Carry Trade, Uncovered Interest Parity and Monetary Policy

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Abstract

It is well documented in the literature that identified vector autoregression models often produce puzzling results when the effect of unexpected monetary policy movements is estimated. Many authors find that raising interest rate generates protracted appreciation of the exchange rate (the so-called delayed overshooting puzzle) which is in contradiction with traditional theory of exchange rate dynamics based on uncovered interest parity. Brunnermeier et al. (2009) relates delayed overshooting to slowly moving carry trade activity. Plantin and Shin (2011) build a model in which carry traders blow rational speculative exchange rate bubbles in response to monetary tightening further stimulating domestic demand. In our paper we estimate a VAR for a panel of small open economies that are considered as targets for carry trade strategies. We identify structural shocks by allowing the interest rate and exchange rate to react simultaneously to monetary policy and changes in expected risk premium. Our results show that the delayed overshooting is not a robust finding. Exchange rate appreciation and carry trade movements take place almost on impact after an unexpected interest rate hike. Roughly half of the variation in carry trade positions can be explained by domestic interest rate changes and risk premium shocks.
1. INTRODUCTION

There is an unpleasant disconnect between the best practice of monetary policy and empirical tests of exchange rate theories. While central banks’ forecasts and decision-making rely on models assuming some sort of uncovered interest parity (UIP), there seems to be a wide consensus among econometricians that UIP can be rejected with high certainty. Nevertheless, the dynamic relationship between exchange rate and interest rate is of special interest for central banks in small open economies where the exchange rate channel of monetary transmission mechanism is important.

In our paper we focus only on one of the empirical puzzles called delayed overshooting (DOS). According to Dornbusch’s (1976) model in which UIP holds, after an (unexpected) monetary tightening the nominal exchange rate appreciates instantaneously and then gradually depreciates to its new level consistent with purchasing power parity. However, structural VAR estimates, like Eichenbaum and Evans (1995) or more recently Scholl and Uhlig (2008), often show a gradual appreciation lasting even for years.

There are, however, some authors who challenge the identification strategy of the studies reporting DOS. Already McCallum (1994) emphasized that the empirical failure of UIP may be caused by shocks to the exchange rate to which the monetary policy reacts within one period. Since in small open economies exchange rate movements can have a large impact on inflation and output, a quick response of central banks to those shocks can be justified. Cushman and Zha (1997), Kim and Roubini (2000), Faust and Rogers (2003), Bjørnland (2009), Jarociński (2010) and Vonnák (2010) relax the assumption that monetary policy reacts to exchange rate shocks only with delay, which is often implicitly made by Cholesky decomposition of the variance-covariance matrix. Allowing simultaneity between monetary policy and the exchange rate yields impulse responses resembling to Dornbusch’s overshooting model. It should be noted, however, that Scholl and Uhlig (2008) find DOS without assuming recursive structure among the shocks and the variables.

Another issue which recently has received much attention and is presumably related to delayed overshooting is carry trade activity. Carry traders borrow in low-interest-rate currency and lend in high-interest-rate currency. As long as UIP holds, profit of the carry trade strategy is zero on average since the interest rate premium is perfectly offset by the exchange rate depreciation. If we augment the UIP by a (perhaps time-varying) risk premium term, the return of a carry trade position equals this risk premium which can be regarded as the compensation for taking the exchange rate risk. Still, as long as exogenous interest rate changes by the central bank do not affect the risk premium, UIP holds conditionally, and after the infinitesimally short period during which the exchange rate jumps according to Dornbusch’s model, there is no incentive for carry traders to change their exposure. Thus, after a monetary shock we would expect only a very temporary change in speculative positions.

On the contrary, the delayed reaction of exchange rate to monetary policy provides excess return for several periods. After an interest rate hike a carry trader could make profit from higher return on domestic assets as well as from the appreciation of the currency. Since the exchange rate appreciates gradually, DOS would imply protracted carry trade inflow. In the seminal paper of Brunnermeier et al. (2009) slowly moving carry traders and DOS are related to each other. The authors estimate a VAR and show that the reaction of both the exchange rate and carry traders to an interest rate shock is protracted.
In the model of Plantin and Shin (2011) carry traders endogenously amplify the effect of monetary policy on the exchange rate. They assume that carry traders while going long in local currency, increase the credit supply and therefore generate an overheating in domestic demand. In response to this, the central bank increases further the interest rate which attracts more capital from abroad. The result is a monetary policy generated bubble that ends up in a currency crash. In this model the role of carry traders is destabilizing, as opposed to the conventional UIP framework where it is the carry trader who helps the parity condition to be fulfilled quickly. This mechanism is also known as Tosovsky-dilemma, named after an earlier governor of the Czech central bank and appears often in central bank publications and financial market experts’ analysis.

In our paper we deploy a robust econometric methodology to investigate the relationship between monetary policy, exchange rate and carry trade. Similarly to Brunnermeier et al. (2009) we estimate the effect of the interest rate change on carry trade activity and the exchange rate within the same model. By doing this, we have the chance to uncover not only how monetary policy affects the exchange rate and carry trade, but also how carry trade transmits monetary policy shocks. We estimate our structural VAR on a panel of three open economies (Australia, Canada, U.K.) having currencies considered to have been target for carry trade. However, unlike the above-mentioned paper, we distinguish between endogenous and exogenous interest rate movements by identifying monetary policy and other structural shocks. Following the previously mentioned studies that challenged the existence of DOS, we allow the monetary policy to react simultaneously to exchange rate or risk premium shocks by imposing sign instead of zero restrictions.

Our second contribution to the literature is that we try to find the main driving forces behind carry trade. To this end, we identify four domestic and four foreign shocks. The variance decomposition of carry trade data may inform us about whether the exchange rate is a shock absorber or a source of idiosyncratic shocks, and whether traders on the FX-market help the exchange rate react quickly to changes in fundamentals or generate undesired volatility.

Our approach is similar to that of Anzuini and Fornari (2011). Although they focus more on determinants of carry trade and less on DOS, their approach is common with ours in recognizing the importance of the identification of economically meaningful shocks. However, there are essential differences in the model specification. Probably the most important is that while they estimate a VAR on relative variables (domestic minus foreign), we use the original time series. This may have crucial consequences since domestic variables are more likely to track the foreign ones than vice versa. Therefore, we expect a better identification of the relevant structural shocks in our model than in that of the referred study.

Our results show that delayed overshooting is not a robust finding. Our exchange rate impulse response functions resemble rather Dornbusch’s (1976) overshooting model, consistently with UIP. Comparison with the Cholesky identification scheme confirms previous findings that improper identifying restrictions embedded implicitly in the recursive approach can be responsible to some extent for the puzzle. Even carry traders react to monetary policy according to the UIP: the exogenous shift in monetary policy stance induces a contemporaneous change in speculative currency positions which reverts already in the next period. These results suggest that the exchange rate channel of monetary transmission mechanism works as in the textbooks and carry traders play an important role in it. Our findings are in line with those of Kisgergely (2012), who could reject the hypothesis that interest sensitive capital flows can reverse the effect of monetary policy.
Variance decomposition shows that roughly half of the carry trade movements can be attributed to surprise movements in domestic monetary policy stance and changes in risk premium of the domestic currency. While the interpretation of the former is straightforward, the latter is not. As mentioned above, the dynamics of the exchange rate and carry trade after a monetary policy shock suggest that speculative position-taking help the UIP to restore quickly. The realized risk premium of a currency can change for two reasons: either because the fundamentals have changed and carry traders adjust they demand for compensation for taking risk accordingly, or because there is an idiosyncratic shock to carry trade activity. In the first case the role of currency speculation can be considered as greasing, as the new information about the current or future state of the economy is channelled into the exchange rate by carry traders. In the second case, however, currency speculation is a source of shocks that can lead to welfare losses. Unfortunately within our modelling framework it is not possible to decompose risk premium shocks to changes in the risk profile of the economy and changes in the risk taking ability, therefore we cannot draw firm conclusions to what extent carry trade activity is welfare-improving.

The remainder of the paper is structured as follows. Section 2 presents our econometric model and the restrictions used in the identification of the shocks. Section 3 describes our dataset. Section 4 presents the results. Section 5 shows results from alternative specifications as a robustness check. Section 6 concludes.

2. MODELING STRATEGY

During the empirical analysis we build on the methodology presented in Uhlig (2005). By using a structural vector autoregression (SVAR) model we can identify structural, economically meaningful exogenous shocks and causal relationships between them and the endogenous variables.

In particular, a VAR is estimated in the form that is given by

\[ y_t = A_1 y_{t-1} + A_2 y_{t-2} + \cdots + A_p y_{t-p} + C z_t + \varepsilon_t \]

\[ E(\varepsilon_t \varepsilon_t') = \Sigma \]

where \( t=1...T \), \( y_t \) is the vector of endogenous variables included in the VAR: the log of real gross domestic product (\( y_t \)), log of consumer prices (\( p_t \)), log of 3-month money market interest rate (\( i_t \)), log of the nominal exchange rate (\( e_t \)) and a proxy for carry trade positions (\( c_t \)). \( A \) is the coefficient matrix and \( \Sigma \) is the variance-covariance matrix for the one-step ahead prediction error. \( z_t \) is the vector of exogenous variables.

Intrinsically, we are interested in the parameters of the structural VAR

\[ B_0 y_t = B_1 y_{t-1} + B_2 y_{t-2} + \cdots + B_p y_{t-p} + D z_t + \mu_t \]

\[ E(\mu_t \mu_t') = \Sigma_\mu = I_n \]

where \( \mu_t \) is the vector of mutually uncorrelated structural shocks, \( I_n \) is an \( n \)-dimensional identity matrix and

\[ \varepsilon_t = B_0^{-1} \mu_t \]

To disentangle the structural shocks from the reduced-form innovations, we need additional restrictions on \( B_0^{-1} \). One can find several approaches in the literature to carry out that. One is assuming a recursive structure among shocks and their contemporaneous effect on the

Since in a small open economy both monetary policy shocks and sudden swings in carry trade (exchange rate or risk premium shocks) may affect the interest rate and the exchange rate simultaneously, recursive ordering is not appropriate for our purposes. Therefore, we identify the structural shocks using mainly sign restrictions. Zero restrictions are used only for separate financial shocks from those originating in real economy. Sign restrictions have the advantage of robustness at the price of wider confidence bands of impulse responses than in just-identified VARs.

The endogenous part of our VAR consists of GDP, CPI, short term interest rate, exchange rate and carry trade. Following the notation of Kilian (2011), $B_0^{-1}$ can be written as

\[
\begin{pmatrix}
\eta_t^{\text{Prod}} \\
\eta_t^{\text{Prices}} \\
\eta_t^{\text{Interest}} \\
\eta_t^{\text{Exchange}} \\
\eta_t^{\text{Carry}}
\end{pmatrix} = \begin{pmatrix}
0 & 0 & + & + & \times \\
\times & \times & + & - & \times \\
+ & + & + & \times & \times \\
- & + & \times & \times & \times \\
+ & - & \times & \times & \times
\end{pmatrix} \begin{pmatrix}
\epsilon_t^{\text{Monetary}} \\
\epsilon_t^{\text{Risk}} \\
\epsilon_t^{\text{Demand}} \\
\epsilon_t^{\text{Supply}} \\
\epsilon_t^{\text{Carry}}
\end{pmatrix}
\]

where + and − denotes the sign of the restricted impact response and × denotes no restriction.

According to the restrictions, an unanticipated monetary tightening causes the domestic interest rate to increase and the exchange rate to appreciate on impact. Carry traders take long position in local currency due to higher interest rate.\(^1\) An unexpected increase in the risk premium leads to higher interest rate and weakening of the currency, accompanied by a fall in carry trade. We do not impose any restrictions on prices, while, in both cases, the contemporaneous effect of the shock on production is zero, that is GDP responds to these shocks with delay. The latter assumption may receive some criticism as in small open economy production can be sensitive to exchange rate movements within the same quarter. In order to check to what extent our conclusions depend on these restrictions, we estimate a model on monthly data as well as with a pure sign restriction approach. The results are reported in section 5.

We use the standard sign restrictions to identify domestic demand and supply shocks. An unanticipated positive supply shock causes production to increase and prices to fall, while a demand shock causes both production and prices to increase on impact. Demand shocks are associated with an increase in the interest rate as monetary policy tries to counteract inflation. Finally, we leave the fifth domestic shock unidentified.

\(^1\) At first glance it may seem contradicting to identify the effect of monetary policy shocks on exchange rate and carry trade by imposing restrictions on exchange rate and carry trade themselves. Indeed, imposing sign restriction on the impact response and being completely indifferent in the second period response may cause a bias against hump-shaped response function. Still, we think that this bias is not that big as to influence significantly our results. Firstly, among our impulse responses there are several examples when a contemporaneous sign restriction is imposed, but the result is hump-shaped. Secondly, we estimated the same model by imposing the sign restrictions for 4 quarters and we got the same qualitative results. We also estimated it without imposing any restrictions on carry trade. Again, the results are very similar.
Besides domestic factors, foreign shocks may be important drivers of carry trade activity. Thus, we identify foreign shocks as well. The corresponding restrictions are similar to the domestic ones, and are described in details in section 4.3.

3. DATA

Our panel consists of three developed countries (Australia, Canada and the United Kingdom) that can be considered as targets of carry trade activity on our sample. Our choice of this particular group of countries was determined primarily by the availability of carry trade statistics.

We have quarterly data for the macroeconomic variables from 1992Q2 to 2007Q4 taken from the International Financial Statistics (IFS) database. In this way we leave out the recent financial crisis from the sample, as we are interested in monetary transmission and exchange rate dynamics in ‘normal times’. The starting period was chosen due to carry trade data limitations.

Another option would be to include all the countries having long enough carry trade data, like Japan and the United States. The reason for investigating only these three countries is that pooling them together with big, closed economies would question our setup as we assume that the main dynamic properties of the vector of variables are approximately the same across countries.

All GDP and CPI data are seasonally adjusted in the IFS database. However, United Kingdom CPI data seemed to have some remained seasonality in it, therefore we have to correct for that. The end-of-period nominal exchange rates vis-à-vis the U.S. dollar are defined as the local currency price of one unit of foreign currency, thus an increase in the exchange rate means depreciation. The interest rate data is the money market rate.

To control for foreign shocks, we use U.S. GDP, CPI, interest rate and exchange rate data as exogenous in the VAR. U.S. dollar exchange rate vis-à-vis the euro is taken from Eurostat. An increase in the exchange rate means depreciation of the dollar.

Following Brunnermeier et al. (2009), we use the futures position data from the Commodity Futures Trading Commission (CFTC) as a proxy for carry trade activity. It is a widely used measure of speculative positions. We use the last available CFTC positions report in each quarter to construct the net futures position of non-commercial traders in Australian Dollar (AUD), Canadian Dollar (CAD) and British Pound Sterling (GBP), expressed as a fraction of total open interest. According to Brunnermeier et al. (2009), despite its shortcomings, it is the best publicly available data for carry trade activity.

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2 See the results of Brunnermeier et al. (2009).

3 In 2000Q3 the Australian Government introduced a Goods and Services Tax, which results in a level shift in Australian CPI data. Controlling for this with a dummy does not alter our results; therefore we use the original data.

4 Classified by the CFTC, non-commercial traders use futures for speculative purposes and not for hedging against currency risk.

5 One of the main deficiencies is that it does not cover all speculative exchange rate positions as, for instance, hedge funds reportedly trade more in forward markets than in futures markets. Other proxies for carry trade activity also exist, but none of them seem to be more suitable enough to justify a deviation from the approach of Brunnermeier et al. (2009). Returns of Exchange Traded Funds (ETFs) and Exchange Traded Notes (ETNs) are linked to carry-trade strategies making them appealing candidates (see e.g. the DB Harvest of Deutsche Bank or the Intelligent Carry Trade
Of course, the sum of speculative positions reported to CFTC is only a fraction of total open interest. Hence, behaviour of CFTC carry trade does not necessarily apply to all interest sensitive position taking. Still, if we find that CFTC carry traders eliminate excess return quickly, we can safely assume that there are no incentives to take positions by other market participants.

A Bayesian VAR with 4 lags is estimated on quarterly frequency using the previously introduced panel data set. Contemporaneous and one period lagged U.S. data appear as exogenous variables. We use country-specific intercepts in the VAR. Following Uhlig (2005), we use flat prior for the VAR. The coefficients are drawn from the posterior distribution, which is a normal-inverse-Wishart distribution parameterized by the OLS estimates of coefficient and variance-covariance matrices. Calculation of posterior distributions is made following Reppa (2009). 2000 draws satisfying the sign restrictions have been generated.

In order to measure the failure of UIP, we calculate excess return impulse responses. We define excess return as the sum of the interest rate and the expected appreciation expressed in annual term:

\[ z_t = i_t - 4 \times (e_{t+1} - e_t) \]

If UIP holds conditionally after a shock, a positive interest rate differential is offset by the depreciation of the domestic currency resulting in no excess return. In other words, the conditional expectation \( E_t z_{t+p} \) must be zero for all \( p \geq 0 \) as long as UIP holds. The effect of the structural shocks on excess return can be calculated from the impulse responses of the domestic and U.S. interest rates, and the exchange rate.

4. RESULTS

In this section we discuss the empirical results obtained from our benchmark identification scheme, and then briefly compare our results with the Cholesky decomposition. It is followed by an analysis of the effect of foreign shocks. Finally, we present variance decomposition with focus on the determinants of carry trade activity.

4.1. The effect of monetary policy and risk premium shocks in the benchmark model

We are interested first of all in the effect of monetary policy shocks. Separation of them from risk premium shocks (perceived risk and the willingness or ability to risk taking) can be crucial. Therefore we focus here on these shocks. Responses to all the domestic shocks can be found in the appendix.

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6 Standard selection criteria suggest 1-2 lags for the VAR; however, we include 4 lags to be able to reject serial correlation in the residuals.

7 Since U.S. interest rate is assumed to be exogenous and not affected by domestic shocks, when calculating excess return we can ignore it.
Figure 1 shows the estimated impulse responses to a domestic contractionary monetary policy shock and an unfavourable risk premium shock, respectively, up to 5 years after the shock. We report the median, the 2.5th, 16th, 84th and 97.5th percentiles of the posterior distribution.

Figure 1: Responses to a monetary policy and a risk premium shock

The impulse responses are intuitive, albeit not always significantly different from zero. A typical monetary policy shock can be characterized by a 15 basis points interest rate increase, which then starts decreasing, finally dropping slightly below its initial level. The gradual withdrawal of the initial tightening stance reflects some smoothing in the conduct of monetary policy, which is a well-known finding in the literature. The exchange rate appreciates by 1.5 per cent on impact, which is followed by a gradual depreciation towards its initial level. Hence, the adjustment of the exchange rate is instantaneous without any delayed overshooting pattern, in line with the prediction of the Dornbusch (1976) model. We do not observe any significant price puzzle either; the price index starts declining in the second year after the shock, but the effect of the monetary contraction is not significant.\(^8\) Output declines quickly and to a statistically significant extent, which is in line with what we

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\(^8\) It is worth to note, while Uhlig (2005) avoids the price puzzle by construction, we do not impose restrictions on the price level.
expect after a contractionary monetary policy shock. The fast GDP and slow CPI responses resembles the monetary transmission in new-keynesian sticky price models.

Shocks to risk premium increase short term interest rate and depreciates the currency on impact, according to our identifying assumptions. The effect of higher interest rate and weaker currency on GDP is not significantly different from zero. They affect domestic production in the opposite way: while the increase in interest rate reduces domestic demand, the depreciation makes exports more competitive. In the CPI response the exchange rate channel seems to dominate: domestic prices increase, presumably due to the weaker currency. The initial drop in carry trade position is followed by a gradual recovery of risk appetite. In the second year after the shock long speculative positions are significantly higher than originally. This can be explained by the higher interest rate and the still appreciating exchange rate.

The most important result is that exchange rate and carry trade seem to react quickly to monetary policy, and there is no sign of delayed overshooting or prolonged carry trade inflow. Our impulse responses are in favour of Dornbusch (1976) and contradict to Brunnermeier et al. (2009) and Plantin and Shin (2011).

Since drawing conclusions about the shape of impulse responses based on pointwise median can be misleading (Sims and Zha, 1999), we report the posterior distribution of the horizon when exchange rate and carry trade have their maximum response. We calculate two measures to describe the peak response. We call ‘turning point’ the earliest quarter when appreciation turns to depreciation. We call ‘minimum’ the quarter where the exchange rate response has its extreme (minimum) value on the impulse-response horizon, which is 20 quarters. These definitions apply to carry trade with similar logic.

*Figure 2: Posterior distribution of the location of peak response*

The histograms confirm our previous finding that carry traders respond to monetary policy within the same quarter which results in a prompt adjustment of the exchange rate (Figure 2).
A more direct way to assess the role and incentives of carry trade is to quantify the realized return after a shock. If the exchange rate appreciates fast enough to an unexpected rate hike by the central bank, the subsequent depreciation can eliminate the excess return, which is the logic of the uncovered interest parity theorem. The impulse response of (predictable) excess return suggests that the reaction of the exchange rate is even stronger a bit than what the UIP would imply (Figure 3). Right after the shock the excess return becomes slightly negative, suggesting that the rate at which the exchange rate depreciates after the quick appreciation is a bit faster than the corresponding interest rate differential. In the case of risk premium shock the response of excess return is positive for several quarters. This means that the exchange rate reacts very quickly also to this shock and depreciates enough on impact to offer during the subsequent periods, together with the increasing interest rate, a higher return to compensate for the shrinking risk appetite or the higher perceived risk.

**Figure 3: Excess return to monetary policy and risk premium shocks**

![Graph showing excess return to monetary policy and risk premium shocks.](image)

*Note: The solid line is the point-wise median of all successful draws. Dashed and dotted lines encompass the middle 68 and 95 per cent of the posterior distribution.*

4.2. Comparison with the Cholesky decomposition

We briefly discuss the results with the Cholesky decomposition of the covariance matrix with a recursive ordering. This is a standard starting point in the literature and a common comparison studying the effect of monetary policy shocks (see e.g. Bjørnland, 2009 and Uhlig, 2005). Besides, it allows us to highlight the main theoretical difference between the recursive and the sign restrictions approach. In the former case — as long as the interest rate is ordered before the exchange rate, which is usually the case — it is (implicitly) assumed that an ‘exchange rate’ or ‘risk premium’ shock has no immediate effect on the interest rate. However, central banks tend to incorporate information about the exchange rate into their decisions as well as any other data that may influence the evolution of the key variables like consumer prices or output gap. Therefore, we need to take this channel into account to properly identify monetary policy shocks.

Using the same VAR model, we calculate the impulse responses assuming a recursive structure of shocks, too. Our ordering is the following: GDP, CPI, interest rate, exchange rate and carry trade. Here we identify monetary policy shocks as an unexpected increase in the interest rate that affects GDP and CPI only with delay. Note again that the recursive scheme implies that monetary policy does not react to the last two shocks (exchange rate and carry trade) on impact.
The results are displayed in Figure 4. Contrary to the findings in the benchmark model, the dynamic response of the exchange rate exhibits delayed overshooting, reaching its peak response nearly 2 years after the shock. The sluggishness of the exchange rate response is comparable to what Scholl and Uhlig (2008) have found using sign restrictions and somewhat longer than in Bouakez and Normandin (2010). It is also similar to the Cholesky decomposition results of Bjørnland (2009). Consistently with the delayed appreciation, significant carry trade activity can be detected even one year after the shock.

*Figure 4: Responses to a monetary policy shock, Cholesky decomposition*

The posterior distribution of the peak exchange rate response as well as the excess return confirm that the recursive identification scheme does favour for prolonged UIP failure more than the sign restriction approach (Figure 5 and 6). Our conclusion is that identification based on Cholesky decomposition may indeed generate delayed overshooting.\(^9\)

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\(^9\) It is noteworthy that delayed overshooting is not a robust finding even with Cholesky identification. Using 2 lags in the VAR, the mode of peak responses with recursive ordering takes place much earlier. This is in line with Istrefi and Vonnák (2012) who find that Cholesky decomposition does not always yield delayed overshooting.
4.3. Identification of foreign shocks

Since foreign shocks may be important drivers of carry activity, we need to identify U.S. shocks as well in order to explain its variability. In the literature cited above, some attempts have been already made to distinguish domestic and foreign structural shocks. Kim and Roubini (2000), for instance, include the Federal Funds rate to control for foreign monetary policy, but since they do not identify U.S. monetary policy shocks, its movements may reflect other structural shocks as well. Anzuini and Fornari (2011) use their variables in terms of differences to the corresponding U.S. variables, so they cannot separately identify the effect of foreign shocks. We take it for important to distinguish between domestic and foreign
shocks because even if they may have similar short run effect on the differences, due to the asymmetric behaviour between a small and a big country, the medium and long run effects may differ a lot. A trivial example is a monetary policy shock. While in the small country we expect the monetary policy to react to the change in the foreign interest rate, the same is not expected from the central bank of the big country.\footnote{Actually, the latter assumption is imposed by construction in our setup.} Thus, the implication on exchange rate and carry trade response may differ substantially.

In order to identify foreign shocks, we estimate a SVAR separately for the U.S. variables with the same methodology as in the domestic case. The VAR includes basically the same four U.S. variables used in the panel VAR as exogenous, with 4 lags\footnote{The number of lags was selected by looking at the usual information criteria and making sure that the residuals are free of autocorrelation.} on the same sample. The only difference is that we did not include carry trade data and exogenous variables. We identify demand, supply, monetary policy and risk premium shocks using the same restrictions as in the panel model presented before, obviously without the restrictions on carry trade.

In order to calculate the effect of foreign shocks to domestic variables, we randomly draw from the posterior of U.S. impulse responses for each draw from the panel VAR, and feed the former into the latter. Figure 14 in the appendix depicts the estimated impulse responses of the U.S. VAR.

Regarding the response of domestic variables to U.S. shocks, domestic interest rate reacts positively and the exchange rate depreciates after a contractionary U.S. monetary policy shock (Figure 15 in the appendix). GDP and CPI do not show statistically significant responses, neither the main variable of interest, the carry position, although its immediate response is intuitive. Carry trade jumps to an U.S. risk premium shock significantly, but the magnitude is again much smaller than to domestic shock. This suggests that U.S. shocks have a minor role in carry trade activity.

4.4. Variance decomposition

Figure 7 shows the decomposition of the variance of k-step ahead forecast error of the carry trade attributed to different shocks. According to the median estimates, monetary policy and risk premium shocks explain more than 20-20 per cent of carry trade variability over almost the whole horizon. Median estimates are surrounded by large posterior uncertainty. The other shocks seem to play only a minor role in carry trade. This is consistent with the variance decomposition of forecast error of the exchange rate (Figure 16 in the appendix), where the explanatory power of monetary policy and risk premium shocks is similarly high.\footnote{Another issue in recent literature is the connection between monetary policy shocks and exchange rate variation. Our results show that monetary policy shocks explain 20 per cent of exchange rate fluctuations at shorter horizon, while the contribution is 5 per cent at longer horizon. This is broadly in line with Scholl and Uhlig (2008) but smaller than what Bouakez and Normandin (2010) have reported. Kim and Roubini (2000) have had case for around 60 per cent at short horizon.} The median of unexplained variance remained less than 10 per cent at each horizon.
It is worth to mention that the role of U.S. shocks in explaining carry trade is of second order. According to anecdotal evidence, low U.S. interest rate increases risk appetite, resulting in strong interest sensitive inflow into high yield currencies. Our results do not support this observation. The main reason for it can be that domestic monetary policy reacts to foreign shocks so that interest rate differential does not change too much, which discourages carry trade and thereby mitigates the exchange rate response. This interpretation is confirmed by the results as the posterior distribution of the interest rate differential after a U.S. monetary policy shock is quite symmetric around zero at each horizon.

5. ROBUSTNESS ANALYSIS

In this section we test the robustness of the choice of restrictions used to identify the VAR, and the robustness of the results to changing the data frequency. Both tests are motivated by the zero restrictions we imposed in our benchmark model, as explained earlier. In the first experiment we relax the zero restrictions. In the second case we use higher frequency data to make zero restrictions more credible.

5.1. Pure sign restriction approach

First, we consider a pure sign restriction approach as an alternative restriction set. More specifically, our restrictions are the following in this case:

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13 Not shown in the paper, but available upon request.
where the notation is the same as in the benchmark model. Compared to the baseline specification, some additional restrictions are necessary to disentangle the shocks of interest. Particularly, we use sign restrictions for the response of GDP and prices, with the exception of the unrestricted response of GDP to a risk premium shock (see the upper left 2x2 matrix). Furthermore, we assume that the exchange rate appreciates after an unexpected demand shock, and depreciates following a supply shock, which is broadly in line with standard macroeconomic models.

Impulse responses that are in our centre of interest do not alter significantly compared to the benchmark model (Figure 8). The price puzzle is now avoided by construction. No delayed overshooting of the exchange rate can be observed either in this case, and the unrestricted responses of carry activity move in the direction presented previously (Figure 9).

*Figure 8: Responses to a monetary policy and a risk premium shock with pure sign restrictions*

![Graph showing impulse responses to monetary and risk premium shocks](graph_url)

*Note: The solid line is the point-wise median of all successful draws. Dashed and dotted lines encompass the middle 68 and 95 per cent of the posterior distribution.*
Turning to the variance decomposition, Figure 10 shows that monetary policy and risk premium shocks explain less variance of carry activity, and larger explanatory power is attributed to other domestic shocks compared to the benchmark case. This can be a consequence of restricting the sign of the exchange rate response to other shocks as well.
5.2. Monthly frequency

The assumption that GDP and prices respond to monetary policy and risk premium shocks with several months delay can be criticised in case of small open economies where the exchange rate channel is strong. As a robustness check, we estimate the same model on monthly frequency. We use monthly data from 1992M4 to 2007M12 and the VAR included 3 lags of the endogenous variables. In the U.S. VAR we use 7 lags. As GDP data is not available on monthly frequency, we opt for industrial production instead. The authorities of Australia do not publish monthly data on consumer prices and economic activity, therefore we have to restrict our sample to Canada and United Kingdom.

The results depicted on Figure 11 confirm that the exchange rate and carry activity react within a quarter (at most 1-2 months) to a monetary policy shock, generally. Industrial production declines after a monetary policy shock, while the path of consumer prices suggests a persistent price puzzle, but these responses are not statistically significant. Variance decompositions lead to the same conclusion, with monetary policy and risk premium remaining dominant in explaining the total variance of carry activity.

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14 We estimated an alternative version with 9 lags in both panel and U.S. models. Results do not change significantly compared to the case described above.
Figure 1: Responses to a monetary policy and a risk premium shock with monthly data

Note: The solid line is the point-wise median of all successful draws. Dashed and dotted lines encompass the middle 68 and 95 per cent of the posterior distribution. Months are indicated on the horizontal axis.

Our robustness checks confirm the main results of the benchmark model. However, their impulse responses are less convincing in general than the original specification, thus we take it reasonable to stick to the benchmark model.

6. CONCLUSIONS

In our paper we investigated the effect of monetary policy on exchange rate and the role carry trade plays in the exchange rate channel of monetary transmission within the same econometric framework. We estimated a VAR for a panel of 3 small, open economies regarded as target of carry trade strategies. We identified domestic and foreign structural shocks by using sign restrictions.

We found that allowing for simultaneous interest rate and exchange rate reactions to both monetary policy and risk premium shocks, the delayed overshooting found by some other authors can be rejected by high probability. The exchange rate behaves as predicted by uncovered interest parity. Our result suggests that speculative position-taking plays an important role in it. After an unexpected monetary policy shock carry traders react promptly helping the exchange rate jump and eliminating excess return.

Variance decomposition shows that the main drivers of carry trade are domestic monetary policy and risk premium shocks. While in the first case we attribute a beneficial role to
currency speculation in transmitting monetary policy, in the second case carry trade activity may be harmful for the economy by generating inefficient exchange rate shocks.

We tested the robustness of our results to the choice of restrictions used to identify the VAR, and to the data frequency. Our main findings proved to be fairly robust, with the exception of variance decomposition.

7. REFERENCES


Istrefi, Klodiana and Balázs Vonnák (2012): Delayed Overshooting Puzzle in Structural Vector Autoregression Models, mimeo, Goethe Universität, Frankfurt.


Figure 12: Net futures positions of non-commercial traders
Figure 13: Responses to domestic structural shocks, benchmark model

Note: The solid line is the point-wise median of all successful draws. Dashed and dotted lines encompass the middle 68 and 95 per cent of the posterior distribution.
Figure 14: Response of U.S. variables to U.S. shocks

Note: The solid line is the point-wise median of all successful draws. Dashed and dotted lines encompass the middle 68 and 95 per cent of the posterior distribution.
Figure 15: Responses of domestic variables to U.S. shocks

Note: The solid line is the point-wise median of all successful draws. Dashed and dotted lines encompass the middle 68 and 95 per cent of the posterior distribution.
Figure 16: Variance decomposition

Note: The solid line is the point-wise median of all successful draws.