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Exchange rate dynamics, expectations, and monetary policy

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Abstract

This paper re-investigates the implications of monetary policy rules on changes in exchange rate, in a risk-adjusted, uncovered interest parity model with unrestricted parameters, emphasizing the importance of modeling market expectations of monetary policy. I use consensus forecasts as a proxy for market expectations. The analysis on the Deutsche mark, Canadian dollar, Japanese yen, and the British pound relative to the U.S. dollar from 1979 to 2008 shows that, through the expectations of future monetary policy, Taylor rule fundamentals are able to forecast changes in the exchange rate, even over short-term horizons of less than two years. Furthermore, the market expectation formation processes of short-term interest rates change over time and differ across countries, which contributes to the time varying relationship between exchange rates and macroeconomic fundamentals, together with the time varying currency risk premia and exchange rate forecast errors.

Keywords: Exchange Rate, Monetary Policy, Expectation, Learning, VAR,

Consensus Forecast.

JEL-Classification: F31, E52, D83, C32

Non technical summary

Since the study by Meese and Rogoff (1983), the literature has favored the view that exchange rate dynamics are unrelated to macroeconomic fundamentals. Exchange rate models with macroeconomic fundamentals, exogenous money supply, and rational expectations cannot outperform the random walk model for forecasting exchange rate changes over short to medium horizons, although they gain empirical support in the case of long-horizon forecasts. Recent literature proposed to model monetary policy as a reaction function to macroeconomic variables, such as the Taylor rule, instead of an exogenous money supply. They point out a link between fundamentals and exchange rates, but not with strong empirical evidences. Conversely, the literature has documented that the failure of exchange rate models can be attributed to the time varying relationship between the exchange rate and fundamentals. Therefore, we may ask: can modeling monetary policy rules provide a resolution? Does the time varying feature indicate another direction or are the two explanations are pointing to the same solution?

This paper re-investigates the role of monetary policy rules in linking macroeconomic fundamentals and the exchange rate, emphasizing the importance of market expectations of future monetary policy. I first derive the role of monetary policy from the uncovered interest parity (UIP) relationship with unrestricted parameters and currency risk premium. It shows that the expectation of monetary policy differentials is one channel for macroeconomic fundamentals to influence the exchange rate in economies where central banks set their short-term rates in response to these fundamentals. I then use consensus forecasts of short-term interst rate as a proxy for the expectations of monetary policy, to examine the existence of this monetary policy channel. The consensus forecasts, collected by Consensus Economics, are based on the monthly surveys with over 240 financial and economic institutes, regarding their forecasts for interest rate values. The survey forecasts therefore can be considered as a proxy for expectations of participants in the foreign exchange market. The sample covers four currency pairs: the Deutschemark, Canadian dollar, Japanese yen, and the British pound relative to the U.S. dollar from 1989 to 2008.

I find that through the expectation of monetary policy, Taylor rule fundamentals are able to determine exchange rate movement. Furthermore, models with market expectations of short-term interest rate differentials can consistently outperform the random walk in terms of out-of-sample forecasts of changes in the exchange rate. Second, the market participants' expectation formation processes of short-term interest rate change over time and differ across countries. Finally, there are two potential sources for the time varying relationship between macroeconomic fundamentals and exchange rate changes: the monetary policy expectation formation process and the sum of expected currency risk premia and the exchange rate forecast error.

Nichttechnische Zusammenfassung

Seit der Studie von Meese und Rogoff (1983) wird in der Fachliteratur überwiegend die Auffassung vertreten, dass die Wechselkursdynamik nicht mit den gesamtwirtschaftlichen Fundamentaldaten im Zusammenhang steht. Wechselkursmodelle unter Einbeziehung makroökonomischer Fundamentaldaten, eines exogenen Geldangebots und rationaler Erwartungen können Wechselkursänderungen auf kurze bis mittlere Sicht nicht besser vorhersagen als das Random-Walk-Modell, wenngleich es bei langen Prognosehorizonten empirische Bestätigung für ihre Aussagekraft gibt. In der neueren Literatur wird vorgeschlagen, die Geldpolitik als Reaktionsfunktion auf makroökonomische Variablen zu modellieren, z. B. anhand der Taylor-Regel, statt von einem exogenen Geldangebot auszugehen. Diese Untersuchungen deuten auf einen Zusammenhang zwischen Fundamentaldaten und Wechselkursen hin, für den es jedoch keine robuste empirische Evidenz gibt. Andererseits wird festgestellt, dass das Versagen von Wechselkursmodellen auf die im Zeitverlauf variierende Beziehung zwischen Wechselkursen und Fundamentaldaten zurückgeführt werden kann. Daher stellt sich die Frage, ob die Modellierung geldpolitischer Regeln in dieser Hinsicht eine Lösung liefern kann. Deutet das Merkmal der Zeitvariabilität in eine andere Richtung, oder weisen die beiden Erklärungen in die gleiche Richtung?

Das vorliegende Papier beschäftigt sich mit dem Einfluss geldpolitischer Regeln auf die Beziehung zwischen gesamtwirtschaftlichen Fundamentaldaten und Wechselkurs, mit besonderem Augenmerk auf die Rolle der Markterwartungen hinsichtlich der künftigen Geldpolitik. Dabei wird zunächst die Bedeutung der Geldpolitik anhand der ungedeckten Zinsparität mit unbeschränkten Parametern und Währungsrisikoprämien abgeleitet. Hierbei zeigt sich, dass die Erwartung geldpolitischer Differenzen ein Kanal ist, über den die gesamtwirtschaftlichen Fundamentaldaten den Wechselkurs beeinflussen können, sofern es sich um Volkswirtschaften handelt, in denen die Zentralbanken ihre kurzfristigen Zinssätze in Reaktion auf die Fundamentaldaten festsetzen. Anschließend werden Konsensprognosen für die kurzfristigen Zinssätze als Näherungswert für die geldpolitischen Erwartungen herangezogen, um die Existenz dieses geldpolitischen Kanals zu untersuchen. Die von Consensus Economics erhobenen Konsensprognosen basieren auf monatlichen Umfragen zu den Zinserwartungen, an denen mehr als 240 Finanz- und Wirtschaftsinstitute teilnehmen. Somit lassen sich die Umfrageergebnisse als Ersatzindikator für die Erwartungen der

Devisenmarktteilnehmer verwenden. Die Stichprobe bezieht sich auf vier Währungspaare: die Kurse der deutschen Mark, des kanadischen Dollar, des japanischen Yen und des Pfund Sterling zum US-Dollar von 1989 bis 2008.

Die Untersuchung kommt erstens zu dem Ergebnis, dass die der Taylor-Regel zugrunde liegenden Fundamentaldaten bei Berücksichtigung der Erwartungen hinsichtlich der Geldpolitik in der Lage sind, Wechselkursänderungen vorherzusagen. Darüber hinaus schneiden Modelle, die die Markterwartungen in Bezug auf Zinsdifferenzen im kurzfristigen Bereich berücksichtigen, im Hinblick auf Out-of-Sample-Prognosen von Wechselkursänderungen durchweg besser ab als Random-Walk-Modelle. Zweitens ändert sich die Erwartungsbildung der Marktteilnehmer hinsichtlich der Entwicklung der kurzfristigen Zinssätze im Zeitverlauf und ist auch von Land zu Land unterschiedlich. Drittens gibt es zwei mögliche Ursachen für die zeitvariable Beziehung zwischen gesamtwirtschaftlichen Fundamentaldaten und Wechselkursen: Der Prozess der Erwartungsbildung im Hinblick auf die geldpolitische Entwicklung und die Summe aus erwarteten Währungsrisikoprämien und Wechselkursprognosefehlern.

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1 Introduction

Since the study by Meese and Rogoff (1983), the literature has favored the view that exchange rate dynamics are unrelated to macroeconomic fundamentals. Exchange rate models with macroeconomic fundamentals, exogenous money supply, and rational expectations cannot outperform the random walk model for forecasting exchange rate changes over short to medium horizons, although they gain empirical support in the case of long-horizon forecasts.[1] Recent literature proposed to model monetary policy as a reaction function to macroeconomic variables, such as the Taylor rule, instead of an exogenous money supply. They point out a link between fundamentals and exchange rates, but not with strong empirical evidences. Conversely, the literature has documented that the failure of exchange rate models can be attributed to the time varying relationship between the exchange rate and fundamentals. Therefore, we may ask: can modeling monetary policy rules provide a resolution? Does the time varying feature indicate another direction or are the two explanations are pointing to the same solution?

This paper re-investigates the role of monetary policy rules in linking

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[1] See Mark (1995), Mark and Sul (2001).

macroeconomic fundamentals and the exchange rate, emphasizing the importance of market expectations of future monetary policy. I first derive the role of monetary policy from the uncovered interest parity (UIP) relationship with unrestricted parameters and currency risk premium. It shows that the expectation of monetary policy differentials is one channel for macroeconomic fundamentals to influence the exchange rate in economies where central banks set their short-term rates in response to these fundamentals. I then use consensus forecasts of short-term interst rate as a proxy for the expectations of monetary policy, to examine the existence of this monetary policy channel. The consensus forecasts, collected by Consensus Economics, are based on the monthly surveys with over 240 financial and economic institutes, regarding their forecasts for interest rate values. The survey forecasts therefore can be considered as a proxy for expectations of participants in the foreign exchange market. I proceed with this exercise in two steps. First, I examined whether or not the expected interest rate differentials fit the actual exchange rate changes based on co-movement and out-of-sample forecasts. I then explored the link between the expected interest rate differentials and macroeconomic fundamentals by identifying the market expectation formation processes regarding the future short term rates with the aid of VAR learning models.

It is intuitive to model market expectations of future monetary policy when considering the implications of monetary policy rules have in determining the exchange rate. The empirical evidence mentioned above implies that the expectation of future monetary policy acts as a channel for the fundamentals to influence the exchange rate. Specifically, changes in the fundamentals would induce changes in market participants' expectations of future short-term interest rates, in the direction predicted by monetary policy rules perceived by the participants. The resulting changed expected interest rate differential between the two economies further drives capital flows, and hence, exchange rate movement.

However, it is not easy to draw conclusions based on the implications from the recent literature. Engel and West (2006), Engel, Mark and West (2007), and Mark (2009) model exchange rates as a discounted sum of expected future Taylor rule fundamentals. They find that the model implied exchange rate is moderately correlated with the actual exchange rate, but the correlation becomes very weak when evaluating exchange rate change over a short-horizon of less than two years. They model the market expectation of monetary policy based on an assumed expectation formation process, which is not necessarily the process of the market participants. Binici and Cheung (2010) find that the explanatory power of monetary policy rule fundamentals varies across different assumptions of policy rules, indicating that modeling the market perception of policy rules is crucial for the result. Molodtsova and Papell (2009) find that econometric models with Taylor rule fundamentals beat the random walk for most currency pairs when considering forecasts of changes in exchange rates in a one-month period . They incorporate endogenous monetary policy by changing the set of exchange rate determinants from conventional fundamentals to Taylor rule fundamentals. As the relationship between fundamentals and the exchange rate is estimated in a reduced form model with constant linear parameters, it would be difficult to apply the model to study exchange rate change over horizons longer than one month. This difficulty arises because the reduced form model suppresses the expectation channel, which could potentially be reflected in time varying and/or non-linear parameters for the macroeconomic variables. Furthermore, Chen and Tsang (2010) find that Taylor rule fundamentals themselves are insufficient to forecast exchange rate changes over different horizons for major currencies. Variables containing the expectation of future monetary policy in the yield curve improve the forecast ability of the econometric models. Hence, it is necessary to consider modeling the market expectation of monetary policy.

Using consensus forecasts of short-term interest rate as a proxy for future monetary policy expectation is motivated by the literature, which has shown that measuring market expectations based on consensus forecast helps understand puzzles about asset prices. Gourinchas and Tornell (2004) find that the deviation from rational expectations has crucial implications for the currency forward premium and delayed exchange rate puzzles. Bacchetta, Mertens and Van Wincoop (2009) show that the predictability of excess returns across a broad range of assets is closely related to the explanation for the expectation errors of market participants. Piazzesi and Schneider (2011) find that the surveyed forecasts of interest rates help solve the puzzles concerning long-term bond risk premia. Jongen, Verschoor and Wolff (2011) find that the expectation hypothesis for term structure of interest rates is rejected for fewer countries when using the survey based expectations of interest rates, compared with assuming rational expectations. Hence, modeling expectations with consensus forecasts is a beneficial approach.

This paper finds the following results:

First, modeling monetary policy as a reaction function can solve the puzzle that fundamentals are disconnected with exchange rates. Taylor rule fundamentals determine exchange rate movement through the expectation of monetary policy. Models with market expectations of short-term interest rate differentials can consistently outperform the random walk in terms of out-of-sample forecasts of changes in the exchange rate.

Second, although Taylor rule fundamentals play a central role when market participants form expectations of short-term interest rates in Germany, the Euro area and the U.S., these processes cannot be represented by a single learning mechanism. The expectation formation processes change over time and differ across countries. In particular, the evidence for the former property is stronger for U.S. interest rates than it is for German and euro area interest rates.

Third, there are two potential sources for the time varying relationship between macroeconomic fundamentals and exchange rate movements: the monetary policy expectation formation process and the sum of expected currency risk premia derived from UIP relationship and the exchange rate forecast error.

The remainder of the paper is structured as follows: Section 2 presents the exchange rate model, including the modeling strategy in the previous literature. Section 3 introduces the consensus forecast of short-term interest rates. Section 4 evaluates the linkage between the monetary policy and exchange rate movement, and Section 5 studies the relationship between monetary policy and macroeconomic fundamentals by identifying the market expectation formation process regarding the short-term interest rate. Section 6 extends the evaluation in Section 4 to longer horizons given the expectation formation process identified in Section 5. Section 7 concludes.

2 The Exchange Rate Model

2.1 Decomposition

In this section, we demonstrate the implications that endogenous monetary policy has in determining the exchange rate in a conventional model, and subsequently, the modeling strategies used in the previous literature to explore these implications.

We start from an uncovered interest parity (UIP) equation with unrestricted parameters and currency risk premium, which is the major link between changes in the exchange rate and interest rates in the existing literature:

$$E_t \Delta s_{t,t+h} = E_t(s_{t+h} - s_t) = \omega\left(i_t^h - i_t^{h*}\right) + \rho_{t,t+h} \tag{1}$$

where s_t is the logarithm of the nominal bilateral exchange rate at period t, defined as the domestic price of the foreign currency. Furthermore, i_t^h is the interest rate at t with maturity h, and i_t^{h*} is the corresponding foreign interest rate. ω is the coefficient of the interest rate differential. We do not impose any restriction on the sign or magnitude of this coefficient, so it is a general representation for the relationship implied by UIP, in which $\omega = 1$, and other models in which UIP does not hold, as documented as the "interest parity puzzle".[2] $\rho_{t,t+h}$ represents the currency risk premium between t and $t+h$. Because the exchange rate changes over k maturity periods can be written as the sum of exchange rate changes over each maturity period:

$$E_t \Delta s_{t,t+kh} = E_t(s_{t+kh} - s_t) = E_t \Delta s_{t,t+h} + E_t \Delta s_{t+h,t+2h} + \ldots + E_t \Delta s_{t+(k-1)h,t+kh} \tag{2}$$

by combining equation 1 and 2, the exchange rate change over k maturity periods is expressed as

$$E_t s_{t+kh} - s_t = \omega E_t \sum_{i=0}^{k-1} \left(i_{t+ih}^{h} - i_{t+ih}^{h*} \right) + E_t \sum_{i=0}^{k-1} \rho_{t+ih,t+(i+1)h}. \tag{3}$$

If $\varepsilon_{t,t+kh}$ represents the forecast error, that is $s_{t+kh} = E_t s_{t+kh} + \varepsilon_{t,t+kh}$, the actual exchange rate over kh-period horizon becomes:

$$\Delta s_{t,t+kh} = \omega E_t \sum_{i=0}^{k-1} \left(i_{t+ih}^{h} - i_{t+ih}^{h*} \right) + E_t \sum_{i=0}^{k-1} \rho_{t+ih,t+(i+1)h} + \varepsilon_{t,t+kh}. \tag{4}$$

Therefore, exchange rate changes are decomposed into three parts: the expected sum of current and future interest rate differentials between the domestic and foreign country (which are indicators for monetary policies in many advanced economies), the expected sum of current and future currency risk premia, and the forecast error.[3]

Based on this decomposition, any impact that macroeconomic fundamentals have on exchange rate changes must go through one of three channels :

(i) By changing market participants' expectations of domestic and foreign monetary policies. If the central bank sets monetary policy by setting the interest rate in reaction to macroeconomic fundamentals, and this is perceived by market participants, the first term on the right-hand side of Equation 4 can be written as a function of the fundamentals:

$$E_t \sum_{i=0}^{k-1} \left(i_{t+ih}^{h} - i_{t+ih}^{h*} \right) = f_t\left(X_t, X_t^* \right), \tag{5}$$

where $\mathbf{X}_t = \begin{pmatrix} \mathbf{x}_{t,}' & \mathbf{x}_{t-1,}' & \cdots & \mathbf{x}_{t-p}' \end{pmatrix}'$ and $\mathbf{X}_t^* = \begin{pmatrix} \mathbf{x}_{t,}^{*\prime} & \mathbf{x}_{t-1,}^{*\prime} & \cdots & \mathbf{x}_{t-q}^{*\prime} \end{pmatrix}'$.

$\mathbf{x}_t$ denotes the vector of macroeconomic fundamentals at period t in the home country and $\mathbf{x}_t^*$ denotes the foreign counterpart. p and q are the lags chosen by market

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[2]Please see Molodtsova and Papell (2009) pp. 170 for detail discussion.

[3]I did not decompose the level of exchange rate here, as the infinite forward iteration requires a stationary assumption for the exchange rate. See Engel and West (2010). I did not impose this assumption on the model.

participants. Market participants perceive these fundamentals as the variables that central banks will react to by adjusting the short-term interest rates. Therefore, f indicates how monetary policy fundamentals determine the expected sum of future interest rate differentials.

(ii) By changing the market participants' expectations of the risk premium, which is represented by the following equation

$$E_t \sum_{i=0}^{k-1} \rho_{t+ih,t+(i+1)h} = g_t\left(X_t, X_t^*, n_t\right). \tag{6}$$

Here n_t represents a vector containing variables other than monetary policy fundamentals that determine the expected future currency risk premia. g and $\tilde{g}$ respectively map fundamentals and other factors to expected premia.

(iii) By changing the forecast error:

$$\varepsilon_{t,t+3k} = l_t\left(X_t, X_t^*, m_t\right), \tag{7}$$

where, analogously, m_t is a vector of variables determining the forecast error in addition to these fundamentals, l is the corresponding function.

The implication of an endogenous monetary policy is that the market expectations of these policies become a channel for monetary policy fundamentals to influence exchange rate changes. We test this implication with data. In general, if there is evidence that $E_t \sum_{i=0}^{k-1}\left(i_{t+ih}^{h} - i_{t+ih}^{h*}\right)$ is determined by monetary policy fundamentals and it fits $s_{t+kh} - s_t$ well, endogenous monetary policy plays a role.

2.2 Modeling Strategies in the Existing Literature

Analyses of exchange rate determination that consider monetary policy rules can be grouped into two categories:

The first group forecasts the exchange rate with econometric models. These models incorporate the implications of endogenous monetary policy by changing the regressors from a conventional set of fundamentals to Taylor rule fundamentals. Typically, they regress the exchange rate change on fundamentals in the following form:

$$\Delta s_{t,t+kh} = \beta \widetilde{X}_t + \beta^* \widetilde{X}_t^* + \theta \upsilon_t + \varepsilon_t, \tag{8}$$

where $\widetilde{X}_t$ and $\widetilde{X}_t^*$ are the monetary policy fundamentals in the home and foreign countries respectively,[4] and β and β^* are their corresponding parameters. υ_t and its coefficient θ represent the part of exchange rate change explained by factors other than the monetary policy fundamentals.[5] Representative papers include Engel, West and Mark (2008), and Molodtsova and Papell (2009). The relationship between fundamentals and the exchange rate change are represented by the constant parameter β. This reduced form model has no room for the expectation formation process f, hence, when it is applied to study exchange rate changes over more than one maturity period, it potentially misses the effects that fundamentals exert through the expectation channels. Because the representation to capture the effects may go beyond the constant and linear parameters of the model. This is partly confirmed by Chen and Tsang (2010), who find that Taylor rule fundamentals alone are insufficient to forecast exchange rate changes; adding yield curve factors, embedding expectations of future short-term rates and risk premia is necessary. We therefore need to model f to test the implications of endogenous monetary policy.

The second category of literature models the exchange rate based on the UIP relationship and an assumed expectation formation process of monetary policy. This literature was pioneered by Engel and West (2006) (EW06, hereafter) and followed by recent papers by Engel, West and Mark (2008), Mark (2009) and Binici and Cheung (2010). In general, they use certain monetary policy rules to replace $E_t i_{t+ih}^h$ and $E_t i_{t+ih}^{h*}$

[4] $\widetilde{X}_t$ and $\widetilde{X}_t^*$ also include lag variables.

[5] Some papers use panel regressions, such as Engel, West and Mark (2008). I use the time series representation here for the sake of simplicity.

whenever they appear. For example, the specification in EW06 implies that

$$E_t i_{t+ih} = \gamma_\pi E_t \pi_{t+ih} + \gamma_y E_t y_{t+ih} + \gamma_q E_t q_{t+ih} + E_t u_{mt}. \tag{9}$$

This replacement indicates the agent perceives that central banks control interest rate following a Taylor rule with empirically estimated constant parameters. Therefore, the expected sum of the future interest rate differential is written as a function of monetary policy rule fundamentals X_t and X_t^* as follows:

$$\Delta\tilde{s}_{t,t+kh} = \tilde{E}_t \sum_{i=0}^{k-1}\left(i_{t+ih}^{h} - i_{t+ih}^{h*}\right) = \tilde{\alpha}_t\left(\tilde{X}_t\right) + \tilde{\alpha}_t^*\left(\tilde{X}_t^*\right) = \kappa_t\left(\tilde{X}_t, \tilde{X}_t^*\right), \tag{10}$$

where $\tilde{\alpha}_t$ and $\tilde{\alpha}_t^*$ are functions that respectively map the domestic and foreign monetary policy fundamentals in these models to $\tilde{E}_t \sum_{i=0}^{k-1}\left(i_{t+ih}^{h} - i_{t+ih}^{h*}\right)$[6]. They explore the role of the monetary policy rule by evaluating the correlation between $\Delta\tilde{s}_{t,t+kh}$ and the actual exchange rate change, $\Delta s_{t,t+kh}$. κ_t varies across models due to different assumptions of the expected monetary policy rules. Note that there is no guarantee that the functional form and the parameter in equation 9 is the actual rule observed by the market participants, or that κ_t is consistent with the market expectation formation process f_t. The correlations they find between $\Delta\tilde{s}_{t,t+kh}$ and $\Delta s_{t,t+kh}$ are rather weak for a change horizon of less than two years.

To investigate the role of monetary policy rules, a market expectation of interest rates and the expectation formation process (EFP), i.e. f_t, are needed. I therefore discuss the modeling of the EFP of interest rates in the next section.

[6] Note that this formula is not explicitly used in the above-mentioned papers. Some of these papers focus on the level exchange rate and write the expression in terms of levels. It is shown here that if they compute the exchange rate change or return, the model's implied exchange rate can be expressed in this formula.

3 Consensus Interest Rate Forecasts

I obtain the market expected interest rates from survey forecasts of professionals, which represent the subjective market expectations. I used the survey forecast of short-term interest rates in Germany, Canada, Japan, the U.K., and the U.S. from Consensus Economics to study the exchange rate for the four corresponding currencies relative to the U.S. dollar. Consensus Economics surveys over 240 financial and economic institutes regarding their forecasts for interest rate values with 3-month maturities for 3 months into the future. The professional forecasters include financial institutions and economic research institutes.

Our monthly observations of the consensus interest rate forecast started in October 1989 and ended in February 2008. For each economy, I use the mean of the interest rate forecasts from each institute as the representative value for that country. Due to the launch of the euro, from January 1999 onward we study the dynamics of the Euro-U.S. dollar exchange rate. Therefore, the economies relevant to this exchange rate shifts from Germany and the U.S. to the entire Euro area and the U.S. The mean value for the Euro Zone interest rates forecast is composed of forecasts from five Euro Zone economies available from Consensus Economics: Germany, France, Italy, the Netherlands, and Spain.

We can obtain some idea about market perceptions of monetary policy from Figures 1 and 2. The two figures plot the actual U.S. interest rate and the interest rate forecasts made by market participants 3-months ago. The consensus forecasts were systematically above or below the federal funds rate before the mid-1990s, while the forecasts after that remain broadly close to the federal funds rate. This observation may suggest that the market participants' beliefs about a central bank's decision were different from the actual decision before the mid-1990s. Although empirical papers, including Taylor (1993) and Clarida et al (1998) show that the U.S. controlled their short-term rates following the Taylor rule at that time, the public could believe that a different rule was in effect due to the fact that Taylor rule was not well known before early 1990s and that the central bank's communication was less transparent when compared to the latter period.

Figure 1: U.S. Short-term Interest Rate Forecast (Forecast Horizon=3 Months)-pre Euro Era

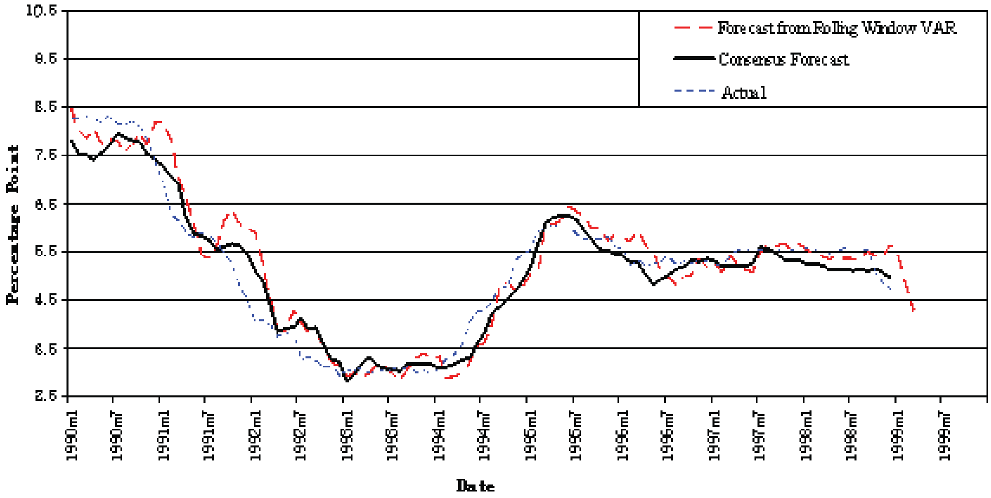
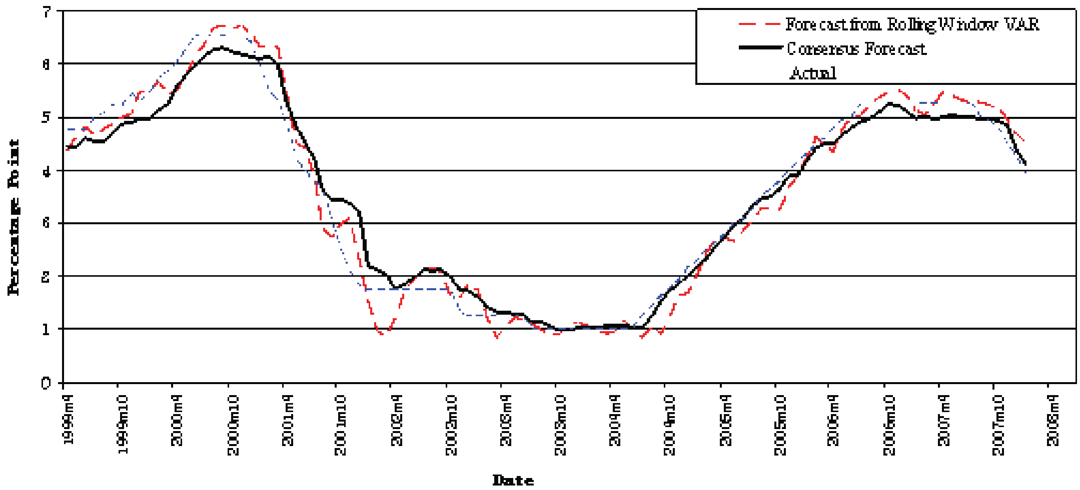


Figure 2: U.S. Short-term Interest Rate Forecast (Forecast Horizon=3 Months)-Euro Era



4 Goodness of Fit of the Monetary Policy Component

To test whether or not the monetary policy channel exists, I proceed in two steps. The first step evaluates how the monetary policy component (first term of the equation 4), fits the actual exchange rate changes, based on the conventional criteria of correlation and out-of-sample forecast. The second step tests the link between the monetary policy component and macroeconomic fundamentals by identifying the agents' expectation formation process. If the monetary policy component are determined by the fundamentals, and at the same time, they can well forecast the exchange rate change, then the monetary policy channel is verified. Since the consensus economics provide forecasts of short-term interest rate 3 months ahead, I construct the corresponding expected interest rate differentials to match the exchange rate changes over six-month horizon in this section, which is written as:

$$\Delta s^m_{t,t+6} = \omega E_t \sum_{i=0}^{1} \left(i^3_{t+3i} - i^{3*}_{t+3i} \right) \tag{11}$$

Note that equation 11 does not imply that expected currency risk premia and exchange rate forecast errors can be ignored for exchange rate determination, it aims at distinguishing the contribution of the monetary policy channel in the exchange rate movement.

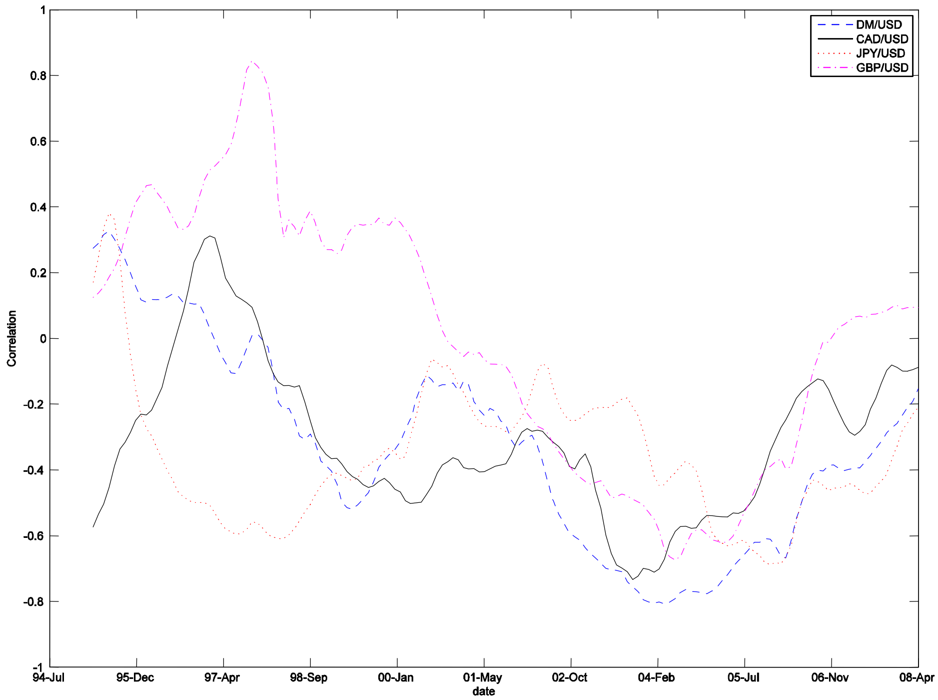
4.1 Correlation

I measure the goodness of fit of $\Delta s^m_{t,t+6}$ primarily through the correlation between $\Delta s^m_{t,t+6}$ and $\Delta s_{t,t+6}$. Additionally, I assume $\omega = 1$ at this step, therefore, the correlation provide information about whether the UIP holds. To observe the potential time varying relationship between $\Delta s^m_{t,t+6}$ and $\Delta s_{t,t+6}$, I compute the correlation with rolling windows. In particular, for each t, I compute $corr(\Delta s_{t,t+6}, \Delta s^m_{t,t+6})$ with 5-year and 10-year data respectively.[7] For example, for the 5-year correlation, the first sample of exchange rate change is between 1989:10 and 1990:4, I compute the correlation for the sample from 1990:4 to 1995:3, and then repeat the exercise for the sample one month ahead, beginning in 1990:5, and so on. Figure 3 plots the 5-year correlation coefficients for the Deutschemark, Canadian dollar, Japanese yen, and the British pound relative to the U.S.

[7] For Germany, from January 1999 onwards, the Euro area interest rate and the Euro-U.S. dollar exchange rate are used. The Euro/dollar exchange rate is converted to DM/dollar rate based on the exchange rate of Euro/DM effective on January 1, 1999.

dollar. Figure 4 plots the corresponding 10-year correlation coefficients.

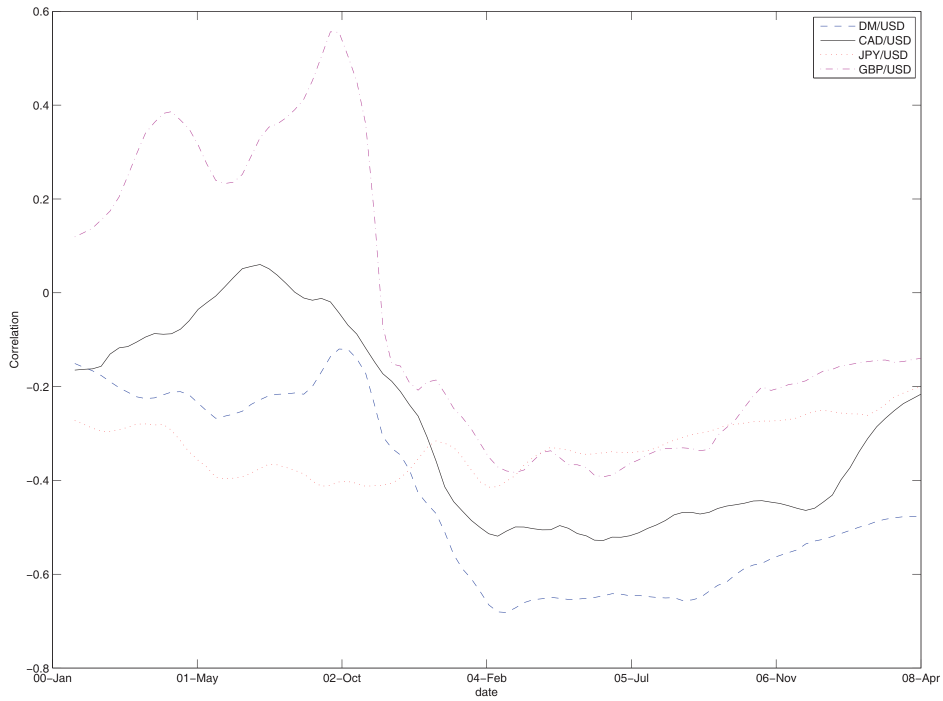
Figure 3: 5-year Correlation between the Monetary Policy Component and Actual Exchange Rate Change over the previous 6 months



Two observations can be drawn from the figures. First, in many sample periods, the monetary component has a moderate to strong correlation with the exchange rate change. The 5-year correlation coefficients range from about -0.8 to 0.8, and the 10-year coefficients range from about -0.7 to 0.6. This runs contrary to the findings in the previous literature, in which the correlation is close to zero.[8] Second, the correlation changes over time. Overall, the coefficients are positive for the former period, which is relatively short, and then become negative in the latter part of the sample. The patterns

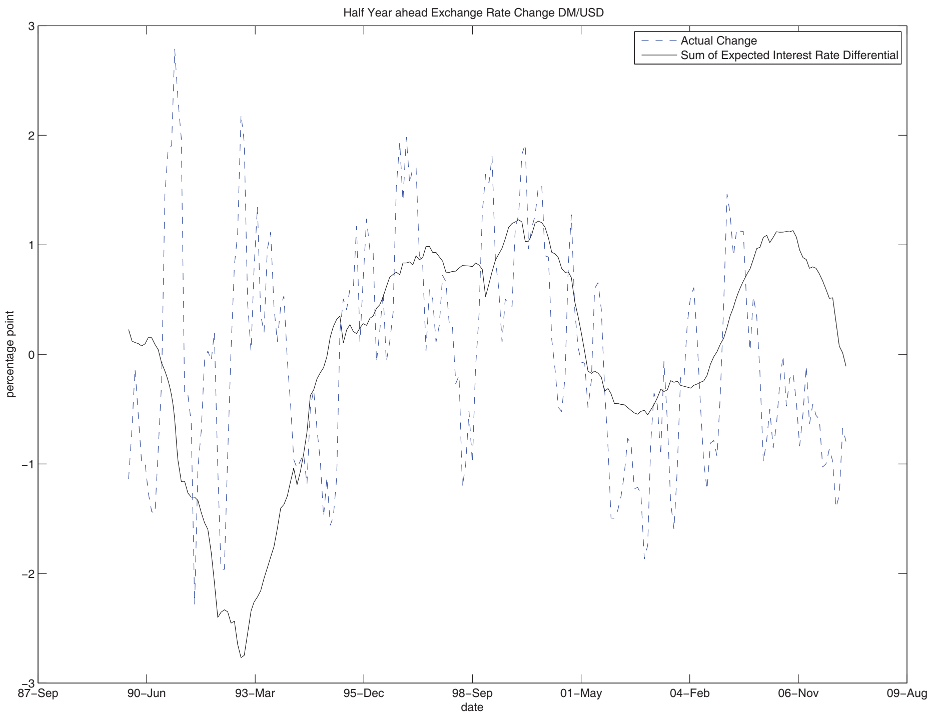
[8]See Engel and West (2006) and Mark (2009). Noted that Mark (2009) studies the real exchange rate, the results are not directly comparable.

Figure 4: 10-year Correlation between the Monetary Policy Component and Actual Exchange Rate Change over the previous 6 months



are shown more clearly in the figure of 10-year coefficients. We can identify the time that the the relationship changes with the aid of Figure 5 through Figure 8. In these figures, I plot the actual exchange rate change and the change implied by the monetary policy component. Because the coefficient is negative for most of the sample periods, for the sake of convenience, I assume $\omega = -1$. We can see that the break point is around 1994 and 1995 for the Deutschemark, Canadian dollar and British pound, and the break point for Japan seems to be at around 1993. Before mid-1990s, the relationship with the monetary policy component is more or less consistent with the prediction of UIP, but after 1995, an increase in the expected future interest rates in the home country relative to the foreign country is associated with the appreciation of the domestic currency relative to that foreign currency. The evidence is strong, with the correlation reaching -0.8 for 5-year samples and -0.7 for 10 year samples. This finding is at odds with the uncovered

Figure 5: Goodness of Fit of the Monetary Policy Component – DM/USD



interest parity prediction, but consistent with the large body of empirical evidence documenting the interest-parity puzzle.[9] These time varying correlations also indicate that the sum of the expected risk premium and forecast errors derived under the UIP assumption are time varying.

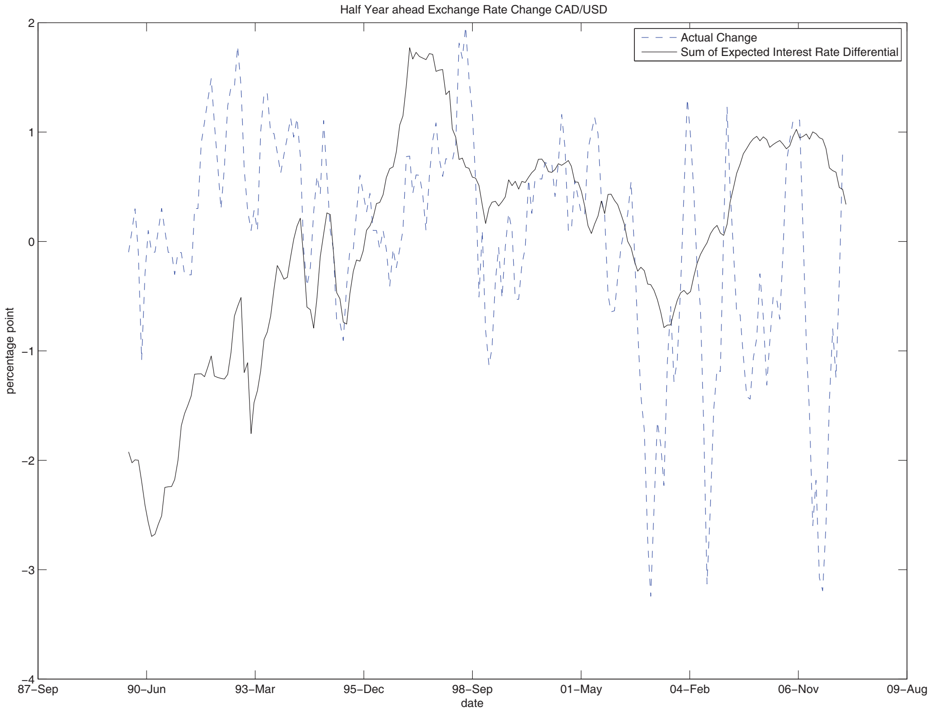
4.2 Out-of-sample Fit

In this section, I evaluate the forecast ability of $\omega E^{1}_{t\,i=0}\left(i^{3}_{t+3i}-i^{3*}_{t+3i}\right)$ based on the out-of-sample fit of the following market expectation model

$$\Delta s^{F,m}_{t,t+6} = a + \omega E_t \sum_{i=0}^{1}\left(i^{3}_{t+3i}-i^{3*}_{t+3i}\right). \tag{12}$$

9 Papers include Fama (1984), Flood and Rose (1996) etc. Lustig and Verdelhan (2007) propose explanation of the positive excess return in terms of consumption growth and risk hedging.

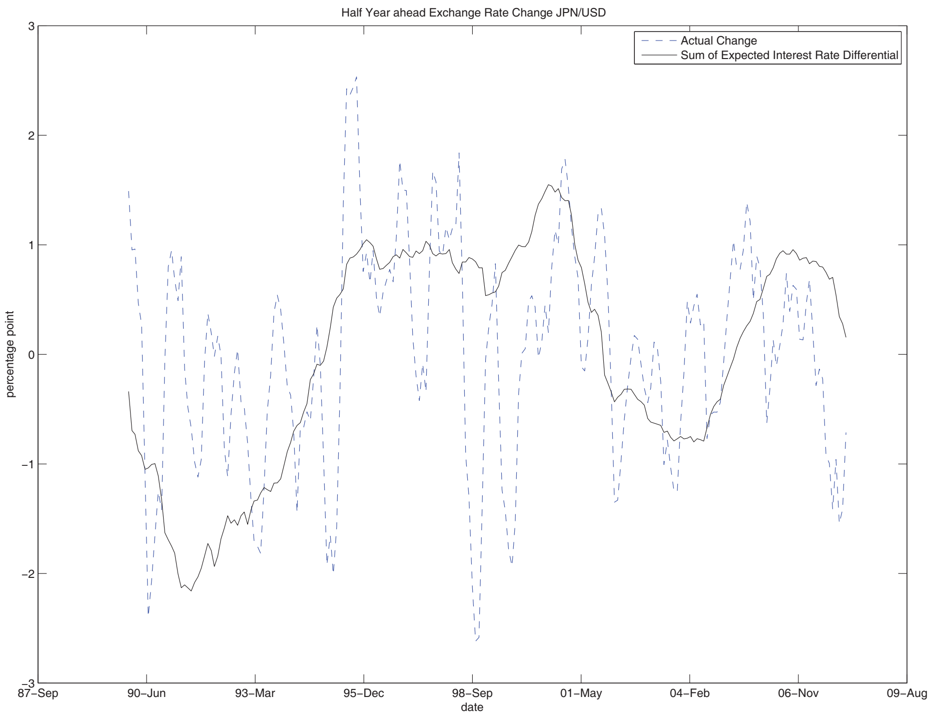
Figure 6: Goodness of Fit of the Monetary Policy Component – CAD/USD



As the correlation coefficients obtained in the last section are time varying, ω is likely to be time varying as well. Therefore, I estimate the constant a and parameter ω from OLS rolling regressions in the form of equation 12 with sample length L. L ranges from 5 to 12 years.[10] The first regression is on a sample of length L starting at the logarithm of the 6 month exchange rate change in April 1990. I forecast the one month out-of-sample exchange rate change with estimates of a and ω and the expected interest rate differential one month out of the sample. The forecast error is the difference between the forecasted exchange rate change from this model and the actual changes. This exercise is repeated starting in May 1990, and so on. Because the random walk model predicts no change in the exchange rate, the forecast error from the random walk is simply the actual exchange rate change. Following the literature, the measure of relative out-of-sample fit of the expectation model is the ratio of root mean square error (RMSE) of the model relative to the RMSE of the random walk. If the model performs better than a random

[10]Note that the parameters do not necessarily represent the causal relationship, due to the missing variable problem. My purpose is to find the parameter that can best match the data.

Figure 7: Goodness of Fit of the Monetary Policy Component – JPY/USD



walk, the ratio is less than one.

Table 1 summarizes the RMSE ratio for four currency pairs and three different sample lengths of 5, 8, and 12 years. Two observations can be drawn from the table. First, we can always find at least one sample length to estimate the parameters over, such that the model can beat the random walk. Second, the optimal sample length differs across countries. For the Canadian dollar relative to the U.S. dollar, models with parameters estimated from a 5 to 10 year sample can outperform the random walk. For the Deutschemark, a sample length from 5 to 9 years outperforms the random walk. For the British pound, the results are favorable for shorter samples of 5 years. For the case of the Japanese yen, the winners are longer samples of 9 to 12 years. I plot the best forecasts for the exchange rate generated in the model for four currencies in Figures 9 through 12. The rolling windows for Deutschemark, Canadian dollar, British pounds are five years, and the rolling window for Japanese yen is 10 years.

Therefore, the monetary policy component fits the actual exchange rate change well,

Figure 8: Goodness of Fit of the Monetary Policy Component – GBP/USD

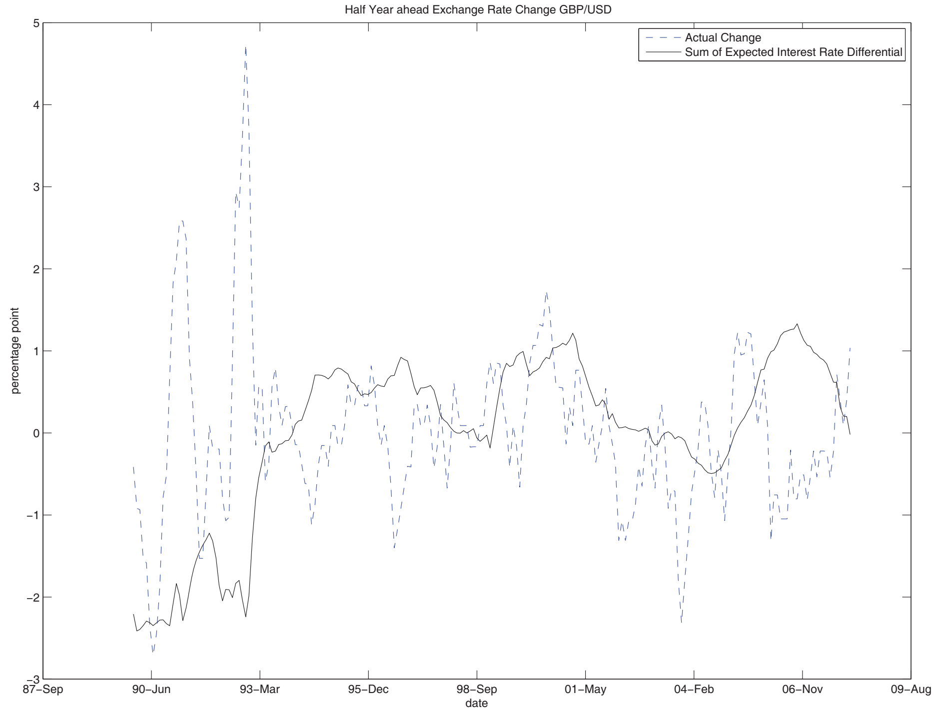


Table 1: Ratio of the RMSE Relative to Driftless Ramdom Walk

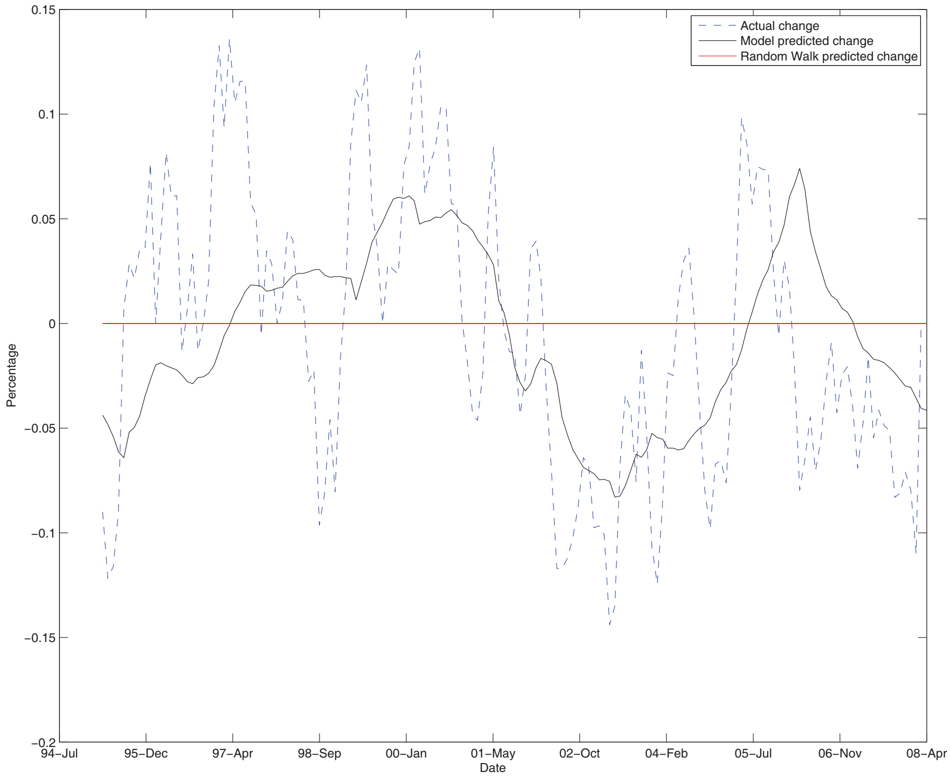
(Exchange Rate Change over 6-month Horizon)

Sample Length	DM/USD	CAD/USD	GBP/USD	JPY/USD
5-year	**0.88**	**0.89**	**0.98**	1.04
8-year	**0.88**	**0.94**	1.07	1.02
10-year	1.05	**0.96**	1.06	**0.92**

based on the conventional criteria of correlation and out-of-sample fit. This result provides a necessary condition for the existence of the monetary policy channel. If the expected future interest rates are determined by macroeconomic fundamentals, it suffices to confirm the existence of the monetary policy channel. To examine the model's performance for exchange rate change over different horizons, I identify the expectation formation process of short-term interest rates in the next section.

5 Expectation Formation Process (EFP) of Monetary Policy Stance

Figure 9: Exchange rate change over half year, DM/USD, actual, predicted

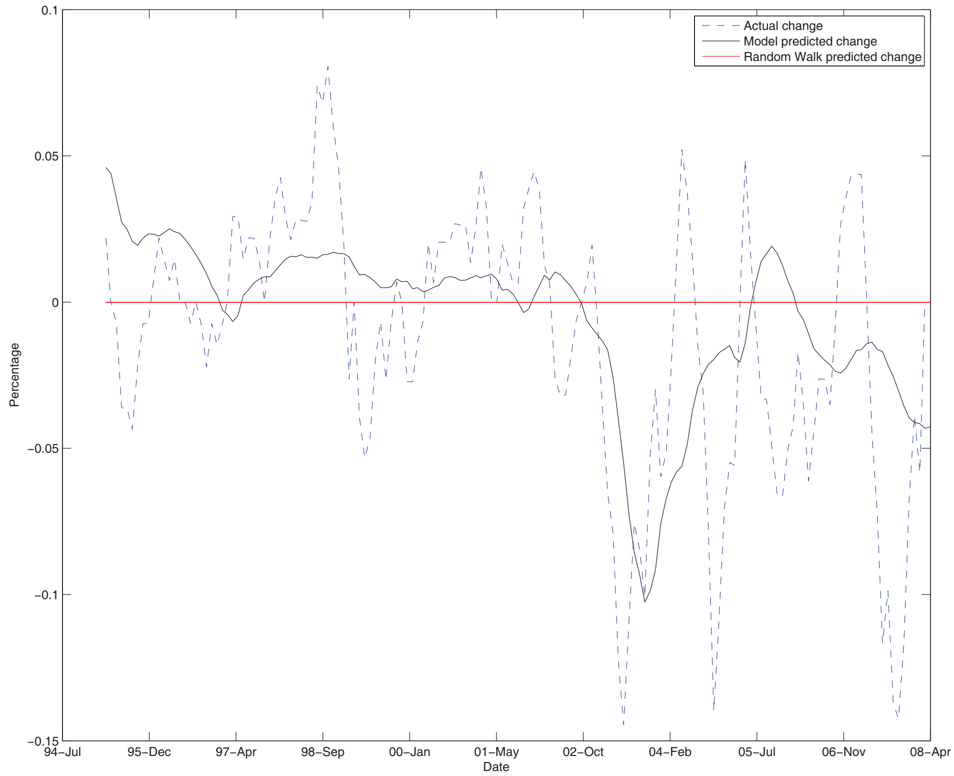


To discern whether the monetary policy fundamentals determine the expected future monetary policy stance, this section identifies the market participants' EFP of short-term interest rates. For the sake of comparing the results with the previous literature, I take Germany and the U.S. as representative cases and study the EFP of the German (Euro area's after 1999) and the U.S. interest rates.

5.1 VAR Learning

The Federal Reserve, German Bundesbank and European Central Bank are generally found to follow a Taylor-type rule when conducting monetary policy (Clarida, Gali and Gertler 1998), and the public is well informed about this. As a result, we assume, as a starting point, that the public incorporates Taylor rule fundamentals in their EFPs and investigate whether the public also considers other variables. Moreover, because the

Figure 10: Exchange rate change over half year, CAD/USD, actual, predicted



functional form of EFP reflects the agents' perceptions about the form of the variables that central banks care about: such as the level or the growth rate; the degree of interest rate smoothness the central bank targets; and the frequency of policy regime changes. We use VARs with different specifications to represent possible EFPs.

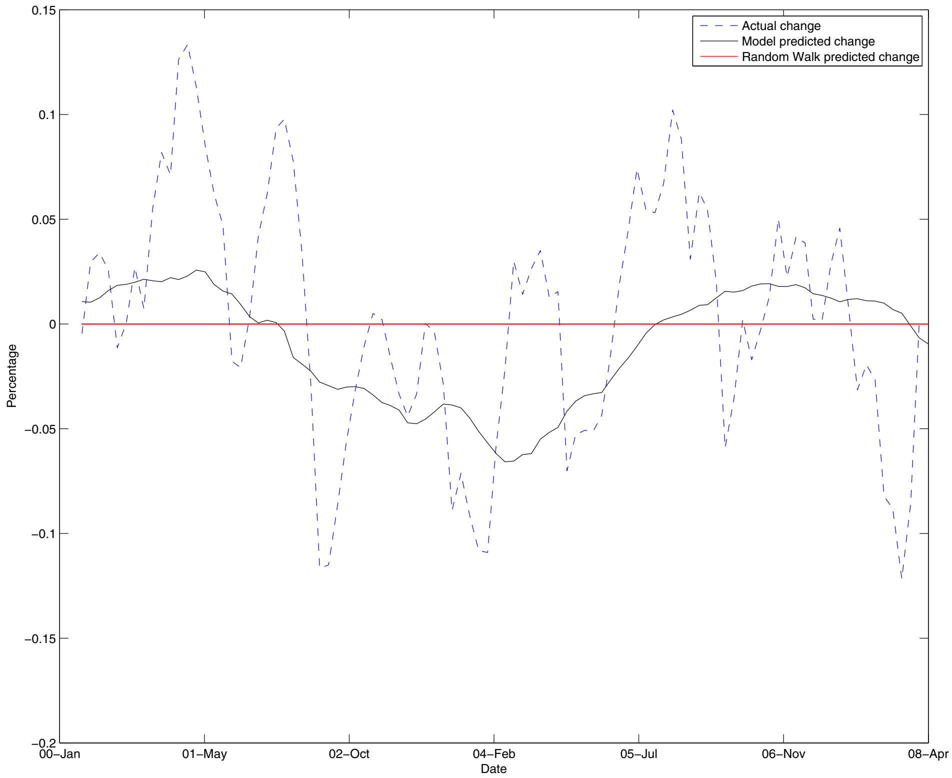
The general form of the VAR is represented by the following equation:

$$\mathbf{x}_t = \boldsymbol{\mu}_t + \sum_{j=1}^{p} \boldsymbol{\varphi}_{j,t} \mathbf{x}_{t-j} + \mathbf{u}_t . \tag{13}$$

Equation 13 is a reduced form VAR with time-varying parameters in $\mathbf{x}_t$ with lag p. $\mathbf{x}_t$ is a vector of the short-term interest rate i_t and other domestic variables determining

i_t's law of motion. μ denotes a vector of constant, and $\mathbf{u}_t$ is the vector of residuals.

Figure 11: Exchange rate change over half year, JPN/USD, actual, predicted



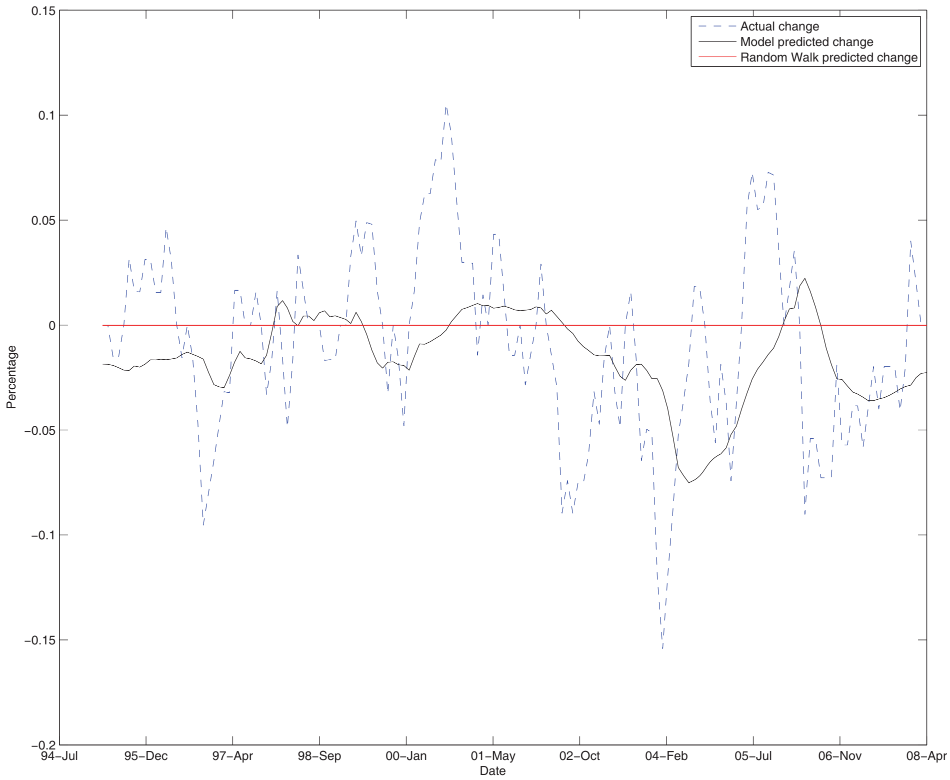
Note that the time-varying coefficients $\boldsymbol{\varphi}_{j,t}$ allow the agents to update their beliefs about interest rates' laws of motions each period. We estimate this VAR using different specifications to capture different possible learning mechanisms of the agents. The specifications differ in the following respects:

1. Variables, representing the perceived driving factors of the interest rate dynamics. We start with the output gap (defined as deviation of industrial production from its HP filtered level) and inflation in both level and growth rate. In addition, given that the information set considered by central banks when setting their monetary policy is huge (literally hundreds of data series)[11] and that this is likely to be known by the public,

[11] Bernanke, Boivin, and Eliasz (2005), p.388.

we do not exclude the possibility that agents incorporate information from a large number of other macroeconomic and financial variables. Therefore, we also adopt the

Figure 12: Exchange rate change over half year, GBP/USD, actual, predicted



factor-augmented VAR (FAVAR) based on Bernanke, Boivin, and Eliasz (2005) (BBE 05, hereafter) to generate the U.S. EFP alternatives. We consider the following specification for the FAVAR.

$$\mathbf{x}_t = \begin{bmatrix} F_t \\ \mathbf{z}_t \end{bmatrix} =^{q}_{j=1} \sum_{j=1}^{q} \mathbf{\Xi}_{j,t} \begin{bmatrix} F_{t-j} \\ \mathbf{z}_{t-j} \end{bmatrix} + \upsilon_t \qquad (14)$$

where F_t denotes the vector of the unobserved factor, $\mathbf{\Xi}_{j,t}$ is the time-varying coefficient vector, υ_t is the residual and q is the lag length. The factor is extracted from more than 70 macroeconomic and financial variables.[12] The variables from which F_t is extracted include indexes of industrial production, manufacturing, emlpoyment, consumption prices, producer prices, stock markets, personal income, money supply and credit.

2. Length of rolling windows, which indicates the length of historical data the agents incorporate in their forecasts. Windows selected here are either fixed with length from 4 to 10 years, meaning the agents use the past 4 to 10 years' information up to the current period, or expanding, implying that the agents do not discard any historical data when they obtain the new data each period.

3. Lag length, which partially reflects the smoothness of the interest rates. Lag length ranges from 1 to 6. Lag length is either set by optimal lag selection criteria or set exogenously.

We estimate VARs with different combinations of the above features, and make forecasts of interest rates one quarter ahead $E_t^{var}(i_{t+3})$. Therefore, a time series of forecasts are produced by each VAR. We pick the VAR that generates forecasts with the highest correlations with the consensus interest rates forecasts $E_t^{cf}(i_{t+3})$ and produce a standard deviation and autocorrelation close to those of the consensus forecasts. This VAR is considered to represent the EFP of the market participants.

The sample data span 1979:1 to 2008:2; details are available in the Appendix. The establishment of the European Central Bank and the launch of the euro means that market participants form their expectations of euro-wide interest rates incorporating euro-wide variables rather than German variables. Therefore, we split the sample into two periods. The first period spans 1979:1 to 1998:12, which we call the pre-euro era in the following sections, and the second spans 1999:1 to 2008:2, which we call the euro era.

5.2 Properties of the Market EFP

In this section, we discuss the properties of the VAR that represents the EFPs of market participants. The market EFP reveals whether policy fundamentals are involved in the

[12] The data is available upon request.

creation of interest rate forecasts and, if so, how information about fundamentals is processed.

We report the best-fit VARs for two countries in the pre- and post-euro eras, respectively; that is, there are four best-fit VARs. We first analyze the results for the former period.

5.2.1 EFP for Pre-euro Monetary Policy

The consensus forecast data are available from 1989:10 onwards, so the 3-month interest rate forecasts being compared for the pre-euro era are for 1990:1 to 1998:12.

The best VAR for the United States is a six-year fixed-rolling window VAR with four lags, including federal funds rate i_t^{us}, output (industrial production) gap, $\hat{y}_t^{us}$ and inflation π_t^{us} . Table 2 shows the properties of this VAR model.

Table 2: Comparison between the U.S. Interest Rate Forecast from Best-fit VAR and Consensus in Pre-euro Era

U.S.	Correlation Coefficient (Consensus, VAR)	Standard Deviation		Auto Correlation (of Lag One)	
		Consensus	VAR	Consensus	VAR
3m ahead	0.98	1.33	1.45	0.97	0.96

The forecast generated from the VAR has a correlation of 0.98 with the consensus forecast. Its volatility also matches the volatility of the consensus forecast well. Because we find that the consensus interest rate forecast is quite persistent with a lag one auto-correlation of 0.97, we also attempt to determine whether the VAR forecast reproduces this property. The VAR forecast's auto correlation of lag one reaches 0.96, which confirms its ability to match the persistency. Figure 1 shows that the VAR forecast tracks the consensus forecast very closely, especially from 1992 on. Some deviations in the VAR forecast from the consensus forecast are relatively large compared to the first two years in the 1990s. This may be because there were structural changes in the mid- to late-1980s, leading agents to use even more recent information (less than 6 years in the past) to form their forecasts.

One fact worth mentioning is that the FAVAR, which incorporates a large amount of information on macroeconomic and financial variables, does not generate forecasts with higher correlation than the parsimonious VAR does. Table 3 compare the best-fit FAVAR forecast and the consensus interest rate forecast.

In summary, in the 1990s, U.S. market participants tended to use information on the output gap and inflation to form their expectations of future short-term interest rates.

Table 3: Comparison between the U.S. Interest Rate Forecast from Best-fit FAVAR and Consensus in Pre-euro Era

U.S.	Correlation Coefficient (Consensus, FAVAR)	Standard Deviation		Auto Correlation (of Lag One)	
		Consensus	FAVAR	Consensus	FAVAR
3m ahead	0.98	1.33	1.48	0.97	0.95

Note The FAVAR that generates an interest rate forecast with the highest correlation with the consensus forecast is in three observed variables $\hat{y}, \pi, i$ and two common factors.

Table 4: Comparison between the German Interest Rate Forecast from Best-fit VAR and Consensus in Pre-euro Era

Germany	Correlation Coefficient (Consensus, VAR)	Standard Deviation		Auto Correlation (of Lag One)	
		Consensus	VAR	Consensus	VAR
3m ahead	0.99	2.42	2.45	0.99	0.98

They perceived frequent structural changes in policy and incorporated only recent data to form their expectations.[13]

The best-fit VAR for Germany comes from the expanding window model with four lags, where the first forecast is made from the first six-year data. Variables included are output (industrial production) gap, $\hat{y}_t^{de}$, inflation growth rate, $\Delta \pi_t^{us}$, and short-term interest rate changes, Δi_t^{us}. Interest rate forecasts are made by transforming the forecast from first difference to levels. Table 4 shows that the correlation between VAR and consensus forecast reaches 0.99 for the 3-month forecast. A visual comparison is provided by Figures 13. Note that the same VAR with either expanding window and 3 lags or with a 6-year rolling window perform similarly, which implies that forecasts based on the average relationship across all historical periods are similar to those using the most recent periods. This indicates that agents do not perceive frequent structural

[13]The relatively low correlation generated from the expanding window VARs confirms this. The results are

changes to monetary policy and that the Bundesbank conducts a stable monetary policy and maintains good credibility. Volatility matches for 3-month forecasts perform well. The high persistency of the consensus forecast is well captured by the VAR forecasts.[14]

Figure 13: German Short-term Interest Rate Forecast (Forecast Horizon=3 Months)-pre Euro Era

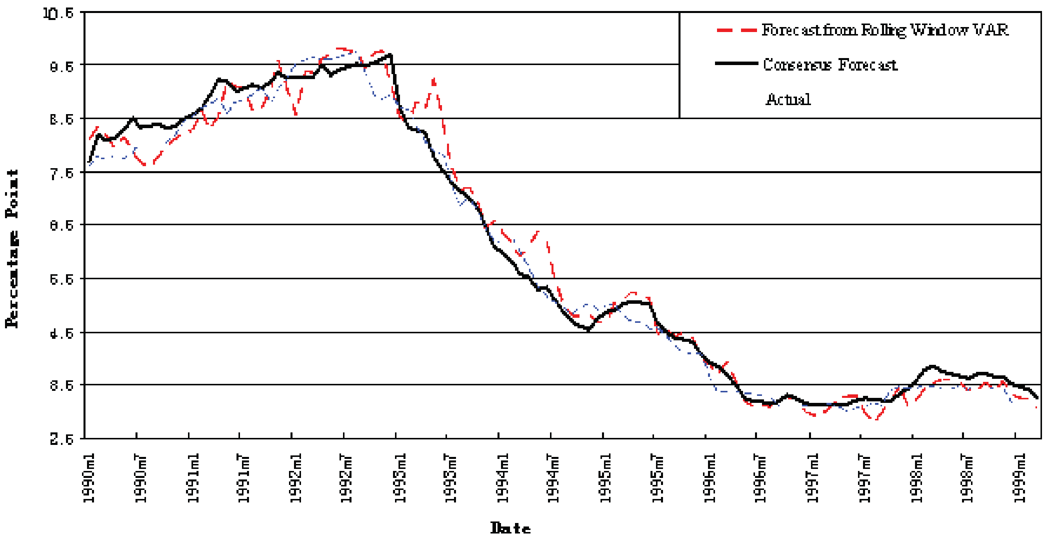


Table 5: Statistical Properties of Short-term Interest Rates in Pre-euro Era

Countries	Mean	Standard Deviation	Auto Correlation of lag			
			1	2	4	10
U.S.	5.16	1.46	0.97	0.93	0.84	0.46
Germany	5.93	2.41	0.99	0.98	0.95	0.83

Summarizing the learning mechanism for the EFP for U.S. and German interest rates from 1990 to 1998, we find that the core variables incorporated into the market

available upon request.

[14]Note that in addition to the expanding window, the best-fit model for Germany differs from the one for the U.S. in the form of variables entering the VAR. The best-fit variables for Germany are interest rate differences, output gaps, and inflation growth, which means that interest rate forecasts are made by converting the interest rate difference to level. The likely reason for this is that the German consensus forecast and the actual interest rate are highly persistent processes, with a lag one autocorrelation equal to 0.99 (Table 5). Making an interest rate forecast from a VAR in the difference of these variables means that the level interest rate is an $I(1)$ process; therefore, the time series of VAR forecast produced in each month is also an $I(1)$ process so that they can match the high persistency. In contrast, the U.S. federal funds rate and its consensus forecast are less persistent than the German short-term rate, so a forecast generated from stationary-level VARs matches the consensus forecasts well.

participants' EFP are the output gap, inflation, and lag interest rate. The VAR in the level of these variables generates the closest interest rate forecasts to the consensus forecast for the U.S., while the VAR in the difference of these variables generates the best-match for interest rate forecasts. U.S. agents tend to perceive frequent structural changes of monetary policy, and the German agents believe the Bundesbank follows a stable policy

Table 6: Statistical Properties of Short-term Interest Rates in Euro Era

Countries	Mean	Standard Deviation	Auto Correlation of lag			
			1	2	4	10
U.S.	3.57	1.85	0.99	0.98	0.93	0.65
Germany	3.23	0.96	0.98	0.94	0.9	0.52

Table 7: Comparison between the U.S. Interest Rate Forecast from Best-fit VAR and Consensus in Euro Era

U.S.	Correlation Coefficient (Consensus, VAR)	Standard Deviation		Auto Correlation (of Lag One)	
		Consensus	VAR	Consensus	VAR
3m ahead	0.99	1.69	1.89	0.99	0.99

rule.

5.2.2 EFP for Euro Era Monetary Policy

The interest rate forecasts for comparison in the euro era cover the horizon from 1999:4 to 2008:2. We avoid the crisis period from 2008 onward because it is generally known that during the crisis period, central banks used non-standard measures that deviated from previous rules. Therefore, it is difficult to use a VAR that implies the rule-based expectation formation process to match the consensus forecast in this period.

For the U.S., the best VAR is a five-year expanding window VAR with four lags, including domestic output (industrial production) gap, $\hat{y}_t^{us}$, inflation growth $\Delta\pi_t^{us}$ and the federal funds rate difference, Δi_t^{us} (Table 7). The expanding window implies that the market participants perceive a stable monetary policy rule from the Federal Reserve in the late 1990s and the first eight years in the twenty-first century, which represents a significant difference compared to the previous ten years. In the euro era, the volatility and persistency of U.S. consensus interest rate forecasts and actual interest rates are larger than the pre-euro era (Table 5 and 6), hence the VARs in differences of variables capture the consensus forecast best. Figures 2 shows the comparison with 3-month forecasts. The trend of consensus forecasts are mostly matched by the VAR forecast, but the volatility that this model generates is higher than the consensus forecast.

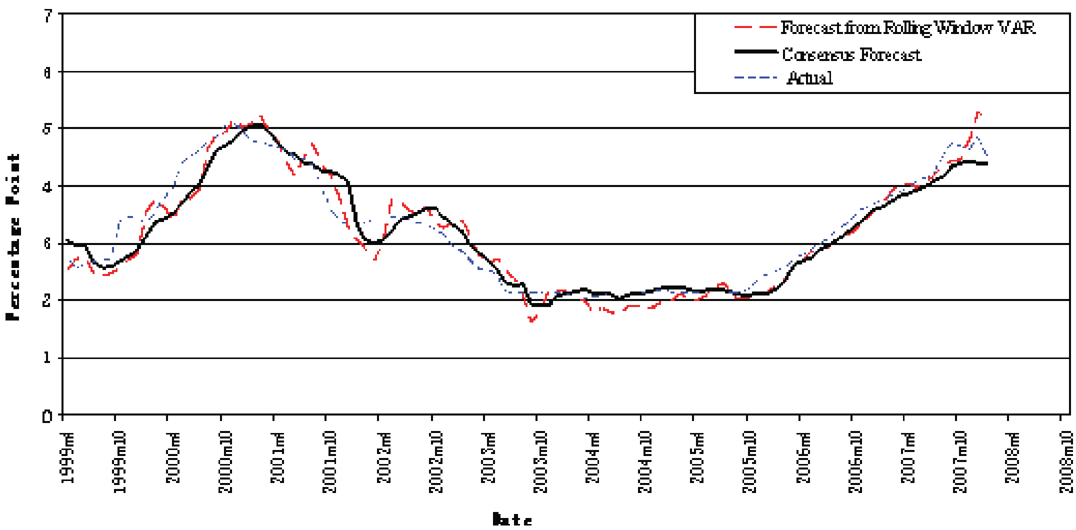
VAR interest rate forecasts with the same specifications also match the German consensus forecast very well. Although the VAR forecasts generate a higher standard deviation than the consensus forecasts (Table 8), they show that the 3-month VAR forecasts are less volatile than in the pre-euro era, which is consistent with the same changes to the consensus forecasts. Figure 14 shows that 3-month VAR forecasts track the consensus tightly.

To summarize the findings, the expectation formation process of future monetary policy

Table 8: Comparison between the German Interest Rate Forecast from Best-fit VAR and Consensus in the Euro Era

Germany	Correlation Coefficient	Standard Deviation		Auto Correlation (of Lag One)	
	(Consensus, FAVAR)	Consensus	VAR	Consensus	VAR
3m ahead	0.97	0.92	0.99	0.98	0.96

Figure 14: German Short-term Interest Rate Forecast (Forecast Horizon=3 Months)-Euro Era



is a function of Taylor rule fundamentals, namely: output gap, inflation, and interest rates. Other information seems to be less crucial. However, the functional forms vary by time and country. The variation implies that the market participants perceive that the monetary policy regime is changing over time. The evidence supporting this finding is stronger in the U.S. than in Germany. Therefore, exercises assuming that agents perceive constant-parameter Taylor rules or follow a single learning process are less likely to reflect the actual EFP of the market participants.

Moreover, we can see that, solely from the perspective of the monetary policy component, there are two sources of the time varying relationship between fundamentals and exchange rates: the expectation formation process of future interest rate and the parameter of expected interest rate differentials. The latter indicates a time varying expected currency risk premia and/or exchange rate forecast error.

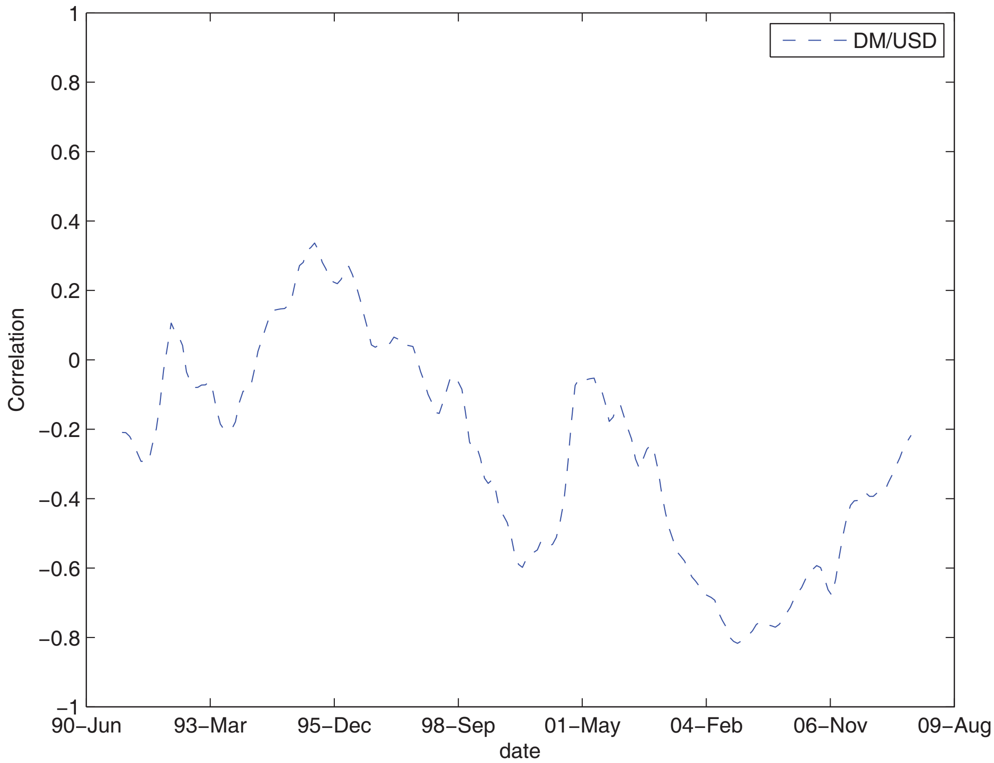
5.3 Robustness Check

After identifying the expectation formation process of short-term interest rates, we can use the process to generate the exchange rate change implied by the market expectation model. For the purposes of a robustness check, I recalculate the correlation exercises for a 6 month exchange rate change with the same methodology as in Section 4.1. Figure 15 and Figure 16 show that the rolling correlation for 5 and 10 years samples have a very similar pattern to the one generated with market survey interest rate forecasts (Figure 3 and Figure 4), which implies that the expectation formation processes identified with VARs are consistent with consensus forecasts. Once we know the EFP, the horizon for exchange rate change is no longer restricted to 6 months in this case. In the next section, we evaluate the goodness of fit of the model for exchange rate changes over, 6-, 12-, 24 and 48-month horizons and compare our results with the previous literature.

6 Comparison with the Previous Literature

In this section, I generate the exchange rate change over different horizons implied by the market expectation model and the identified EFP. I further evaluate the performance of the market expectation model by comparing with the findings in EW06 and Mark (2009). EW06 assumes the market participants believe in constant parameter Taylor rules for both countries and that they have rational expectations, whereas Mark (2009) assumes a

Figure 15: 5-year Correlation between the Sum of Expected Short-term Interest Rate Differential and DM/USD changes over 6-month



constant gain learning environment for market participants in both countries.[15] Because EW06 only study the Deutschemark-U.S. dollar exchange rate, I split the sample into pre-Euro and Euro era subsamples and compare the coefficient for these two periods. Furthermore, because EW06 only show the correlation for the exchange level and a 1 month change, I replicate EW06 to derive the results for changes with a longer horizon. The correlations for pre-euro era are shown in Table 9.

The correlations between the model-implied and the actual exchange rate change over 1 quarter found in the three models are very similar (around 0.1). However, the

[15]Mark (2009) studies the real exchange rate instead of the nominal exchange rate.

correlation found in the market expectation model over horizons of 6 months to 4 years are far larger than the ones generated by the other 2 models. In particular, the correlation found in the market expectation model reaches 0.21 for the 1-year return and climbs to nearly 0.6 for the 4 year return, while the correlation found in the other 2 models remains at around 0.1.

Table 9: Comparison of correlation with Mark (2009) and Engel and West (2006) -Pre-euro Era

1979-1998	Market Expectation	Constant Gain Learning Mark (2009)	Rational Expectation EW (2006)
1-quarter return	0.1	0.009	0.1
half year return	0.13	-	0.03
one-year return	0.21	0.049	0.16
two-year return	0.27	0.084	0.09
four-year return	0.58	0.156	0.03

The correlations for the Euro era differ from the pre-euro era in two respects: negative signs and a larger magnitude, as shown in Table 9. Because Mark (2009) does not compute the correlation of the subsample for the Euro-era, I only compare with EW06 for the studies on nominal exchange rates. As we found in the rolling correlation in Section 4.1, it is not surprising that the correlation for the euro-era is negative. The correlation for the market expectation model is -0.38 for a 3-month return and increases to -0.66 for the 2-year return before decreasing to -0.4 for the 4-year return. The market expectation model yields a higher correlation than the rational expectation model for short horizons of less than one year.

The results show that modeling the expectation of monetary policy based on market expectations would improve the goodness of fit of the monetary policy component for exchange rate change, compared to our previous findings.

7 Conclusion

This paper explores the implications of modeling monetary policy as a reaction function in determining exchange rate movements (endogenous monetary policy). The stylized model implies that macroeconomic fundamentals would influence exchange rate changes

Figure 16: 10-year Correlation between the Sum of Expected Short-term Interest Rate Differential and DM/USD changes over 6-month

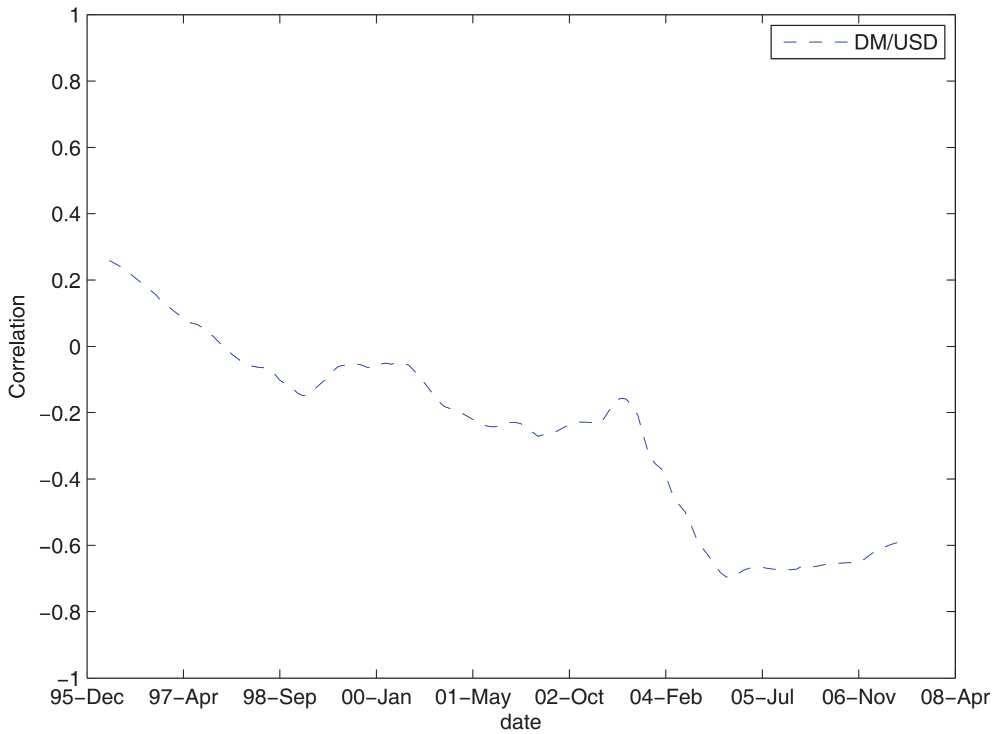


Table 10: Properties of Model Implied Exchange Rate Return with Market Participants' Expectation-Euro Era

1999-2008	Market Expectation	Rational Expectation EW06
1-quarter return	-0.38	-0.1
half year return	-0.52	-0.22
one-year return	-0.6	-0.29
two-year return	-0.66	-0.61
four-year return	-0.4	-0.46

through inducing changes in the expectation of monetary policies. In particular, I model the market expectation based on the consensus forecast of short-term interest rates and study the market participants' expectation formation process for future interest rates.

The analysis of the Deutschemark, euro, Canadian dollar, Japanese yen, and British pound relative to the U.S. dollar from 1979 to 2008 shows that expectations of monetary policies play the role of a channel between Taylor rule fundamentals and exchange rate movements. Through this channel, Taylor rule fundamentals are able to forecast exchange rate change and outperform the random model. Moreover, two potential sources for the time varying relationship between exchange rate and fundamentals are: the time varying expectation formation process of the market participant, regarding short-term interest rates and the unstable relationship between the expected interest differential, and exchange rate movement. Results suggest that the expectation formation processes for interest rates by market participants change over time and differ across countries; it is insufficient to model them using a single learning mechanism. Moreover, further studies of the expected risk premium and exchange rate forecast error may help explain the unstable relationship between expected interest rate differentials and the exchange rate.

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8 Appendix A: Data Description

Consensus interest rate forecast: forecast of the interest rate with 3-month maturity 3-month ahead. Source: Consensus Economics, 1989:10-2008:2.

Exchange Rate:

Variable	Source	Sample Period
Exchange Rate	IFS	1979: 1-1998:12
	CEIC	1995:1-2008:2

Note: Deutsche Mark price per U.S. dollar before 1999 is the original data used in Engel and West (2006).

Data for VAR learning:

Germany 1979: 1-1998:12		
Variables	**Source**	**Remark**
Industrial Production	IFS 66.c and Bundesbank	Logarithm is taken. Data are combined from West German data for 1979-1990 and German data from 1990-1998. Adjustment to smooth the data according to Engel and West (2006) is involved.
Consumer Price Index	IFS 64. and Bundesbank	
Money Market Rate	IFS 60b	

Note: The above are all original data used in Engel and West (2006).

United States 1979: 1-1998:12		
Variables	**Source**	**Remark**
Industrial Production Index	IFS 66.c	Logarithm is taken.
Consumer Price Index	IFS 64.	
Federal Funds Rate	IFS 60b	

Note: The above are all original data used in Engel and West (2006).

Euro Area 1995:1-2008:2		
Variables	**Source**	**Remark**
Industrial Production Index	CEIC (Eurostat EUBGADGA)	Logarithm is taken Seasonally adjusted .
Harmonized Consumer Price Index	CEIC (ECB EUICB)	
Money Market Rate	CEIC (ECB EUMCAC)	Euro interbank market 3-month rate.

United States 1995:1-2008:2		
Variables	**Source**	**Remark**
Industrial Production	CEIC (IMF 217893801)	Logarithm is taken. Seasonally adjusted.
Consumer Price Index	CEIC (IMF 217892101)	Logarithm is taken. Seasonally adjusted by the author.
Federal Funds Rate	IFS	

Note: The above are all original data used in Engel and West (2006).

Data for U.S. FAVAR learning: available upon request.

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