)(C \square \Lambda)(V \square 1)| \).

5.2.2. \( B > 0 \): Eq. (20) describes the UIP differential when just \( B \) is positive.

\[
E(\Delta s_{t+1}|I_t) = \Theta(CB \square 1)\ell_t + \Theta(\lambda \square 1)E(\Delta \ell_{t+1}|I_t) + [(C \square \Lambda)\Theta(CB \square 1) + C]\nu_t \\
+ (\lambda \square 1)(C \square \Lambda)\Theta E(\Delta \nu_{t+1}|I_t) + E(\Delta x_{t+1}|I_t) 
\]

Where \( \Theta \) equals \( 1/[1+B(\lambda \square C)] \). Stabilizing interest rates affects every term in eq. (20) except \( E(\Delta x_{t+1}|I_t) \).
To highlight the role of monetary policy, eq. (21) shows how just stabilizing interest rates affects $^\wedge$ when errors are white noise and $(\lambda[1])$ is zero.

$$^\wedge = \{CB\sigma + C(C\Lambda)^2\sigma^2 \}/\{\sigma + (C\Lambda)^2\sigma^2 \} \tag{21}$$

Stabilizing interest rates increases $^\wedge$. When $B$ is zero, eq. (20) collapses to eq. (18). Whether $^\wedge$ is positive or negative without interest rate stabilization, stabilizing interest rates increases $^\wedge$.

The economics are straightforward. When the Fed stabilizes interest rates a positive $i_t$ produces a positive $s_{t+1}$. Starting in the same steady state as before, regardless of the liquidity effect, a positive $i_t$ increases $i_t$. The Fed responds with an expansionary open market operation. As long as $C$ is not zero, that open market operation produces a positive $s_{t+1}$. As a result, $i_t$ and $s_{t+1}$ are both positive.

Eq. (22) shows the solution for $^\wedge$ when errors are structured and $(\lambda[1])$ is not zero. Structured errors do not affect $^\wedge$ unless CIP holds.

$$^\wedge = \{CB\sigma + C(C\Lambda)^2\sigma^2 + (\lambda[1])(R^1)i + (\lambda[1])(C\Lambda)^2(V^1)i + (\lambda[1])(C\Lambda)^2\sigma^2 \}/\{\sigma + [(C\Lambda)^2\sigma^2 \} \tag{22}$$

Whether or not $(C\Lambda)$ is negative, CIP increases $^\wedge$ because all the terms with $(\lambda[1])$ in them are positive and in the numerator.

5.2.3. Macro stabilization. Eq. (23) describes the deviations from UIP when just $D$ is positive.

$$E(\Delta s_{t+1}|I_t) = i_t + \Lambda(Du_{t+1} + v_t) + E(x_{t+1}|I_t) + (\lambda[1])E(\Delta x_{t+1}|I_t) + (\lambda[1])(C\Lambda)DE(\Delta u_{t+1}|I_t)Du_{t+1}$$

$$+ (\lambda[1])(C\Lambda)E(\Delta v_{t+1}|I_t) \tag{23}$$

Macro stabilization affects deviations in essentially the same way as ordinary open market operations.

To highlight the role of monetary policy eq. (24) describes $^\wedge$ when just $D$ is positive, errors are white noise and $(\lambda[1])$ is zero.

$$^\wedge = \{C(C\Lambda)(D^2\sigma^2 + \sigma^2) \}/\{\sigma + (C\Lambda)^2(D^2\sigma^2 + \sigma^2) \} \tag{24}$$

Macro stabilization affects $^\wedge$ in essentially the same way as ordinary open market operations. If $(C\Lambda)$ is positive, $^\wedge$ is positive. If $(C\Lambda)$ is negative, $^\wedge$ is negative. If $\sigma$ and $\Lambda$ are both zero, then $^\wedge$ is 1.0. The economics also are the same as for ordinary open market operations.

Eq. (25) shows the solution for $^\wedge$ when errors are structured and $(\lambda[1])$ is not zero.
\[
\hat{\lambda} = \{ C(C\Lambda)(D^2\sigma^2 + \sigma^2) + (\lambda \cdot 1)(R \cdot 1)\sigma + (\lambda \cdot 1)(U \cdot 1)(C\Lambda)^2D^2\sigma^2 + (V \cdot 1)\sigma^2 \} \\
/ \{ \sigma + (C\Lambda)^2D^2\sigma^2 + (C\Lambda)^2\sigma^2 \}
\] (25)

As before, CIP increases \(\hat{\lambda}\) because all the terms containing \((\lambda \cdot 1)\) are positive and in just the numerator. Structured errors reduce that effect by reducing terms with \((\lambda \cdot 1)\).

5.2.4. Exchange rate stabilization. Eq. (26) describes the deviations from UIP when the Fed just leans against the wind.

\[
E(\Delta s_{t+1})\Pi[I_t] = [\lambda \cdot 1] \Pi[\Phi E(\Delta v_{t+1} | I_t) \cdot \Omega \Phi x_{t+1}] + \Pi (\lambda \cdot 1)(C\Lambda) \cdot \Omega \Phi x_{t+1}]
\]

(26)

Where \(\Omega\) equals \([(\Lambda - C)F - H]X\), \(\Phi\) equals \([(Z - CF)X]/[1 + ZX]\) and \(\Pi\) equals \(1/(1 + ZX)\).

Leaning against the wind almost guarantees that UIP will fail. It is highly unlikely that the right-hand side of eq. (23), and the expected speculative return \(p_t\), would be zero.

To highlight the role of monetary policy, eq. (27) describes \(\hat{\lambda}\) when the Fed just leans against the wind, error terms are white noise and \((\lambda \cdot 1)\) is zero.

\[
\hat{\lambda} = \{ [C(C\Lambda)(1 + ZX) + \Omega C^2 \Phi]/(1 - \Phi^2) \} \sigma^2 + \Omega \{ \Phi/(1 - \Phi^2) \} \sigma^2 \}
\]

\[
/ \{ \sigma(1 + ZX)^2 + [(C\Lambda)(1 + ZX)]^2 + (\Omega C)^2 \{ 1/(1 - \Phi^2) \} \} \sigma^2 + \Omega^2 \{ 1/(1 - \Phi^2) \} \sigma^2 \}
\] (27)

Leaning against the wind increases liquidity effects by increasing the absolute value of \(C(C\Lambda)\). But it also contributes to negative \(\hat{\lambda}\) on its own. Complete sterilization implies that \(\Omega\) is negative and that \(\Phi\) is positive and less than one, which implies that \(\Omega C^2 \Phi/(1 - \Phi^2) \sigma^2\) and \(\Omega \{ \Phi/(1 - \Phi^2) \} \sigma^2\) are both negative.

To see the economics, this time start with equilibrium in \(t-2\). Then a positive \(v_{t-1}\) produces a positive \(\Delta s_{t}\), to which the Fed responds by selling sterling. With complete sterilization, the Fed buys the same amount of domestic short-term assets. To restore its sterling deposits at the Bank of England, the Fed sells short-term sterling assets. Both transactions tend to slightly reduce \(\lambda_{t-1}^{14}\).

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\(^{14}\) If there is no sterilization and \(\Lambda > C\), selling sterling increases \(\lambda_{t-1}\).
As pointed out earlier, leaning against the wind slows down the rise in exchange rates by introducing positive autocorrelation into $\Delta s_t$. Other things equal, a positive $\Delta s_t$ implies a positive $\Delta s_{t+1}$.

Essentially the same mechanism produces a negative response to a positive $\chi_{t-1}$.

Eq. (28) describes $^\wedge$ with CIP and structured error terms.

$$^\wedge=\left\{ \left[ (\lambda C) \Pi \{ R + [(\Phi C) / (1+\Phi R)] \} + \Omega \Pi^2 (\lambda I)^2 \{(1+R)(\Phi C R \Phi) / [(1+\Phi R)(1+\Phi)] \} \right] \sigma^2 + \Omega \Pi^2 \{ \Phi (1+\Phi^2) \} \right\} \sigma_2$$

$$\frac{1}{\\{ 1 + 2 \Omega \Pi (\lambda I)^2 \{ (1+R)(1+\Phi R) \} + 2 \Omega \Pi^2 (\lambda I)^2 \{(1+R)(1+\Phi R) / [(1+\Phi R)(1+\Phi)] \} \} \sigma^2 + \Omega \Pi^2 \{ 1 / (1+\Phi R) \} \sigma_2 + \Omega \Pi^2 \{ (\lambda C) \Pi \{ (1+R)(1+\Phi R) \} / [(1+\Phi R)(1+\Phi)] \} \sigma^2 + \Omega \Pi^2 \{ 1 / (1+\Phi R) \} \sigma_2 \}$$

(28)

Where $\Omega$ still equals $[(\lambda C) FX \Theta \Pi]$, but now $\Pi$ equals $1/(1+ZX \Theta (\lambda I) \Omega)$ and $\Phi$ equals $[ZX \Theta CF X \Theta (\lambda I) \Omega] / [(1+ZX \Theta (\lambda I) \Omega)]$.

As long as $\Omega$ is negative, and $\Phi$ is positive and less than one, the coefficient for $\sigma_2$ in the numerator is negative. The corresponding coefficient for $\sigma$ is positive. As long as $\Omega$ and $(C \lambda)$ are both negative and $\Pi$ and $\Phi$ are both positive and less than one, CIP reduces the negative contribution to $^\wedge$ from ordinary open market operations because all the terms containing $(\lambda I)$ in the coefficient for $\sigma_2$ in the numerator of eq. (28) are positive.

5.2.5. Interaction: The solution for $^\wedge$ in the Appendix shows how all the policies interact. Macro stabilization does not affect the effect of interest rate stabilization or leaning against the wind because $D$ only appears with $u_t$. However stabilizing interest rates and leaning against the wind interact with all
of the error terms. It would appear that it is difficult for monetary policy to avoid distorting international financial markets. The extent of the distortion is an empirical issue.

5.3. Forward bias.

Monetary policy and CIP explain the forward bias. The \(^{\wedge}\) implied by eq. (5) equals \(^{\wedge}\) because \((f, \square s_t)\) equals \(\cdot\). \(^{\wedge}\) is negative when monetary policy produces a negative \(^{\wedge}\).

The basic lesson from Table 6 is this: the forward-bias puzzle and failure of UIP can be explained by monetary policy. Monetary policy can produce forward bias, the failure of UIP and related puzzles by distorting financial markets in ways that do not necessarily involve faulty expectations. Of course those same policies may also create faulty expectations. I leave that possibility for others to investigate.

5.4. Equilibrium.

The model in Table 6 shows how conventional monetary policies can produce negative \(^{\wedge}\) and \(^{\wedge}\). But it is only the beginning of a complete explanation of these puzzles. The same monetary policies produce expected speculative returns, that is \(f_t E(s_{t+1} | I_t)\) that are not zero. Speculators respond to those expected speculative returns. That response creates risk premiums and affects \(^{\wedge}\) and \(^{\wedge}\) in ways not considered here.

If future research indicates that estimates of \(b\) and \(\beta\) describe equilibrium states, then the next step is to expand the model to explain how responses to expected speculative returns create equilibrium transaction costs and risk premiums.\(^{15}\) If future research indicates that those estimates do not describe equilibrium states, then the next step is to develop the appropriate equations of motion for transaction costs and risk premiums.

6. Related puzzles.

\(^{15}\) Without restrictions, “transaction costs” can explain anything and are, therefore, useless. The simplest way to restrict transaction costs is to assume that they behave like other costs. Alchian (1959) probably provides the best available description of such costs.
A convincing explanation for the forward-bias puzzle and failure of UIP should explain, or at least be consistent with, the related puzzles. The model in Table 6 meets that criterion. The same cannot be said for most of the alternative explanations.

6.1. Carry Trade puzzle.

The monetary approach explains the Carry Trade Puzzle; monetary policies that produce negative \(^{\uparrow}\) and \(^{\downarrow}\) produce the expected speculative returns behind the carry trade. Commercial banks and other institutions with relatively low transaction costs take positions based on these expected returns. Those positions create risk premiums. The literature has it backwards. Risk premiums do not cause expected speculative returns; expected returns cause risk premiums and the Carry Trade.

6.2. Commodity puzzle.

The monetary approach explains the Commodity Puzzle. Monetary policy produces negative \(^{\uparrow}\), CIP transmits that negativity to the \(^{\downarrow}\) in foreign exchange markets. The \(^{\uparrow}\) in commodity markets are mostly positive because nothing transmits the negativity in \(^{\downarrow}\) directly to commodity \(^{\uparrow}\).

6.3. Levels versus Differences.

The monetary approach in Table 6 and CIP explain the Levels versus Differences Puzzle. CIP and super consistency explain why regressing \(s_{t+1}\) against \(f_t\) produces coefficients close to 1.0. Monetary policy explains why \(^{\downarrow}\) is negative.

CIP implies that \(\Delta f_{t+1} = \Delta s_{t+1} + \Delta (t+1)\), which implies that \(f_{t+1} = f_t + \Delta s_{t+1} + \Delta (t+1)\). Therefore CIP implies that \(s_{t+1} = f_{t+1} - f_t = \Delta s_{t+1} + \Delta (t+1)\), which produces the following test equation where CIP implies that all the \(g_i\) equal one except \(g_0\):

\[
s_{t+1} = g_0 + g_1 f_t + g_2 \Delta s_{t+1} + g_3 (t)
\]

(29)

\(s_{t+1}\) and \(f_t\) have unit roots while \(\Delta s_{t+1}\) and \(\Delta (t)\) are stationary.\(^{16}\) As a result, even though monetary policy produces negative \(^{\downarrow}\) when regressing \(\Delta s_{t+1}\) against \(f_t \Box s_t\), CIP and super consistency imply that

\(^{16}\) It is often difficult to reject a unit root for long rates like consol rates, which suggests that the Levels versus Differences Puzzle might not hold for very long maturities.
regressing \( s_{t+1} \) against just \( f_t \) produces coefficients close to 1.0 because \(^\wedge\) approaches 1.0 rapidly even when \( \Delta s_{t+1} \) and \( \iota \) are omitted from eq. (29).

6.4. Time Dependency Puzzle.

With \( B, D, F, X, C, \lambda, \Lambda, \sigma_2, \sigma, \sigma_2 \) all constant for simplicity, Table 6 cannot explain the Time Dependency Puzzle. But monetary policy can because \( B, D, F, X, C, \lambda, \Lambda, \sigma_2, \sigma, \sigma_2 \) and \( \sigma_2 \) are all likely to change over time.

For example, \( F \) is constant in Table 1 and the discussion often assumes that \( F \) is zero. While most central banks routinely sterilize, the degree of sterilization can vary over time. That variation affects \(^\wedge\) and \(^\wedge\). In addition, central banks buy more domestic T bills when \( u_t \) is +3% than they sell when it is -3%. They also usually lean against the wind more when foreign exchange markets are "turbulent" than when they are "calm". All that variation is consistent with Time Dependency.

I leave it up to future research to determine whether or not such variation fully explains the Time Dependency Puzzle.

6.5. Maturity puzzle.

Using a simple model where the Fed follows a Taylor rule, Chinn and Meredith (2004) show that monetary policy is consistent with the maturity puzzle. The model in Table 6 explains in more detail how monetary policy explains the Maturity Puzzle.

As maturity increases several things happen: (1) \((C\Lambda)\) increases as liquidity effects fade and inflationary effects increase, (2) The effects of interest rate stabilization disappear as \( B \) goes to zero, (3) The temporary effects of intervention disappear and \( \Phi \) goes to zero, and (4) Beyond about one year, the effects of CIP also disappear \([(1-\lambda) \to 0]\) because forward markets essentially disappear beyond about one year.
As $\Lambda$, $B$, $X$, $\Phi$, and $(1 - \lambda)$ all go to zero, the solution for $^\wedge$ in the Appendix collapses to

$$[C^2D^2\sigma^2 + C^2\sigma^2 \lambda] [\sigma + C^2D^2\sigma^2 + C^2\sigma^2].$$

As $\sigma$, which is probably very small relative to $\sigma^2$ and $\sigma^2$, also goes to zero, $^\wedge$ goes to one.

Monetary policy also explains the Miller version. Table 6 implies that using short maturities produces negative $^\wedge$ while long-maturities produces positive $^\wedge$. Now consider regressing short maturity $\Delta s_{t+1}$ against long maturity $\lambda$. As the maturity of $\lambda$ increases, the relatively strong liquidity effects and relatively weak inflationary effects that would produce a negative $\lambda$ for short maturities in response to a positive $\nu_t$ disappear. $C-\Lambda$ increases and $\lambda$ for long maturities increases until a positive $\nu_t$ produces a positive $^\wedge$. That change in the sign of $\lambda$ produces a positive $^\wedge$ and explains Miller's versions of the Maturity Puzzle.

6.6. Inflation, Outlier and Development Puzzles.

To expand the relevant data set for these three puzzles, Table 7 combines Tables 1 and 2 in Frankel and Poonawala (2010) with Table 4 in Bansal and Dahlquist (2000). I begin with the 28 countries in Table 4 in Bansal and Dahlquist (2000) and then add the 10 countries from Frankel and Poonawala that are not included in Bansal and Dahlquist. They are denoted with an *.

| Country        | FX     | Inflation | $^\wedge$ | Country        | FX     | Inflation | $^\wedge$ |
|----------------|--------|-----------|----------|----------------|--------|-----------|----------|
| Taiwan*        | PB-P   | NA        | 0.14     | South Africa*  | IF     | 6.8       | -3.27    |
| Saudi Arabia* | P      | -0.3      | -0.08    | Sweden         | IF     | 7.3       | 0.56     |
| Kuwait*        | PB-P   | 1.5       | 0.40     | U.K.           | IF     | 7.8       | -1.35    |
| Finland*       | IF €   | 1.7       | -5.47    | Hong Kong      | CB     | 8.6       | -0.01    |
| New Zealand*   | IF     | 1.8       | -3.99    | India          | IF     | 8.8       | -0.98    |
| Norway*        | IF     | 2.4       | -3.84    | Czech Rep.     | P-MF   | 10.4      | 1.35     |
| Japan          | IF     | 2.6       | -2.21    | Spain          | IF €   | 10.6      | 0.67     |
| Germany        | EMS €  | 3.1       | -0.56    | Hungary*       | CP-P   | 10.8      | 0.75     |
| Netherlands    | EMS €  | 3.1       | -1.38    | Italy          | EMS €  | 10.9      | 0.08     |
| Switzerland    | IF     | 3.2       | 1.05     | Philippines    | IF     | 12.6      | 0.81     |
| Singapore      | PB-MF  | 3.5       | -1.26    | Portugal       | PB €   | 16.3      | 0.46     |
| Ireland*       | EMS €  | 3.7       | -5.63    | Greece         | MF €   | 16.7      | -0.38    |
| Austria        | EMS €  | 4.1       | -0.76    | Venezuela      | PB P   | 25.1      | 0.71     |
| Malaysia       | PB P   | 4.2       | 0.35     | Indonesia*     | MF     | 28.4      | 0.15     |
| Belgium        | EMS €  | 4.4       | -0.77    | Mexico         | IF     | 43.2      | -1.40    |
| Canada         | IF     | 5.0       | -1.04    | Turkey         | MF-IF  | 54.9      | 0.28     |
| Denmark        | ERM    | 5.6       | -0.56    | Poland         | CP IF  | 80.7      | 0.46     |
| Thailand       | P-MF   | 5.6       | 0.53     | Argentina      | M NF   | 435.5     | 0.08     |
| France         | EMS €  | 6.3       | 0.00     |                |        |           |          |
| Australia      | IF     | 6.4       | -8.40    |                |        |           |          |
Fixed (F); Independent Float (IF); Managed Float (MF); Pegged (P); Pegged to Basket (PB); Crawling Peg (CP); Target Band (TB); Currency Board; European Monetary System (EMS); euro (€).

For the countries from Bansal and Dahlquist (2000) I use their annual inflation rates and $\wedge$. For the additional 10 countries I use the $\wedge$ from Frankel and Poonawala (2010) and average CPI inflation rates from FRED for December 1996 to April 2004, which is the typical interval in Frankel and Poonawala (2010). I list the countries in an ascending order of inflation.

I also include a description of each country's foreign exchange market labeled FX from Exchange Arrangements and Exchange Restrictions published by the IMF. If FX changed during the relevant interval, the first entry describes the beginning of the interval and the second the end.

6.6.1: Inflation and Outliers: The inflation and outlier puzzles are, from a monetary policy point of view, essentially the same thing. Whether it is for a given exchange rate over time or for different exchange rates across space and/or time, nominal interest rate differentials and forward premiums are outliers primarily because inflation differentials are outliers.

Table 7 strongly supports inflation effects. Using inflation rates as the key, the RATS Spearman rank correlation test between inflation and $\wedge$ is significant at 1%.

6.6.2. Development Puzzle: But the significance of inflation hides an important problem. Comparing developed and developing countries compares apples to oranges. The inflation effect illustrates the difference; the same test using just developed countries produces a test statistic that is significant at well beyond 1%, but using just developing countries produces a test statistic that is not even close to significant at 10%.

Developed countries are relatively homogeneous. They have relatively stable monetary regimes and most follow similar monetary policies. They also have almost no trade or capital controls, well developed financial markets and generally have flexible exchange rates versus the U.S. dollar.

Developing countries are heterogeneous with respect to these characteristics. Monetary regimes vary from very stable like Hong Kong to highly unstable like Argentina and Venezuela. In addition
many developing countries have trade and/or capital controls and few have well developed financial markets. Finally some are pegged closely to the U.S. dollar like Hong Kong and Saudi Arabia while others float like South Africa, but most have some sort of managed exchange rate. Those differences affect their monetary policies. Central banks in countries with tightly pegged exchange rates cannot conduct monetary policy in the same way as those in countries with flexible exchange rates.

Table 7 illustrates how these differences interact to produce the Development Puzzle. The two countries with the lowest inflation are Saudi Arabia and Kuwait, which are tightly pegged to the U.S. dollar. As expected, both $\hat{\sigma}$s are larger than those for developed countries with higher inflation. If the pegs were perfect, the $\hat{\sigma}$s would have to be zero. On the other hand South Africa, which has a flexible rate and a fairly small inflation rate for a developing country, has a negative $\hat{\sigma}$, $-3.27$.

As Table 7 shows, with respect to exchange rates, most developing countries fall in between the two extremes of flexible and tightly pegged. Most of those countries have inflation rates well above the average inflation rate for developed countries, which is 6.15%. Other things equals, those relatively high inflation rates tend to increase $\hat{\sigma}$.

Finally the financial markets in developing countries tend to have higher transaction costs than the more developed markets in developed countries, which tend to bias $\hat{\sigma}$s for developing countries toward zero.

Given the generally higher transaction costs, the prevalence of managed exchange rates and relatively high inflation among developing countries, it would be more of a puzzle if they did not have relatively large $\hat{\sigma}$.

6.8. Alternative explanations.

The two most widely cited explanations for the failure of UIP and the forward-bias puzzle are risk premiums and the failure of rational expectations. For a detailed discussion of these two alternatives see Sarno (2005, 678). Less frequently cited alternatives include: nonlinearities [Sarno et
al (2006), peso problems and fads [Sercu and Vinaimont (2006)], perpetual learning [Chakraborty and Evans (2008)], adverse selection [Burnside et al (2009)], career risk [Liu and Sercu (2009)], "deep habits" [Moore and Roche (2010)], infrequent portfolio decisions [Bacchetta and van Wincoop (2010)], carry and momentum trading [Baillie and Chang (2011)], over confidence [Burnside et al (2011)] and most recently an intertemporal approach to UIP with errors in expectations [Miller (2014)].

Risk premiums and the failure of rational expectations are difficult to reconcile with the related puzzles. To be consistent, risk would have to be lower, or expectations more rational, in developing markets. The same would have to be true for longer maturities and for commodity markets. How can risk premiums or the failure of rational expectations explain the Inflation and Outlier Puzzle?

Unlike most appeals to less than Rational Expectations, Miller (2014) provides concrete examples of less than Rational Expectations that may explain the Maturity Puzzle. Although expectations in his Model I are not rational in the short-run, they converge to rational in the long run. But Miller needs to explain how his models can explain the Carry Trade Puzzle, Commodity Puzzle, Development, Inflation and Outlier Puzzles, the Levels versus Differences Puzzle and the Time Dependency Puzzle.

Other alternatives also do not seem to provide viable explanations for the related puzzles. For example, how do perpetual learning, infrequent portfolio decisions or adverse selection explain the Carry Trade, Commodity, Development, Inflation, Maturity and Time Dependency puzzles? If advocates of those or other alternatives want their alternative to be taken seriously then they will need to show how they can explain, or are at least consistent with, the related puzzles. Until then monetary policy appears to be the most consistent with all the evidence.

7. Summary and Conclusions.

Taken together, the failure of UIP, the forward-bias puzzle and their related puzzles seem to suggest that something is fundamentally wrong in international financial markets. They also pose a
serious challenge to open economy macroeconomics. But everything falls into place when one looks at these puzzles through the lens of monetary policy.

When monetary regimes are stable and interest rates short term, conventional open market operations cause UIP to fail. The liquidity effects of expansionary open market operations create negative interest differentials while the inflationary effects raise future exchange rates. Leaning against the wind in foreign exchange markets reinforces this effect. Covered interest parity carries it over to short-term forward exchange markets.

The Carry Trade exists because the same monetary policies create expected returns to speculation. (Expected returns create risk premiums, not the reverse.) There is a Commodity Puzzle because covered interest parity does not transmit the liquidity effects of monetary policy to commodity markets. There is a Maturity Puzzle because as maturity increases the liquidity effects of monetary policy fade while the inflationary effects intensify. There is an Inflationary and Outlier Puzzle because inflation reduces liquidity effects relative to inflationary effects.

There is a Development puzzle because monetary policy is similar between developed countries but not between developed and developing countries. In developed countries monetary regimes are relatively stable, there are no serious trade or capital controls, financial markets are well developed and, as a result, transaction costs are low. Finally, and probably most important of all, developed countries generally have, and have had since the early 1970s, flexible rates versus the U.S. dollar.

In developing countries monetary regimes range from highly stable like Hong Kong and Saudi Arabia to highly unstable like Argentina and Venezuela. Most have serious trade and/or capital controls combined with underdeveloped financial markets. Most important of all, although some like Hong Kong and Saudi Arabia have currencies that are tightly pegged to the U.S. dollar while a few have flexible rates, most have some sort of managed exchange rate. The fact that the Inflationary
Puzzle holds for developed countries, but not for developing countries, illustrates one effect of the important differences between developed and developing countries.

The model in Table 6 that describes the effects of monetary policy also explains the Levels versus Differences puzzle. It explains why regressing future changes in spot exchange rates against forward premiums and interest rate differentials can produce negative coefficients. Covered interest parity and super consistency explain why regressing future spot rates against current forward rates produces coefficients close to one.

Monetary policy also provides a simple explanation for the Time Dependency Puzzle. Monetary policies, and how the public interprets those policies, change over time. Usually foreign exchange intervention is sterilized, but both the intensity of intervention and the degree of sterilization vary over time. Finally central banks are more likely to respond to high than low unemployment. These and other changes in policy, and the public’s response to them, can explain the Time Dependency Puzzle.

One totally unexpected result of developing the implications of the model in Table 6 is that it has changed the way I think about uncovered interest parity. Initially I accepted the conventional interpretations discussed in Section 2.1. But I now believe that what are called the failure of UIP and the Forward-Bias Puzzle are primarily the result of ignoring the liquidity effects of the open market operations that lie behind the inflation that is at the heart of UIP.

References

Akram, Q., Rime, D., Sarno, L., 2008. Arbitrage in the Foreign Exchange Market: Turning on the Microscope. Journal of International Economics 76, 237-253.

Alchian, A., 1959. Costs and Outputs. In: Abramovitz M. et al (Eds.), The Allocation of Economic Resources, Stanford University Press, Stanford, CA.

Alexius, A., 2001. Uncovered Interest Parity Revisited. Review of International Economics, 9, 505-517.

Anker, P., 1999. Uncovered interest parity, monetary policy and time-varying risk premia. Journal of International Money and Finance 18, 835-851.
Aslan, Ō., Korap, H., 2010. Does the uncovered interest parity hold in short horizons?. Applied Economic Letters 17, 361-365.

Bacchetta, P., van Wincoop, E., 2010. Infrequent Portfolio Decisions: A Solution to the Forward Discount Puzzle. American Economic Review 100, 870-904.

Baillie, R., 2011. Possible solutions to the forward bias puzzle. Journal of International Financial Markets, Institutions and Money 21, 617-622.

Baillie, R., Chang, S., 2011. Carry trades, momentum trading and the forward premium anomaly. Journal of Financial Markets 14, 441-469.

Balke, N., Wohar, M. E., 1998. Nonlinear Dynamics and Covered Interest Rate Parity. Empirical Economics 23, 535-559.

Bansal, R., Dahlquist, M., 2000. The forward premium puzzle: different tales from developed and emerging economies. Journal of International Economics 51, 115-144.

Beine, M., Laurent, S., Lecourt, C., 2003. Official central bank interventions and exchange rate volatility: Evidence from a regime-switching analysis. European Economic Review 47, 891-911.

Bjørnland, H., (2009). Monetary policy and exchange rate overshooting, Dornbusch was right after all, Journal of International Economics 79, 64-77.

Bouakez, H., Normandin, M., 2010. Fluctuations in the foreign exchange market: How important are monetary policy shocks?. Journal of International Economics 81, 139-153.

Burnside, C., Eichenbaum, M., Rebelo, S., 2008. Carry Trade: The Gains of Diversification. Journal of the European Economic Association 6, 581-588.

Burnside, C., Eichenbaum, M., Rebelo, S., 2009. Understanding the Forward Premium Puzzle: A Microstructure Approach. American Economic Journal: Macroeconomics 1, 127-154.

Burnside, C., Han, B., Hirshleifer, D., 2011. Investor Overconfidence and the Forward Premium Puzzle. Review of Economic Studies 78, 523-558.

Chakraborty, A., Evans G.W., 2008. Can perpetual learning explain the forward-premium puzzle? Journal of Monetary Economics 55, 477-490.

Chinn, M., 2006. The (partial) rehabilitation of interest rate parity in the floating era: Longer Horizons, alternative expectations, and emerging markets. Journal of International Money and Finance 25, 7-21.

Chinn, M., Meredith, M., 2004. Monetary Policy and Long-Horizon Uncovered Interest Parity. IMF Staff Papers 51, 409-430.
Cushman, D. O., Zha, T, 1997. Identifying monetary policy in a small open economy under flexible exchange rates. The Journal of Monetary Economics 39, 433-448.

Edison, H.J., 1993, The effectiveness of central bank intervention: A survey of the literature after 1982, International Finance Section, Department of Economics, Princeton University.

Eichenbaum, M., Evans C.L., 1995. Some empirical evidence on the effects of shocks to monetary policy on exchange rates, The Quarterly Journal of Economics 110, 975-1009.

Einzig, P., 1937. The Theory of Forward Exchange. Macmillan and Co., London.

Fama, E., 1984. Forward and Spot Exchange Rates. Journal of Monetary Economics 14, 319-338.

Fama, E., French, K.R., 1987. Commodity Futures Prices: Some Evidence on Forecast Power, Premiums, and the Theory of Storage. The Journal of Business 60, 55-73.

Fatum R., 2008. Daily effects of foreign exchange intervention: Evidence from Official Bank of Canada data. Journal of International Money and Finance 27, 438-454.

Faust, J., Rogers, J., H., 2003. Monetary Policy's role in exchange rate behavior. Journal of Monetary Economics 50, 1403-1424.

Fong, W., Valente, G., Fung, J.K.W., 2010. Covered interest arbitrage profits: The rol of Liquidity and credit risk. Journal of Banking and Finance 34, 1098-1107.

Frankel, J., Poonawala, J., 2010. The forward market in emerging currencies: Less biased than in major currencies. Journal of International Money and Finance 29, 585-598.

Grilli, V., Roubini, R., 1996. Liquidity models in open economies: Theory and empirical evidence. European Economic Review 40, 847-859.

Han, B., 2004. Is the forward premium puzzle universal?. Applied Economics Letters 11, 131-134.

Heinlein, R., Krolzig, H-M., 2012. Effects of Monetary Policy on the US Dollar/UK Pound Exchange Rate. Is There a "Delayed Overshooting Puzzle"? Review of International Economics 20, 443-467.

Hochradl, M., Wagner, C., 2010. Trading the forward bias: Are there limits to speculation?. Journal of International Money and Finance 29, 423-441.

Kearns, J., 2007, Commodity Currencies: Why Are Exchange Rate Futures Biased if Commodity Futures Are Not?. The Economic Record, 260, 60-73.

Kim, S., Roubini, N., 2000, Exchange rate anomalies in the industrial countries: A solution with a structural VAR approach. The Journal of Monetary Economics 45, 561-586.
Kirkos, D.G., 2002. Discrete Policy Interventions and Rational Forecast Errors in Foreign Exchange Markets: The Uncovered Interest Parity Hypothesis Revisited. International Journal of Finance and Economics 7, 327-338.

Lafuente, J.A., Ruiz, J., 2006, Monetary policy and forward bias for foreign exchange revisited: Empirical evidence from the US-UK exchange rate. Economic Modelling 23, 238-264.

Levich, R., 1979. On the efficiency of markets for foreign exchange. In: Dornbusch, R., Frenkel, J. (Eds.), International Economic Policy: Theory and Evidence, John Hopkins, Baltimore, MD.

Liu, F., Sercu, P., 2009. The Forex Forward Puzzle: The Career Risk Hypothesis. The Financial Review 44, 371-404.

Lothian, J., R., Wu, L., 2011. Uncovered interest-rate parity over the past two centuries. Journal of International Money and Finance 30, 448-473.

Mark, N.C., Moh, Y-K., 2007. Official intervention and the forward premium anomaly. Journal of Empirical Finance 14, 499-522.

McCallum, B., T., 1994. A reconsideration of the uncovered interest parity relationship. Journal of Monetary Economics 33, 105-132.

Miller, N.C., 2014. Exchange Rate Economics. Edward Elgar, Cheltenham, UK.

Moore, M.J., Roche, M.J., 2010. Solving exchange rate puzzles with neither sticky prices nor trade costs. Journal of International Money and Finance 29, 1151-1170.

Neely, C. J., 2001. The Practice of Central Bank Intervention: Looking Under the Hood. Federal Reserve Bank of St. Louis, 83, 1-10.

Paya, I., Peel., D. A., Spiru, A., 2010. The forward premium puzzle in the interwar period and deviations from covered interest parity. Economic Letters 108, 55-57.

Phillips, L., Pippenger, J., 1993. Stabilization of the Canadian Dollar: 1975-1986. The Canadian Journal of Economics 26, 416-446.

Pippenger, J., 2008a. Freely floating exchange rates do not systematically overshoot. Journal of International Finance and Economics 8, 37-56.

Pippenger, J., 2008b. The Law of One Price: An Interpretation of the Literature and some New Evidence, Journal of the Academy of Business and Economics 8, 37-56.

Pippenger, J., Phillips, L., 1973. Stabilization of the Canadian dollar: 1952-1960. Econometrika 41, 797-815.

Pippenger, J. Phillips L., 2008. Some pitfalls in testing the law of one price in commodity markets. Journal of International Money and Finance 27, 915-925.
Rogoff, K., 1996. The Purchasing Power Parity Puzzle. Journal of Economic Literature 34, 647-668.

Sarno, L., 2005. Viewpoint: Towards a solution to the puzzles in exchange rate economics: where do we stand?. Canadian Journal of Economics 38, 673-708.

Sarno, L., Valente, G., Leon, H., 2006. Nonlinearity in Deviations from Uncovered Interest Parity: An Explanation of the Forward Bias Puzzle. Review of Finance 10, 443-482.

Scholl, A., Uhlig, H., 2008. New evidence on the puzzles: Results from agnostic identification on monetary policy and exchange rates. Journal of International Economics 76, 1-13.

Sercu, P., Vinaimont, T., 2006. The Forward Bias in the ECU: Peso Risks vs. Fads and Fashions. Journal of Banking and Finance 30, 2409-2432.

The New Palgrave Dictionary of Economics, second edition, 2008, Palgrave Macmillan, New York, N.Y., 2008.

**APPENDIX**

\[ \sigma_{\Delta t+1, t/\sigma} = \{ \Theta \Pi(C \Sigma \Lambda) \{ 1 + B(C \Sigma \Lambda) \Theta \{ 1 / (1 + 2) \Phi U) \} + (\lambda \Pi 1) (C \Sigma \Lambda) ^3 \Pi \Theta ^2 \{ U + [(\Phi \Pi 1) / (1 + \Phi U)] \} \]
\[+2\Omega^2 \Theta^2 \Pi \Gamma (\lambda \cdot 1) (C \cdot \Lambda) [(1 + B(C \cdot \Lambda) \Theta) \{(1 + \Phi U \cdot \Phi U \cdot 1)/(1 + \Phi U \cdot \Phi U)\}]
\]
\[+2\Omega^2 \Theta^4 \Pi^2 (\lambda \cdot 1)^2 (C \cdot \Lambda)^2 \{(1 + \Phi U \cdot \Phi U)/(1 + \Phi U \cdot \Phi U)\}\] \(\Phi^2\) \(\sigma^2\)
\[+ [(C \cdot \Lambda) \Theta]^2 + 2\Omega \Theta^2 \Pi \Gamma (C \cdot \Lambda) \Theta + \Pi \Gamma (C \cdot \Lambda) \Phi \{(1 + \Phi V)/(1 + \Phi V)\} + 2\Omega \Theta^2 \Gamma (\lambda \cdot 1) (C \cdot \Lambda)^2 \{(1 + \Phi V)/(1 + \Phi V)\}
\]
\[+ \Omega \Theta [\Pi \Gamma (C \cdot \Lambda) \Theta + \Pi \Gamma \Phi \{(1 + \Phi V)/(1 + \Phi V)\}]
\]
\[+ 2\Omega^2 \Theta^2 \Pi (\lambda \cdot 1) (C \cdot \Lambda) \Phi \{(1 + \Phi V)/(1 + \Phi V)\}
\]
\[+ 2\Omega \Theta (\lambda \cdot 1) (C \cdot \Lambda) \Pi \Theta (\lambda \cdot 1) (C \cdot \Lambda) \Pi \Theta \{(1 + \Phi V)/(1 + \Phi V)\}\] \(\sigma^2\)
\[+ [(\Omega \Theta \Pi)^2 \{1/(1 + \Phi^2)\}] \sigma^2\]

Where \(1/[1 + B(\Lambda \cdot C)]\) equals \(\Theta\), \(\Omega\) equals \((\Lambda \cdot C) F X / H X\), \(1/(1 + Z X \cdot \Theta (\lambda \cdot 1) \Omega)\) equals \(\Pi\). and
\(Z X \cdot \Theta C B \Omega \cdot C F X \cdot \Theta (\lambda \cdot 1) \Omega) [1 + Z X \cdot \Theta (\lambda \cdot 1) \Omega]\) equals \(\Phi\).