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U.S. MONETARY POLICY AND INTEREST RATE PASS-THROUGH

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Abstract: We analyze the international transmission of interest rates under pegged and non-pegged exchange rate regimes, demonstrating that transmission depends upon the informational properties of a base country’s interest rate change. We differentiate between interest rate movements which are predictable/unpredictable and dependent/independent (i.e., a function of non-monetary factors such as cost-push inflation). Under capital mobility, we show that predictable or dependent interest rate changes should elicit interest rate pass-through for an imperfectly credible peg that is less than unity, whilst interest rate changes that are unpredictable and independent should elicit pass-through greater than unity. Using a real-time identification of unpredictable and independent U.S. federal funds rate changes, we provide evidence consistent with these propositions. When the federal funds rate change is unpredictable and independent, the joint hypothesis of unit within-month pass-through to pegs and zero within-month pass-through to non-peggs cannot be rejected. The same hypothesis is strongly rejected following actual, aggregate federal funds rate changes which include predictable and dependent components. In a dynamic context, we find that maximum interest rate pass-through to pegs is delayed. Moreover, even though there is a full transmission of unpredictable and independent federal funds rate changes, they explain only a small portion of pegged regime interest rate changes.

JEL Classification: F33, F41, F42

Keywords: interest rate pass-through, monetary policy identification, open economy trilemma, exchange rate regime.

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1 Introduction

International interest rate linkages have long been an important research focus in open economy macroeconomics. When capital is mobile, a no-arbitrage condition relating similar Home and Foreign assets is expected to hold. Consequently, if Home pegs its exchange rate vis-à-vis Foreign, then the Home interest rate must equal the Foreign interest rate. If Home’s interest rate is allowed to deviate from Foreign’s rate, international capital flows shift the exchange rate away from its pegged value, leading to the abandonment of the peg. Such logic leads to the open economy monetary policy trilemma, which states that countries may only achieve at most two of three objectives simultaneously: (1) exchange rate stability; (2) domestic monetary autonomy; and (3) international capital mobility. Thus, under capital mobility and perfect credibility, interest rate pass-through from a base country to a pegged exchange rate regime is predicted to be unity, demonstrating the sacrifice of domestic monetary autonomy for exchange rate stability. Conversely, interest rate pass-through from all other countries to a non-pegged exchange rate regime is predicted to be zero, demonstrating their complete monetary autonomy at the cost of exchange rate stability.

In recent years, several studies have tested the trilemma’s predictions by estimating the relationship of one country’s interest rate to another country’s interest rate, conditional upon the bilateral exchange rate regime. Frankel, Schmukler, and Servén [2004] find some evidence that small open economies achieved greater short-run monetary autonomy during the 1990s by allowing the value of their currency to float. However, such countries are found to implement foreign interest rate changes in full in the long-run, irrespective of their exchange rate regime. Shambaugh [2004] investigates the importance of the trilemma using a new *de facto* exchange rate regime classification. In the absence of capital controls, he finds that long-run interest rate pass-through under a peg is up to one and a half times larger than that under a non-peg. However, the hypothesis of full long-run pass-through is rejected for all exchange rate/capital control regime com-

Underlying the trilemma’s benchmark predictions is the assumption that a pegged exchange rate regime is perfectly credible. When a peg is imperfectly credible, estimated pass-through will depend upon the covariance of Foreign’s interest rate with unobserved bilateral exchange rate expectations and the relative risk premium paid upon Home’s assets [Shambaugh, 2004]. We argue that these unobserved covariances are systematically related to the informational properties of Foreign’s interest rate movements. Specifically, we consider foreign interest rate changes which are either predictable or unpredictable from the market’s perspective, and either dependent upon non-monetary innovations or independent of such innovations. When the exchange rate is a forward-looking jump variable, a foreign interest rate change that is either predictable and independent or unpredictable and dependent is expected to generate a negative covariance with the unobserved variables, leading to an estimated pass-through under a peg that is less than unity. In contrast, when a foreign interest rate change is unpredictable and independent, or predictable and dependent, the covariances with the unobserved variables are expected to be positive, leading to an estimated pass-through under a peg that is greater than unity. We estimate interest rate pass-through conditional upon the informational properties of a foreign interest rate change; the results are consistent with these predictions. Such findings support the empirical relevance of the trilemma’s logic when a pegged regime is imperfectly credible.

How might the informational properties of a foreign interest rate change influence bilateral exchange rate expectations and the risk premium? Consider a future Foreign interest rate increase that is predictable from the market’s current information set. If Home maintains a peg versus Foreign that is imperfectly credible, then agents perceive some probability that Home’s interest rate will not move in line with the predicted increase in Foreign’s interest rate. 

Ceteris paribus, forward-looking agents will short Home’s currency immediately, creating pressure for its depreciation. To maintain the peg, Home’s
interest rate must increase in advance of Foreign’s interest rate, to compensate for an increase in the perceived revaluation probability. Such temporal decoupling of Home and Foreign interest rate changes implies that estimated pass-through will be less than unity – the unobserved covariances are negative.

When a Foreign interest rate change reflects the dependence of Foreign monetary policy upon economic conditions, estimated interest rate pass-through to a peg nation will be less than unity. Consider a positive Foreign inflation innovation which leads to an increase in the Foreign interest rate. If the real exchange rate is mean-reverting, Foreign inflation encourages Foreign depreciation, since the internal purchasing power of Foreign currency is diluted by inflation. This will offset any pressure for Foreign appreciation that arises from a higher Foreign interest rate. As a result of pressures on the exchange rate being muted, there may be little need for Home to increase its interest rate. A peg can be maintained without fully accommodating Foreign’s interest rate change. There is ample evidence of the importance of such effects. In an early paper, Engel and Frankel [1984] demonstrate how an interest rate rise may be associated with an exchange rate depreciation when the interest rate rise reflects an increase in the inflation premium. Faust, Rogers, Wang, and Wright [forthcoming] find that the US$ depreciates in response to news announcements indicating a higher than expected consumer price index (CPI). ¹

In general, estimated interest rate pass-through under a non-peg also depends upon the unobserved covariances of foreign interest rates with bilateral exchange rate expectations and the risk premium. The benchmark trilemma prediction of zero pass-through under a non-peg implicitly assumes that exchange rate expectations respond one-for-one in the opposite direction to a Foreign interest rate change, such that arbitrage opportunities are removed without the need for interest rate convergence. If they respond less than one-for-one, then estimated pass-through under a non-peg will be positive. When foreign interest rate changes are predominantly predictable and independent or unpredictable

¹Clarida and Waldman [forthcoming] remark that such announcements could appreciate the exchange rate if they prompt sufficiently large interest rate increases (e.g., by an inflation targeting monetary authority). Our predictions hold even then, since the relationship between the interest rate and the expected exchange rate would still be attenuated.
and dependent, we expect such attenuation in the response of exchange rate expectations and the risk premium, leading naturally to positive estimated interest rate pass-through under a non-peg. There are other explanations for positive pass-through under non-pegs. For example, overlapping monetary policy objectives will lead to attenuation bias in the unobserved covariances. We discuss such possibilities after presenting our results.

We evaluate the importance of the foreign interest rate’s informational properties in estimates of international monetary codependence. This entails estimating interest rate pass-through from two measures of U.S. interest rate changes: (1) actual, aggregate federal funds rate changes, representing time-varying mixtures of predictable/unpredictable and dependent/independent components; and (2) identified, real-time unpredictable and independent U.S. federal funds rate changes. The unpredictable and independent U.S. interest rate change is isolated using the monetary policy identification procedure outlined by Romer and Romer [2004]. Under capital mobility, estimated within-month pass-through in response to an unpredictable and independent U.S. interest rate change is 0.80 under pegs and -0.01 under non-pegs. In contrast, an aggregate federal funds rate increase is associated with pass-through of 0.52 under pegs and 0.13 under non-pegs. When the same relationships are estimated using annual data, estimated within-year pass-through in response to an unpredictable and independent federal funds rate change is 1.33 for pegs and 0.38 for non-pegs, while the equivalent statistics in response to an aggregate federal funds rate change are respectively 0.66 and 0.42.

The results support the hypothesis that predictable or dependent elements of the aggregate change in the federal funds rate lead to estimated pass-through which is less than unity under pegs and which is greater than zero under non-pegs. This has implications for tests of the trilemma’s benchmark predictions. When an unpredictable and independent foreign interest rate change is employed, the joint hypothesis of unit within-month pass-through for pegs and zero within month pass-through for non-pegs cannot be rejected at any conventional significance level. The same hypothesis is rejected at the 1%

We prefer the term codependence to interdependence, as it includes the possibility that some third factor generates bilateral dependence.
level using the aggregate federal funds rate. At the same time, however, we find that the proportion of Home interest rate changes that can be explained by Foreign interest rate changes is small in all cases, regardless of the informational properties of Foreign’s interest rate change. There are clearly factors other than Foreign’s interest rate which influence Home’s interest rate. Depending upon the nature of the omitted factors, this may indicate that there is greater scope for monetary autonomy under a peg than is predicted under the traditional trilemma interpretation.

To account for the possibility of sluggish adjustment, we also estimate dynamic models, recovering interest rate pass-through for horizons from 0 to 12 months. Using an unpredictable and independent U.S. interest rate change, we find that maximum dynamic interest rate pass-through under a peg occurs at the 1 month horizon. Moreover, it is over twice the magnitude of pass-through at the same horizon under a peg that is estimated using the aggregate federal funds rate. The dynamic estimates also show significant interest rate pass-through under a non-peg for horizons beyond 4 months. We discuss these findings in light of recent theoretical and empirical work on exchange rate adjustment.

Finally, we undertake a host of robustness checks, including: the use of alternative exchange rate regime classifications; the introduction of error correction effects in the dynamic models; and sub-sample stability analysis. Our initial findings are generally robust.

The paper proceeds as follows. In section 2, we outline a framework for understanding interest rate pass-through when foreign interest rate changes can be distinguished according to their predictability and dependence. We then review existing empirical work and consider how it relates to this framework. In section 3, we describe the econometric methodology employed. In section 4, we present and discuss our results in detail. In section 5, we consider the robustness of our results and in section 6 we conclude with a summary of our main arguments and findings.
2 Interest rate pass-through

Using an international no-arbitrage condition, we explain how interest rate pass-through is predicted to be unity under a perfectly credible peg and zero under a classic float (non-peg), when capital is mobile. We then analyze how the informational properties of Foreign interest rate changes (specifically, their predictability and dependence) affect estimated interest rate pass-through under an imperfectly credible peg. We close the section with a discussion of previous empirical investigations of international monetary codependence and the associated inference regarding the relevance of the open economy trilemma.

2.1 International no-arbitrage conditions and interest rates

Under capital mobility, international no-arbitrage conditions are expected to hold. Such conditions state that the risk-adjusted nominal returns on a Home fixed-income asset and an identical Foreign fixed-income asset should be the same. The standard covered interest rate parity (CIP) condition between similar Home and Foreign fixed-income assets may be written as:

\[(1 + R_t) = (1 + R^*_t) \left( \frac{F_t}{S_t} \right) \Rightarrow r_t = r^*_t + f_t - s_t,\]

where \(r = \ln (1 + R)\), \(r^* = \ln (1 + R^*)\), \(f = \ln (F)\) and \(s = \ln (S)\). \(R\) denotes the nominal interest rate in decimal terms, \(F\) denotes the one-period ahead forward exchange rate in units of Home currency per Foreign currency, and \(S\) denotes the nominal exchange rate in units of Home currency per Foreign currency. Time advances in discrete increments. Foreign variables are indicated by an asterisk. Suppose that the logarithm of the forward exchange rate is defined as:

\[f_t = E_t (s_{t+1}) + \rho_t,\]
where $\rho$ denotes the risk premium associated with fixing a future exchange rate trade of Foreign currency for Home currency today.\(^3\)

Substituting this expression into the CIP condition, we have that:

$$
\begin{align*}
    r_t &= r^*_t + E_t(s_{t+1}) - s_t + \rho_t \\
    \Delta r_t &= \Delta r^*_t + \nabla [E_t(s_{t+1}) - s_t] + \Delta \rho_t,
\end{align*}
$$

where $\nabla [E_t(s_{t+1}) - s_t] = [E_t(s_{t+1}) - s_t] - [E_{t-1}(s_t) - s_{t-1}]$. Notice that the $\nabla$ operator works on both the variables’ indices and the investor’s information set, which is necessary when differencing a term which depends upon expectations. This leads naturally to the following regression:

$$
\Delta r_t = \alpha + \beta \Delta r^*_t + u_t, \quad (1)
$$

where $\alpha + u_t = \nabla [E_t(s_{t+1}) - s_t] + \Delta \rho_t$.

The slope coefficient $\beta$ is defined to be interest rate pass-through and gives a measure of monetary codependence. This measure of pass-through is analyzed by Borensztein et al. [2001], Shambaugh [2004], and Obstfeld et al. [2004, 2005] to assess the importance of the open economy trilemma. Frankel et al. [2004] evaluate the trilemma using a regression in levels. In sections 3.3 and 5, we discuss how inference may be influenced by such specification choices, contingent upon the underlying data generating process. For now, we confine our discussion to inference associated with the first-difference specification.

Denote a variable in deviations form by a tilde, so that $\tilde{x}_t = x_t - \overline{x}$. The asymptotic

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\(^3\)Note that the approximation $\ln E_t(S_{t+1}) \approx E_t(\ln S_{t+1}) = E_t(s_{t+1})$ is invoked. Assume that any errors due to Siegel’s paradox (related to this approximation) are negligible. We use the term risk premium loosely. From the perspective of economic theory, $\rho$ is a composite of a Jensen’s inequality component (which is important even for a risk-neutral investor) and a component embodying the utility valuation of risk [Engel, 1992].
OLS estimator of $\beta$ is given by: 

$$
\hat{\beta} = \frac{\text{cov} \{ \Delta \tilde{r}_t, \Delta \tilde{r}^*_t \}}{\text{var} \{ \Delta \tilde{r}^*_t \}} = \frac{\text{cov} \left\{ \left( \Delta \tilde{r}^*_t + \nabla[E_t (\tilde{s}_{t+1}) - s_t] + \Delta \tilde{\rho}_t \right), \Delta \tilde{r}^*_t \right\}}{\text{var} \{ \Delta \tilde{r}^*_t \}} = 1 + \frac{\text{cov} \left\{ \nabla[E_t (\tilde{s}_{t+1}) - s_t], \Delta \tilde{r}^*_t \right\} + \text{cov} \left\{ \Delta \tilde{\rho}_t, \Delta \tilde{r}^*_t \right\}}{\text{var} \{ \Delta \tilde{r}^*_t \}}.
$$

A natural benchmark value for $\hat{\beta}$ is thus one. If $\hat{\beta}$ is different from one, then it must be due to the presence of non-zero covariances of Foreign interest rate changes with either the difference in the expected rate of depreciation from time $(t-1)$ to time $t$, or the change in the risk premium, both of which are unobserved variables in the context of the interest rate pass-through regression. The sign and magnitude of the unobserved covariances will depend on the following factors:

1. the bilateral exchange rate regime and its credibility.
2. the nature of Foreign’s interest rate change (e.g., its predictability, dependence, and persistence).
3. agent or market frictions, such as information acquisition and processing costs (which may lead to sluggish expectations adjustment), or transactions costs (which may lead to a failure of the no-arbitrage condition).
4. uninsurable shocks, which might lead to shifts in the utility valuation of exchange rate risk (i.e., the risk premium changes).
5. other direct or indirect bilateral linkages in international goods and asset markets.

---

4 By writing down an asymptotic estimator, we are asserting that the variances and covariances exist and are stationary, when appropriately conditioned.
(e.g., an increase in world oil prices may synchronize interest rate increases across countries to the extent that they share a common exposure to oil prices).

Previous empirical work has attempted to control for the unobserved covariances by conditioning upon an exchange rate regime measure. If a peg is perfectly credible, the unobserved covariances are zero and estimated pass-through will be unity, since changes in the expected rate of depreciation and the risk premium are zero. Under a pure float, the change in the expected rate of depreciation exactly offsets the interest rate differential in order to eliminate arbitrage opportunities. The unobserved covariances equal minus the variance of the Foreign interest rate and pass-through will be zero. Frankel et al. [2004], Shambaugh [2004], and Obstfeld et al. [2004, 2005] test these predictions.

2.2 The nature of foreign interest rate changes and inference

We now focus on how the informational properties of foreign interest rate changes affect the unobserved covariances mentioned earlier, and thus inference regarding interest rate pass-through. As far as we know, such influences have not previously been explored. We consider two properties of foreign interest rate changes in detail: their predictability and their dependence upon non-monetary innovations.

Consider a binary exchange rate regime classification – peg and non-peg. Assume that the peg is imperfectly credible. There is a perceived positive probability of a change in the peg at some future time.\(^5\) Suppose that there are no frictions, no uninsurable shocks, and no other bilateral linkages.\(^6\) Furthermore, suppose that foreign interest rate changes are persistent. Four possible combinations of foreign interest rate properties may then be delineated: (1) unpredictable and independent; (2) predictable and independent; (3) unpredictable and dependent; and (4) predictable and dependent. We now consider

\(^5\)We abstract away from target zone exchange rate regimes. Generally, they will admit a deviation from full interest rate pass-through which is a function of the size of the bands.

\(^6\)If there are frictions, uninsurable shocks, and/or other bilateral linkages, then the interest rate pass-through predictions which follow must be adjusted. For simplicity, we abstract away from these concerns. Later, we will discuss how they might affect estimated interest rate pass-through.
each of these cases, first in the context of a peg and then in the context of a non-peg. In the thought experiment, we assume $\Delta \rho_t = 0 \forall t$. In general, if $\Delta \rho_t$ moves in the same direction as $\nabla [E_t (s_{t+1}) - \bar{s}]$ with a Foreign interest rate change, our baseline predictions are maintained. If they do not move together, then the expected exchange rate depreciation covariance must be larger in magnitude than the risk premium covariance.

How reasonable is such risk premium behavior? Using a Lucas, Jr. [1982] style exchange rate model, Engel [1992] shows that Home currency denominated assets are relatively riskier than Foreign assets if Home’s marginal utility covaries positively with the exchange rate – Home’s marginal utility tends to be high when the exchange rate is high. If the covariance of Home’s marginal utility and the exchange rate rises with increases in the expected rate of depreciation, then the unobserved covariance of risk premium changes with Foreign interest rate changes will have the same sign as the unobserved covariance of the expected rate of depreciation changes with Foreign interest rate changes. The predictions below then unambiguously follow.\(^7\)

### 2.2.1 Pegged exchange rate regime

Suppose that a Foreign interest rate increase occurs at time $t = 0$ which is both unpredictable and independent of other open economy determinants. For an imperfectly credible peg, the market’s expected rate of depreciation will rise ($E_t (s_{t+1}) > s_t = \bar{s}$) at the time the Foreign interest rate increase occurs, even if Home increases their interest rate contemporaneously. This arises from the perceived increased probability of a devaluation.\(^8\) There is thus a positive covariance of the change in the expected rate of depreciation with the Foreign interest rate change, leading to $\hat{\beta} > 1$. There will be more

\(^7\)See Obstfeld and Rogoff [2003] for a new open economy macroeconomic model from which they generate a closed form expression for the risk premium. In their model, Home’s exchange risk premium declines with Home’s monetary variability. Monopoly distortions and sticky prices mean that marginal utility is negatively correlated with the exchange rate. In general, the exact behavior of the exchange risk premium depends upon the specific assumptions of the model. In fact, the effective risk premium may depend upon the investor’s perspective (e.g., Home versus Foreign). We do not address such possibilities.

\(^8\)A forward solution for the expected exchange rate change from the no-arbitrage interest parity condition exhibits this effect. Such a solution implicitly assumes the existence of an infinitely-lived investor.
than full interest rate pass-through. Assuming that the information arrives at time $t = 0$ when the Foreign interest rate change occurs, the pattern of Foreign interest rate changes and unobserved variable changes is:

<table>
<thead>
<tr>
<th></th>
<th>$t = -1$</th>
<th>$t = 0$</th>
<th>$t = 1$</th>
<th>$t = 2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\Delta r^*_t$</td>
<td>0</td>
<td>$+$</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>$\nabla [E_t (s_{t+1}) - \bar{s}]$</td>
<td>0</td>
<td>$+$</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

For concreteness, we have assumed here that expectations are unchanged after the Foreign interest rate change and that the peg is maintained. More generally, as long as the depreciation expectation does not increase by more than the mean expectation given the maintenance of the peg, the above covariance structure will occur.

Suppose that a Foreign interest rate increase occurs at time $t = 1$ which is predictable one-period ahead and independent. For an imperfectly credible peg, the market’s future expected rate of depreciation will rise for the reasons set out above ($E_t (s_{t+1}) > s_t = \bar{s}$) before the interest rate rise occurs ($\Delta r^*_t = 0$). This generates a negative covariance of the difference in the expected rate of depreciation with the Foreign interest rate change, leading to $\hat{\beta} < 1$. There will be less than full interest rate pass-through. Assuming that the information arrives at time $t = 0$ while the Foreign interest rate change occurs at time $t = 1$, the pattern of interest rate changes and unobserved variable changes is:

<table>
<thead>
<tr>
<th></th>
<th>$t = -1$</th>
<th>$t = 0$</th>
<th>$t = 1$</th>
<th>$t = 2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\Delta r^*_t$</td>
<td>0</td>
<td>0</td>
<td>$+$</td>
<td>0</td>
</tr>
<tr>
<td>$\nabla [E_t (s_{t+1}) - \bar{s}]$</td>
<td>0</td>
<td>$+$</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Similar to the first case, we have assumed unchanged expectations and maintenance of the peg.

Suppose that a Foreign interest rate increase occurs at time $t = 0$ which is unpredictable and dependent (e.g., an inflation innovation in Foreign leads to a Foreign interest
rate increase). If the real exchange rate is mean-reverting, Foreign inflation encourages future Foreign depreciation, since the internal purchasing power of Foreign currency is diluted by inflation. In the event that this inflation effect upon the future path of the exchange rate more than offsets any expected appreciation of Foreign’s currency (depreciation of Home’s currency) arising from the peg’s imperfect credibility, the market’s expected rate of Home depreciation will fall \((E_t (s_{t+1}) < s_t = \bar{s})\) at the time the interest rate rise occurs \((\Delta r_t^* > 0)\). This generates a negative covariance of the difference in the expected rate of depreciation with the Foreign interest rate change, leading to \(\hat{\beta} < 1\).

There will be less than full pass-through. Intuitively, the increases in Foreign inflation and Foreign interest rates exert offsetting effects on the exchange rate, such that the pressure for exchange rate adjustment is muted; Home can maintain its peg without fully accommodating Foreign’s interest rate increase. Assuming that the information arrives at time \(t = 0\) when the Foreign interest rate change occurs, the pattern of expected interest rate changes and unobserved variable changes is:

<table>
<thead>
<tr>
<th>(t)</th>
<th>(t = -1)</th>
<th>(t = 0)</th>
<th>(t = 1)</th>
<th>(t = 2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(\Delta r_t^*)</td>
<td>0</td>
<td>+</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>(\nabla [E_t (s_{t+1}) - \bar{s}])</td>
<td>0</td>
<td>−</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Similar to the first case, we have assumed unchanged expectations and maintenance of the peg.

Lastly, suppose that a Foreign interest rate increase occurs at time \(t = 1\) which is predictable one-period ahead and dependent. Similar to the reasoning in the previous case for a dependent Foreign interest rate change, the market’s expected rate of depreciation will fall \((E_t (s_{t+1}) < s_t = \bar{s})\) before the interest rate rise occurs \((\Delta r_t^* = 0)\). This generates a positive covariance of the difference in the expected rate of depreciation with the Foreign interest rate change, leading to \(\hat{\beta} > 1\). There will be more than full interest rate pass-through. Assuming that the information arrives at time \(t = 0\) while the Foreign interest rate change occurs at time \(t = 1\), the pattern of expected interest rate changes and
<table>
<thead>
<tr>
<th>Predictability Property</th>
<th>Dependence Property</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unpredictable</td>
<td>+</td>
</tr>
<tr>
<td>Predictable</td>
<td>-</td>
</tr>
</tbody>
</table>

Table 1: Unobserved Covariance Predictions for the Foreign Interest Rate Change under a Peg

omitted variable changes is:

\[
\Delta r_t^* = 0 \quad 0 \quad + \quad 0
\]

\[
\nabla [E_t (s_{t+1} - \bar{s})] = 0 \quad - \quad 0 \quad 0
\]

Similar to the first case, we have assumed unchanged expectations and maintenance of the peg.

To summarize, relative to the benchmark value of $\hat{\beta} = 1$, the unobserved covariances move estimated interest rate pass-through under a peg in the direction indicated in table 1 for the corresponding Foreign interest rate change properties. In general, Foreign interest rate changes are time-varying mixtures of these properties. Estimated interest rate pass-through will reflect the unobserved covariances associated with the dominant properties of the Foreign interest rate change. In contrast, we predict that estimated interest rate pass-through should be greater than or equal to unity under a peg following an unpredictable and independent change in the Foreign interest rate. We will leverage these insights by estimating pass-through in response to both aggregate federal funds rate changes and an identified unpredictable and independent U.S. interest rate change.

2.2.2 Non-pegged exchange rate regime

Under a non-peg, the expected rate of depreciation will respond one-for-one in the opposite direction to an unpredictable and independent Foreign interest rate increase. This implies that the unobserved covariance is exactly equal to minus the variance of the Foreign interest rate change, leading to $\hat{\beta} = 0$. There will be zero interest rate pass-through,
which is the classic prediction according to the trilemma’s logic.

When Foreign interest rate changes are predictable and independent or unpredictable and dependent, the unobserved covariance will be less negative. In the absence of frictions, a predictable Foreign interest rate change will affect the expected rate of depreciation at the time of information arrival and not at the time of action, attenuating the contemporaneous covariance of exchange rate expectations and Foreign interest rate changes. A Foreign interest rate change which is dependent upon non-monetary innovations (such as a Foreign inflation innovation) will tend to offset the exchange rate consequences of changes in the international interest rate differential, attenuating the unobserved covariance. Bluedorn and Bowdler [2006] demonstrate the empirical relevance of such effects for the realized exchange rate. They show that predictable and dependent U.S. federal funds rate changes lead to attenuation bias in subsequent exchange rate responses. Such attenuation biases will mean that pass-through under non-pegs is positive.

2.3 Previous literature

The first studies to empirically investigate the predictions of the trilemma were Flood and Rose [1995] and Rose [1996]. Flood and Rose [1995] find little relationship between US$ exchange rate volatility and interest rate volatility for eight industrial countries during the period 1960-91. To the extent that capital is mobile in their sample, such an ‘exchange rate disconnect’ runs counter to the trilemma’s predictions. In a panel framework over the period 1967-1992, Rose [1996] finds that exchange rate volatility is weakly related to bilateral monetary divergence and capital mobility, lending some support to the trilemma’s predictions.9

Frankel, Schmukler, and Servén [2004] estimate the conditional response of domestic interest rate levels to foreign interest rate levels over the period 1970-1999. Using a monthly panel dataset, they find that long-run pass-through is virtually identical across

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9 Although he does not pursue it, Rose notes that the trilemma imposes restrictions upon international interest rate differentials through no-arbitrage conditions under capital mobility.
exchange rate regimes and is significantly less than one. This finding holds using both the IMF’s *de jure* classification or Levy-Yeyati and Sturzenegger [2003]’s *de facto* classification. When they condition upon the decade (a proxy for capital mobility), they find that long-run interest rate pass-through is always either greater than one or insignificantly different from one in the 1990s, refuting the relevance of a long-run trilemma.\(^\text{10}\)

Frankel et al. also estimate a series of country/regime-specific error-correction models using data from the 1990s. They find that the short-run interest rate adjustment speed is higher under pegs than non-peggs, providing some support for the trilemma’s logic in the short-run.

Borensztein, Zettelmeyer, and Philippon [2001] argue that common shocks to monetary policy may generate a positive correlation of interest rates across countries that is independent of the bilateral exchange rate regime, thwarting inference regarding the trilemma’s predictions. An even more serious problem arises when the choice of a peg is positively related to the presence of common shocks, as is advocated under optimum currency area criteria. They could lead to an overstatement of the trilemma’s relevance.\(^\text{11}\)

Borensztein et al. [2001] attempt to eliminate the common shocks explanation by using federal funds rate futures changes to isolate U.S. monetary policy shocks over the period 1989-2000. They then estimate the interest rate response to such U.S. policy changes for 8 countries in both static and dynamic country-specific frameworks. Borensztein et al. [2001] find that a comparison of Hong Kong (a fixer) with Singapore (a floater) showed behavior consistent with the trilemma, while a comparison of Argentina (a fixer) with Mexico (a floater) was inconclusive.

Shambaugh [2004] constructs a new *de facto* annual, bilateral exchange rate regime classification for the express purpose of testing the trilemma’s predictions in the post-Bretton Woods (1973-2000) era. If exchange rate expectations reflect actual exchange

\(^{10}\)Frankel et al. acknowledge that there are likely omitted variables, such as monetary policy credibility, trade linkages, and international asset portfolio composition, which might affect this inference.

\(^{11}\)To effectively eliminate this possibility, we need to observe a counterfactual correlation – how does a peg nation’s interest rate under a non-peg regime covary with the base country’s interest rate given an unchanged distribution of common shocks? In practice, this will never be directly observed.
rate behavior, then a *de facto* measure will more accurately capture the credibility of an exchange rate regime. Shambaugh accounts for the possibility of unrelated nonstationarity in interest rates across countries by differencing the domestic (local) and foreign (base) interest rates.\textsuperscript{12} Contrary to the results of Frankel et al. [2004], Shambaugh finds that pegging the exchange rate exerts a significant positive effect upon long-run interest rate pass-through. However, pass-through is below one for pegs and above zero for non-peggs.\textsuperscript{13} When additional controls are introduced (such as financial development, bilateral trade, etcetera), maximum interest rate pass-through is somewhat closer to unity. In country/regime-specific error correction models fitted using monthly data, Shambaugh finds that the adjustment speed is faster for pegs than non-peggs (similar to Frankel et al.). The null of *no* long-run cointegrating relationship is rejected more frequently for pegs than non-peggs, suggesting that pegging entails the sacrifice of some monetary autonomy.

Obstfeld, Shambaugh, and Taylor [2005] consider interest rate pass-through over the Gold Standard (1870-1914), Bretton Woods (1959-1970), and post-Bretton Woods (1973-2000) eras, which all vary in their exchange rate/capital control regime combination.\textsuperscript{14} Obstfeld et al. construct a *de facto* exchange rate regime measure using the methodology described in Shambaugh [2004]. Using empirical models similar to those employed by Shambaugh [2004], they find that when capital is mobile (the Gold Standard era and the 1990s), the choice of a pegged exchange rate regime leads to higher pass-through. When capital is immobile (the Bretton Woods era and the 1970s-1980s), there is no sacrifice of monetary autonomy when a pegged exchange rate regime is implemented. Although the difference in pass-through across peg and non-peg regimes is always positive, the level is below one for pegs and above zero for non-peggs, similar to Shambaugh’s findings.

\textsuperscript{12} If interest rate adjustment plays out within a year, the coefficient on the annual foreign interest rate change is an estimate of long-run pass-through.

\textsuperscript{13} Shambaugh proposes several possible explanations for such a finding, including: common shocks (positive bias for non-peggs), changes in global uncertainty (negative bias for peggs), and violations of the no-arbitrage condition due to transactions costs or target zones (negative bias for peggs).

\textsuperscript{14} Obstfeld, Shambaugh, and Taylor [2004] undertake a similar analysis for the inter-war period.
3 Econometric methodology and data

In this section, we describe the methodology we employ to evaluate interest rate pass-through to the informational properties of foreign interest rates. Specifically, we compare estimated interest rate pass-through for pegs and non-peggs to: an identified, unpredictable and independent U.S. interest rate change; and the aggregate federal funds rate change, which is a mixture of the informational properties outlined in section 2. We divide the discussion into three parts: (1) identification of unpredictable and independent U.S. federal funds rate changes; (2) classification strategies for exchange rate regimes; and (3) specification of the econometric model and the data employed.

3.1 Informational property identification

We follow the procedure outlined by Romer and Romer [2004] to identify unpredictable and independent U.S. federal funds rate changes. Romer and Romer consider U.S. monetary policy over the period 1969-1996. They employ a two-step procedure to isolate unanticipated and exogenous changes in U.S. monetary policy, as captured by the federal funds rate. In the first step, narrative evidence is used to determine the size of the federal funds rate change targeted by the Federal Open Market Committee (FOMC) at their scheduled meetings. In the second step, the targeted federal funds rate change is regressed upon the Federal Reserve’s Greenbook (in-house) forecasts of real output growth, inflation, and unemployment over horizons of up to six months. These represent the central objective variables of the Federal Reserve.\(^{15}\) The real-time forecasts in the second-step regression embody the current information set, allowing for the real-time unanticipated component to be properly isolated.\(^{16}\) Formally, Romer and Romer estimate the following

\(^{15}\)See Board of Governors of the Federal Reserve [2005], or the International Banking Act of 1978 (the Humphrey-Hawkins Act).

\(^{16}\)Employing real-time views/information regarding the potential output gap, Orphanides [2003] finds that Federal Reserve behavior is remarkably stable over time. This implies that the estimation of a single, time-invariant real-time response for the Federal Reserve is an appropriate restriction.
regression:

\[ \Delta f_f^m = \alpha + \beta f_f^{m-1} + \sum_{j=-1}^{2} \gamma_j \hat{\Delta} y^m_{m,j} + \sum_{j=-1}^{2} \lambda_j \left( \hat{\Delta} y^m_{m,j} - \hat{\Delta} y^{m-1,j} \right) \]

\[ + \sum_{j=-1}^{2} \varphi_j \hat{\pi}^m_{m,j} + \sum_{j=-1}^{2} \theta_j \left( \hat{\pi}^m_{m,j} - \hat{\pi}^{m-1,j} \right) + \rho \hat{n}^m_{m,j=0} + \varepsilon_m \]

(2)

where \( m \) indexes FOMC meetings, \( j \) indexes the quarter relative to the current meeting’s quarter, \( ff \) is the target federal funds rate, \( \Delta y \) is real output growth, \( \pi \) is inflation, \( n \) is the unemployment rate, and a hat denotes the real-time forecast for a variable. Greek letters denote population parameters.

The residuals from this regression are the targeted interest rate changes which are orthogonal to the Federal Reserve’s economic forecasts.\(^{17}\) Romer and Romer [2000] demonstrate that the Greenbook forecasts encompass alternative private-sector forecasts. This implies that the residuals here are likely to be unpredictable from the perspective of the market. Furthermore, as the forecasts provide the best real-time estimate of the U.S. economy’s path accounting for any expected non-monetary innovations, the target federal funds rate changes which are orthogonal to the economic forecasts will be largely independent of such non-monetary innovations. This implies that the Romer and Romer two-step monetary policy identification procedure can isolate an interest rate change which is unpredictable and independent. It is thus a prime candidate for use in understanding open economy codependence and the trilemma, as outlined in section 2.2.

We take the meetings-based residuals from regression 2 and cumulate them to give a daily level series. We then average across days within a month to obtain a monthly level. We take the first difference of the natural log of one plus the monthly average of the level series to obtain an empirical counterpart to the Foreign interest rate change, \( \Delta r^*_t \) introduced in section 2.1. The resulting series is thus comparable to the period average observations for Home and Foreign interest rate changes that will be used in other

\(^{17}\)The regression formulation given here assumes that the Federal Reserve only responds to the expected mean values of its objective variables and not to their higher moments.
parts of the empirical work. A similar method is employed to construct a corresponding unpredictable and independent U.S. interest rate change at the annual frequency. For the rest of the paper, we denote the unpredictable and independent U.S. interest rate change by UM (unpredictable monetary policy) and the aggregate federal funds rate by FF.

As mentioned briefly in section 2.2, we require that the foreign interest rate change exhibit some persistent effect upon the foreign interest rate level; foreign interest rate changes are not purely transitory in their level effect. This is equivalent to the requirement that the coefficients in the autoregressive representation of $\Delta r_t^*$ do not sum to negative unity. This condition is satisfied for both UM and FF. An AR(12) model for UM yields a sum of autoregressive coefficients equal to -0.07. Under the assumption that such changes do not affect other federal funds rate components, this implies that 93% of an unpredictable and independent interest rate change is sustained at a one year horizon. If this assumption is relaxed, the degree of persistence at the one year horizon decreases slightly to 74%. A similar AR(12) model for FF suggests that their degree of persistence is 111% at the one year horizon.

### 3.2 Exchange rate regime classification

In investigating the monetary policy trilemma, Shambaugh [2004] constructs a *de facto* binary exchange rate regime classification for a sample of up to 155 countries by analyzing monthly time series data on the exchange rate for the currency of a local country against the currency of a base country.\(^{18}\) This is the exchange rate regime classification that we employ in the main part of our analysis. In section 5, we consider alternative exchange rate regime classifications and provide a discussion of the advantages of Shambaugh’s classification in the context of the objectives of this paper. Shambaugh collected monthly data on exchange rates for each country’s currency versus all major global currencies and any major regional currencies. If a currency stayed within 2 percent of a central value against a major currency throughout a particular year, the major currency

\(^{18}\)For a full explanation of his classification methodology, see Shambaugh [2004].
was defined as the base against which the local currency was pegged. Otherwise, the exchange rate was defined as a non-peg. In total, the exchange rate regime classification generates an unbalanced panel covering 155 countries over the years 1972-2000. To parallel the treatment of pegs, Shambaugh defined a base country for those countries that were classified as non-pegs. The base was either a country of historical importance for the local country, a nearby dominant economy to which other currencies were pegged, or the United States.

Approximately 50% of the country/year observations have the U.S. as the base country. To maximize the sample available for contrasting the interest rate consequences of UM and FF (defined for the U.S.), we reclassify non-U.S. base observations as follows: (1) if a country pegs its currency versus a base currency that is pegged to the US$, then the country in question is classified as a peg versus the US$; (2) if a country pegs its currency versus a currency that is not pegged to the US$, it is classified as a non-peg versus the US$; and (3) if a country’s currency is not pegged when the base is a country other than the U.S., it is treated as a non-peg versus the US$. We denote this binary exchange rate classification variable by $P$, where $P = 1$ for a peg and $P = 0$ for a non-peg.\textsuperscript{19}

### 3.3 Model specification and estimation

In order to measure interest rate pass-through, we first estimate static panel regressions of the following form:

$$\Delta r_{i,t} = (\alpha^P + \beta^P \Delta r^*_{i,t}) \cdot P_{i,t} + (\alpha^{NP} + \beta^{NP} \Delta r^*_{i,t}) \cdot (1 - P_{i,t}) + u_{i,t},$$

where $i$ indexes countries, $t$ indexes time, and all variables are defined as before. Superscripts $P$ and $NP$ denote peg and non-peg regime coefficients. Such a model nests the separate interest rate pass-through equations for pegs and non-pegs analyzed in section 2, derived from CIP as seen in equation (1). It is typical of the literature investigating

\textsuperscript{19}All of our results are qualitatively the same when using the peg and non-peg observations originally identified by Shambaugh [2004].
the trilemma [Shambaugh, 2004, Obstfeld et al., 2004, 2005]. Frankel et al. [2004] additionally condition upon the realized inflation differential in a levels regression, but find that it has virtually no effect upon estimated pass-through. $\beta^P$ measures pass-through under pegs, while $\beta^{NP}$ measures pass-through under pegs. We assess pass-through at two different horizons by estimating equation (3) over monthly and annual data.

It is important to note that when the data occurs with a lower frequency than the FOMC meetings (e.g., annual average interest rates), pass-through from predictable interest rate changes may be over-stated. For example, if a federal funds rate increase in February induces adjustment by a pegging country in January, the change in the annual average interest rate for the peg will exceed the annual average federal funds rate change – pass-through will be biased upwards. Accordingly, if predictable federal funds rate changes occur predominantly within years rather than across years, pass-through at longer horizons is better evaluated using autoregressive distributed lag models fitted using monthly data. This suggests a dynamic specification such as:

$$\Delta r_{i,t} = \left( \alpha^P + \sum_{l=1}^{L} \mu^P_l \Delta r_{i,t-l} + \sum_{l=0}^{L} \beta^P_l \Delta r^*_{i,t-l} \right) \cdot P_{i,t}$$

$$+ \left( \alpha^{NP} + \sum_{l=1}^{L} \mu^{NP}_l \Delta r_{i,t-l} + \sum_{l=0}^{L} \beta^{NP}_l \Delta r^*_{i,t-l} \right) \cdot (1 - P_{i,t}) + u_{i,t}$$

(4)

where the maximum lag $L$ is selected using the Akaike Information Criterion (AIC).\footnote{In almost all cases, the choice of $L$ based on the AIC was the same as the choice based on the Bayes Information Criterion (BIC).}

We use the dynamic models to calculate pass-through estimates from months 0 to 12 in response to a sustained increase in the U.S. interest rate measure.

### 3.3.1 Home interest rates

The Home interest rate is the period average overnight money market rate for a country’s own-currency, taken from the International Monetary Fund’s (IMF) *International Financial Statistics*. As an overnight rate, it is roughly comparable to the U.S. federal
funds rate, which is the basis for the Foreign interest rate measures we employ (described in section 3.1). The overnight money market rate is closely related to domestic monetary policy instruments.

We employ the actual Home interest rate changes in our analysis. Since we wish to understand international monetary codependence, we want to ensure that the Home interest rate measure comprises the entire panoply of predictable/unpredictable and dependent/independent changes. If we only focused upon unpredictable and independent Home interest rate changes, pass-through under both pegs and non-peggs would be zero. By definition, a pegged exchange rate regime engages in monetary policy that is dependent – a peg’s policy is dependent upon the base country’s policy. To capture all possible channels (both direct and indirect) through which codependence with the Foreign interest rate may manifest, we need to consider all components of Home’s interest rate changes. In view of this it would seem natural to control for factors such as Home inflation or Home output growth, or their expected values, which may account for dependent Home interest rate movements. However, the inclusion of such variables in the models would complicate the identification of interest rate pass-through. For example, estimated pass-through depends upon the covariance of the change in the Foreign interest rate and the change in the expected rate of depreciation, but expected depreciation likely affects inflation expectations, and therefore holding the latter constant in a regression would obscure evidence for the predictions set out in section 2.\footnote{The threats to valid inference from omitting terms describing Home macroeconomic conditions arise when such terms correlate with Foreign interest rate changes that are transmitted to Home. Asymptotically, we would expect unpredictable and independent Foreign interest rate changes to be uncorrelated with local macroeconomic conditions, but this need not be true of other components of the federal funds rate. We elaborate upon this in the discussion of our results in section 4.}

Consequently, we estimate pass-through without controlling for macroeconomic variables in the Home country.\footnote{This is common practice in the related literature [Shambaugh, 2004, Obstfeld et al., 2005].}

### 3.3.2 Sample description

The sample consists of country/time observations from years during which restrictions on capital mobility were not in effect, as reported in the IMF’s *Annual Report on Exchange*
**Arrangements and Exchange Restrictions.** We exclude observations associated with capital controls since the predictions set out in section 2 rely on a no-arbitrage condition, which is unlikely to hold when legal restrictions apply to the movement of capital.\(^{23}\) After applying the inclusion criteria, the sample consists of 33 countries (peg observations occur for 7 of these countries) with an average panel time series' length of 116 months. The baseline sample comprises 3824 pairs of monthly interest rate changes, with 10\% of the total relating to pegs. Pegs are a smaller percentage of the baseline sample than that employed by Shambaugh because most of the observations reclassified as described in section 3.2 are non-pegs.\(^{24}\)

We also report results from a trimmed sample which excludes outliers. Outlying observations were identified by Cook’s distance statistic using a threshold of \(4/(N - v - 1)\) where \(N\) is the number of observations and \(v\) the number of slope parameters [Belsey et al., 1980]. We assess the \(N\) and \(v\) terms separately for pegs and non-pegs, in order to account for differences in the residual variance across the two sub-samples.

### 3.3.3 Standard error considerations

As described in section 3.1, UM is a generated regressor, and thus the coefficient standard errors must be adjusted to account for the additional sampling uncertainty. Accordingly, standard errors are calculated via bootstrapping. Specifically, we re-sample the data 1000 times by drawing pairs of observations with replacement, re-estimate the model for each bootstrap sample, and calculate the standard error of the resulting coefficient distribution. The paired bootstrap procedure is robust to heteroscedasticity in the error distribution but not to serial correlation [Brownstone and Valletta, 2001]. As seen in appendix table A.2, we accept the null of serially uncorrelated errors for each regression.

Generated regressors are not an issue when FF is employed. However, to ensure

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\(^{23}\)To ensure that we use only established peg and no capital control observations in the estimation, we also exclude the first observation immediately after the removal of capital controls and the first observation from a peg regime. As Shambaugh [2004] does, we exclude a small number of observations corresponding to hyperinflations or periods of administratively set interest rates. See Shambaugh [2004] for further details. These sample restrictions do not drive our results.

\(^{24}\)A full description of the sample is provided in appendix A.1.
comparability, we calculate bootstrapped standard errors for models where FF is an explanatory variable. Interestingly, the bootstrapped standard errors are nearly identical to classic heteroscedasticity robust standard errors in all cases. Furthermore, the standard errors do not change if we allow for contemporaneous cross-sectional dependence. Overall, our inference is not affected by the exact choice of standard error calculation.

3.3.4 Parameter homogeneity

All of the specifications that we employ assume that the slope coefficients are common across countries.\textsuperscript{25} Such pooling is necessary because some of the individual time series are too short to allow the estimation of country-specific equations. However, unobserved heterogeneity in the slope coefficients can lead to inconsistency.\textsuperscript{26}

For our application, we have explored the issue in some detail. The sample inclusion criteria eliminate heterogeneity along the capital restrictions’ dimension, but are unable to completely account for differences in credibility across pegs. A formal test of the static models cannot reject cross-sectional parameter homogeneity for the UM responses (see appendix table A.2). However, there is some evidence for parameter heterogeneity in the dynamic models and the static models for the FF responses. Homogeneity is a stronger requirement in the more highly parameterized dynamic models. FF responses may exhibit heterogeneity due to the changing composition of its informational content. In these circumstances, we interpret the pass-through estimates as average treatment effects. Then, the key threat to inference is whether or not average pass-through is driven by extreme cases. In section 5, we drop one country at a time from the sample, comparing the estimates across sub-samples. We find that the parameter estimates are stable across sub-samples, meaning that estimated pass-through is likely a good average measure of behavior.

\textsuperscript{25}In general, we also restrict the intercepts to be identical across countries. If we allow for country fixed effects, there is little change in the results.

\textsuperscript{26}Pesaran and Smith [1995] make this point with respect to heterogenous short-run dynamics in a cointegrated panel context.
3.3.5 Misspecification concerns

All of the models that we estimate are in first differences, relating Foreign interest rate changes to Home interest rate changes. For our study, this is a natural specification, since we are concerned with the informational properties of Foreign interest rate changes. Unpredictability and independence are fundamentally properties of changes and not levels. Econometrically, the specification is valid if the interest rate data are stationary, or non-stationary and not cointegrated. However, if they are cointegrated, the models that we estimate are misspecified due to the absence of an error correction term to capture long-run convergence [Hendry, 1995]. In section 5, we address this possibility by augmenting each dynamic model with an error correction term constructed with the Home interest rate and the federal funds rate. This extension does not affect our main conclusions.

4 Empirical results

We now present our empirical results. We first discuss the pass-through estimates from the static models and then continue with pass-through estimates from the dynamic models.

4.1 Pass-through estimates from static models

In table 2, we report within-month pass-through under pegs and non-peg following changes in UM and FF. We also present hypothesis tests for: (1) the null of unit pass-through; (2) the null of unit pass-through under pegs and zero pass-through under non-peg; and (3) the null of equal pass-through under pegs and non-peg against the alternative that peg pass-through is greater than non-peg pass-through.

In response to a 100 basis point (b.p.) increase in FF, within-month pass-through

\footnote{The existence of a cointegrating relationship implies that interest rate series are integrated of order one, (I(1)). Although we do not present formal evidence concerning the time series of the data, our earlier discussion of the persistence properties of interest rate changes indicated that they are stationary, implying that interest rate levels are I(1).}
to a pegged regime is 52 b.p. in the full sample; this is significantly less than unity at the 1% level. The estimate accords with Shambaugh [2004]'s findings for pass-through at an annual horizon. In contrast, an increase in UM is associated with a pass-through of 80 b.p. in the full sample; the hypothesis of unit pass-through cannot be rejected at standard significance levels. This suggests that there is a greater Home contemporaneous response under a peg to an unpredictable and independent base country interest rate change, as predicted in section 2.2.1. Neither the full sample or trimmed sample results show greater than unit pass-through following a UM change, which we argued may occur under imperfect credibility of the peg. We will discuss this point in more detail later.

Pass-through under a non-peg to a UM change is insignificantly different from zero at standard levels, which accords with the baseline prediction in section 2.2.2. In contrast, following a 100 b.p. increase in FF, pass-through is 13 b.p. in the full sample and 11 b.p. after excluding outliers. These responses are small but highly significant. They suggest that non-pegs are not isolated from U.S. federal funds rate changes. As discussed in section 2, one explanation is that changes in the federal funds rate that are dependent on inflation innovations are associated with smaller changes in the expected exchange rate than are changes in UM, such that estimated pass-through is not reduced to zero following a change in FF. Another candidate explanation is that overlapping monetary objectives lead to correlated responses to common innovations (e.g., a world oil price increase affects both Home and Foreign inflation and output expectations). Since their interest rate responses are correlated, the expected rate of depreciation and risk premium do not change, leading to positive estimated pass-through under a non-peg. By eliminating the dependent component of U.S. interest rate changes, UM is less likely to be influenced by common innovations than is FF. Hence, estimated pass-through under a non-peg from UM is closer to zero than it is from FF.

We can thus see that the difference between peg and non-peg pass-through is larger following changes in UM than it is following changes in FF. For example, in the full sample results the difference in pass-through across pegs and non-pegs is more than twice as large.
following a change in UM than following a change in FF (81 b.p. versus 39 b.p.); in the
trimmed sample, it is 1.5 times as large (79 b.p. versus 53 b.p.). The larger peg/non-peg
differences observed following changes in UM are reflected in the joint tests of unit
pass-through under pegs and zero pass-through under non-peggs. This hypothesis cannot
be rejected when UM is the measure of U.S. monetary policy, but is always rejected at
the 1% level when FF is the measure of U.S. monetary policy.

Despite the higher estimated pass-through under a peg from UM, the corresponding
$R^2$ statistics are low and smaller than those for the regressions using FF. There are
two reasons for observing relatively low $R^2$ statistics. Firstly, it is likely the case that
some Home interest rate changes are offsetting responses to domestic concerns which are
unrelated to Foreign interest rate changes. For example, if Home experiences a local
inflation innovation, they will increase their interest rate to prevent their exchange rate
from depreciating, thus maintaining the peg. Such Home interest rate changes need not
be correlated with Foreign interest rate changes, meaning that the explanatory power
of the pass-through regression is low. Secondly, we have argued that when the Foreign
interest rate changes in a predictable fashion, the Home interest rate may respond in
advance. Such temporal decoupling of interest rate changes does not imply that Home is
free from Foreign’s influence in setting monetary policy, but will imply a reduction in the
$R^2$ statistic in regressions that include FF. In regressions that include UM, predictable
Foreign interest rate changes are excluded from the model by construction and a low $R^2$ is
again to be expected. Consequently, full transmission of unpredictable and independent
interest rate changes may be observed, but this need not be associated with a high $R^2$
statistic – the latter is not an unambiguous measure of monetary codependence.\footnote{This logic also suggests that the low $R^2$ statistics associated with the peg samples should not necessarily be taken as a sign that pegging does not entail a loss of monetary autonomy. However, we do not emphasize this point given that our focus is the extent of interest rate transmission.} We also
note that the larger $R^2$ statistics observed for the FF regressions may occur for reasons
related to the dependence of interest rate changes. If dependent interest rate movements
include responses to common innovations, they will have greater overall explanatory

\textit{27}
power for Home interest rate changes than does UM, from which such responses are eliminated.

We present estimated pass-through at the annual frequency in table 3. Our main conclusions from the monthly data are supported by the annual results. Pass-through under a peg is much higher in response to UM changes. Moreover, the difference in pass-through across pegs and non-pegs following a UM change is up to four times that observed following an FF change.

There are two interesting comparisons between the monthly and annual results that we make at this stage, although we defer detailed discussion of them until section 4.2. Firstly, within-year pass-through following a 100 b.p. change in UM is 133 b.p., which accords with our predictions in section 2.2.1 for an imperfectly credible peg. Estimated pass-through is not significantly larger than one; this is likely due to the loss of estimation precision with a smaller sample size. The differences in pass-through at the monthly and annual frequencies suggest that full interest rate adjustment is not instantaneous. Secondly, pass-through from either UM or FF under a non-peg is approximately 0.4 after one year, significant at the 5% level. This finding is contrary to the baseline predictions set out in section 2.

4.2 Pass-through estimates from dynamic models

To evaluate pass-through at horizons between one month and one year, we estimated the dynamic model given by regression (4) in section 3.3. Using the AIC, we selected a maximum lag of 4. Figure 1 shows estimated pass-through from this model out to a 12 month horizon. The lines are the Home interest rate level response to a 100 b.p. increase in either UM or FF, with the associated standard errors. Pass-through for horizon \( h \) is calculated by cumulating the Home interest rate changes generated by the dynamic model up to and including period \( h \). This approach assumes that the initial change in UM or FF is sustained for one year. Since the pass-through estimates for \( h > 0 \) are non-linear functions of the model coefficients, the standard errors that we report are obtained
using the delta method with the bootstrapped coefficient covariance matrix. In table 4, we report the maximum and minimum distances between pass-through under pegs and non-peg. For the horizons at which maxima and minima occur, we report the joint hypothesis tests introduced in tables 2 and 3. We now outline the dynamic results for pegs and non-peg separately, including some discussion of the findings.

4.2.1 Dynamic behavior under a peg

Figure 1 supports a basic finding from the static regressions – at all horizons, pass-through under a peg from UM exceeds that from FF, sometimes by more than a factor of 2. Interest rate pass-through under a peg following a UM change is less than unity on impact and only slightly larger than pass-through following an FF change. One month later, however, pass-through from UM under a peg increases to 1.37 in the case of the full sample and to 1.27 in the case of the trimmed sample; interest rate adjustment in the Home country rapidly agrees with the predictions from section 2.2.1. In the case of the trimmed sample, pass-through estimates under a peg exceed unity by more than one standard error in some cases (e.g., at horizon three). In contrast, pass-through at the 1 month horizon following an FF change is much smaller, at 0.60 in the full sample case and 0.75 after excluding outliers; they are close to the contemporaneous pass-through estimates.

Dynamic pass-through from UM under a peg exhibits two main characteristics: (1) maximum pass-through is slightly delayed; and (2) pass-through declines somewhat after achieving an early maximum but continues to exceed that in response to FF.

A candidate explanation for the delay in maximum pass-through from UM is that there are agent and/or market frictions generating sluggish adjustment in asset markets (see section 2.1). For the thought experiments in sections 2.2.1 and 2.2.2, we assumed that such frictions were negligible. We now delineate three candidate sources of friction.

Firstly, the size of the dependent/independent component of a U.S. interest rate change is only gradually learned by agents. Since the response to a Foreign interest
rate change varies with its degree of dependence or independence, the optimal initial response given some uncertainty over the origins of a Foreign interest rate change may be an average of the responses to independent and dependent changes. Once learning occurs, however, either the full response to an independent Foreign interest rate change can occur (if the Foreign interest rate change was independent), or pass-through can be reduced (if the Foreign interest rate change was dependent). This manifests as more sluggish pass-through from UM, and relatively flat dynamic pass-through from FF, because FF is a mixture of dependent and independent elements.

Secondly, information acquisition and processing costs may result in sluggish adjustment in asset markets. Such channels have recently been articulated for foreign exchange in a series of papers by [Bacchetta and Van Wincoop, 2005, 2006a,b]. Essentially, it is costly to update and process information, leading to sluggish adjustment of asset prices relative to a frictionless market. This shrinks the unobserved covariances of changes in the expected rate of depreciation and the risk premium with Foreign interest rate changes, leading to lower estimated interest rate pass-through. If information processing costs interact with the informational properties of Foreign interest rate changes, then the temporal behavior of pass-through from UM should differ to that from FF.29

Thirdly, the perceived credibility of a peg may vary with the horizon. If a peg is successfully maintained over time in response to a UM change, then its credibility should also increase ceteris paribus. As the peg’s credibility is established, the change in agents’ exchange rate expectations and risk premium should approach zero. This implies that estimated pass-through moves downward from its peak towards unity. Since UM requires a larger peak response than FF (described in section 2.2.1), the establishment of credibility should have a consequently larger effect upon dynamic pass-through from UM than from FF. This is seen in the later downward sloping part of the UM trajectory.30

29 More prosaic frictions, such as transactions costs and sterilizing interventions, may also generate sluggish adjustment.
30 There are other explanations. If the persistence of a Foreign interest rate change diminishes over time, then dynamic pass-through under a peg should decline. The results briefly presented in section 3.1 indicated some evidence of this. However, given that the decline is much less marked in the trimmed sample, we do not explore these possibilities in detail.
Understanding the possible consequences of agent and/or market frictions in asset markets and their empirical significance is an important and promising research topic. Although the candidate explanations we delineated above may account for the dynamic behavior of our empirical results for pegs, we do not attempt to directly measure their relative empirical importance here, leaving such a course to future work.

4.2.2 Dynamic behavior under a non-peg

Dynamic pass-through under a non-peg is approximately zero in response to both UM and FF at short horizons (less than 4 months). As seen in table 4, the differences between pass-through under a peg and under a non-peg are particularly large following a change in UM. Moreover, the joint hypothesis of unit pass-through from UM under a peg and zero pass-through under a non-peg cannot be rejected at the 5% level at horizons of 0-2 months. Four months after a Foreign interest rate change, the level of pass-through under a non-peg rises to approximately 0.4 from UM and 0.3 from FF, both significant at the 5% level.

As mentioned in sections 2.1 and 4.1, exposure to common innovations and overlapping monetary objectives are a candidate source of positive covariance across non-pegs, which we observe in dynamic pass-through from both UM and FF. Other explanations, which do not rely upon common innovations and overlapping monetary objectives, are also consistent with a positive covariance across non-pegs. We consider three in the remainder of this section.

Firstly, international competition for investment funding may result in smaller countries’ market interest rates being pulled towards larger countries’ interest rates (such as the U.S.). In a structural VAR framework, Kim [2001] provides evidence that U.S. interest rate innovations shift world real interest rates, generating positive interest rate pass-through to the non-U.S. G-7 nations.

Secondly, the exchange rate changes caused by Foreign interest rate changes may lead to local inflationary and/or output pressures, depending upon the degree of exchange
rate pass-through to imports and exports. If exchange rate pass-through is substantial, then Home may wish to bring their local interest rate into line with the Foreign interest rate, in order to prevent further exchange rate-induced inflation.

Thirdly, covered interest rate parity dynamically binds all interest rates on similar assets together, even under a non-peg regime. The extent of the restraint is determined by the time horizon of investors and their expectations of future interest rate policy. For example, if Foreign interest rates are expected to be permanently above Home interest rates and investors have an infinite horizon, then Home’s currency will immediately depreciate until it has a value of zero. For the exchange rate to be well-defined, Home and Foreign nominal interest rates must be expected to converge in a limiting sense.

5 Robustness

In this section, we evaluate the robustness of our main results to various perturbations in our baseline estimation methodology. We consider: (1) the use of alternative exchange rate regime classifications; (2) the inclusion of an error correction term in the dynamic models; and (3) the sub-sample stability of estimated pass-through.

5.1 Alternative exchange rate regime classifications

We examine the sensitivity of our results to Shambaugh’s exchange rate regime classification by estimating pass-through under two alternative exchange rate regime classifications: Reinhart and Rogoff [2004] and Levy-Yeyati and Sturzenegger [2003]. Both are de facto exchange rate classification schemes. They differ in what observed exchange rate characteristics are employed to determine the regime that is relevant for a currency at a given time.

Reinhart and Rogoff [2004] incorporate information on the behavior of black market (parallel) exchange rates in order to diagnose peg and non-peg regimes that may be mislabeled using data on only official market exchange rates. For our study, the distinction
between black market and official rates may be irrelevant, since we focus solely on countries without capital restrictions. A more important difference between the Reinhart and Rogoff and Shambaugh codings is that the former leads to a 4-way regime classification: hard pegs, crawling pegs, crawling pegs with bands, and free floats.\textsuperscript{31} Reinhart and Rogoff’s classification scheme therefore allows for more heterogeneity in pass-through across the non-peg sample than does the baseline classification.\textsuperscript{32} Furthermore, the alternative scheme uses a slightly different methodology to that employed by Shambaugh – pegs are determined according to the exchange rate’s odds ratio for being outside a 2% band over a 5 year window.

Levy-Yeyati and Sturzenegger [2003] use evidence from foreign exchange interventions to identify \textit{de facto} pegs. They assume that foreign exchange intervention will be required under a peg, leading to measurable volatility in foreign reserves for a pegged regime. If a currency is officially labeled as a peg while foreign exchange reserves do not show sufficient volatility, they exclude the regime from consideration due to lack of evidence. Levy-Yeyati and Sturzenegger also differentiate between floats and dirty floats, thus allowing for some heterogeneity amongst non-peggers. Although Shambaugh argues that the regime classification that he derives is more suitable for evaluating international interest rate transmission, we consider results based on the alternative coding given its prominence in recent research (e.g., Frankel et al. [2004]).

For comparability, we mapped the respective schemes into a single exchange rate variable which lies between 0 and 1, where 0 denotes a pure float (or the equivalent) and 1 denotes a hard peg (or the equivalent). Intermediate values indicate that the regime was somewhere between a pure float and a hard peg along the exchange rate continuum. Under the Reinhart and Rogoff scheme, \( P \in \{0, 0.33, 0.67, 1\} \). For the Levy-Yeyati and Sturzenegger scheme, \( P \in \{0, 0.5, 1\} \). We then estimated our empirical models using

\textsuperscript{31}An additional fifth category is specified for freely falling exchange rates associated with exchange rate crises or periods in which inflation in the Home country exceeds 40%. We do not include this group in our analysis.

\textsuperscript{32}It should be noted, however, that the crawling peg with bands category is empty in the sample we employ here.
the alternative exchange rate variables. For the dynamic model, the AIC indicated a maximum lag of 4 under both measures. The sample consists only of observations which are designated as having a U.S. base by Shambaugh. This means that there is no reclassification of non-U.S. bases, unlike the sample discussed in section 3.2. Reclassification would be somewhat more involved when there are multiple non-peg categories. When we use the Reinhart and Rogoff measure, the sample consists of 1608 observations (7% are pegs and 53% are crawling pegs). When we use the Levy-Yeyati and Sturzenegger measure, the sample consists of 1403 observations (22% are pegs and 15% are dirty floats). We also created a trimmed sample for each measure, diagnosing outliers by the procedure documented in section 3.3.2.

Figure 2 shows dynamic pass-through following a 100 b.p. increase in either UM or FF under the polar (0 and 1) categories identified by Reinhart and Rogoff. Figure 3 shows the same output under the polar (0 and 1) categories identified by Levy-Yeyati and Sturzenegger. The results using the Reinhart and Rogoff measure largely bear out the conclusions drawn using the benchmark classification. In particular, pass-through under a peg from UM exceeds that from FF at horizons 1 to 12. The unit pass-through hypothesis under a peg cannot be rejected at the 5% level following a UM change, but is always rejected at the 5% level following an FF change. On impact, pass-through is somewhat lower than in the baseline case from either UM or FF. However, the response to UM increases rapidly during the next two months, yielding the hump-shaped dynamic relationship we found previously. In trimmed sample, pass-through from UM exceeds unity at horizon 2. On the whole though, there is less evidence for greater than unit pass-through than in the baseline case. The non-peg responses are similar to those from the benchmark classification.

The results using the Levy-Yeyati and Sturzenegger measure differ across the full and trimmed samples. In the full sample, pass-through under a peg from UM generally

\[\text{pass-through from UM vs. FF under Reinhart and Rogoff measure}\]

\[\text{pass-through from UM vs. FF under Levy-Yeyati and Sturzenegger measure}\]

\[\text{trimmed sample}\]

\[\text{pass-through from UM exceeds unity at horizon 2}\]

\[\text{non-peg responses are similar to those from benchmark classification}\]

\[\text{results using Levy-Yeyati and Sturzenegger measure differ across full and trimmed samples}\]

\[\text{pass-through under a peg from UM generally}\]

---

33 We checked that each country identified by Shambaugh as having a U.S. base is similarly identified under the alternative regime classifications.

34 A separate threshold for the distance statistic was used for each regime type.
exceeds that from FF. It is greater than 1 at horizons 1 and 3. However, the maximum difference between the two is slightly smaller than in the baseline case. In the trimmed sample, the differences in pass-through under a peg from UM versus FF are smaller still; the wedge between pass-through under a peg and under a non-peg is comparable across UM and FF. A possible reason for the lack of robustness using the Levy-Yeyati and Sturzenegger measure is that their coding procedure eliminates many genuine peg and non-peg observations because their associated foreign reserve volatilities do not match those expected under the assumption that reserves are the sole instrument of exchange rate stabilization. Consequently, it is a highly selected sub-sample. If the excluded observations are important in identifying pass-through from UM, their omission will inevitably lead to a weakening of the results. Shambaugh [2004] also finds that estimated pass-through is sensitive to the use of the Levy-Yeyati and Sturzenegger classification. He argues that his de facto classification is more appropriate for evaluating interest rate transmission under various exchange rate regimes. Accordingly, we emphasize our core results ahead of those presented in the lower panel of figure 3.

5.2 Error correction in the dynamic models

We now compare pass-through in response to UM and FF using error correction models. In section 3.3.5, we argued that the first difference specification is the natural framework within which to evaluate interest rate pass-through from UM, since unpredictability and independence are fundamentally properties of interest rate changes and not levels. However, if there exists a long-run levels relationship between Home and Foreign interest rates, the lagged deviation of that relationship is an omitted variable from the regression in differences. If such error correction effects are important, their omission may lead to bias in estimated interest rate pass-through.

We explored this possibility using monthly data to estimate the static levels relationship between Home interest rates and the U.S. federal funds rate. The relationship is allowed to differ across exchange rate regimes, but is constrained to be identical across
countries within regime; the long-run cointegrating relationship of interest rates is the same within regime type. We allowed intercepts in the levels relationship to vary across both countries and regime type. The estimated slope coefficient was 0.52 for pegs and 0.42 for non-peg, both significant at the 1% level. We defined an error correction term (denoted \( ec \)) as the residual from a pooled levels regression. We then added the first lags of the error correction terms to the dynamic model expressed in regression (4), allowing for the \( ec \) effect to vary by regime. To conserve space, we do not analyze the integration and cointegration properties of the data in detail. However, if the lagged error correction terms are significant when added to the model in first differences, then the levels equations from which they are derived are cointegrating relations [Hendry, 1995]. Moreover, the interest rate series are I(1) or at least approximately I(1) over the sample.

We used the same error correction term in the dynamic pass-through regressions with either UM or FF. This implies that all federal funds rate changes exert the same effect on Home interest rates in the long-run, since the long-run equilibrium federal funds rate should not be characterized by unpredictable and/or independent movements. Such interest rate changes can be distinguished in the short-run and we therefore allowed them to generate different levels of pass-through via the distributed lag terms in the U.S. interest rate measure. The error correction augmented-results for dynamic pass-through under a peg from UM and FF are given below. Bootstrapped standard errors are in parentheses underneath the estimated coefficients.

\[
\Delta r_t = -0.001 - 0.122 \Delta r_{i,t-1} + 0.020 \Delta r_{i,t-2} + 0.111 \Delta r_{i,t-3} - 0.176 \Delta r_{i,t-4} + 0.697 \Delta U M_{i,t} \\
+ 0.789 \Delta U M_{i,t-1} - 0.441 \Delta U M_{i,t-2} + 0.088 \Delta U M_{i,t-3} - 0.272 \Delta U M_{i,t-4} - 0.172 ec_{i,t-1} \quad (5)
\]

\[N = 339 \quad R^2 = 0.24 \quad AR(1) = -0.82 \quad (p-val: 0.41)\]

\(^{35}\)These estimates are slightly lower than the Shambaugh [2004]’s median estimates using individual country models.
\[
\Delta r_t = -0.0002 - 0.181\Delta r_{i,t-1} + 0.006\Delta r_{i,t-2} + 0.125\Delta r_{i,t-3} - 0.160\Delta r_{i,t-4} + 0.551\Delta FF_{i,t} \\
+0.152\Delta FF_{i,t-1} - 0.010\Delta FF_{i,t-2} + 0.153\Delta FF_{i,t-3} - 0.019\Delta FF_{i,t-4} - 0.158\epsilon c_{i,t-1} \quad (6)
\]

\[N = 339 \quad R^2 = 0.27 \quad AR(1) = -0.79 \quad (p-val: 0.43)\]

The error correction terms are negatively signed and significant for both UM and FF. When interest rates in the U.S. exceed those in the Home country (\(ec\) is negative), there is upward adjustment of Home interest rates, consistent with cointegration between the two series. Crucially, conditioning on the error correction term does not alter our central finding that pass-through under pegs is much larger following UM changes than following FF changes. For example, \textit{ceteris paribus}, contemporaneous pass-through following a 100 b.p. UM increase is 70 b.p.; one month later, it is 145 b.p. The corresponding estimates following an FF change are respectively 55 and 67 b.p.\footnote{These calculations account for pass-through that occurs via both the short-run adjustment terms and the error correction term.} The results suggest that attenuation arising from predictable and dependent changes in the federal funds rate is actually slightly greater than those obtained in section 4.2.1 when we did not control for error correction terms. A potential reason for the stability of the results even after controlling for error correction effects is that any initial disequilibrium in interest rate levels is limited because the sample includes only pegged regimes that have been instituted for at least one month. To the extent that the interest rate levels have adjusted to equilibrium by the start of the sample, pass-through estimates from the first difference specification will not be distorted. This is what we observe.

To conserve space, we highlight only a few points from the dynamic models for non-peggs which include an error correction term.\footnote{Full details are available upon request.} Firstly, the error correction terms are negatively signed and significant at the 1% level, either when UM or FF are the U.S. interest rate measure in the short-run dynamics. The implied long-run positive pass-through under a non-peg is consistent with the significant 12 month responses discussed in
section 4.2.2. Secondly, pass-through at horizons 0 and 1 was -0.025 and 0.15 respectively following a change in UM, while it was 0.06 and 0.19 respectively following a change in FF. The estimates are similar to pass-through estimated using the first difference specification without an error correction term.

5.3 Sub-sample stability

We now evaluate the robustness of our results to the cross-country parameter homogeneity assumption discussed in section 3.3.4. Specifically, we re-estimated each of the baseline static and dynamic models over the set of sub-samples where one country at a time is omitted. If interest rate adjustment in a particular country is exceptional and drives our baseline results, then estimated pass-through across the sub-samples will be characterized by some instability. We briefly summarize our findings.38

For the set of sub-samples, median within-month static pass-through under a peg was 0.81 following a change in UM and 0.52 following a change in FF. Median static pass-through estimate under a non-peg was -.01 and 0.13 respectively. All of the estimates are extremely close to the full sample results reported in table 2. Furthermore, in almost all sub-samples, the evidence for higher pass-through from UM under a peg and for larger differences between pass-through from UM under a peg and under a non-peg, was preserved. The sub-sample where Kuwait was omitted was exceptional. Specifically, pass-through under a peg was 0.21 following a UM change and 0.67 following an FF change. However, some investigation revealed that this instability relates to the exact timing of pass-through, not its size. When Kuwait is omitted from the annual sample, within-year pass-through under a peg is 1.49 from UM and 0.65 from FF. Moreover, the difference between pass-through under a peg and a non-peg is 111 b.p. from UM and 23 b.p. from FF. When we re-estimated the dynamic models after omitting Kuwait, pass-through under a peg from UM is 0.05 on impact and 2.32 at the 1 month horizon. Such extensive pass-through accords with our predictions. There is a short delay in pass-through when

---

38 Full details are available upon request.
Kuwait is omitted from the sample, leading to some sensitivity of the static monthly results.

The remaining sub-sample results confirm the stability of the baseline full sample results. Median within-year pass-through under a peg is 1.32 from UM (ranging from 1.27 to 1.49) and 0.63 from FF (ranging from 0.55 to 0.88). The corresponding statistics under a non-peg are 0.38 (ranging from 0.32 to 0.45) and 0.42 (ranging from 0.25 to 0.45). Median dynamic pass-through under a peg at the 1 month horizon was 1.40 from UM (ranging from 0.91 to 2.32) and 0.60 from FF (ranging from 0.50 to 1.30). The corresponding non-peg statistics were 0.13 (ranging from 0.05 to 0.17) and 0.16 (ranging from 0.14 to 0.18). Overall, our main findings are robust.

6 Conclusion

We argued that the informational properties of Foreign interest rate changes are important in understanding their international transmission to Home’s interest rate, conditional upon their bilateral exchange rate regime. When an imperfectly credible peg is predictable and independent or unpredictable and dependent, Foreign interest rate changes will lead to less than unit estimated interest rate pass-through, because their covariance with unobserved changes in the expected rate of depreciation and risk premium will be negative. In contrast, unpredictable and independent or predictable and dependent interest rate changes will generate positive covariances with the unobserved variables, leading to estimated pass-through under a peg exceeding unity. Our results indicated that pass-through under a peg following an aggregate U.S. federal funds rate change was less than unity at all horizons out to one year. This is evidence that aggregate U.S. federal funds rate changes represent informational mixtures which are dominated by predictable/independent and unpredictable/dependent components. On the other hand, identified unpredictable and independent federal funds rate changes yielded pass-through under a peg that is close to unity on impact and which exceeds unity one month later
(and at all other horizons in the year following a change).

There has recently been much debate about the relevance of the open economy trilemma (see section 2.3). Our results indicate that the difference in interest rate passthrough across pegs and non-peggs is twice as large following an unpredictable and independent change in the federal funds rate as opposed to a change in the aggregate federal funds rate. Consequently, the support for the open economy trilemma’s logic is even stronger when Foreign interest rate changes are unpredictable and independent. Under capital mobility, an imperfectly credible pegged exchange rate regime responds more than one-for-one to unpredictable and independent Foreign interest rate changes.

Our results have implications for future theoretical and empirical work. They indicate that the informational properties of interest rate changes should be included in any empirical evaluation of their international transmission. We focused on how the predictability and dependence properties of Foreign interest rate changes interact with the bilateral exchange rate regime, finding them to be important determinants. In further extensions, researchers could consider additional properties, such as the sign of Foreign interest rate changes. Our results also highlight possible avenues for theoretical work. Understanding open economy codependence will require an understanding of how the informational properties of interest rate changes interact with their transmission. Such concerns might be integrated into recent models of sluggish adjustment which embed learning and information acquisition and processing costs.
References


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Notes: Pass-through statistics measure the within month response of foreign interest rates to a 1 percentage point increase in (i) UM, the unpredictable and independent US interest rate measure; (ii) FF, the aggregate federal funds rate. Standard errors are given in parentheses. * and ** denote significance at the 5% and 1% levels respectively. All standard errors and hypothesis tests are based on bootstrapped covariance matrices obtained using 1000 replications.
### Table 3:
Static Foreign Interest Rate Pass-through (Annual Frequency)

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Notes: Pass-through statistics measure the within year response of foreign interest rates to a 1 percentage point increase in (i) UM, the unpredictable and independent US interest rate measure; (ii) FF, the aggregate federal funds rate. Standard errors are given in parentheses. * and ** denote significance at the 5% and 1% levels respectively. All standard errors and hypothesis tests are based on bootstrapped covariance matrices obtained using 1000 replications.
Table 4:
Differences in Dynamic Interest Rate Pass-through Across Pegs and Non-pegs

<table>
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<tr>
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<th>Joint tests (p-value)</th>
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<tr>
<td></td>
<td>IRPT\textsuperscript{P} - IRPT\textsuperscript{NP}</td>
<td>Timing (months)</td>
<td>H\textsubscript{0}: IRPT\textsuperscript{P} = I, IRPT\textsuperscript{NP} = 0</td>
<td>H\textsubscript{0}: IRPT\textsuperscript{P} = IRPT\textsuperscript{NP}</td>
<td>H\textsubscript{A}: IRPT\textsuperscript{P} &gt; IRPT\textsuperscript{NP}</td>
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<tr>
<td><strong>UM</strong></td>
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**Excluding outliers**

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<td>IRPT\textsuperscript{P} - IRPT\textsuperscript{NP}</td>
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Notes: IRPT\textsuperscript{P} is interest rate pass-through under pegs and IRPT\textsuperscript{NP} is interest rate pass-through under non-pegs. Timing refers to the number of months after a change in monetary policy at which the difference in pass-through under pegs and non-pegs is observed. Standard errors are based on delta method expansions of bootstrapped covariance matrices obtained using 1000 replications. * and ** denote significance at the 5% and 1% levels respectively. Sample size and R\textsuperscript{2} statistics for UM (FF) are as follows. Full sample, peg: N=339 (339), R\textsuperscript{2}=0.20 (0.22). Full sample, non-peg: N=3308 (3308), R\textsuperscript{2}= 0.11 (0.12). Excl. outliers, peg: N= 326 (328), R\textsuperscript{2} =0.1 (0.25). Excl. outliers, non-peg: N=3187 (3176), R\textsuperscript{2}=0.03 (0.04).
**Figure 1:**

**Dynamic Foreign Interest Rate Pass-through**

Shambaugh Exchange Rate Regime Classification

Note: Experiment is a 1 percentage point permanent increase in US interest rate measure. Responses represent level change in foreign interest rate. Standard errors are calculated via delta–method using bootstrapped coefficient standard errors.
Figure 2:

**Dynamic Foreign Interest Rate Pass-through**
Reinhart & Rogoff Exchange Rate Regime Classification

Note: Experiment is a 1 percentage point permanent increase in US interest rate measure. Responses represent level change in foreign interest rate. Standard errors are calculated via delta–method using bootstrapped coefficient standard errors.
Figure 3:

Dynamic Foreign Interest Rate Pass–through
Levy–Yeyati & Sturzenegger Exchange Rate Regime Classification

Note: Experiment is a 1 percentage point permanent increase in US interest rate measure. Responses represent level change in foreign interest rate. Standard errors are calculated via delta–method using bootstrapped coefficient standard errors.
Table A.1:
Sample Composition

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<tr>
<th>Country</th>
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<th>Starts month</th>
<th>Ends year</th>
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Dates indicate the length of each country time series included in the sample used for the static monthly regressions (dynamic models use slightly shorter series due to the lagging of variables). In most instances, the time series used for the static annual regressions are based on the years spanned by the monthly data.
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<th>Model Diagnostics</th>
<th>Autocorrelation tests</th>
<th>Parameter homogeneity tests</th>
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AR(1) tests the null of no first order error autocorrelation and AR(2) the null of no second order error autocorrelation. The parameter homogeneity tests refer to the null of equality of all slope coefficients under a peg or non-peg. All tests are based on regressions that use Shambaugh’s exchange rate regime classification. The test statistics for parameter homogeneity are calculated using covariances obtained from 100 bootstrap replications. All p-values are calculated using the asymptotic distributions for the test statistics.