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The Empirics of International Monetary Transmission: Identification and the Impossible Trinity

The transmission of monetary policy across borders is central to many open economy models. Research has tried to evaluate the "impossible trinity" through estimating international interest rate linkages under alternative exchange rate regimes using realized base country interest rates. Such interest rates include anticipated and endogenous elements, which need not propagate internationally. We compare international interest rate responses under pegged and non-pegged regimes to identified, unanticipated, and exogenous U.S. interest rate changes and realized U.S. interest rate changes. We find important differences in estimated transmission from the two sets of measures—identified interest rate changes demonstrate a greater concordance with the impossible trinity than realized rate changes.

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THE IDEA THAT monetary policy autonomy depends on the choice of exchange rate regime has long been prominent in international macroeconomics. According to the "impossible trinity" or open economy trilemma, when capital is mobile a country that maintains a fixed (or pegged) exchange rate against a

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foreign currency must implement the foreign interest rate. In order to restore autonomy, the country in question must either abandon its exchange rate target and allow the currency to float, or implement restrictions on capital mobility. The logic behind this trade-off features in a number of well-known macroeconomic models, including the textbook Mundell–Fleming model of fiscal and monetary policy in open economies and the family of new, open economy macroeconomic models pioneered by Obstfeld and Rogoff (1995).

A large empirical literature addresses the testable implications of the open economy trilemma. Flood and Rose (1995) and Rose (1996) examine trade-offs between exchange rate volatility and measures of monetary divergence. They find either no support or weak support for the trade-offs implied by the trilemma. More recently, Miniane and Rogers (2007) identify U.S. interest rate shocks from structural vector autoregressions (SVARs) and estimate their transmission to a range of foreign interest rates. Consistent with the trilemma logic, the transmission to pegged exchange rate regimes is stronger, although the effect is not significant at conventional levels. In other recent work, the trilemma has been evaluated through a comparison of interest rate pass-through, defined as the response of one country's interest rate (e.g., Home) to changes in another country's interest rate (e.g., Foreign) across peg and non-peg regimes.[1] Recent examples include *inter alia* Frankel, Schmukler, and Servén (2004), Shambaugh (2004), and Obstfeld, Shambaugh, and Taylor (2004, 2005).

A key question is whether interest rate pass-through is systematically higher under pegs than non-pegs. In addressing this issue, Shambaugh (2004) emphasizes comparisons based upon *de facto* as opposed to *de jure* exchange rate regime classifications. He reports evidence that a peg imposes a constraint on monetary policy in the form of higher interest rate pass-through. By contrast, Frankel et al. (2004), using different exchange rate regime classifications, find that full interest rate pass-through cannot be rejected in many cases, even for non-pegs.

While the results obtained using *de facto* regime classifications suggest that exchange rate pegs are associated with constraints on monetary policy, the stronger predictions from the simplest theory of the trilemma, namely, that when capital is mobile pass-through to pegs is unity and pass-through to pure floats (non-pegs) is zero, are generally rejected. The difference in interest rate pass-through across pegs and non-pegs, which measures the constraint from pegging, is significantly smaller than this theoretical benchmark. A number of explanations for deviations from unit pass-through to pegs and zero pass-through to non-pegs have been proposed. Obstfeld et al. (2005) show that narrow target zones for exchange rates (broadly classified as pegs) can induce less than unit pass-through. At the other end of the spectrum, "fear of floating" may partially constrain exchange rates under non-pegs, such that pass-through exceeds zero.

In this paper, we provide a different perspective. We argue that the appropriate interpretation of interest rate pass-through requires an understanding of the nature

1. Throughout the rest of the paper, we use Home to refer to the country whose interest rate is responding and Foreign to refer to the country that originates an interest rate change.

of foreign interest rate changes. Foreign (base country) interest rate changes that are either anticipated or endogenous to foreign inflation will propagate differently than will foreign rate changes that are *both* unanticipated and exogenous. In our empirical analysis, we provide evidence that isolating unanticipated and exogenous U.S. interest rate changes yields pass-through estimates closer to the theoretical benchmarks. Associated with these findings, there is an increase in the pass-through differential between pegs and non-pegs. However, the uncertainty attached to estimates of interest rate pass-through from unanticipated and exogenous interest rate changes is such that equal levels of pass-through from identified and realized U.S. interest rate changes cannot be ruled out with high levels of confidence.

How might the identification of foreign interest rate changes matter? In practice, interest rate changes are usually endogenous responses to macroeconomic conditions, which may influence their international transmission. For example, when a foreign interest rate rise is a response to foreign inflation or expected foreign inflation, the pressure for an appreciation of the foreign currency (from the interest rate differential) may be partly offset by pressure for depreciation, in order to stabilize the real exchange rate in the face of the inflation shock. If the pressures for exchange rate adjustment are muted, countries that peg to a foreign currency will be able to offset them *without* fully accommodating the rise in foreign interest rates—pass-through will be less than unity even when capital is mobile and the peg is perfectly credible.

A similar effect can arise via a different channel if foreign interest rate changes are anticipated. Suppose that foreign interest rate increases are responses to fundamentals that are unlikely to attenuate exchange rate pressures (e.g., demand-driven export growth) but that such policy moves are predictable. Substitution toward assets denominated in the foreign currency may then occur prior to the actual foreign interest rate increases, at the time at which information on fundamentals becomes available. To stabilize the exchange rate against such currency flows, countries that peg to the foreign currency must accommodate the foreign interest rate rise *in advance* of its implementation. Interest rate linkages estimated from regressions of domestic interest rates on current and past foreign interest rate movements will then be less than unity, even though the maintenance of a peg does constrain domestic monetary policy.

In Section 1, we develop these arguments, describing how the nature of foreign interest rate changes may affect pass-through to pegs and non-pegs. Analytically, it turns out that the interest rate pass-through differential between pegs and non-pegs may either increase or decrease, depending upon the nature of foreign interest rate changes. The point we emphasize is that following actual foreign interest rate changes, pass-through to pegs may be less than unity and pass-through to non-pegs greater than zero. Consequently, the constraint on monetary policy from pegging can be underestimated.

Our main contribution is thus to estimate interest rate pass-through to pegs and non-pegs under capital mobility, after controlling for anticipated and endogenous movements in foreign monetary policy. Taking the United States as the foreign country, we estimate and compare interest rate responses to unanticipated and exogenous U.S. interest rate changes identified via two different approaches: an extension of the procedure pioneered by Romer and Romer (2004) and a Kuttner (2001) style procedure. Romer and Romer's approach allows us to isolate the component of intended U.S. federal funds rate changes that is unrelated to the Federal Reserve Greenbook (in-house) forecasts of U.S. output growth, inflation, and unemployment. Kuttner's approach allows us to calculate the unanticipated component of an intended federal funds rate change using federal funds futures price changes around Federal Open Market Committee (FOMC) meetings.

Our results indicate that within-month pass-through from an unanticipated and exogenous U.S. interest rate change (based upon the extension of Romer and Romer 2004) is 0.78 for pegs and 0.08 for non-pegs. The corresponding estimates using realized federal funds rate changes, which mix identified policy changes with those that are partly anticipated and endogenous, are 0.52 and 0.16. The identification of U.S. interest rate changes that are more plausibly unanticipated and exogenous increases the distance between peg and non-peg estimates of within-month pass-through from 0.36 to 0.70. In a sample of end-of-day interest rates, we find that day-to-day pass-through from an identified U.S. interest rate change ranges from 0.69 to 1.01 for pegs and 0.10 to 0.44 for non-pegs, depending upon the identification procedure employed. By contrast, estimated day-to-day pass-through from realized federal funds rate changes is 0.20 for pegs and −0.03 for non-pegs.

The uncertainty associated with our estimates is large enough that we are unable to reject the equality of pass-through from identified versus realized Foreign interest rate changes. In particular, the 68% confidence interval (CI) for the difference between peg and non-peg within-month pass-through from identified policy changes is [0.45,0.95] and the 95% CI is [0.20,1.20]. Although the 68% CI excludes the differential estimated using realized federal funds rate changes (in fact, the 68% CIs for the two estimates do not overlap), the 95% CI includes it. The uncertainty associated with the day-to-day pass-through estimates is larger still. This suggests that identical interest rate transmission across anticipated/unanticipated and endogenous/exogenous U.S. interest rate changes cannot be ruled out.

The paper proceeds as follows. In Section 1, we discuss expected levels of interest rate pass-through when foreign interest rate changes can be distinguished according to their predictability and endogeneity. In Section 2, we describe our econometric methodology and identification approaches. Section 3 contains our baseline results, and in Section 4 we consider the robustness of these results to several important extensions of our econometric procedures. We conclude in Section 5 with a summary of our main arguments and findings.

1. INTEREST RATE PASS-THROUGH

In this section, we show how an international no-arbitrage condition is related to a standard interest rate pass-through regression. For the case of perfect capital mobility, we consider how estimated pass-through to imperfectly credible pegs and non-pegs varies in response to foreign interest rate changes that differ according to their predictability and endogeneity. The conclusion that we emphasize is that estimated interest rate transmission from realized interest rate changes may *understate* the differences between pegs and non-pegs.

1.1 International No-Arbitrage Conditions and Interest Rates

Under capital mobility, international no-arbitrage conditions are expected to hold. The standard covered interest rate parity (CIP) condition between similar Home and Foreign fixed-income assets is

$$(1 + R_t) = \left(1 + R_t^*\right)\left(\frac{F_t}{S_t}\right)$$
$$\Rightarrow r_t = r_t^* + f_t - s_t,$$

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. Foreign variables are indicated by an asterisk. Suppose that the logarithm of the forward exchange rate is defined as

$$f_t = E_t\left(s_{t+1}\right) + \rho_t,$$

where ρ denotes the exchange rate risk premium associated with fixing a future exchange rate trade of Foreign currency for Home currency today.[2]

Substituting this expression into the CIP condition, we have that

$$\Delta r_t = \Delta r_t^* + \Delta\left[E_t\left(s_{t+1}\right) - s_t\right] + \Delta\rho_t,$$

where the differencing is also done with respect to information sets.[3] This leads naturally to the following regression specification:

$$\begin{aligned} \Delta r_t &= \alpha + \beta\Delta r_t^* + u_t, \\ \text{where } \alpha + u_t &= \Delta\left[E_t\left(s_{t+1}\right) - s_t\right] + \Delta\rho_t. \end{aligned} \tag{1}$$

The slope coefficient β is defined to be interest rate pass-through; it is a measure of monetary codependence. This measure of pass-through is analyzed by Borensztein, Zettelmeyer, and Philippon (2001), Shambaugh (2004), and Obstfeld et al. (2004, 2005). Frankel et al. (2004) evaluate the trilemma using a regression in interest rate

2. 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, ρ 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).

3. Specifically, the difference operator is $\Delta[E_t(s_{t+1}) - s_t] = [E_t(s_{t+1}) - s_t] - [E_{t-1}(s_t) - s_{t-1}]$.

levels, obtaining a related pass-through measure. In Section 2.3, we discuss how inference may be influenced by such specification choices. 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 $\tilde{x}_t = x_t - \bar{x}$. The asymptotic OLS estimate of β is given by

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

A natural benchmark value for $\hat{\beta}$ is thus unity. If $\hat{\beta}$ is different from unity, then (assuming that the CIP condition holds) it must be due to the presence of non-zero covariances of Foreign interest rate changes with either the change 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.

Previous empirical work has implicitly focused on the link between the unobserved covariances and the exchange rate regime. In the case of a perfectly credible peg, the unobserved covariances are zero because changes in the expected rate of depreciation and the risk premium are always equal to zero. Estimated pass-through will then be unity.[4] In contrast, under a pure float without other economic interdependencies, 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.

In practice, pegged exchange rate regimes may not be perfectly credible. There is then the possibility that exchange rate expectations adjust in response to foreign interest rate changes (e.g., due to a change in the probability that a peg is abandoned). In the remainder of this section, we explore how the predictability and endogeneity of foreign interest rate changes may affect estimated pass-through. Our exploration of foreign interest rate endogeneity in this context is narrow. We consider how non-monetary innovations that raise foreign inflation may impact pass-through. Other aspects of interest rate endogeneity may lead to different expected levels of pass-through, and whether those effects dominate the ones we describe is an empirical matter.

While the properties of foreign interest rate changes are our focus, we stress that other factors may influence the unobserved covariances. Examples include frictions to exchange rate and expectations adjustment (e.g., transactions costs and information acquisition/processing costs), changes to the risk premium from the utility valuation of risk, and linkages related to goods and asset markets. The latter may manifest as common shocks (e.g., an increase in world oil prices may synchronize interest rate increases across countries) and/or interdependence (e.g., an inflation innovation in

4. This is slightly oversimplified. More exactly, interest rate pass-through will be *nearest* unity under a perfectly credible peg. It can be shown that the Jensen inequality component of the exchange rate risk premium described by Engel (1992) can generate negative pass-through bias even under a credible peg.

one country leads to a terms-of-trade change for its trading partners). Throughout our discussion, we allude to how such factors may influence pass-through.

1.2 The Nature of Foreign Interest Rate Changes and Inference

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. Suppose that foreign interest rate changes exert an effect on the foreign interest rate level that is at least partially persistent. In the following thought experiments, we assume $\Delta\rho_t = 0 \forall t$. In general, if $\Delta\rho_t$ moves in the same direction as $\Delta[E_t(s_{t+1}) - \bar{s}]$ following a Foreign interest rate change, our baseline predictions are maintained.

How reasonable is such risk premium behavior? Using a Lucas (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 (e.g., consumption falls are associated with exchange rate depreciations). 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 with Foreign interest rate changes. The predictions below then unambiguously follow.

The logic here is also applicable to the case where there is a difference in the default risk associated with the underlying assets, which may be confounded with the usual exchange rate risk premium. If Home's marginal utility covaries positively with the risk differential and this in turn covaries positively with the exchange rate, then the below predictions again follow. For our application, we carefully match overnight interest rate series across countries. Any variation in risk differentials for the underlying assets should be minimal, given the short maturity of the assets.

Pegged exchange rate regimes. Suppose that a Foreign interest rate increase occurs at time t that is both unanticipated and exogenous to non-monetary innovations. For an imperfectly credible peg, interest rate pass-through from such a change will be *greater* than unity. 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 interest rates contemporaneously by an identical amount. The perceived positive probability of devaluation and the pressure for a larger exchange rate adjustment interact to give this result. There is thus a *positive* covariance of the change in the expected rate of depreciation with the Foreign interest rate change, leading to $\hat{\beta} > 1$. Home must compensate investors for any expected devaluation following the change in fundamentals. For concreteness, we have assumed here that the regime is maintained. We carry this assumption throughout to simplify our discussion.

Suppose that a Foreign interest rate increase occurs at time t that is anticipated one period ahead and exogenous (e.g., a preannounced change in the composition of the FOMC's voting membership that represents a shift in central bank preferences). For an imperfectly credible peg, interest rate pass-through from such a change will be *less* than unity. The market's future expected rate of depreciation will *rise* for the reasons set out above ($E_{t-1}(s_t) > s_{t-1} = \bar{s}$) *before* the interest rate rise occurs ($\Delta r^*_{t-1} = 0$). This generates a *negative* covariance of the difference in the expected rate of depreciation with the Foreign interest rate change, leading to $\hat{\beta} < 1$. Home raises interest rates before Foreign to compensate investors for the increased expected depreciation rate. Such preemptive action weakens the empirical correlation between the two interest rate series.

Suppose that a Foreign interest rate increase occurs at time t that is unanticipated and endogenous to a Foreign inflation innovation. For an imperfectly credible peg, interest rate pass-through from such a change will be *less* than unity. If the real exchange rate is mean reverting, Foreign inflation encourages Foreign depreciation, since the internal purchasing power of Foreign currency is diluted. If the purchasing power dilution countervails any expected appreciation of Foreign's currency from the Foreign interest rate increase, 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 $\hat{\beta} < 1$. 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.

Finally, suppose that a Foreign interest rate increase occurs at time $t = 1$ that is anticipated one period ahead and endogenous to a Foreign inflation innovation. For an imperfectly credible peg, interest rate pass-through from such a change will be *greater* than unity. Similar to the reasoning in the previous case for an endogenous Foreign interest rate change, the market's expected rate of depreciation will *fall* ($E_{t-1}(s_t) < s_{t-1} = \bar{s}$) *before* the interest rate rise occurs ($\Delta r^*_{t-1} = 0$). This generates a *positive* covariance of the difference in the expected rate of depreciation with the Foreign interest rate change, leading to $\hat{\beta} > 1$. See Table 1 for a summary of the signs predicted for the unobserved covariances under the above Foreign interest rate taxonomy.

As noted earlier, other aspects of endogenous Foreign monetary policy may generate different effects on pass-through (e.g., a positive Foreign export demand shock). Our purpose here is not to be exhaustive in our consideration of endogenous interest rate changes but to propose a possible mechanism by which interest rate pass-through to pegs may be underestimated using actual Foreign interest rate changes. This motivates the empirical work that we undertake. That said, how reasonable is the

TABLE 1

Unobserved Covariance Sign Predictions for the Foreign Interest Rate Change under a Peg

	Endogeneity property	
Predictability property	Exogenous	Endogenous
Unanticipated	+	−
Anticipated	−	+

assumption that endogenous Foreign interest rate increases are correlated with Foreign depreciations?

Engel and Frankel (1984) demonstrate how an interest rate rise may be associated with a Foreign depreciation when the Foreign interest rate rise reflects an increase in the inflation premium (due to unintended money growth in their paper). More recently, Drazen and Hubrich (2006) argue that interest rate increases can indicate weak fundamentals, which depreciate the currency. Supporting the notion that weak fundamentals may induce depreciation, Faust et al. (2007) find that the U.S. dollar depreciates in high frequency data after news announcements indicating a higher than expected consumer price index (CPI). However, Clarida and Waldman (2008) remark that such announcements could appreciate the exchange rate if they prompt sufficiently large interest rate increases. The critical theoretical determinant is the aggressiveness of the central bank response to inflation. For the United States, Clarida and Waldman do not find any evidence of exchange rate appreciation in response to inflationary news. These papers provide some basis for the exchange rate effects that underpin our pass-through predictions following endogenous Foreign interest rate changes.

In this subsection, we have focused upon a hard peg that is not perfectly credible. What is the likely pattern of interest rate pass-through under target zone exchange rate regimes? Target zones allow for some flexibility in the exchange rate in the current period, such that the change in the expected rate of depreciation from a foreign interest rate change is reduced. This implies that values of the covariance of foreign interest rate changes and the expected rate of depreciation set out earlier in this subsection, will be attenuated, such that biases in interest rate pass-through under target zones will be smaller than under hard pegs.

Obstfeld et al. (2005) simulate interest rate pass-through under a target zone regime when Home interest rates respond to domestic fundamentals (appropriately defined). They demonstrate that the correlation of a target zone country's fundamentals with the base country's interest rate is an important determinant of estimated pass-through. This approach has implications for the transmission of unanticipated and exogenous monetary policy. For low interest rate pass-through to arise under a target zone in response to an unanticipated and exogenous Foreign interest rate change, domestic fundamentals should be positively related to exchange rate expectations and negatively related to Foreign interest rate changes. For example, if a foreign interest rate rise induces recession, there will be pressure for Home interest rates to fall, even from unanticipated and exogenous interest rate changes. As the target zone width grows, the effect becomes larger.

Non-pegged exchange rate regimes. If the international no-arbitrage condition is the only connection between Home and Foreign, the expected rate of depreciation under a non-peg will respond one for one in the opposite direction to a Foreign interest rate increase that is both unanticipated and exogenous. This implies that the unobserved covariance is exactly equal to minus the variance of the Foreign interest rate change, leading to $\hat{\beta} = 0$.

When a Foreign interest rate increase is anticipated and exogenous, the unobserved covariance will be *positive*, since Home's exchange rate jump depreciates one period *before* the Foreign interest rate increase, simultaneously causing a decrease in Home's expected rate of depreciation. As the expected rate of depreciation falls one period prior to the Foreign interest rate increase, the unobserved covariance will be positive. A *positive* unobserved covariance also arises following an unanticipated and endogenous Foreign interest rate increase, since Home's exchange rate jump appreciates contemporaneously, leading to an increase in Home's expected rate of depreciation. In contrast, when a Foreign interest rate increase is anticipated and endogenous, the increase in the expected rate of depreciation occurs one period earlier than in the unanticipated and endogenous case, yielding a *negative* unobserved covariance.[5] Estimated pass-through under a non-peg will reflect the unobserved covariances associated with the dominant properties of the Foreign interest rate. Thus, the exact level of pass-through to non-pegs is an empirical issue.

More generally, pass-through following a Foreign interest rate change will reflect the nature of any economic interdependencies between Home and Foreign. For example, common shocks to the economies of Home and Foreign (e.g., world oil price hikes), may induce similar endogenous interest rate increases, raising pass-through. Alternatively, suppose Home's economy expands following a real exchange rate depreciation due to trade links between Home and Foreign. The attendant inflationary pressure for Home may lead to a Home interest rate increase, raising pass-through. The latter case is interesting because it implies that unanticipated and exogenous Foreign interest rate changes may be associated with positive pass-through to non-pegs.

2. ECONOMETRIC METHODOLOGY AND DATA

In this section, we describe the methodology that we use to evaluate how interest rate pass-through under different exchange rate regimes is related to the nature of foreign interest rate changes. The approach involves comparing estimated interest rate pass-through to pegs and non-pegs following: an identified, unanticipated, and exogenous U.S. interest rate change; and the realized federal funds rate change, which represents a mixture of the properties outlined in Section 1. We divide the discussion into three parts: (i) identification of unanticipated and exogenous U.S. federal funds rate changes, (ii) exchange rate regime classification schemes, and (iii) the econometric model specification and its estimation.

5. Note that the unobserved covariances for a particular type of interest rate change under a non-peg is always of *opposite* sign to that noted for the same type of interest rate change in the peg case. Why? Under a peg, the expected rate of depreciation is calculated assuming that the peg is maintained in the current period but may adjust to the equilibrium non-peg value in the future. Under a non-peg, the equilibrium value is immediately achieved since the exchange rate is a jump variable. Thus, the expected rates of depreciation in the two cases will necessarily be of opposite signs according to the international no-arbitrage condition.

2.1 The Nature of Interest Rate Changes and Identification

We consider two identification approaches to isolate unanticipated and exogenous U.S. federal funds rate changes. The first approach is an extension of the procedure outlined by Romer and Romer (2004), which is based upon combining information on intended U.S. policy rate changes and the Federal Reserve's in-house macroeconomic forecasts. The second approach follows Kuttner's (2001) procedure, which is based upon the information embodied in the federal funds futures market prices.

Intended U.S. monetary policy changes and macroeconomic forecasts. Romer and Romer (2004) consider U.S. monetary policy over the period 1969–96. 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 FOMC at its 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 6 months. These represent the central objective variables of the Federal Reserve (see Board of Governors of the Federal Reserve 2005, or the International Banking Act of 1978 (the Humphrey-Hawkins Act)). The real-time forecasts are conditional upon the assumption that no policy action is taken at the meeting for which they are formulated; they represent the Federal Reserve's best estimate of the economy's path in the absence of active policy. Accordingly, their use in the second-step regression allows for the real-time unanticipated and exogenous component of monetary policy to be properly isolated. Formally, Romer and Romer estimate the following regression:[6]

$$\Delta ff_m = \alpha + \beta ff_{m-1} + \sum_{j=-1}^{2} \gamma_j \widehat{\Delta y}_{m,j} + \sum_{j=-1}^{2} \lambda_j (\widehat{\Delta y}_{m,j} - \widehat{\Delta y}_{m-1,j}) + \sum_{j=-1}^{2} \varphi_j \hat{\pi}_{m,j} + \sum_{j=-1}^{2} \theta_j (\hat{\pi}_{m,j} - \hat{\pi}_{m-1,j}) + \rho \hat{n}_{m,j=0} + \varepsilon_m, \quad (2)$$

where m indexes FOMC meetings, j indexes the quarter relative to the current meeting's quarter, ff is the target federal funds rate, Δy is real output growth, π is inflation, n is the unemployment rate, a hat denotes the real-time forecast for a variable, and ε is an error term. Other 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. In Section 2, we argued that changes to monetary policy that are orthogonal to expected inflation should be used to evaluate interest rate pass-through, whereas this identification also controls

6. Employing real-time views/information, Orphanides (2003, 2004) 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.

for forecasts for real variables. The latter can be interpreted as proxies for expected inflation at horizons beyond two quarters, or as a means of controlling for monetary policy movements that are predictable from a market perspective (market information does not include the Greenbook forecasts, but may be correlated with the Greenbook forecasts).

How successful is this method likely to be in isolating unanticipated and exogenous monetary policy? Romer and Romer (2000) and Bernanke and Boivin (2003) demonstrate that the Greenbook forecasts encompass alternative private sector forecasts. To the extent that economic forecasts are the main driver of anticipated and endogenous policy, the residuals are likely to be both unanticipated from the perspective of the market, and orthogonal to the effects of any non-monetary innovations affecting the economy captured in the forecasts.[7]

In a recent contribution, Faust and Wright (2008) highlight that Greenbook forecasts are conditional upon a specific path for the intended federal funds rate, which presumes no change to the target at the current meeting but the possibility of target changes at future meetings. To the extent that these assumptions over future policy are incorrect, endogenous policy changes may contaminate the identified shock series. Similarly, there may be other sources of anticipated policy changes which are not fully accounted for by the Greenbook forecasts. If these endogenous or anticipated changes are important, the pass-through estimates after applying the identification procedure will be pulled toward the estimates from actual U.S. interest rate changes. To address such concerns, we also consider results from an alternative identification procedure, which we describe in the next subsection.

In order to update the Romer and Romer (2004) monetary policy identification from 1996 to 2000, we extend the series for Δff_m using the change in the target federal funds rate that was announced after each FOMC meeting since 1994. From 1994 to 1996 inclusive, both the Romer and Romer identified, intended federal funds rate change and the announced, target federal funds rate change are available—their correlation is essentially 1.[8] Given such consonance, we argue that the pooling of the two series is defensible. We perform the forecast orthogonalization described above with a set of Greenbook forecasts updated to the end of 2000.[9] To evaluate pass-through to interest rates at the monthly frequency, we take the meetings-based residuals from regression (2) estimated through 2000 and cumulate them to give a daily level series. We then average across days within a month, in order to obtain average level series at

7. Recently, Romer and Romer (2008) evaluate the forecasting properties of the FOMC member forecasts relative to the Greenbook forecasts and find that the Greenbook forecasts consistently encompassed the FOMC member forecasts (despite being conditional forecasts). If FOMC member decisions respond to their own private forecasts, any resulting change in policy stance represents a valid unanticipated and exogenous monetary policy change. Why? After controlling for the Greenbook, there is no evidence that FOMC member forecasts predict the future path of the economy. Consequently, any residual policy response to the FOMC member forecasts may be considered exogenous.

8. There is one instance in which the series differ. For the meeting on September 28, 1994, Romer and Romer argue that the language associated with the FOMC transcripts amounted to the intention to tighten by 12.5 basis points, even though there was no change in the announced, target federal funds rate.

9. The results that we report in Section 3 are robust when estimated using a sample that ends in 1996m12 (viz., using only the original Romer and Romer 2004 series).

the monthly frequency. We then take the first difference of the natural log of one plus the decimalized level series, to obtain empirical counterparts to the Foreign interest rate change (Δr_t^* introduced in Section 1.1). The resulting series are comparable to the monthly average observations for Home and Foreign interest rate changes that will be used in other parts of the empirical work.

We also construct a purely meeting-based series of unanticipated and exogenous U.S. monetary policy changes using the Romer and Romer (2004) identification approach, spanning October 1988 to December 2000. This covers the period for which we are able to calculate federal funds futures price-based unanticipated monetary policy changes (described in the next section). The meeting-based residuals from the Romer and Romer orthogonalization regression are mapped to the dates within the period when the FOMC meeting outcomes were effectively known by the market (again, described below). For the rest of the paper, we denote the target/Greenbook-based unanticipated and exogenous U.S. interest rate change by UM (unanticipated monetary policy). Changes in the realized federal funds rate are denoted by FF.

Federal funds futures price changes. The federal funds futures market was established in October 1988 by the Chicago Board of Trade. Futures contracts are written on a monthly basis. They are settled upon the history of the effective federal funds rate within the contract month. Consequently, from their inception onward, Kuttner (2001) is able to use the daily change in the market price of the current month futures contract around Federal Reserve monetary policy interventions to infer the size of the unanticipated component of U.S. monetary policy changes. The procedure involves scaling the day-to-day difference in closing prices for the current month futures contract on the day of a Federal Reserve intervention. Specifically, the unanticipated component is calculated as

$$u_{t,s} = -\left(\frac{D_s}{D_s - t + 1}\right)(f_{t,s} - f_{t-1,s}),$$

where the intervention occurs on day t in month/year s, D_s is the number of days in month/year s, $f_{t,s}$ is the closing price of the federal funds futures contract for month/year s, and $u_{t,s}$ is the unanticipated component of the intervention. Near the end of the month, the scaling factor grows extremely large, potentially magnifying the influence of any noise in price movements. Consequently, Kuttner recommends that the unscaled change in next-month's federal funds futures contract be used whenever the date of an intervention occurs in the last 3 days of the month.[10]

We follow Kuttner's (2001) procedure with a few modifications. First, we only consider U.S. monetary policy actions (or inactions) that are associated with scheduled FOMC meetings (similar to the Romer and Romer 2004 approach). Second, the dates when monetary policy actions are revealed to the market are determined according to

10. If the intervention occurs on the first day of the month, the change is calculated from the difference between the current month contract price and the next-month contract price from the last day of the previous month.

the method described in Bernanke and Kuttner (2005). Roughly speaking, over the period October 1988 to January 1994, this means that we use the scaled difference between the closing price from the day *after* the concluding date of an FOMC meeting and the price from the FOMC meeting's concluding date. From February 1994 onward, we take the scaled difference between the closing price from the day *of* the concluding date of an FOMC meeting and the price from the day prior to the FOMC meeting's concluding date.[11] Finally, based upon Hamilton's (2007) findings regarding the influence of noise in the federal funds futures prices, we take the unscaled change in the next-month contract price whenever the date of an intervention occurs in the last 20% of a month.[12]

For the rest of the paper, we denote the futures-identified U.S. interest rate change by FF-FUT. A possible concern with FF-FUT is that it still includes components of endogenous policy to the extent that the Federal Reserve has better information about the economy's future path than the market. In related work, we provide some evidence that shocks identified via the Kuttner (2001) method from the federal funds futures market are comparable to those identified using the combination of the intended federal funds rate and Greenbook information (Bluedorn and Bowdler 2008). Such cross-validation is reassuring. It suggests not only that FF-FUT is comparatively free of endogenous policy components but also that UM is comparatively free of anticipated policy components.

We argue that the identification approaches employed here will minimize biases, not only compared to the realized federal funds rate but also compared to policy shocks from SVARs, such as those employed by Miniane and Rogers (2007) in their study of international monetary transmission. The latter approach relies on current and lagged values of output, prices, and other variables to control for policy changes that are either endogenous to forecasted economic conditions or anticipated from market information. If the Greenbook forecasts contain information over and above that included in the VAR to which policymakers react, then the identification will not isolate unanticipated and exogenous monetary policy. A similar argument applies if the futures market possesses information over and above that included in the VAR about expected policymaker actions.

2.2 Exchange Rate Regime Classification and Inclusion Criteria

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.[13] This is the exchange rate

11. FOMC policy decisions at a meeting have been publicly announced since February 1994. See the data set documentation for a more detailed explanation of the differencing.

12. We also tried the more elaborate corrections for the federal funds futures-based unanticipated monetary policy measure that Hamilton (2007) advocates. The results for daily interest rate pass-through were broadly similar, leading us to opt for the simpler Kuttner (2001) formulation.

13. For a full explanation of his classification methodology, see Shambaugh (2004).

regime classification that we employ in the main part of our analysis (alternative classifications are considered in Section 4.3). 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% of a central value against a major currency throughout a particular year, the major currency 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 United States as the base country. To maximize the sample available for contrasting the interest rate consequences of UM and FF (defined for the United States), we reclassify non-U.S. base observations as follows: (i) if a country pegs its currency versus a base currency that is pegged to the U.S. dollar, then the country in question is classified as a peg versus the U.S. dollar, (ii) if a country pegs its currency versus a currency that is not pegged to the U.S. dollar, it is classified as a non-peg versus the U.S. dollar, and (iii) if a country's currency is not pegged when the base is a country other than the United States, it is treated as a non-peg versus the U.S. dollar. In implementing the reclassification, we check that each of the bilateral relationships are characterized by capital mobility, to ensure that the reclassified observations are comparable to those for which the United States was originally identified as the base country.[14] Finally, for countries which joined the Eurozone in January 1999, we use observations through the end of 1998, and we introduce a new country, Eurozone, for the period 1999–2000. The Eurozone is classified as a non-peg versus the U.S. dollar. We denote the extended binary exchange rate regime classification variable by P, where $P = 1$ for a peg and $P = 0$ for a non-peg.

2.3 Model Specification and Sample

To measure interest rate pass-through, we estimate static panel regressions of the following form:

$$\Delta r_{i,t} = \left(\alpha^P + \beta^P \Delta r^*_{i,t}\right) \cdot P_{i,t} + \left(\alpha^{NP} + \beta^{NP} \Delta r^*_{i,t}\right) \cdot (1 - P_{i,t}) + \varepsilon_{i,t}, \qquad (3)$$

where i indexes countries, t indexes time, Δ is a difference operator, ε is a mean-zero error term, and all variables are defined as in equation (1). Superscripts P and NP denote peg and non-peg regime coefficients. Such a model is typical of the

14. As it ends up, the procedure described here only increases the size of the non-peg sample. All of our results are qualitatively the same when using only the peg and non-peg observations originally identified by Shambaugh (2004) for the United States.

literature investigating the trilemma (Shambaugh 2004, Obstfeld et al. 2004, 2005).[15] All of the specifications that we employ assume that the slope coefficients are common across countries, similar to previous work.[16] By focusing on a sample of countries that do not maintain capital controls, we eliminate an important potential source of parameter heterogeneity. Formal evidence relating to this issue was obtained from tests of cross-sectional parameter homogeneity at both the monthly and daily frequencies (see Appendix Table A3). For specifications using UM and FF-FUT, the tests tend to support pooling. For specifications using FF, there is evidence of heterogeneity in monthly responses but not daily responses. Such heterogeneity affects all of the previous work that relies upon realized foreign interest rates analogous to FF.

Given our interest in estimating international transmission, it may seem natural to control for domestic factors such as Home inflation or Home output growth to account for some endogenous Home interest rate movements. However, the inclusion of such variables would complicate the identification of interest rate pass-through. For example, recall that estimated pass-through depends upon the covariance of the change in the Foreign interest rate with the change in the expected rate of depreciation. If Home's current inflation is a function of the exchange rate's expected rate of depreciation, then its inclusion in the regression will remove part of the unobserved covariance which is critical to the predictions set out in Section 1. Consequently, as is standard in much of the literature, we estimate pass-through without controlling for macroeconomic variables in the Home country.[17]

The models at the monthly frequency are estimated in first differences, relating monthly Foreign interest rate changes to monthly Home interest rate changes. For the models at the daily frequency, Home interest rate changes are defined to be the difference between the Home interest rate on day $t + 2$ from its value on day $t - 1$, assuming that the FOMC meeting associated with the Foreign interest rate occurs on day t.[18] Econometrically, the specification is valid if the interest rate data are stationary, or nonstationary 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). As a check, we augmented the specifications with an error correction term and found that it did not affect any of our main conclusions.

15. 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.

16. We also restrict the intercepts to be identical across countries within regimes. If we allow for country-regime fixed effects, there is little change in the results.

17. On a related point, it is important to use realized Home interest rates to get an accurate measure of pass-through, rather than an exogenous measure that adjusts for endogenous policy, given that Home's interest rate responses to Foreign's interest rate changes are examples of endogenous monetary policy.

18. Note that Foreign interest rate changes in the daily data are *not* transformed to be the change in the logarithm of 1 plus the Foreign interest rate level. They are rather the raw, identified U.S. monetary policy change, as described in Section 2.1. Since the implied interest level and interest rate change are small over the daily data period, the usual Taylor approximation for the logarithmic transformation is extremely accurate.

For the models at the monthly frequency, the Home interest rate that we use 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*. For the models at the daily frequency, the Home interest rate is the end-of-day overnight interest rate, taken from a variety of sources (see Appendix Table A2 for details). As overnight rates, they are roughly comparable to the U.S. federal funds rate, which is the basis for the Foreign interest rate measures we employ.

The sample consists of country/time observations from years during which there are no restrictions on capital mobility, as reported in the IMF's *Annual Report on Exchange Arrangements and Exchange Restrictions* (*AREAER*) and codified by Shambaugh (2004). We exclude observations associated with capital controls since the predictions set out in Section 1 rely on a no-arbitrage condition, which is unlikely to hold when legal restrictions apply to the movement of capital. In Section 4.2, we consider the robustness of our results to an alternative capital controls measure based upon the work by Chinn and Ito (2006, 2008).

To ensure that we use only established peg and no capital control observations in the estimation, we also exclude the first month immediately after the removal of capital controls and the first month after the institution of a peg regime. Similar to Shambaugh (2004), we exclude a small number of observations corresponding to hyperinflations or periods of administratively set interest rates (additionally, we exclude the month immediately after the end of such episodes, to ensure that interest rate changes used in the empirical work do not draw on them). We follow Shambaugh's classification of hyperinflation years in constructing both the monthly and daily data sets. We update Shambaugh's classification of administratively set interest rates at the annual frequency using information on monthly interest rate changes. We add observations when there is within-year variation in monthly interest rates. Similarly, we exclude some observations relative to the sample that would have been obtained using Shambaugh's annual coding, because we find long periods in which there are no within-year interest rate changes in the monthly data.[19]

After applying the inclusion criteria, the monthly sample consists of 37 countries (including the Eurozone), covering the period 1973m02–2000m12. Peg observations occur for 8 of these countries and the average length of a country/regime time series is 61 months for pegs and 104 months for non-pegs. The baseline sample comprises 5,072 pairs of monthly interest rate changes, with 12% of the total relating to pegs. Pegs are a smaller percentage of our baseline sample than was the case in the sample used by Shambaugh (2004) because of our focus on only those countries that are pegged to the U.S. dollar and for which an overnight interest rate series exists. However, the absolute sizes of the samples are always large enough that we are confident in their statistical efficacy.

19. The additional inclusions (after taking account of the other inclusion criteria) from the update to the administratively set indicator are Kuwait 1979m2:1980m12, and the Maldives 1989m7:1989m12 and 1993m2:1993m12. The additional exclusions (again, after taking account of the other inclusion criteria) are Niger in 1995:1996, Vanuatu 1987m1:1988m1 and 1990m1:1992m1, and Hong Kong 1994m1 (the observation for Hong Kong is excluded because it represents the first month after a long period of no change in the interest rate).

The daily sample consists of 23 countries (including the Eurozone), drawing from the period 1988m11–2000m12. Due to the limited temporal coverage, sample size is more of a concern for the daily data. Peg observations occur for only three of these countries. The baseline sample comprises 1,532 pairs of day-to-day interest rate changes, with pegs accounting for 7.4% of the total. When considering the results in Section 3.2, we discuss sample size issues. A description of the monthly and daily samples and the variables used (with sources) is provided in Appendix Tables A1 and A2.

Standard error considerations. As described in Section 2.1, UM is a generated regressor. To account for the additional sampling uncertainty introduced by its generation, standard errors are calculated via bootstrapping. Specifically, we resample the data 1,000 times by drawing pairs of observations with replacement, reestimate the model for each bootstrap sample, and calculate the standard error of the resulting coefficient distribution. The paired bootstrap procedure is robust to heteroskedasticity but not to serial correlation of the errors (Brownstone and Valletta 2001). As seen in Appendix Table A3, we cannot reject the null of AR(1) serially uncorrelated errors at the 1% level in any instance and cannot reject at the 5% level in most instances (other diagnostics that we do not report also provide strong evidence that higher order error serial correlation is not present). In order to check that our inferences are not affected by possible serial correlation, we also calculated standard errors clustered at the country level to allow for arbitrary within-cluster autocorrelation and heteroscedasticity. Standard errors calculated via this procedure are actually smaller than the bootstrapped standard errors that we report, and provide somewhat stronger support for the results that we present in Section 3. Even in the presence of generated regressors, inference against a zero null hypothesis with clustered standard errors will still be valid (Pagan 1984).

Uncertainty from generated regressors is not an issue when FF or FF-FUT is employed. However, to ensure comparability, we calculate bootstrapped standard errors for models where FF or FF-FUT is an explanatory variable. The bootstrapped standard errors are nearly identical to clustered standard errors in all cases.

3. EMPIRICAL RESULTS

We now present our empirical results, first for monthly data and then for daily data.

3.1 Pass-Through Estimates from Monthly Data

In the top half of Table 2, we report within-month pass-through under pegs and non-pegs following changes in UM and FF. We also present: (i) a test of the the null hypothesis of unit pass-through, (ii) the difference between peg and non-peg pass-through and its standard error, and (iii) a test of the null hypothesis of unit pass-through to pegs and zero pass-through to non-pegs.

TABLE 2

BASELINE INTEREST RATE PASS-THROUGH

U.S. interest rate measure	Exchange rate regime	β	H_0: $\beta = 1$ (p-value)	N	R^2	$\beta^P - \beta^{NP}$	H_0: $\beta^P = 1$, $\beta^{NP} = 0$ (p-value)
				Monthly frequency			
UM	Peg	0.78** (0.22)	0.30	607	0.015	0.70** (0.25)	0.47
	Non-peg	0.08 (0.10)	0.00	4,465	0.0001		
FF	Peg	0.52** (0.09)	0.00	607	0.027	0.36** (0.09)	0.00
	Non-peg	0.16** (0.05)	0.00	4,465	0.002		
				Daily frequency			
UM	Peg	0.69 (0.51)	0.53	114	0.020	0.51 (0.63)	0.73
	Non-peg	0.17 (0.33)	0.01	1,418	0.0001		
FF-FUT	Peg	1.01 (0.88)	0.99	114	0.017	0.52 (1.03)	0.66
	Non-peg	0.49 (0.53)	0.34	1,418	0.0003		
FF	Peg	0.20 (0.16)	0.00	114	0.013	0.25 (0.19)	0.00
	Non-peg	−0.05 (0.12)	0.00	1,418	0.0001		

NOTES: Pass-through statistics measure the within month or day-to-day response of Home interest rates to a 1 percentage point increase in (i) UM, the unanticipated and exogenous US interest rate measure; (ii) FF, the aggregate intended federal funds rate; and (iii) FF-FUT, the federal funds futures-based monetary policy shock (only for the daily data). The construction of the U.S. interest rate measures at the two frequencies is described in the main text. The monthly data cover the period 1972m1–2000m12. The daily data are drawn from 1988m10 to 2000m12. The daily data are the changes in interest rates around scheduled FOMC meetings, as defined in the main text. The exchange rate regime indicator and underlying capital mobility indicator are both from Shambaugh (2004). Standard errors are given in parentheses. * and ** denote significance at 5% and 1%, respectively. All standard errors and hypothesis test results are based on bootstrapped covariance matrices that use 1,000 replications.

In response to a 100 basis point (b.p.) tightening of U.S. monetary policy, within-month pass-through to pegs is 78 b.p. when policy is measured using UM and 52 b.p. when measured using FF. The amount by which interest rate pass-through deviates from unity is roughly halved when a measure of foreign monetary policy that mixes anticipated/unanticipated and endogenous/exogenous interest rate changes is replaced by one that isolates unanticipated and exogenous changes. The 68% CI for pass-through to pegs from UM is [0.56,1.00], and the 95% CI is [0.34,1.22]. Unit pass-through and greater than unit pass-through to pegs (the natural benchmark discussed in Section 1.1), cannot be ruled out, but this in part reflects the estimation uncertainty. A point estimate for pass-through to pegs that is less than one may reflect either frictions that delay pass-through (e.g., those described in Section 1.1, or the effects from sterilizing interventions in currency markets) or anticipated/endogenous interest rate movements that are not purged from UM.

The 95% CI for UM does not exclude pass-through equal to 0.52, the value estimated from FF. When the standard error bands are calculated by means of clustering at the country level, the 95% CI for pass-through from UM narrows somewhat to

[0.46,1.10] but still includes the interest rate pass-through estimated from realized federal funds rate changes. In this context, it is important to note that FF is an amalgam of UM and anticipated and/or endogenous interest rate changes. Pass-through from FF will be a function of pass-through from these components, including UM. As pass-through from UM exceeds that from FF by 26 b.p., it is possible that pass-through from anticipated and/or endogenous elements of U.S. rate changes is much lower than the 0.52 estimated for FF movements. Formal inferences along these lines would require a more complete decomposition of federal funds rate movements than that used in this paper.

Interest rate pass-through to non-pegs is 8 b.p. from UM and 16 b.p. from FF. The lower level of pass-through from UM is consistent with the claim in Section 1 that anticipated or endogenous monetary policy may elicit positive pass-through, either because the covariance between interest rate changes and the change in the expected rate of depreciation is positive in such cases or because of the effects of common shocks. However, the contrast in pass-through across policy measures is smaller than in the peg case, and equality of the two estimates cannot be ruled out given the estimation uncertainty.

When UM is the foreign interest rate change measure, a joint test of the hypotheses that pass-through to pegs is unity and pass-through to non-pegs is zero cannot be rejected at any conventional significance level (p-value of 46%). For FF, the joint test rejects the two hypotheses. In part, this reflects the greater precision with which the effects of FF are estimated. However, if we use the covariance matrix from UM and the point estimates from FF, the two hypotheses are still rejected (p-value of 3.3%). Thus, smaller estimation uncertainty is not the sole source of the rejection of the joint hypothesis for pass-through from FF. The magnitudes of the pass-through estimates, which may reflect influences from anticipated and/or endogenous policy changes, also contribute to the result.

A comparison of interest rate pass-through across pegs and non-pegs provides a measure of the constraint on monetary policy as a result of pegging the exchange rate. When policy is measured using UM, the increment to pass-through associated with pegging is 70 b.p., compared with 36 b.p. when policy is measured using FF. Controlling for anticipated and endogenous interest rate changes roughly doubles the estimated constraint on monetary policy from pegging but also increases the uncertainty associated with that estimate. In the case of UM, the 68% confidence interval is [0.46, 0.94] and the 95% confidence interval is [0.22, 1.18]. The latter interval includes 0.36, the increment to pass-through when policy is measured using FF. When using clustered standard errors the 95% interval narrows to [0.32, 1.08]. These estimates provide some support for the notion that anticipated or endogenous components in realized foreign monetary policy changes contribute to a constraint on monetary policy associated with pegging that is smaller than that implied by the benchmark trilemma.

Overall, the monthly pass-through estimates are consistent with our argument that the international propagation of anticipated or endogenous movements in foreign monetary policy (the United States here) is different from that from unanticipated and exogenous policy changes. There is evidence that pass-through to pegs and non-pegs is closer to the theoretical benchmarks, and that the constraint from pegging is larger than previously believed. However, estimation uncertainty means that changes to estimated pass-through from the monetary policy identification are not significant at standard levels.

The R^2 statistics are low across all exchange rate regimes and monetary policy measures. While this might be expected in the case of non-pegs, the result is more surprising in the case of pegs. We postulate two reasons for low explanatory power. First, some Home interest rate changes may be responses to domestic concerns that 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. Second, we have argued that when the Foreign interest rate changes in an anticipated 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 does imply a lower R^2 for the simple pass-through regression.[20] We also note that the R^2 for the UM regression is lower than that for the FF regression. This is not surprising given the econometric endogeneity of FF changes. If endogenous Foreign interest rate changes include responses to common, international shocks, they will have greater explanatory power for Home interest rate changes than will changes in UM, from which such responses are largely eliminated.

3.2 Pass-Through Estimates from Daily Data

In the bottom half of Table 2, we report day-to-day pass-through under pegs and non-pegs following changes in UM, FF-FUT, and FF. We also present the statistics and hypothesis tests that were detailed for the monthly results.

In response to a 100 b.p. tightening of U.S. monetary policy, day-to-day pass-through to pegs is 69 b.p. when policy is measured using UM, 101 b.p. when measured using FF-FUT, and 20 b.p. when measured using FF. The point estimates for pass-through from identified monetary policy changes ranges from three and a half to fives times that from changes in the realized interest rate. However, there is a high degree of estimation uncertainty associated with all of these estimates—the null of no effect cannot be rejected for any of the monetary policy measures. Sample size is a likely driver of the large standard errors. As noted earlier, there are only three countries that pass the baseline inclusion criteria, have a U.S. dollar peg sometime over the period 1988–2000, and have daily data for an overnight interest rate. They are Canada, Hong Kong, and Indonesia. In fact, Hong Kong accounts for 85% of the observations in the sample. Pass-through from FF-FUT is thus extremely similar to that estimated by Borensztein et al. (2001) for Hong Kong alone (albeit over a different set of days and interest rate concepts).

Interest rate pass-through to non-pegs is 17 b.p. from UM, 49 b.p. from FF-FUT, and −5 b.p. from FF. All are estimated with a higher degree of uncertainty than

20. Such logic suggests that a low R^2 under a peg does not necessarily signify that pegging entails no loss of monetary autonomy.

pass-through to pegs. Despite non-peg pass-throughs from UM and FF-FUT both being larger than that from FF, the joint hypothesis that peg pass-through is unity and non-peg pass-through cannot be rejected for either UM or FF-FUT (*p*-values over 0.60). However, it is soundly rejected for FF, reflecting the dramatically lower peg pass-through from FF. As in the monthly sample, the difference between peg and non-peg pass-through from either identified U.S. interest rate change measure is approximately double the size of the difference from FF. The daily pass-through estimates support the picture that emerged from the monthly sample, albeit with a much higher degree of estimation uncertainty.

4. ROBUSTNESS

In this section, we evaluate the robustness of our main results to various perturbations in our baseline methodology. We consider: (i) the subsample stability of estimated pass-through, (ii) the use of an alternative capital control classification, (iii) the use of alternative exchange rate regime classifications, and (iv) a sample restricted to cases where the signs of the identified U.S. monetary policy change and the realized federal funds rate change coincide.

4.1 Subsample Stability

We estimated the baseline monthly regression over the set of subsamples where one country at a time is omitted. The key findings are briefly summarized here; full details are available upon request. Excepting the subsample obtained after excluding Kuwait, within-month pass-through to pegs ranged from 0.77 to 0.84 following a change in UM and from 0.49 to 0.53 following a change in FF. Furthermore, evidence for larger differences between peg and non-peg pass-through when UM is the policy measure was preserved in each case. The one example of instability occurred when Kuwait was omitted from the sample. In that case, pass-through under a peg was 0.30 from UM and 0.59 from FF, and the increase in pass-through from pegging was 23 b.p. using UM and 43 b.p using FF. However, further analysis demonstrated that this instability relates to the timing of pass-through rather than the level. Specifically, we aggregated the monthly data to an annual frequency and estimated static pass-through regressions (full details are available in an earlier working paper version of the paper). When observations for Kuwait are omitted, pass-though to pegs is 0.84 from UM and 0.60 from FF, and the increments to pass-through from pegging are 55 b.p. using UM and 19 b.p. using FF. These results are similar to those from the full sample monthly estimates. Thus, while contemporaneous pass-through from UM to pegs falls somewhat after excluding Kuwait, pass-through in the months that follow rises much more quickly, as does the increment to pass-through from pegging. Based on this evidence, we conclude that while interest rate movements in Kuwait are influential for the estimated timing of pass-through, the same is not true of the final level of interest rate pass-through, and that evidence supporting the predictions from Section 1 is observed across the range of countries in our core sample.

The analysis of cross-sectional stability at the daily frequency requires more caution. As noted previously, the peg sample comprises just three countries, and one of them, Hong Kong, accounts for 98 of the 114 observations. When Hong Kong is excluded from the sample, pass-through to pegs is −0.31 (UM), 1.83 (FF-FUT), and .09 (FF). Each of these estimates is insignificant at conventional levels. Interest rate pass-through to non-pegs, which was less than peg pass-through in the full sample, is more robust across subsamples for each of the three policy measures and, as in the full sample, is insignificant at conventional levels. Some fragility in the peg results is unsurprising given the very small sample for which daily overnight interest rate data are available, and therefore we emphasize the importance of the results from lower frequency data when assessing the robustness of our result that unanticipated and exogenous U.S. monetary policy propagates differently to more general interest rate movements.

4.2 Alternative Capital Control Classification

As noted in Section 2.2, we restrict our baseline samples to include only those country/time observations from years when international capital flows were unrestricted, based upon Shambaugh's (2004) codification of the information in the IMF's *AREAER*. Concerns about the validity of the capital control information in the *AREAER* have led to the construction of a variety of alternative international capital mobility indicators by several researchers (e.g., Quinn 1997, Miniane 2004, Chinn and Ito 2006, 2008).

Since Chinn and Ito's (2006, 2008) measure of capital account openness has the largest spatio-temporal coverage, we use it to construct an alternative binary capital mobility indicator for our sample. Specifically, we code countries with average capital account openness that is larger than the grand median of the measure as having mobile capital, and those with average openness below the grand median as having immobile capital. This is similar to the split that Miniane and Rogers (2007) implement with Miniane's (2004) data in their study. We then combine the Chinn and Ito binary capital mobility indicator with our other inclusion criteria (see Section 2.2) to derive a new sample. The monthly and daily samples constructed from the revised inclusion criteria are larger than their baseline counterparts. The monthly data set contains 8,838 observations; 10% are pegs. The daily data set contains 1,893 observations; 6.2% are pegs.

The results, presented in Table 3, are similar to the baseline results. However, precision is higher in the sample based upon the Chinn and Ito binary capital mobility indicator. In response to a 100 b.p. tightening of U.S. monetary policy, within-month pass-through to pegs is 81 b.p. when policy is measured using UM and 55 b.p. when measured using FF. Within-month pass-through to non-pegs is roughly the same across UM and FF (11 b.p. versus 9 b.p.), although only non-peg pass-through from UM is statistically insignificant. The difference between within-month peg and non-peg pass-through from UM is identical to that estimated using Shambaugh's *AREAER*-based capital control indicator (70 b.p.). The difference for FF is about a third larger

TABLE 3

Interest Rate Pass-Through (Chinn–Ito Capital Control Measure)

U.S. interest rate measure	Exchange rate regime	β	H_0: $\beta = 1$ (p-value)	N	R^2	$\beta^P - \beta^{NP}$	H_0: $\beta^P = 1$, $\beta^{NP} = 0$ (p-value)
				Monthly frequency			
UM	Peg	0.81** (0.16)	0.22	887	0.014	0.70** (0.18)	0.21
	Non-peg	0.11 (0.09)	0.00	7,951	0.0002		
FF	Peg	0.55** (0.07)	0.00	887	0.029	0.46** (0.08)	0.00
	Non-peg	0.09* (0.04)	0.00	7,951	0.0005		
				Daily frequency			
UM	Peg	0.94* (0.46)	0.89	112	0.045	0.83 (0.56)	0.93
	Non-peg	0.11 (0.30)	0.00	1,781	0.00		
FF-FUT	Peg	0.73 (0.88)	0.76	112	0.01	0.34 (1.02)	0.69
	Non-peg	0.39 (0.48)	0.20	1,781	0.0002		
FF	Peg	0.03 (0.11)	0.00	112	0.0004	−0.08 (0.20)	0.00
	Non-peg	0.11 (0.16)	0.00	1,781	0.0003		

Notes: Pass-through statistics measure the within month or day-to-day response of Home interest rates to a 1 percentage point increase in (i) UM, the unanticipated and exogenous U.S. interest rate measure; (ii) FF, the aggregate intended federal funds rate; and (iii) FF-FUT, the federal funds futures-based monetary policy shock (only for the daily data). The construction of the US interest rate measures at the two frequencies is described in the main text. The monthly data cover the period 1972m1–2000m12. The daily data are drawn from 1988m10 to 2000m12. The daily data are the changes in interest rates around scheduled FOMC meetings, as defined in the main text. The exchange rate regime indicator is from Shambaugh (2004). Standard errors are given in parentheses. * and ** denote significance at 5% and 1%, respectively. All standard errors and hypothesis test results are based on bootstrapped covariance matrices that use 1,000 replications.

than that estimated with the baseline sample (46 b.p.). This reflects the lower non-peg pass-through relative to the baseline. As before, the joint hypothesis of unit peg pass-through and zero non-peg pass-through is rejected for FF but accepted for UM.

In the daily sample, the results for pass-through from UM are the most consistent with the trilemma logic. Peg pass-through from UM is 94 b.p. and is significant at the 5% level. Non-peg pass-through from UM is 12 b.p. and is statistically insignificant. Day-to-day peg pass-through from FF-FUT is smaller (73 b.p.) than that estimated in the baseline daily sample. There is also no improvement in precision for the FF-FUT results. Estimated pass-through from FF is the least supportive of the trilemma logic. Both peg and non-peg pass-through from FF are near zero. In fact, peg pass-through is lower than non-peg pass-through (3 b.p. versus 11 b.p.). Neither the set of pass-throughs from FF-FUT or FF is statistically significant at conventional levels.

Overall, the conclusions from the baseline sample hold up extremely well in the sample based upon an alternative capital control classification. The results also lend some stronger support to the assertion that the use of unanticipated and exogenous identified foreign interest rate changes is critical in evaluations of the trilemma with high-frequency data.

4.3 Alternative Exchange Rate Regime Classifications

We examine the sensitivity of our results to Shambaugh's exchange rate regime classification by estimating pass-through under updated versions of the classifications due to Reinhart and Rogoff (2004) and Levy-Yeyati and Sturzenegger (2003). Ilzetzki, Reinhart, and Rogoff (2008a, 2008b) provide a monthly classification that updates the four-way coding compiled by Reinhart and Rogoff. The regimes are: hard pegs, crawling pegs, crawling pegs with bands, and free floats.[21] Reinhart and Rogoff's classification scheme therefore allows for more heterogeneity in pass-through across the non-peg sample than does the baseline classification.[22] Levy-Yeyati and Sturzenegger (2005a, 2005b) update the classification from Levy-Yeyati and Sturzenegger (2003), who use evidence from foreign exchange interventions to identify *de facto* pegs. If a currency is officially labeled as a peg but foreign exchange reserves do not show the volatility associated with interventions to support a peg, they exclude the regime from consideration. Levy-Yeyati and Sturzenegger also differentiate between floats and dirty floats/intermediate regimes, thus allowing for some heterogeneity among non-pegs.

The sample comprises only observations designated as having a U.S. base by Shambaugh (2004) (i.e., there is no reclassification of non-U.S. bases).[23] Reclassification would be somewhat more involved when there are multiple non-peg categories. When we use the Reinhart and Rogoff measure (hereafter, RR), the monthly sample consists of 2,407 observations (16.5% are hard pegs and 50.2% are crawling pegs). The daily sample consists of 614 observations (18.6% are hard pegs and 33.5% are crawling pegs). When we use the Levy-Yeyati and Sturzenegger measure (hereafter, LYS), the monthly sample consists of 2373 observations (29.9% are fixes and 18.2% are intermediates). The daily sample consists of 627 observations (28.7% fixes and 15.9% intermediates). We apply the inclusion criteria described in Section 2.2. All samples are subsamples from the corresponding baseline cases described in the previous section.

Table 4 shows monthly and daily pass-through under the four categories identified by RR.[24] The monthly results indicate higher levels of interest rate pass-through to hard pegs and crawling pegs than to managed floats and freely floating regimes, and interest rate transmission for the first two categories is stronger when estimated using UM as opposed to FF. The main puzzle is that pass-through to hard pegs is

21. 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.

22. It should be noted, however, that the crawling peg with bands category is tiny in our sample (20 or fewer observations).

23. We checked that each country identified by Shambaugh (2004) as having a U.S. base is similarly identified under the alternative regime classifications.

24. These results are estimated from smaller samples than are the baseline results, given data availability. If within month pass-through is estimated using the Shambaugh classification and the restricted samples the results are very similar to the baseline results. Reestimating daily interest rate pass-through yields similar pass-through to pegs, while non-peg pass-through drops below zero in the case of UM and FF but rises to 1.13 in the case of FF-FUT.

TABLE 4

Interest Rate Pass-Through (Reinhart–Rogoff Exchange Rate Classification)

U.S. interest rate measure	Exchange rate regime	β	H_0: $\beta = 1$ (p-value)	N	R^2
			Monthly frequency		
UM	Hard peg	0.25 (0.44)	0.09	397	0.001
	Crawling peg	0.48* (0.23)	0.02	1,208	0.003
	Managed float	−0.55 (7.15)	0.83	20	0.001
	Freely floating	−0.13 (0.13)	0.00	782	0.002
FF	Hard peg	0.14 (0.20)	0.00	397	0.001
	Crawling peg	0.29** (0.10)	0.00	1,208	0.005
	Managed float	−0.56 (4.37)	0.72	20	0.001
	Freely floating	0.04 (0.07)	0.00	782	0.001
			Daily frequency		
UM	Hard peg	0.53 (0.54)	0.38	114	0.013
	Crawling peg	−0.80 (1.82)	0.32	206	0.0004
	Managed float	−1.51 (1.87)	0.18	14	0.094
	Freely floating	0.01 (0.14)	0.00	280	0.00
FF-FUT	Hard peg	0.85 (0.86)	0.86	114	0.012
	Crawling peg	2.56 (3.58)	0.66	206	0.002
	Managed float	5.85 (5.22)	0.35	14	0.153
	Freely floating	−0.13 (0.28)	0.00	280	0.002
FF	Hard peg	0.23 (0.15)	0.00	114	0.017
	Crawling peg	−1.35 (0.81)	0.00	206	0.008
	Managed float	0.71 (0.83)	0.72	14	0.037
	Freely floating	0.07 (0.05)	0.00	280	0.01

Notes: Pass-through statistics measure the within month or day-to-day response of Home interest rates to a 1 percentage point increase in (i) UM, the unanticipated and exogenous U.S. interest rate measure; (ii) FF, the aggregate intended federal funds rate; and (iii) FF-FUT, the federal funds futures-based monetary policy shock (only for the daily data). The construction of the U.S. interest rate measures at the two frequencies is described in the main text. The monthly data cover the period 1972m1–2000m12. The daily data are drawn from 1988m10 to 2000m12. The daily data are the changes in interest rates around scheduled FOMC meetings, as defined in the main text. The underlying capital mobility indicator is from Shambaugh (2004). Standard errors are given in parentheses. * and ** denote significance at 5% and 1%, respectively. All standard errors and hypothesis test results are based on bootstrapped covariance matrices that use 1,000 replications.

less than pass-through to crawling pegs using both policy measures. A comparison of the Shambaugh and RR classifications helps cast light on this puzzle. The sample of 1,208 crawling pegs contains 203 observations from Shambaugh's peg category, including observations for Kuwait, a country whose inclusion in the sample matters for the speed of interest rate transmission (see Section 4.1). Estimated pass-through for this group of 203 observations from UM is 0.93. Clearly, this group is important in driving both the baseline peg estimates in Table 2 and the crawling peg results in Table 4. The reason for higher pass-through to the Shambaugh pegs that RR label crawling pegs than to the Shambaugh pegs that RR label hard pegs is unclear. One possibility is that the crawling pegs commit to a local trend in the exchange rate, but their discretion to deviate from that path is actually less than the deviations from a stationary target allowed for hard pegs.

Estimates of interest rate pass-through to the RR regime classifications are statistically insignificant. In terms of magnitudes, pass-through to hard pegs is comparable to pass-through to pegs in the baseline daily results. The difference between hard peg and freely floating pass-through is larger using the identified policy measures than it is using realized interest rate changes. The magnitude of the hard peg estimate reflects the fact that over 90% of the baseline peg sample is included in the RR hard peg sample; proportionately, the sample attrition is much less than in the monthly case. The anomaly in the daily results occurs in the case of the crawling pegs, for which pass-through is negative using FF and UM but in excess of 200% using FF-FUT. Given that these estimates are highly insignificant (much more so than in the monthly estimates for crawling pegs), we do not emphasize them here.

Table 5 shows the same output under the three categories identified by LYS. An important point to bear in mind when considering these results is that there is less agreement between the Shambaugh and LYS codings than between the Shambaugh and RR codings. For example, in the monthly data, each of the three groups identified by LYS contains both pegs and non-pegs from the Shambaugh classification, and approximately 30% of the LYS fixes are non-pegs in the baseline Shambaugh coding. Furthermore, when the results from the Shambaugh coding are reestimated using the subsample for which the LYS classification is available, the within month peg-pass-through from UM is 0.32, and the non-peg pass-through 0.18. Using the LYS classification alters the sample such that even the results from our baseline regime coding are sensitive. In Table 5, the within month pass-through to LYS intermediates is larger from UM than from FF, but the same is not true for LYS fixes (recall that the LYS fixes are a mixture of pegs and non-pegs from the Shambaugh coding). The daily LYS results indicate larger wedges between pass-through to fixes and floats using identified policy measures, consistent with the baseline results, but pass-through to the intermediate category is not always higher for an identified measure than it is for FF.

Overall, the results from the LYS classification of exchange rate regimes reveal some differences relative to our baseline estimates. Shambaugh (2004) also finds that estimated pass-through is sensitive to the use of the LYS classification and argues that his classification is more appropriate for evaluating interest rate transmission. Accordingly, we emphasize our core results ahead of those in Table 5, particularly given the increased estimation uncertainty associated with the smaller samples from the alternative regime classifications.

TABLE 5

INTEREST RATE PASS-THROUGH (LEVY-YEYATI/STURZENEGGER EXCHANGE RATE CLASSIFICATION)

U.S. interest rate measure	Exchange rate regime	β	$H_0: \beta = 1$ (p-value)	N	R^2
			Monthly frequency		
UM	Fix	0.39 (0.49)	0.21	709	0.001
	Intermediate	0.52 (0.75)	0.52	433	0.001
	Float	0.12 (0.17)	0.00	1,231	0.001
FF	Fix	0.47** (0.18)	0.00	709	0.004
	Intermediate	−0.02 (0.21)	0.00	433	0.00
	Float	0.13 (0.08)	0.00	1,231	0.003
			Daily frequency		
UM	Fix	0.83 (2.32)	0.94	180	0.00
	Intermediate	−0.15 (1.45)	0.43	100	0.00
	Float	−0.03 (0.13)	0.00	347	0.00
FF-FUT	Fix	4.71 (6.40)	0.56	180	0.003
	Intermediate	1.26 (2.35)	0.91	100	0.001
	Float	−0.10 (0.25)	0.00	347	0.001
FF	Fix	−1.73 (1.00)	0.01	180	0.01
	Intermediate	0.75 (0.64)	0.69	100	0.011
	Float	0.11* (0.05)	0.00	347	0.017

NOTES: Pass-through statistics measure the within month or day-to-day response of Home interest rates to a 1 percentage point increase in (i) UM, the unanticipated and exogenous U.S. interest rate measure; (ii) FF, the aggregate intended federal funds rate; and (iii) FF-FUT, the federal funds futures-based monetary policy shock (only for the daily data). The construction of the U.S. interest rate measures at the two frequencies is described in the main text. The monthly data cover the period 1972m1–2000m12. The daily data are drawn from 1988m10 to 2000m12. The daily data are the changes in interest rates around scheduled FOMC meetings, as defined in the main text. The underlying capital mobility indicator is from Shambaugh (2004). Standard errors are given in parentheses. * and ** denote significance at 5% and 1%, respectively. All standard errors and hypothesis test results are based on bootstrapped covariance matrices that use 1,000 replications.

4.4 Coincidence of Identified and Realized U.S. Monetary Policy Change Signs

Shambaugh (2004) makes the point that identified policy shocks can arise when interest rates do not change, but fundamentals predict that they should change. A natural question is whether pass-through is expected to occur in such instances. Our perspective is that it should. When fundamentals point to a foreign interest rate change, exchange rate expectations may adjust in advance, thereby forcing countries that peg to adjust their interest rates in order to maintain exchange rate stability. If the foreign interest rate does not in fact change, a negative foreign interest rate shock is recorded. In response, countries that peg can reverse any interest rate increases that market pressures had forced upon them, yielding interest rate pass-through. In order

TABLE 6

INTEREST RATE PASS-THROUGH (IF SGN[IDENTIFIED U.S. MP Δ] = SGN[FF])

U.S. interest rate measure	Exchange rate regime	β	H_0: $\beta = 1$ (p-value)	N	R^2	$\beta^P - \beta^{NP}$	H_0: $\beta^P = 1$, $\beta^{NP} = 0$ (p-value)
				Monthly frequency			
UM	Peg	0.86**	0.54	395	0.024	0.65**	0.14
		(0.23)				(0.25)	
	Non-peg	0.21	0.00	2,906	0.001		
		(0.11)					
FF	Peg	0.51**	0.00	395	0.033	0.38**	0.00
		(0.10)				(0.10)	
	Non-peg	0.12**	0.00	2,906	0.002		
		(0.05)					
				Daily Frequency			
UM	Peg	1.53*	0.42	70	0.089	1.45*	0.68
		(0.66)				(0.71)	
	Non-peg	0.08	0.01	937	0.000		
		(0.35)					
FF	Peg	0.21	0.00	70	0.012	0.22	0.00
		(0.22)				(0.29)	
	Non-peg	−0.004	0.00	937	0.000		
		(0.17)					
FF-FUT	Peg	1.14	0.91	76	0.028	0.46	0.48
		(1.30)				(1.47)	
	Non-peg	0.68	0.57	1,019	0.001		
		(0.55)					
FF	Peg	0.20	0.00	76	0.019	0.24	0.00
		(0.16)				(0.21)	
	Non-peg	−0.04	0.00	1,019	0.000		
		(0.12)					

NOTES: Pass-through statistics measure the within month or day-to-day response of Home interest rates to a 1 percentage point increase in (i) UM, the unanticipated and exogenous U.S. interest rate measure; (ii) FF, the aggregate intended federal funds rate; and (iii) FF-FUT, the federal funds futures-based monetary policy shock (only for the daily data). The construction of the US interest rate measures at the two frequencies is described in the main text. The monthly data cover the period 1972m1–2000m12. The daily data are drawn from 1988m10 to 2000m12. The daily data are the changes in interest rates around scheduled FOMC meetings, as defined in the main text. The exchange rate regime indicator and underlying capital mobility indicator are both from Shambaugh (2004). Note that the sample inclusion criteria here result in no observations where FF = 0 being included. Standard errors are given in parentheses. * and ** denote significance at 5% and 1%, respectively. All standard errors and hypothesis test results are based on bootstrapped covariance matrices that use 1,000 replications.

to investigate this issue empirically, we reestimate our baseline results after excluding observations if (i) the change in FF is exactly zero, or (ii) the sign of the identified policy change is different from the sign of the FF change. The second condition accounts for cases in which the policy rate changes, but by less than fundamentals predict, such that the identified shock is of opposite sign to the actual FF change. Note that the second condition requires separate subsamples, one based on UM/FF sign comparisons and one based on FF-FUT/FF sign comparisons.

The results are presented in Table 6. At the monthly frequency our estimates change very little relative to the baseline case; only non-peg pass-through from UM varies by more than just a few basis points. This suggests that interest rate shocks arising when there is no change in FF are propagated internationally in the same way as shocks generated when the intended policy rate does change. At the daily frequency, there is evidence of higher levels of pass-through to pegs from identified interest rate changes that are of the same sign as FF changes. Although the changes in pass-through are small relative to the estimation uncertainty, it is noteworthy that interest rate pass-through to pegs from UM is significant at the 5% level in the restricted sample. Furthermore, pass-through to pegs from UM increases relative to that from FF, and the increment to pass-through associated with pegging is 145 b.p. in the UM case, compared to just 22 b.p. in the FF case. Overall, our argument that interest rate pass-through does not depend on whether FF actually changes is supported at the monthly frequency but not the daily frequency, possibly indicating that interest rates around the world take time to adjust to interest rate surprises occurring as a result of inaction after FOMC meetings.

5. CONCLUSION

We have argued that the nature of Foreign interest rate changes is important in understanding Foreign's interest rate transmission to Home's interest rate, conditional upon the bilateral exchange rate regime. Under an imperfectly credible peg, anticipated or endogenous 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 the risk premium is *negative*. In contrast, unanticipated and exogenous interest rate changes will generate *positive* covariances with the unobserved variables, leading to estimated pass-through under a peg that *exceeds* unity. This implies that the identification of Foreign interest rate changes influences the interpretation of estimated interest rate pass-through and thus inference regarding the relevance of the monetary policy trilemma.

Our results indicated the difference between within-month pass-through to pegs and non-pegs from an identified U.S. interest rate change is twice that from a realized U.S. interest rate change. Pass-through to a peg from an identified U.S. interest rate change is also much closer to unity (a simple trilemma benchmark) than it is from a realized U.S. interest rate change. Interest rate pass-through estimated from daily data illustrates the contrast even more starkly. Pass-through to a peg from identified U.S. interest rate changes (via either the Romer and Romer–style procedure or the Kuttner-style futures-based procedure) is three to five times as large as that seen from realized U.S. interest rate changes. The wedge between peg and non-peg pass-through following an identified U.S. interest rate change is again roughly twice that from a change to the actual interest rate. However, estimation uncertainty in the daily sample is high.

Our results have implications for future empirical and theoretical studies. They indicate that a consideration of the nature of foreign interest rate changes should be included in empirical evaluations of international interest rate transmission. The appropriate interpretation of estimated pass-through depends upon the identification of foreign interest rate changes. We focused upon unanticipated and exogenous foreign interest rate changes. In future extensions, researchers might investigate how different properties (e.g., rate changes that are directly attributable to changes in the expectations of specific macroeconomic conditions) affect international transmission.

TABLE A1

Sample Composition

	Monthly				Daily			
	Starts		Ends		Starts		Ends	
Country	Year	Month	Year	Month	Year	Month	Year	Month
			Peg observations					
Argentina	1993	2	2000	12				
Bahrain	1985	8	1997	7				
Bahrain	1997	10	2000	12				
Canada	1990	2	1991	12	1991	2	1991	12
El Salvador	1997	2	2000	12				
Hong Kong	1994	2	2000	12	1988	11	2000	12
Indonesia	1992	2	1993	12	1993	2	1993	12
Kuwait	1979	2	1980	12				
Kuwait	1993	2	2000	12				
Malaysia	1989	2	1991	12				
			Nonpeg observations					
Australia	1984	2	2000	12	1988	11	2000	12
Austria	1991	2	1998	12	1992	2	1998	12
Belgium	1973	2	1998	12				
Bolivia	1995	2	2000	12				
Canada	1975	2	1989	12	1992	2	2000	12
Canada	1992	1	2000	12				
Denmark	1988	2	2000	12	1997	2	2000	12
Eurozone	1999	2	2000	12				
Finland	1991	2	1998	12	1992	2	1998	12
France	1990	2	1998	12	1991	2	1998	12
Germany	1973	2	1998	12	1988	11	1998	12
Guatemala	1997	2	2000	12				
Indonesia	1983	2	1984	3	1988	11	1991	12
Indonesia	1985	2	1985	12	1994	2	2000	12
Indonesia	1986	6	1991	12				
Indonesia	1994	1	2000	12				
Ireland	1992	2	1998	12	1993	2	1998	12
Italy	1990	2	1998	12	1991	2	1998	12
Japan	1979	2	2000	12	1989	2	2000	12
Kuwait	1981	1	1990	7				
Kuwait	1992	12	1992	12				
Luxembourg	1990	2	1998	12				
Malaysia	1973	2	1988	12	1993	8	1997	12
Malaysia	1992	1	1997	12				
Maldives	1987	2	1989	12				
Maldives	1993	2	1993	12				
Mexico	1981	5	1981	12				
Netherlands	1975	2	1998	12	1988	11	1998	12
New Zealand	1985	2	2000	12	1988	11	2000	12
Norway	1995	2	2000	12	1996	1	2000	12
Peru	1995	11	1995	12				
Portugal	1993	2	1998	12				
Singapore	1978	2	1998	12	1988	11	1998	12
Spain	1994	2	1998	12	1995	2	1998	12
Sweden	1993	2	2000	12	1994	2	2000	12
Switzerland	1992	2	2000	12	1993	2	2000	12
United Kingdom	1979	2	2000	12	1988	11	2000	12
Uruguay	1996	2	2000	12				
Vanuatu	1986	6	1986	12				
Vanuatu	1988	2	1989	12				
Vanuatu	1992	2	1992	12				
Vanuatu	1998	2	2000	12				
Venezuela	1988	2	1989	12	1997	2	2000	12

Note: Dates indicate the start and end month for each country time series included in the samples used for the monthly and daily regressions.

TABLE A2

Data Sources

Variable	Source
Monthly home money market rates (overnight, interbank)	International Financial Statistics (January 2008), series 60B.ZF
Daily home money market rates (overnight, interbank)	Global Financial Data (various data series)
U.S. federal funds rate	International Financial Statistics (January 2008), series 60B.ZF
Federal funds futures settlement prices	Chicago Board of Trade
Intended federal funds rate changes/levels	Romer and Romer (2004) available at: http://www.e-aer.org/data/sept04_data_romer.zip Post-1996, announced target changes available at: http://www.federalreserve.gov/fomc/fundsrate.htm
Federal Reserve Greenbook forecasts	Federal Reserve Bank of Philadelphia, available at: http://philadelphiafed.org/econ/forecast/
Exchange rate regime classification	Shambaugh (2004) available at: http://www.dartmouth.edu/~jshambau/ Reinhart and Rogoff (2004) available at: http://www.wam.umd.edu/~creinhar/Papers.html Levy-Yeyati and Sturzenegger (2003) available at: http://profesores.utdt.edu/~fsturzen/Publications.htm
Capital controls indicator	Shambaugh (2004) available at: http://www.dartmouth.edu/~jshambau/
Hyperinflation indicator	Shambaugh (2004) available at: http://www.dartmouth.edu/~jshambau/
Administratively set rate indicator	Shambaugh (2004) available at: http://www.dartmouth.edu/~jshambau/
Chinn–Ito capital controls measure	Chinn and Ito (2006, 2008) available at: http://www.ssc.wisc.edu/~mchinn/research.html

TABLE A3

Model Diagnostics

		Autocorrelation tests		Parameter homogeneity tests	
		Peg	Nonpeg	Peg	Nonpeg
UM	Monthly	−1.67	−2.32	6.16	30.84
		p-value = 0.10	p-value = 0.02	p-value = 0.52	p-value = 0.53
	Daily	0.07	0.08	1.75	18.64
		p-value = 0.50	p-value = 0.19	p-value = 0.42	p-value = 0.61
FF	Monthly	−1.7	−2.33	13.78	56.2
		p-value = 0.09	p-value = 0.02	p-value = 0.06	p-value = 0.01
	Daily	0.07	0.08	0.65	9.14
		p-value = 0.51	p-value = 0.19	p-value = 0.72	p-value = 0.99
FF-FUT	Daily	0.06	0.08	1.53	16.23
		p-value = 0.60	p-value = 0.20	p-value = 0.47	p-value = 0.76

Note: The monthly autocorrelation test is an LM test of the null hypotheses of no first-order error autocorrelation. The daily autocorrelation test is the robust t-ratio for the slope coeffiecient in a regression of the daily regression residual from the current meeting on the daily regression residual from the previous meeting. The parameter homogeneity tests are chi-square tests of the null of equality of slope coefficients across countries. All tests are based on regressions that use Shambaugh's exchange rate regime classification. The test statistics for parameter homogeneity are calculated using standard errors obtained from 1,000 bootstrap replications. All p-values are calculated using the asymptotic distributions for the test statistics.

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