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General and specific statistical properties of foreign exchange markets during a financial crash

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ABSTRACT

We investigate minute-by-minute foreign exchange rate (FX) data of 14 currencies with different exchange-rate regimes during a financial crash, and divide these data into several stages according to their respective tendencies: depreciation stage (stage 1), fluctuating stage (stage 2), and appreciation stage (stage 3). The tail distribution of FX rate returns satisfies a power-law structure for different types of currencies. We find the absolute value of the power-law exponent is smaller in emerging markets than in developed markets, especially during the stage 1, and is greatest in pegged currencies.

We also find that the correlation properties of the FX rate return series have quite disparate results among the various types of currencies. Currencies in developed markets respectively have weak persistence and anti-persistence in short and long timescales; whereas the pegged currencies and currencies in emerging markets show different degrees of anti-persistence in various timescales. Further analyses on the data in divided stages indicate that emerging markets and pegged currencies have more prominent dual fractal structures after the depreciation stage, while the developed markets do not. Hurst exponent analyses on the sign series yield similar results to that on the original return series for most currencies. The magnitude series of the returns provide some unique results during a crash. The developed market currencies have strong persistence and exhibit a weaker correlation in the depreciation and appreciation stages. In contrast, the currencies of emerging markets as well as pegged currencies fail to show such a transformation, but rather show a constant-correlation behavior in the corresponding stages of a crash. These results indicate that external shocks exert different degrees of influence during different stages of the crash in various markets.

1. Introduction

Financial time series analysis is one of the main research fields for economists and statistical physicists [1–5]. In the last decade, several stylized statistical properties of financial market data have been observed. For example, some studies have found that the logarithmic returns of financial market data feature a long-tail distribution [6–11]. Other studies have shown that the return volatility series possess a strong long-range correlation [12–20]. These results reflect the commonalities among stock markets [12–20], foreign exchange (FX) markets [21–23], and other commodity markets (including diamond price markets [24], gold and silk markets [25,26], agricultural futures [27,28], crude oil markets [29–31], and so on).

Besides these commonalities, compared with other markets, currency exchange markets have various exchange rate regimes and are more vulnerable to national political and economic policy as well as international interaction [32,33]. In

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accordance with such uniqueness, previous studies have indicated that FX markets have a strong influence on stock and commodity markets, and the statistical and correlation properties of the FX rate data depend on the exchange rate regime and the degree of market development [34,35]. However, these studies focus on daily data in normal periods with relatively long time spans, and few studies have investigated the statistical properties of the high frequency FX rate data in relatively shorter time spans during financial crashes. In addition, during the different stages of a crash, the currency exchange rate will reflect various tendencies which have a significant impact on trading behavior, but the effect of this phenomenon on the statistical properties of FX rate data has scarcely been investigated. This paper aims to address these problems.

The remainder of the paper is organized as follows. In Section 2, we describe our foreign exchange rate data and methodology. In Section 3, the cumulative distribution function of the logarithmic returns is investigated. In Section 4, we use detrended fluctuation analysis (DFA) to analyze the persistence of return series, along with their sign and magnitude series. Concluding remarks are included in Section 5.

2. Data and methodology

2.1. Description of data

We analyze foreign exchange data (returns to US dollars) at one minute intervals during the global financial crisis between Aug 2008 and May 2009. Taking the various exchange rate regimes and different degrees of market efficiency into account, fourteen types of currency are chosen. For the floating exchange rate system, we consider six currencies with larger trading volume in efficient markets: Australian dollar (AUD/USD), Canadian dollar (CAD/USD), Euro (EUR/USD), Pound sterling (GBP/USD), Japanese yen (JPY/USD), and Swiss franc (CHF/USD). We also investigate six currencies from emerging markets: Brazilian real (BRL/USD), Indian rupee (INR/USD), South Korean won (KRW/USD), Russian ruble (RUB/USD), Taiwan dollar (TWD/USD), and South African rand (ZAR/USD). In addition, two representative pegged currencies in efficient and emerging market are also analyzed: Hong Kong dollar (HKD/USD) and Chinese yuan (CNY/USD) [32]. We compare the statistical and correlation properties of the FX rate data in different periods of the crash. According to the FX rate tendencies as well as some economics events, the FX rate data series in the floating exchange rate system can be divided into three stages:
stage 1 (depreciation stage), whose increment of daily closing mid FX rate is mostly a large negative value, lasts from Aug 2008 to late October 2008 when the currency holders started to transfer their vast resources to the safe haven-US dollars [36]; stage 2 (fluctuating stage), whose daily FX rate increments are both positive and negative, lasts until early March 2009 when the global financial crisis began to ease and the US Federal Reserve expanded the activity of QE1 (the first round of quantitative easing) [37–39]; stage 3 (appreciation stage) lasts from early March 2009 to late May 2009 with the mostly positive increment of daily FX rate. We also notice that for the RUB, since the Russian economy ties with the international oil price closely, the ruble depreciated durably with the depreciation of oil price until late January 2009 when the Russian central bank spent $200 billion to defend the currency [40]. As a result, late January 2009 is the time node for separation between stage 1 (plummet stage) and stage 2 (fluctuating stage). Then the ruble rebounds and enters the stage 3 (appreciation stage) in early March 2009 due to the easing of global crisis [37].

However, Japanese yen had the special trend during the financial crisis. It appreciated dramatically until the early December 2008 when the investors of other currencies transferred their resources to the yen to complete the risk aversion. Such trend will eventually force the Japan government to take steps to suppress the appreciation of yen [41–43]. In late January 2009, yen began to depreciate due to the decline of total export amount of Japan [44]. Therefore, the early December 2008 and late January 2009 are the two time nodes for separation among the stage 1 (appreciation stage), stage 2 (fluctuating stage) and stage 3 (depreciation stage).

Meanwhile, with respect to the pegged currency, the FX rate data can be separated into one or two stages: appreciation/fluctuating stage (stage 1) and fluctuating stage (stage 2) (see Figs. 1–3).

2.2. Detrended fluctuation analysis (DFA)

For FX rate data, we define the minute-by-minute logarithmic return by

$$r(t) = \ln p(t) - \ln p(t-1), \tag{1}$$

where $p(t)$ is the FX rate at minute t. We use Detrended Fluctuation Analysis (DFA) as proposed by Peng et al. to analyze the Hurst exponent of the return series [45]. The DFA method consists of the following 3 steps:

(I) Create a new time series $y(i)$ from the logarithmic return:

$$y(i) = \sum_{k=1}^{i} (x(k) - \bar{x}), \tag{2}$$

where $x(i)$ is the ith point in target time series such that $x(i) \equiv r(t)$, $\bar{x}$ is the average value of all $x(k)$.