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Segmentation and time-of-day patterns in foreign exchange markets

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ABSTRACT

This paper sheds light on a puzzling pattern in spot foreign exchange markets: domestic currencies appreciate (depreciate) systematically during foreign (domestic) working hours. This phenomenon spans many years and several exchange rates, and overrides calendar effects. We argue that it is mainly due to liquidity and inventory patterns that emerge from the combination of two factors: domestic agents tend to be net buyers of foreign currency and to trade mostly in their country's working hours. The prevalence of domestic (foreign) traders demanding the counterpart currency during domestic (foreign) working hours implies sell-price (buy-price) pressure on the domestic currency during domestic (foreign) working hours.

1. Introduction

This paper provides puzzling evidence on spot exchange rates: home currencies depreciate systematically during domestic working hours and appreciate during the working hours of the foreign counterpart country. Our database covers more than a decade's worth of data stored in a high-frequency database, with several currency pairs that, taken together, cover more than 63% of total market turnover by currency pair in 2007 (BIS, 2007). A clear picture emerges: first, this pervasive time-of-day pattern is highly significant in statistical terms; second, it spans many years and overrides calendar effects.

The first aim of this study is to document the statistical significance of these time-of-day patterns.[1] The second is to propose an explanation. We argue that the main explanation is related to directional liquidity patterns. In particular, these patterns are derived from a combination of two factors. First, domestic agents tend to be net buyers of foreign currency. This can be explained by increasing international diversification coupled with rapid growth in wealth worldwide over the past few decades. It is also consistent with the stylised fact that international portfolios are long (short) in foreign (domestic) currency (e.g. Lane and Milesi-Ferretti, 2007). An additional explanation is the transactions hypothesis proposed by Cornett et al. (1995), i.e. the bias to denominate and invoice international transactions in the exporting firm's currency. Second, investors have a tendency to trade mainly during their own country's working hours. Among the institutional reasons supporting this practice, there is the convention of closing or reducing open positions on exchange rates out of the liquidity clustering during the main working hours. In aggregate, the combination of these two factors creates sell-price (buy-price) pressure on the domestic currency during domestic (counterpart) working hours. In a trading environment with an imperfectly elastic supply and risk-averse agents, the purchase of foreign currency during domestic hours gives rise to cyclical patterns in terms of liquidity demand and inventory imbalances, engendering a depreciation (appreciation) of the home currency during domestic (foreign) working hours.

Our study adds to the extant literature in two key regards. First, it examines in finer detail the cross-sectional and time-series characteristics of intraday returns on spot exchange rates across different time zones, working time periods and calendar events. While research on equity markets has found some significant day-of-week or intraday patterns on returns,[2] the literature to date

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[1] In a related study, Breedon and Ranaldo (2008) focus on the economic significance of these time-of-day regularities.

[2] For example, French (1980) finds that Friday close to Monday close returns are significantly negative. More recently, Cliff et al. (2007) find that overnight returns are strongly positive and they explain most of the equity premium for US stocks.

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has little to say about the intraday patterns of exchange rate returns. In most previous studies, attention has instead been devoted to intraday volatility or bid-ask spreads.[3] The notable exceptions are Cornett et al. (1995),[4] Ito (1987), Ito and Roley (1987, 1991)[5] and Wasserfallen (1989)[6] but their papers present mixed and partial results. In particular, Cornett et al. (1995) and Wasserfallen (1989) find that the US dollar depreciates at the beginning of the US working day whereas Ito and Roley (1987, 1991) find the opposite. Moreover, these studies are unable to put forward any comprehensive explanation. The transactions hypothesis of Cornett et al. (1995) is a complementary hypothesis to explain why US firms are likely to be net buyers of foreign currency during US trading hours. But it cannot explain the round-the-clock and pervasive phenomenon. Second, the goods/services trade accounts only for one-third of end-user trading in foreign exchange markets (BIS, 2007). Thus, the dominant part of financial transactions remains unexplained.

Second, this research focuses on liquidity. While information effects have been carefully identified in the literature,[7] much less is known about how liquidity influences exchange rate movements. Berger et al. (2008) investigate the joint behaviour of order flow and exchange rates at different sampling frequencies. Breedon and Vitale (2005) propose a structural model of exchange rate determination which disentangles the portfolio-balance and information effects of order flows. Marsh and O'Rourke (2005) address the question of whether information and/or liquidity can explain the positive contemporaneous correlation between exchange rate changes and net order flows. Here, we relate cyclical appreciations and reversals of the domestic currency to directional liquidity and inventory patterns.

This paper is structured as follows. Section 2 provides statistical evidence on time-of-day market patterns. In Section 3, we propose an explanation for the time-of-day patterns. Section 4 presents the main empirical findings. Section 5 concludes the paper.

2. Time-of-day patterns

2.1. Data

The database has been kindly provided by Swiss-Systematic Asset Management SA, Zurich. It includes spot exchange rates for the following currency pairs: CHF/USD, DEM/USD, EUR/USD, GBP/USD, JPY/EUR and JPY/USD. The sample periods cover the beginning of January 1993 to the end of August 2005 for the CHF/USD, GBP/USD and JPY/USD exchange rates and from January 1999 to August 2005 for EUR/USD and JPY/EUR. Data for DEM/USD cover the period from January 1993 to December 1998. The date of the euro's introduction dictates the time periods for the euro and the deutschmark. We use the tick-by-tick FXFX Reuters midquote price (the average price between the representative ask and bid quotes). The characteristics of these data have been discussed at length in previous studies.[8] Although indicative quotes have their shortcomings,[9] the microstructure literature shows that for frequencies shorter than tick frequency, the indicative midquote is very representative (Danielsson and Payne, 2002).

We also augmented our dataset with firm quotes from the Electronic Brokerage Services (EBS) on the EUR/USD spot exchange rates from 1999 to the end of June 2007. These additional data allow us to compare indicative and firm quotes.

To conduct this study, we carefully organised our database as follows: first, we accounted for differences in daylight savings times by expressing time in terms of Greenwich Mean Time (GMT). Second, we organised our database in five-minute intervals. If no trades occurred in a given five-minute interval, we used the last quotes in the previous time interval. Finally, since our database included weekends, we excluded weekend hours according to the definitions reported in Table 1, i.e. the beginning and end of working hours in the different time zones.[10]

For the sake of presentation, we investigate exchange rate movements over four-hour periods. These time brackets are the most efficient solution for analysing non-overlapping intraday periods in the different working hours of each world region. First, they decompose round-the-clock time into homogenously and regularly spaced intervals. The four-hour timeframe coincides pretty well with the opening and closing times of the main international equity markets. In particular, trading hours from midnight to 04:00 GMT, from 08:00 to midday, and from 16:00 to 20:00 GMT mirror the main trading activity in Japan, Europe and the US, respectively. Second, a four-hour interval is a reasonable length of time for marketable intraday trading, and also minimises issues such as entry and exit timing, transaction costs, trading slippages and possible delays in 'indicative' quotes. We also analysed these patterns on an hourly basis. These additional findings are perfectly in line with those analysed here, and are available upon request.

2.2. Statistical significance

Fig. 1 presents time-of-day return patterns on EUR/USD in graphical form. It shows 24 cross-sectional averages of annualised log returns over four hours, which are computed using the nearest quotes to the end of the four-hour period. To annualise, four-hour returns are multiplied by 260. Using two-sample *t*-tests, these charts also show if the acceptance of the null hypothesis of equality in means of non-overlapping returns falls below the *p*-value of 5% or 1%. In Fig. 1, black (grey) bars mean that an average return over a specific four-hour period is different at a 1% (5%) significance level. The charts on the other exchange rates (available upon request) deliver a very similar picture. Fig. 1 clearly shows that the domestic currency tends to depreciate during domestic working hours and to appreciate during the working hours of counterpart countries. More specifically, the US dollar appreciates significantly from 08:00 to 12:00 GMT and the euro appreciates significantly from 16:00 to 22:00 GMT. It is worth noting that Reuters and EBS patterns are very similar (the correlation coefficient is 0.95). This suggests that Reuters indicative quotes are closely related to trading data.

[3] The pioneers in collecting and analysing high-frequency data were Olsen & Associates (e.g. Dacorogna et al., 1993; Olsen et al., 1997; Müller et al., 1990). Other studies that, inter alia, have made significant contributions to the literature are Andersen and Bollerslev (1997, 1998), Baillie and Bollerslev (1990), Bollerslev and Domowitz (1993), Harvey and Huang (1991), Hsieh and Kleidon (1996), Ito and Hashimoto (2005). The predictability of exchange rates has recently been studied by, among others, Dueker and Neely (2007), Guo and Savickas (2008) and Sarantis (2006).

[4] Cornett et al (1995) use several years of intraday data on foreign exchange futures from the international money market.

[5] Ito (1987) and Ito and Roley (1987, 1991) have a few snapshots of the yen-dollar exchange rate at the opening and closing in the Tokyo and New York markets.

[6] Wasserfallen (1989) analyses the bid prices quoted by UBS on the interbank market for CHF/USD exchange rates in 1983. He also finds that the Swiss franc declines (increases) in value especially in the early morning of European (US) trading.

[7] In particular, see the seminal paper by Evans and Lyons (2002), in which the order flow is the main determinant of exchange rates because it conveys information. Other papers have investigated information asymmetry, e.g. Osler et al (2006) and Payne (2003).

[8] Including Müller et al (1990), Dacorogna et al (1993) and Goodhart et al (1996).

[9] Lyons (1995) stresses three limitations related to 'indicative' quotes: they are not tradable; they are representative only for the interbank market; during very fast markets, 'indicative' quotes may be updated with a short delay. Martens and Kofman (1998) show that futures on DEM/USD tend to lead the 'quoted' spot market by up to three minutes. On the other hand, Goodhart et al (1996) conclude that FXFX indicative quotes can be taken as a very good and close proxy for that in the Reuters 2000-2.

[10] The inclusion of weekends leaves the main results unchanged. But it has the disadvantage of blurring some of the intraday effects.