Preliminary Master Thesis

Price discovery for currencies traded in two markets: An empirical microstructure approach

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1 Introduction

The market for foreign exchange is the backbone of international trade and global investing. It is the most liquid market in the world, with an average daily turnover of USD 5.1 trillion in April 2016 (Bank for International Settlements, 2016). Exchange rates affect output and employment through real exchange rates; inflation through the cost of imports and commodity prices; and international capital flows through the risks and returns of different assets (King, Osler, & Rime, 2013). Indeed, exchange rates affect 'everything', which justifies the amount of attention exchange rates get from importers and exporters, institutional investors and financial institutions, the media, as well as academia.

The high liquidity in the foreign exchange market implies that information relevant for prices is incorporated rapidly, motivating researchers to find which factors that explain exchange-rate variations the most. The transition from fixed to floating-rate regimes after the collapse of Bretton Woods made exchange-rate research a hot topic. Early models focused on macro factors such as interest rates, money supply, trade balance, etc., models which in theory sound appealing and which are easy to understand and in line with general economic theory. However, these models have not been able to explain enough to put the question of how prices are determined to rest.

In fact, macro models have been empirical failures (Evans & Lyons, 2002a), and out-of-sample forecasting has been difficult. Even the best models have not been able to outperform the naive random walk model. This has lead research into a new area of exchange-rate research, including the micro-based view of asset pricing models. The (most) interesting micro variable in this field has shown to be order flow. In fact, in Evans and Lyons' (2002a) hybrid model including both macroeconomic determinants and microstructure determinants (order flow), they find that their model accounts for about 60 percent of daily changes in the DM/USD exchange rate.

2 Literature review

In macroeconomics, the most renowned theories for explaining exchange-rate variations are based on parity conditions and no-arbitrage arguments. Macro fundamentals like interest rates, output, inflation, and trade balances do all have impact on exchange rates, and information about these variables should

help forecast future exchange rates. The early empirical works on exchange-rate determination have assumed that information on fundamentals relevant for exchange rates is public (heterogeneity among agents), and researchers have based their models on economic theories like uncovered interest parity (UIP) and purchasing power parity (PPP).

However, the above theories on fundamentals' contribution to exchange-rate changes have proven to be empirical failures. One study highlighting the poor performance of the macroeconomic models from the 70s was Meese and Rogoff (1983). This study compared the out-of-sample forecasting ability of several well-known macro models with the simple random walk model. These models include the flexible-price and sticky-price monetary models of Frenkel-Bilson and Dornbusch-Frankel, and Hooper-Morton's sticky-price model incorporating current account. In their analysis based on RMSE they found that the simple random walk model performed no worse than the structural models, even though actual realized values of future macro fundamentals were used as input in the structural models. Several subsequent studies unsuccessfully attempted to over-turn the Meese and Rogoff analysis at short horizons (Frankel & Rose, 1995), leaving the field of exchange-rate research in a crisis (Evans & Lyons, 2002a).

However, so many variables and models had been explored within the macro field of exchange rate research, "...so it is not easy to think of variables that have escaped consideration in an exchange rate equation" (Meese, 1990). Yet, even the best macro models had disappointing explanatory power, forcing researchers to continue exploring the possibility that important variables have in fact been omitted from the exchange-rate equation. This does not mean that UIP and PPP does not hold as long-term or equilibrium theories, but the pure macro models based on these theories have low contribution in the short term. For periods shorter than one year, surprising events and other information embedded in market participants' minds have a large role in determining exchange-rate variations – the question is how this information is channeled into exchange rates. Looking to the microeconomics of asset pricing, researchers started to focus on the trading-process variables in the FX market to see if any relevant price information were reflected via any of these variables. One variable that has shown to have great impact on the explanatory power of exchange-rate models is order flow. Evans and Lyons (2002a) describe order flow as a measure of buying or selling pressure. It is the net of buyer-initiated orders and seller-initiated orders. According to market microstructure, infor-

mation about the 'aggressor' of the trades moves exchange rates (King et al., 2013).

Evans and Lyons (2002a) studied interdealer order flow at a daily basis on the Deutsche Mark and Yen price of the US Dollar. Their hybrid model consisting of both a macro component (interest-rate differential) and a micro component (order flow) accounted for about 60 percent of the variation in the DM/USD exchange rate, quite an increase from the macro models rarely explaining more than 10 percent. These results have been confirmed by subsequent studies, with good results both for major currencies (e.g., Berger, Chaboud, Chernenko, Howorka, & Wright, 2008; Breedon & Vitale, 2010; Chinn & Moore, 2011; Danielsson & Love, 2006; Killeen, Lyons, & Moore, 2006; Payne, 2003) and for smaller currencies (e.g., Evans & Lyons, 2002b; Scalia, 2008; Smyth, 2009) including emerging market currencies (e.g., Menkhoff & Schmeling, 2008). The studies cited above all use interdealer order flow as a proxy for price-relevant information. As interdealer order flow is a result of customer-dealer order flow it is natural to assume that information about exchange rates is conveyed via customer order flow as well. This is verified by a number of studies (e.g., Bjønnes, Rime, & Solheim, 2005; Gyntelberg, Loretan, Subhanij, & Chan, 2009; King, Sarno, & Sojli, 2010; Marsh & O'Rourke, 2005; Onur, 2008; Rime, 2001; Wu, 2012).

The papers mentioned above cover a wide range of currencies, time periods, sample sizes, and observation frequencies. Some use the same approach as Evans and Lyons' Portfolio Shift model, while others have used the SVAR-approach of Hasbrouck (1991) (e.g., Menkhoff & Schmeling, 2008; Payne, 2003) or the cointegration framework (e.g., Bjønnes et al., 2005; Chinn & Moore, 2011; Killeen et al., 2006). The conclusion they share is that positive order flow leads to an appreciation of the foreign currency, and that variations in order flow explain much of the variations in exchange rates.

3 Research question and methodology

Our broad aim in this thesis is to investigate price discovery for the Polish Zloty (PLN). The PLN is traded in two markets – the Euro (EUR) and the US Dollar (USD), and we want to analyze in which of these markets price is determined. Our method of investigating this question is through models with the order flow variable, as order flow has shown abilities to explain a significant part of the price variations. The analysis will focus on the Polish Zloty to Euro

and US Dollar exchange rates, though we will include other currency pairs for comparison and verification. The first model we use is the Portfolio Shifts model of Evans and Lyons (2002a), where we want to verify that order flow does indeed have explanatory power for variations in the PLN price of Euro and US Dollar. The second stage in our analysis is a vector autoregression (VAR) model like the one used by Payne (2003), where we allow for an analysis of the interdependency between trading activity and currency returns.

3.1 Portfolio Shifts Model

The theoretical framework in this part relies on that in the paper of Evans and Lyons (2002a), where they explain exchange-rate variation using a so-called Portfolio Shifts model. The model can be described in short as follows: The trading day is divided into three rounds of trading, and explain how the spot price moves as a result from trading activity in these rounds. In round 1 all market participants observe innovations in payoffs, r_t, on which dealers base their quotes to buy or sell any amount from or to the public. In round 2 dealers trade with each other, and in round 3 dealers trade with the public again to share overnight risk.
The pricing relation is written as follows:

$$\Delta P_t = r_t + \lambda \Delta x_t$$

That is, the change in price from the end of period t-1 to the end of period t depends on innovations in payoffs r_t and price adjustment required to induce re-absorption of the public's portfolio shift from round 1 reflected in $\lambda \Delta x_t$.
To analyze this empirically, we will start with the same specification as Evans and Lyons (2002a), the following regression model:

$$\Delta P_t = \beta_1 \Delta (i_t - i_t^*) + \beta_2 \Delta X_t$$

The macro component is the change in the interest-rate differential from the end of period t-1 to the end of period t. We expect, based on numerous similar studies, that there is a notable positive relation between change in order flow and change in exchange rates. Our aim is to further analyze the possible variation of this relation in the period before and after Poland joined the EU, which led to a shift from USD to EUR as the main trading currency. With a reference to network theory, we expect there to be a stronger relationship between order flow and currency return in the PLN/EUR market than in the PLN/USD market, simply because of higher trading volumes in the Euro

market. However, what is interesting about the fact that there exist two markets in which the Polish Zloty is traded, is that the two markets may convey different price-relevant information. If some price-relevant information on the Zloty is first discovered in the dollar market, then including dollar order flow in the euro model (or vice versa if the conclusion is that the dollar market is the 'real' price-discovery market) should improve the model.

3.2 Vector Autoregression

An interesting question to ask when investigating where prices are determined concerns the interdependency of the variables assumed to convey information. Does trading activity affect currency returns, or do currency returns affect trading activity? A natural assumption is that it goes both ways. In an attempt to answer these questions we will make use of the same framework as Payne (2003) with a VAR model that looks like the following:

$$r_t = \sum_{i=1}^{P} a_i r_{t-i} + \sum_{i=0}^{P} \beta_i x_{t-i} + \epsilon_{1,t}$$

$$x_t = \sum_{i=1}^{P} \gamma_i r_{t-i} + \sum_{i=1}^{P} \delta_i x_{t-i} + \epsilon_{2,t}$$

As opposed to the PS model above, which is to some degree based on macroeconomic theory (UIP), the VAR approach is a-theoretical and thus a pure statistical exercise. Although not based on any specific exchange-rate theory, the VAR approach has some desirable advantages when investigating the interdependency of currency return and trading activity. First, we do not need to impose restrictions on which variables that are exogenous – all variables are treated as endogenous, which is favorable when investigating an unknown relationship. Second, VARs have shown to be better in out-of-sample forecasting for similar relationships (McNees, 1986). (Brooks, 2014)

In Payne's (2003) VAR model there is only one equation in which a contemporaneous variable appear (trading activity in the return equation). Thus, this model has an implicit assumption that trading activity precedes quote revisions. Including contemporaneous terms in only one of the equations allows for estimation using OLS, whereas if both equations had a contemporaneous term the VAR would not be identified.

A potentially difficult aspect with vector autoregression models is lag selection, especially when we have no clear expectations on how many lags are appropriate for this relation. Adding lags will decrease the residual sum of squares (RSS), but also decrease the degrees of freedom. Using an information criterion to choose number of lags will help assessing the tradeoff between a decrease in RSS and loss of degrees of freedom by adding extra lags in the equations. Payne (2003) used Schwarz information criterion to choose the VAR's order, which has a quite strict penalty term for including extra lags. However, when choosing order of our VAR we will have to evaluate the pros and cons of the different types of information criteria.

Further, we will look at possible variations in the relation in periods with macro data releases in order to say something about if information from data releases is impounded directly into prices or indirectly via order flow.

4 Data

Our supervisor, Dagfinn Rime, has provided us with a data set that includes variables explaining trading activity (in addition to the order flow variable, it contains volume, number of trades, and number of ask and bid quotes). The data frequency is daily and spans from November 10, 1999 to December 9, 2014. The long period and high frequency of our data will support any inferences made. For macro variables we will use Datastream.

5 Plan for completing the thesis

So far, our work with the thesis has been somehow sporadic due to internships and exchange during the fall semester. We are determined to work steadily towards our goal of finishing the analysis and early write-up before June. With our progress so far, we will spend most of our time in EViews 7, writing a script/program to analyze the data. Submission should be feasible before the summer of 2017.

Besides analyzing the data in EViews 7, we also have a lot of reading to do. Reading so far has been concentrated around a few key articles, as well as skimming through other related papers. During the analysis, it will be important for us to write down key findings and sentences to later write full paragraphs and sections. Once the analysis is finished, the major part of our writing, rephrasing, and reviewing is left. Our goal is to have a readable paper

with short and concise discussions. This preliminary paper will be the basis of our Master Thesis, but the most time-consuming work is still to be done.

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