Some empirical evidence on the effects of U.S. monetary policy shocks on cross exchange rates

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\begin{abstract}
This paper examines the impact of U.S. monetary policy shocks on the cross exchange rates of sterling, yen and mark. The main finding of the paper is a ‘delayed overshooting’ pattern for all currency cross rates examined (sterling/yen, yen/mark and mark/sterling) following an unexpected U.S. monetary policy change, which in turn generates excess returns. We also provide evidence that the ‘delayed overshooting’ pattern in cross exchange rates is accompanied by asymmetric interventions by central banks in the foreign exchange markets under consideration triggered by a U.S. monetary policy shock.
\end{abstract}

\section{Introduction}

Following the classic Dornbusch (1976) ‘overshooting’ model on the impact of monetary policy on exchange rates and interest rates in the presence of price stickiness, a large empirical literature has focused on the assessment of these effects.\textsuperscript{1} The standard theoretical framework predicts that a monetary tightening leads to an immediate exchange rate ’overshooting’. Several empirical papers have focused on the impact of U.S. monetary policy on interest rates and exchange rates vis-à-vis the U.S. dollar, and have established that the peak timing of this response occurs one to three years after rather than immediately (‘delayed overshooting’). This accumulated evidence creates in turn a ‘conditional forward premium puzzle’ with opportunities for excess returns by borrowing abroad and investing in the U.S. Although the standard ‘forward premium puzzle’ is well documented in empirical studies of the foreign exchange market (Froot \& Thaler, 1990; Hodrick, 1987), the puzzle now arises \textit{conditional} on an exogenous change in U.S. monetary policy.

In particular, Eichenbaum and Evans (1995) have shown that, in response to a tighter U.S. monetary policy, the dollar exhibits a ‘delayed overshooting’ behaviour of two to three years vis-à-vis the major currencies, a pattern that is confirmed by Clarida and Gali (1994). ‘Delayed overshooting’ is also assessed by Evans (1994), who uses weekly data and finds that the dollar overshoots with a delay of two to three years vis-à-vis the mark and the yen, and Lewis (1995), who finds that the dollar appreciates against the mark and the yen for the first five months after the monetary policy shock. Eichenbaum and Evans (1995) also offer empirical evidence that after a contractionary U.S. monetary policy shock, domestic interest rates rise relative to foreign interest rates and the dollar appreciates. Kalyvitis and Michaelides (2001) adopt a specification with relative output and prices in order to capture the relative business cycle position of the U.S. and the domestic country; this approach solves the ‘delayed overshooting’ effect, but the authors report persistent deviations from the uncovered interest rate parity hypothesis.

The ‘delayed overshooting’ and the ‘conditional forward premium puzzle’ are specific examples of how economies might be influenced by monetary policy abroad. However, the size of these impacts is likely to vary between countries due, for instance, to discrepancies in the structural characteristics of the economy, differences in nominal rigidities and/or asymmetries in the monetary policy functions of foreign countries driven by differential responses to deviations of inflation or output from the respective targets. A challenging empirical issue is therefore the potential asymmetry of ‘delayed overshooting’ between cross exchange rates, i.e. whether the magnitude of, say, the dollar appreciation against

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\textsuperscript{1} See Christiano, Eichenbaum, and Evans (1999) for an extensive survey of the relevant studies.
major currencies following a U.S. monetary policy tightening differs. This question was originally posed by Frankel (1986), but has only recently received some attention in the study by Lobo, Darrat, and Ramchander (2006) who examine the impact of changes in the Federal Funds Rate (FFR) target on daily dollar exchange rates and find that surprises associated with monetary contraction have a larger effect compared to monetary easing for the sterling, mark and Canadian dollar rates, whereas the opposite holds for the yen.

Taking ‘delayed overshooting’ as a stylized fact, in this paper we first attempt to investigate how and to what extent cross exchange rates of major currencies (sterling, Japanese yen and German mark) respond to U.S. monetary policy shocks. In this vein, we define ‘delayed overshooting’ as a change in the three cross exchange rates examined, which is triggered by a contractionary U.S. monetary policy shock, and gradually continues for some months or quarters after the shock. We also assess the response of interest rate differentials between the three countries (UK, Japan and Germany) and the existence of excess returns in these economies. To this end, we use the Structural Vector Autoregression (SVAR) approach that has been routinely used in the recent literature, in which we proxy U.S. monetary policy changes by the Romer and Romer (2004) narrative index (RR). This measure of U.S. monetary policy is better equipped to overcome the endogeneity and anticipatory biases that are inherent in other standard indices, such as the FFR or the non-borrowed reserves ratio.

We find a ‘delayed overshooting’ pattern for all the currency cross rates examined (sterling/yen, yen/mark and mark/sterling) when the Federal Reserve tightens U.S. monetary policy. Specifically, the mark appreciates with a delay relative to the yen with a peak at around ten months following the U.S. monetary policy shock, whereas the mark appreciates against the sterling, and the sterling against the yen with a peak at around six months after the shock. We find that the responses of exchange rates and interest rates following the U.S. monetary policy tightening leave room for excess returns in the three foreign exchange markets under consideration.

Next, we take our analysis one step further by attempting to explore whether the driving force of ‘delayed overshooting’ in the cross exchange rates has been asymmetric foreign exchange interventions by central banks (that is, interventions following a specific foreign monetary policy shock, which differ in size and/or direction). Our investigation is motivated by several studies that have investigated the repercussions of foreign exchange intervention on the exchange rate following a monetary policy shock. Lewis (1995) has reported that central banks intervene to support a monetary policy that is consistent with their exchange rate targets, as monetary policy changes driven by domestic targets may trigger counter-movements in the exchange rate. Bonser-Neal, Roley, and Sellon (1998) have claimed that interventions may at times react to past monetary policy actions, e.g. if U.S. monetary authorities wished to keep the exchange rate path within a particular zone. They find that not only various policies were evident at different periods, but also that the exchange rate responses to FFR changes are unaffected when one controls for central bank foreign exchange intervention. Kim (2003, 2005) has examined the joint effects of monetary policy and foreign exchange intervention on the U.S.–Canada exchange rate and has found evidence that delayed overshooting can be explained by interventions in the foreign exchange market intended to weaken the exchange rate appreciation following a monetary policy tightening.

Given these points, we use recently published foreign exchange intervention data to assess the potential impact of central bank intervention in the foreign exchange markets under consideration following a U.S. monetary policy shock. Our evidence shows that the ‘delayed overshooting’ pattern in cross exchange rates is accompanied by asymmetric foreign exchange interventions. The evidence points towards a ‘leaning-with-the-wind’ intervention policy by the Japanese monetary authorities, a finding that is in accordance with an effort to drive the yen to its new equilibrium against the dollar following a U.S. monetary policy tightening. In contrast, we find evidence of a ‘leaning-against-the-wind’ intervention by the German monetary authorities, which is consistent with a strengthening of the mark against the dollar following a U.S. monetary policy shock.

The paper makes two contributions in the relevant literature. First, the ‘delayed overshooting’ pattern of cross exchange rates has, to our knowledge, been unnoticed in existing empirical studies on the monetary policy transmission mechanism. Given the robustness of our empirical results, this pattern is likely to have comprised a substantial factor of exchange rate variability in the floating rate era. Second, the paper points out a source of exchange rate variability triggered by asymmetric central bank interventions, which offers a route for further explorations of the role of central banks in excess exchange rate movements, a role that is now conditional on an external monetary policy shock.

The rest of the paper is structured as follows. Section 2 outlines the empirical methodology and the data utilized. Section 3 assesses the impact of the monetary policy shocks using a SVAR model, while Section 4 develops robustness analysis. Section 5 explores the role of foreign exchange interventions. Finally, Section 6 concludes the paper.

2. Methodology and data

2.1. Empirical specification

The empirical studies on ‘delayed overshooting’ are largely based on VAR models with U.S. monetary policy typically being identified by exogenous shocks in the FFR, the ratio of non-borrowed to total reserves or the target FFR. In their extensive study on the empirical effects of U.S. monetary policy on dollar exchange rates, Eichenbaum and Evans (1995) estimated VAR models for the U.S. and the other G7 economies, including U.S. and foreign output, prices, interest rates, U.S. non-borrowed reserves, the FFR and the nominal U.S. dollar exchange rate vis-à-vis the foreign currencies, and assuming a recursive VAR structure in which the monetary policy shock is identified as an orthogonal innovation to the FFR or non-borrowed reserves.

Subsequent empirical studies on the impact of monetary policy on asset prices have mostly involved VARs with identification imposed as restrictions mapping the reduced-form shocks to structural shocks. Cushman and Zha (1997) constructed a two-country SVAR model assuming block exogeneity for the domestic variables of a small open economy (Canada) relative to the external (U.S.) variables. Their specification resolves some standard empirical puzzles, like the domestic currency depreciation following a domestic monetary policy contraction and the ‘price puzzle’.

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2 Bonser-Neal, Roley, and Sellon (1998) use the FFR target as a monetary policy indicator and find that the dollar overshoots immediately after the shock, thus exhibiting the classic Dornbusch (1976) ‘overshooting’ pattern. These authors claim that due to large deviations of the actual FFR (used in previous studies) from the FFR target, the latter should be considered as a better proxy for the true monetary policy measure. Bonser-Neal et al. (1998) also criticize the use of VARs for inaccurately measuring monetary policy effects due to problems related to the limitation of the information set. They claim that monetary policy may be inadequately represented when measured by shocks in the FFR within a VAR context; see also Rudebusch (1998). Another main category of U.S. monetary policy measures is known as the ‘narrative approach’ (Romer & Romer, 1989); Eichenbaum and Evans (1995) find that the ‘delayed overshooting’ pattern also arises when the dates identified by Romer and Romer (1989) are used to identify U.S. monetary policy contractions.
but the authors find short-run deviations from uncovered interest rate parity. Kim and Roubini (2000) used a non-recursive VAR that allows monetary policy to respond contemporaneously to exchange rate shocks and resolved partially the ‘delayed overshooting’ effect and the ‘conditional forward premium puzzle’. Furthermore, the authors provide evidence that, in response to an unexpected increase in the U.S. monetary policy rate, the short-term interest rates of non-U.S. G7 countries increase and their currencies relative to the dollar depreciate on impact. Faust and Rogers (2003) have assessed the robustness of conclusions drawn from SVAR models relative to changes in the identifying assumptions and find that the ‘delayed overshooting’ result is sensitive to the assumptions adopted. In contrast, they provide evidence that deviations from uncovered interest rate parity are robust to various assumptions and, moreover, that the estimates of the share of exchange rate variance due to monetary policy shocks can take quite large values.

Given these considerations, our identification of U.S. monetary policy is based on a number of standard structural assumptions. Our general empirical strategy is to develop a two-economy setup and include an external economy (U.S.) that is assumed to be large and relatively closed. Thus, we assume that a U.S. monetary policy shock reflects an exogenous shock for other economies, which in turn respond to domestic and external developments. The country pairs considered are UK–Japan, Japan–Germany and Germany–UK, a choice that is mainly dictated by the high economic integration among these economies and the almost perfect substitutability of their assets in international financial markets.

Our SVAR specification reports the effects of a shock in the monetary policy of a large foreign economy on the interest rates of country pairs and their corresponding cross exchange rates. This specification is broadly based on the identification scheme proposed by Kim and Roubini (2000) and is modified to account for the responses of two countries’ variables to an exogenous shock in the monetary policy of the foreign economy. In particular, we assume that the structural shocks, \( e(t) \), are related to the reduced-form residuals, \( u(t) \), by \( e(t) = G_0 \cdot u(t) \) with the contemporaneous coefficient matrix, \( G_0 \), given by:

\[
\begin{bmatrix}
e_{I1} \\
e_{I2} \\
e_{P1} \\
e_{P2} \\
e_{MR1} \\
e_{MR2} \\
e_{XR1/2} \\
e_{PW} \\
e_{RR}
\end{bmatrix}
= \begin{bmatrix}
1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
a_3 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\
a_5 & 0 & a_8 & 0 & 1 & 0 & 0 & 0 & 0 \\
a_7 & 0 & a_10 & 0 & a_11 & 0 & 1 & 0 & a_12 \\
0 & 0 & 0 & 0 & a_{13} & 0 & 1 & 0 & a_{14} \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
\end{bmatrix}
\begin{bmatrix}
a_1 & 0 & u_{IP1} & u_{IP2} & u_P1 & u_P2 & u_{IR1} & u_{IR2} & u_{XR1/2} & u_{PW} & u_{RR}
\end{bmatrix}
\]

The vector of variables for countries 1 and 2 consists of the log of output (\( I_1 \) and \( I_2 \)), the log of the price index (\( P_1 \) and \( P_2 \)), the log of a narrow monetary aggregate (\( M_1 \) and \( M_2 \)), the central bank interest rate (\( R_1 \) and \( R_2 \)), the log of the nominal cross exchange rate expressed in units of the currency of country 1 in terms of the currency of country 2 (\( XR_{1/2} \)), and the log of the world commodity price index (\( PW \)). Finally, the U.S. monetary policy indicator (\( RR \)) is given by Romer and Romer (2004); see Section 2.2 for more details on the \( RR \) indicator. In the SVAR methodology, identification is achieved by imposing contemporaneous restrictions on the structure of the economy and the stochastic structure of the model (Bernanke, 1986; Blanchard & Watson, 1986; Sims, 1986). The relation between the structural and the reduced-form disturbances implies then that there are \( n(n + 1) \) free parameters to be estimated and we need at least \( n(n - 1)/2 \) restrictions on \( G_0 \) to achieve identification when the diagonal elements are normalized to 1’s (Kim & Roubini, 2000).

The equations of the model are divided into three blocks that broadly follow Gordon and Leeper (1994), Kim (1999), and Kim and Roubini (2000). The first block with four equations represents the goods markets in countries 1 and 2 under the plausible assumptions that real activity does not respond contemporaneously to the price level, the monetary aggregate, the interest rate and the exchange rate of the domestic economy. Thus, firms cannot adjust their output contemporaneously due to inertia and other adjustment costs, although unexpected changes in prices or financial variables affect real activity in the long run. We also assume that there are no contemporaneous mutual effects between the real sectors of the two countries and that both output and prices do not respond contemporaneously to innovations in the \( RR \) indicator, which are sensible assumptions given our monthly data frequency.

The second block describes the demand and supply of money. Specifically, the 5th and 6th equations represent the money demand functions for the two countries where the standard approach with the demand for real money balances depending on real income and the opportunity cost of holding money is adopted. Next, the 7th and 8th equations describe the monetary policy rule with the discount rate set by the central bank after observing the current domestic monetary aggregate and the exchange rate vis-à-vis the other foreign country (cross exchange rate). Jang and Ogaki (2004) have shown that results from VARs on the effects of U.S. monetary policy on exchange rates are sensitive to this assumption, which is consistent with central bank policy. Notice that the central bank does not react to shifts in the current values of the monetary aggregate of the foreign economy and to the domestic and foreign output and price levels, due to information delays in data availability. Also, following Kim and Roubini (2000), the domestic interest rates are restricted from responding contemporaneously to unexpected shifts in the external (U.S.) monetary policy shocks, an assumption that seems plausible due to information delays and the focus of monetary authorities on domestic developments.

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3 Although central banks typically do not admit targets for the exchange rate, they definitely pay attention to exchange rate developments. For example, the Bank of England’s Inflation Report reviews explicitly how the current level of the sterling and its forecasted path will impact the inflation forecast and, in turn, monetary policy. Also, both the Bank of Japan and the Bundesbank were concerned with the exchange rate. See McKinnon (1995) for a relevant point on the Bank of Japan’s monetary policy reaction. The Bundesbank’s Monthly Reports mentioned frequently how fluctuations in the mark exchange rate would be mirrored into monetary policy, as a weak (strong) mark indicated possible inflationary pressures (demand contraction); see also Clarida (2001). Evidence from VARs reported by Clarida and Gertler (1997) showed that the day-to-day money rate, the instrument of Bundesbank monetary policy, indeed responded to the mark in the way described above.
Finally, in the third block of the system the 9th equation is an arbitrage condition where we assume that the cross exchange rate is contemporaneously affected by all previous variables. The world commodity price index is exogenous to any domestic variable. Last, we treat the RR index as not responding to the foreign countries’ variables, although we allow for contemporaneous response to the world commodity price index. This reflects the widespread view that the Federal Reserve has conducted monetary policy acting as the leader in international interest rate movements and has been less concerned with external factors than other central banks.4

2.2 Data and estimation

To identify U.S. monetary policy shocks we use the (cumulated) indicator proposed by Romer and Romer (2004), who have further developed the narrative approach introduced by Friedman and Schwartz (1963) and formalized by Romer and Romer (1989). In Romer and Romer (2004) a series of intended FFRs around the meetings of the Federal Open Market Committee is first derived. To account for endogenous interest rate changes linked to economic conditions, the series is regressed upon the Federal Reserve’s internal forecasts of inflation and real activity with the residuals representing changes in the intended funds rate that are orthogonal to information on future economic conditions. Romer and Romer (2004) find that the policy effects are substantially stronger and quicker using this indicator relative to other conventional U.S. monetary policy measures, like innovations in the FFR or the non-borrowed reserves. However, to assess the robustness of our results to the adoption of the RR index, we shall also use alternatively the FFR and the indicator proposed by Bernanke and Mihov (1998); see Section 4 for more details.

To estimate the SVAR model outlined above, the following variables were used. Output (IP) is measured by the industrial production index, the price level (P) by the consumer price index, and money (M) by the monetary aggregate M1, with the exception of the UK for which M0 is used (all series are seasonally adjusted). We also used the key central bank interest rate (IR), the nominal cross exchange rate (XR1/2) expressed in units of the currency of country 1 for a unit of the currency of country 2, the World All Commodities Prices index (PW), and the RR index. All data are taken from the IMF’s International Financial Statistics with the exception of the Romer and Romer (2004) U.S. monetary policy index, which is provided by the authors. The dataset used to estimate the model consists of monthly observations covering the period 1980:01–1996:12 and the reduced-form specifications are estimated with 6 lags and a constant unless otherwise noted.5

3. The effects of monetary policy shocks on cross exchange rates

In this section we assess the effects of a U.S. monetary policy shock on the cross exchange rates and the interest rates for the three economies considered (UK, Japan and Germany) in the context of the model developed in the previous section. Fig. 1 displays the impulse responses of the variables of interest for the UK–Japan, Japan–Germany and Germany–UK pairs following a contractionary U.S. monetary policy shock (illustrated as a positive one standard deviation of the RR index). Solid lines are the point estimates, and dotted lines represent one-standard-error bands for a 48-month period derived from 8000 draws by Monte Carlo integration following Sims and Zha (1999).

The results for output, prices and monetary aggregates (not reported here) show that tightening U.S. monetary policy affects foreign output for a period lasting up to one year. The response of the price level is insignificant for all the pairs of countries indicating the absence of any ‘price puzzle’. The monetary aggregates increase significantly for Japan and Germany, but are found to diminish in the case of the UK following the U.S. monetary policy tightening. Turning to the variables of interest, we observe that after a RR contractionary shock the central bank interest rates in the UK and Germany remain virtually unaffected (see first two rows of Fig. 1). However, the Japanese interest rate rises immediately and persistently. In addition, all cross exchange rates exhibit a ‘delayed overshooting’ pattern (see third row of Fig. 1). Specifically, the mark appreciates with a delay relative to the yen with a peak at around ten months following the U.S. monetary policy shock, whereas the ‘delayed overshooting’ pattern for the sterling/yen and the mark/sterling is somewhat shorter. The mark appreciates against sterling, and sterling against the yen with a peak at around six months after the shock; this behaviour is in line with the appreciation of the mark against the yen.

The overall picture suggests that there may be room for excess returns in the pairs of countries considered: to investigate this hypothesis we estimate the effects of a monetary policy shock on ex-post excess returns on the basis of our estimated SVAR.6 The results are presented in the last row of Fig. 1, showing the point estimates and the one-standard-error bands of the impulse responses for a 48-month period following a tightening monetary policy shock in the RR indicator. We find that the hypothesis of no excess returns can be rejected in all cases at around four-to-six months following the U.S. monetary policy shock, pointing towards a short-lived violation of uncovered interest rate parity.

We next assess the extent to which U.S. monetary policy shocks have been a prominent source of exchange rate fluctuations during the period under consideration, in order to shed some light on the causes of exchange rate volatility, which often occurs despite the apparent stability in the domestic macroeconomic environment. External monetary policy shocks might also provide – at least partially – an explanation for the periodic turbulence that has been observed, e.g. in the Exchange Rate Mechanism of the European Monetary System (EMS). Table 1 summarizes the percentage of the n-step ahead forecast errors in the central bank interest rates and the cross exchange rates that is attributable to innovations in U.S. monetary policy. As can be readily seen, a non-negligible part of the cross exchange rates variation for all pairs of countries can be attributed to the U.S. monetary policy shock: this effect exceeds 10% of total variation for the cross exchange rates under

4 Notice that the Federal Reserve’s policy decisions are usually based on permanent changes rather than short-term developments in foreign capital markets. This may explain, to some extent, the neglect of contemporaneous shocks in foreign interest rates in their monetary policy stance. The Federal Reserve has traditionally been concerned with U.S. developments (as prescribed in the 1977 amendment to the Federal Reserve Act) and has rarely made policy decisions based on international considerations, perhaps with the exception of some contractions during steep dollar changes (see also Cooper and Little, 2001). Along this reasoning, the output, prices and monetary aggregates of the large, external economy (U.S.) are not included here for two reasons. First, these effects are already incorporated in the RR index and, second, we focus on the effects on cross exchange rates and not on the exchange rates vis-à-vis the dollar.

5 The choice of the starting period was based on the point raised by Clarida, Gali, and Gertler (1998) that during 1979 there were large regime shifts in the conduct of monetary policy by the major central banks, as the control of inflation became their primary objective. The availability of the RR monetary policy measure as provided by Romer and Romer (2004) determined the ending period of our sample.

6 The impulse responses of excess returns are related to the impulse responses of the interest rates and the cross exchange rate as follows: \( ER^{1/2} = IR_0 - IR_1 + XR_{-1}^{1/2} \).
consideration at a one-to-three-year horizon, reaching 23% for the yen/mark rate in the second year after the shock. To convey a sense of the uncertainty associated with these point estimates, the standard errors are also reported. Although the confidence intervals are wide, we find that U.S. monetary policy shocks are significant for the variation of cross exchange rates, particularly for the yen/mark.

A smaller, but non-negligible part of the variation in interest rates is also attributable to the RR shock, especially at a longer horizon.

To sum up, our evidence points towards a strong response of the interest rate in Japan following a contractionary U.S. monetary policy shock. At the same time, we observe a ‘delayed overshooting’

Table 1

<table>
<thead>
<tr>
<th>Period</th>
<th>UK–Japan</th>
<th>Japan–Germany</th>
<th>Germany–UK</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>UK rate</td>
<td>Japan rate</td>
<td>German rate</td>
</tr>
<tr>
<td></td>
<td>Sterling/yen</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1–3</td>
<td>0.4323 (0.618)</td>
<td>2.5387 (1.757)</td>
<td>1.7183 (1.769)</td>
</tr>
<tr>
<td>4–6</td>
<td>2.3010 (2.375)</td>
<td>7.1177 (4.508)</td>
<td>5.1830 (4.340)</td>
</tr>
<tr>
<td>7–12</td>
<td>3.5102 (3.047)</td>
<td>8.3110 (6.168)</td>
<td>13.2217 (7.370)</td>
</tr>
</tbody>
</table>

Notes: The number of periods denotes months after the shock. Standard errors are in parentheses.
pattern in the cross exchange rates between the currencies of UK, Japan and Germany, indicating the substantial impact of the U.S. monetary policy shocks on the foreign currencies.

4. Sensitivity tests

This section presents some sensitivity tests on the empirical impact of U.S. monetary policy on foreign interest rates and cross exchange rates. First, we note that the specification presented in Section 2 entails a detailed framework for investigating the impact of external monetary policy shocks on individual country’s variables, but we are also interested in examining the impact on the relative position of the two countries. To this end, we follow Kalyvitis and Michaelides (2001) and use a model specified in relative terms, which has been shown to eliminate ‘delayed overshooting’ in the assessment of the effects of U.S. monetary policy shocks when a recursive error structure is adopted. This approach requires the estimation of fewer parameters, increasing the degrees of freedom, and allows us to assess the robustness of our results based on the previous specification. The results confirm our previous findings. Output and prices are little affected by a tightening U.S. monetary policy shock, with the sole exception of the relative price level for Japan–Germany that becomes negative in the short run. The monetary aggregates increase in the case of Japan and Germany, while they fall in the case of the UK. The Japan–Germany interest rate spread widens. Furthermore, the impulse responses of the cross exchange rates show ‘delayed overshooting’ in line with our previous results. The hypothesis of no excess returns is again rejected in all cases at around four-to-six months. Finally, the percentage of the n-step ahead forecast errors in the cross exchange rates that is attributable to innovations in U.S. monetary policy is lower compared to our previous findings, but remains above 10% at a one-to-three-year horizon.

In order to assess the robustness of our results to the U.S. monetary policy index, we use two alternative measures. The first measure is the FFR that has been proposed by Bernanke and Blinder (1992) and has been routinely utilized by the majority of studies attempting to assess empirically the impact of U.S. monetary policy. The second measure, also used by Kalyvitis and Michaelides (2001), is the Bernanke and Mihov (1998) indicator (BM) that is based on a model of commercial bank reserves and Federal Reserve operating procedures and has the ability of reflecting both interest rate and reserves targeting policies. According to Bernanke and Mihov (1998) the Federal Reserve has exercised both types of monetary policy: non-borrowed reserves targeting in the period from late 1979 to late 1982, and FFR targeting from 1983 onwards. Therefore, the BM indicator provides an overall measure of monetary policy stance. We thus estimate the impulse responses by using alternatively these two measures of U.S. monetary policy in the place of the RR indicator for both the benchmark and the relative terms model.

For the UK–Japan pair, the response of the sterling/yen cross rate to FFR innovation exhibits a statistically significant appreciation of the sterling against the yen, which is similar to the response following the shock in the RR index. However, the sterling/yen cross rate remains virtually unaffected following a shock in the BM indicator. Both central bank interest rates exhibit an immediate and significant rise after a U.S. monetary policy shock when the FFR and BM indicators are used; moreover, the response of the central bank interest rate spread shows an increase for the model with relative variables. Regarding the presence of excess returns, under both U.S. monetary policy measures (FFR and BM) the hypothesis of no excess returns can be rejected for the fourth month under the benchmark model and for a longer period lasting up to one year for the relative terms model. The impulse responses to innovations in the FFR for the Japan–Germany pair are close to the responses to the RR indicator with similar short-term excess returns generated immediately after the FFR shock. The impulse responses following the shock to the BM index differ from those generated when the RR index is used. In particular, the yen rate shows a significant appreciation relative to the mark on impact, while there is no evidence of excess returns. As regards the Germany–UK pair, the impulse responses of all variables following the FFR and BM innovations are similar to those obtained by the RR indicator, with the exception of the mark/sterling rate whose response is found to be statistically insignificant for the relative terms model. Again, there is evidence of excess returns for the second quarter under the benchmark model and for the fourth month for the relative terms model following a monetary policy shock to either the FFR or the BM indicator.

5. Interpreting the evidence: a foreign exchange intervention approach

Given our empirical findings so far, which have established the ‘delayed overshooting’ effect for the pairs of countries under consideration, in this section we attempt to interpret the reaction of cross exchange rates after the U.S. monetary policy shock by investigating the role of foreign exchange intervention. The latter are broadly classified into two types according to their targets: (i) as ‘leaning-against-the-wind’ policies, under which the authorities aim at mitigating the dominant trend in the exchange rate (for example selling a currency when it is appreciating) and (ii) as ‘leaning-with-the-wind’, when the authorities seek to hasten the exchange rate trend in the expected direction (like accelerating the depreciation of a currency to the desired level). Our investigation aims at identifying the potential impact and direction of foreign exchange intervention following a foreign monetary policy shock in conjunction with our previous finding of ‘delayed overshooting’ in cross exchange rates. Given this purpose, we follow Kim (2003, 2005) in our empirical setup to investigate the extent to which foreign exchange intervention responses are significant following a U.S. monetary policy shock.8

8 Given the data availability for the FFR, we can also investigate the impulse responses over a longer sample period. However, monetary data for Germany are available up to end-1998, so we experiment only with UK and Japan data. The series of the World All Commodities Prices index was discontinued in 2003 and was extrapolated using the newly released series by IMF. Notice that in May 2006 the Bank of England introduced Money Market Reform and ceased the publication of M0. We estimate the impulse responses over the period 1980:01–2006:04 and we assess that all results are in line with our previous findings. Another robustness test involves the use of the real exchange rate instead of the nominal rate. Given short-run price rigidities, we are interested in testing whether monetary policy shocks translate into real exchange movements as well. Hence, this modification allows us to investigate the impact of U.S. monetary policy shocks on the relative competitiveness of other countries and, moreover, facilitates comparisons with earlier studies (like, for instance, Eichenbaum & Evans, 1995). The results verify our earlier findings that sterling appreciates significantly against the yen, and the mark against both the yen and sterling. The rise in the interest rate in Japan remains statistically significant and we find again short-lived excess returns in all cases under both models that are close to those reported earlier on.

9 Following the Plaza Agreement (September 1985) and the Louvre Accord (February 1987) according to which central banks conducted coordinated foreign exchange transactions aiming at mitigating the overevaluation of the U.S. dollar, and, generally, stabilizing exchange rates by means of interventions, several authors have investigated the conduct of foreign exchange market intervention and its impact on the exchange rate. See, among others, Schwartz (2000), Sarno and Taylor (2001), Dominguez (2003) and Neely (2005) for detailed surveys on interventions in the foreign exchange market and the related theoretical and empirical literature.
To this end, we extend our empirical specifications to account for the impact on foreign exchange intervention. Notice that some studies have attempted to identify foreign exchange intervention by changes in central bank reserves. This approach, however, has been criticized because reserves may fluctuate excessively due to changes in valuation or interest receipts. In addition, they do not include intervention operations like hidden reserves, which involve changes in official deposits of foreign currency with domestic currency and are regularly used by many central banks. Taking these considerations into account, the dataset we use in our study covers reported interventions (in millions of domestic currency) in dollars and marks by the Bank of Japan during the period 1991–1996, in dollars by the Bundesbank during the period 1979–1995 when interventions ceased, and in dollars and marks by the Bank of England during the period 1988–1993 when interventions ceased. We then define foreign exchange interventions by each central bank as the ratio of net transactions (purchases or sales) of the three foreign currencies under consideration during the corresponding month over the domestic monetary base defined as money in circulation and credit institutions’ current accounts for Japan and Germany, and money in circulation (MO) for the UK.

After including the foreign exchange interventions the contemporaneous coefficient matrix \((G_0)\) becomes:

\[
\begin{bmatrix}
eIR_1 \\
eIR_2 \\
eFEI_1 \\
eFEI_2 \\
eXR1/2 \\
ePW \\
erR \\
\end{bmatrix} = \begin{bmatrix}
1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & a1 & 0 & \nu_{eIP_1} \\
0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & a2 & 0 & \nu_{eIP_2} \\
a3 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & a4 & 0 & \nu_{eIP_3} \\
a5 & 0 & a8 & 0 & 1 & 0 & a9 & 0 & 0 & 0 & 0 & 0 & a6 & 0 & \nu_{eIP_4} \\
a7 & 0 & a8 & 0 & 1 & 0 & a9 & 0 & 0 & 0 & 0 & 0 & a6 & 0 & \nu_{eIP_5} \\
a10 & 0 & a11 & 0 & 1 & 0 & a12 & 0 & 0 & 0 & 0 & 0 & a16 & 0 & \nu_{eIP_6} \\
0 & 0 & 0 & a13 & 0 & 1 & 0 & a14 & 0 & a15 & a16 & 0 & \nu_{eIP_7} \\
0 & 0 & 0 & 0 & 0 & 0 & a17 & 0 & 1 & 0 & a18 & a19 & a20 & 0 & \nu_{eIP_8} \\
0 & 0 & 0 & 0 & 0 & 0 & a21 & 0 & 1 & 0 & a22 & 0 & 0 & \nu_{eIP_9} \\
0 & 0 & 0 & 0 & 0 & 0 & a23 & 0 & 1 & a24 & 0 & 0 & \nu_{eIP_{10}} \\
a25 & a26 & a27 & a28 & a29 & a30 & a31 & a32 & a33 & a34 & a35 & a36 & 0 & \nu_{eIP_{11}} \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & \nu_{eIP_{12}} \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & a37 & 1 & \nu_{eRR} \\
\end{bmatrix}
\]

We assume that the foreign exchange intervention variables, termed \(FEI_1\) and \(FEI_2\), respectively, react contemporaneously to the exchange rate, while the central bank interest rate is set contemporaneously in reaction to domestic monetary aggregate and exchange rate changes as in the benchmark specification. Furthermore, we allow contemporaneous interactions between the two policies. The rest of the variables are structured as before.

Fig. 2 depicts the impulse responses of the interest rates, the foreign exchange interventions and the cross exchange rates for an 18-month period following a RR monetary policy shock. For the UK–Japan pair of countries, intervention rises only for the Bank of Japan, whereas the intervention by the Bank of England remains unaffected (see the third and fourth row of the first column in Fig. 2). Interestingly, the ‘delayed overshooting’ pattern for the sterling/yen exchange rate is now insignificant (see the last row). The second column in Fig. 2, which plots the corresponding figures for the Japan–Germany pair, confirms this pattern. Again, the rise in intervention by the Bank of Japan triggers dollar purchases, which are now accompanied by dollar purchases by the Bundesbank. Again, the ‘delayed overshooting’ pattern in the yen–mark cross rate is virtually eliminated. Moreover, the response of the Bank of Japan central rate is insignificant. These findings are in accordance with a ‘leaning-with-the-wind’ intervention by the Japanese monetary authorities who expect the yen to depreciate against the dollar following the U.S. monetary policy contraction, and decide to buy dollars in an attempt to stabilize the domestic currency at a higher level. The evidence presented here seems therefore to support the view that, conditional on a U.S. monetary policy shock, the Japanese monetary authorities have attempted to drive the yen to its new equilibrium against the dollar.

The picture is somewhat different when we turn to the Germany–UK pair (see the corresponding rows of the third column in Fig. 2). The response of the Bundesbank is to sell dollars following the U.S. monetary contraction. This can be interpreted as a ‘leaning-against-the-wind’ intervention by the German monetary authorities, which aim at strengthening the mark against the dollar. Following the ‘leaning-against-the-wind’ intervention in support of the mark and the lack of intervention by the Bank of England, the mark appreciates with a delay against sterling after the U.S. monetary policy tightening. The evidence is consistent with the low inflation target implemented by the Bundesbank and its leading role in the EMS with German monetary authorities intervening in the foreign exchange market after an unexpected U.S. monetary tightening to prevent the depreciation of the mark vis-à-vis the dollar, which would have affected the stability of the EMS, and in turn generated a strong response in the mark/sterling exchange rate.

We close this section by stressing that even though asymmetric short-lived foreign exchange interventions appear to be a potential mechanism generating prolonged ‘delayed overshooting’ in currency crosses following an external monetary policy shock, an...
in-depth treatment of this causal channel is beyond the scope of the present paper. Given the short data span, we view our results on the response of foreign exchange interventions as a first step towards understanding the repercussions for excess exchange rate fluctuations triggered by foreign monetary policy innovations. A more extensive investigation regarding the relationship of the response of foreign exchange interventions in conjunction with cross exchange rate responses, possibly by using intervention data covering larger periods as well as higher frequency exchange rate data, seems therefore warranted.

6. Concluding remarks

This paper has investigated the effects of U.S. monetary policy shocks on foreign interest rates and cross exchange rates. Building upon the spirit of Eichenbaum and Evans (1995) and using a SVAR approach, we first attempted to assess the impact of unanticipated U.S. monetary policy on foreign interest rates and cross exchange rates in the UK, Japan and Germany. We provided evidence in support of ‘delayed overshooting’ in all the currency crosses examined (sterling/yen, yen/mark and mark/sterling) accompanied by excess returns in the foreign exchange markets considered, whereas a non-negligible portion of exchange rate variability between the currency crosses can be attributed to the U.S. monetary policy shock. We then investigated the possibility that ‘delayed overshooting’ in cross exchange rates is triggered by central bank interventions in the corresponding foreign exchange market following the U.S. monetary policy shock. Our evidence indicated the presence of asymmetric foreign exchange interventions, which are likely to have generated ‘delayed overshooting’ effects in the cross exchange rates examined. Thus, our paper stresses another aspect of asymmetry in central bank behaviour during the floating exchange rate era, namely the possibility that exchange rate fluctuations were generated by foreign exchange interventions following external monetary policy disturbances.

We close the paper by noting that here we focused on the international effects of monetary policy that mainly arise through the exchange rate channel and work through the uncovered interest rate parity condition. These effects may be exacerbated by the presence of asymmetries in the monetary policy functions of foreign countries, like differential responses to deviations of inflation or output from the respective targets. To sharpen our understanding of the implications generated by the conduct of foreign monetary policy, we delegate a more in-depth analysis of the structural characteristics of domestic monetary policy responses following external shocks to future research.
Acknowledgements

Financial support through project ‘Pythagoras II’ co-financed by the European Social Fund and the Ministry of Education in Greece is gratefully acknowledged. We have benefited from useful discussions with S. Brissimis, H. Gibson, D. Kosma, A. Michaelides, E. Pappa on earlier drafts and from comments and suggestions by an anonymous referee and seminar participants at the Athens University of Economics and Business and the 5th Annual European Economics and Finance Society conference. The usual disclaimer applies.

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