# Currency Crash and Speculative Currency Investment under Flexible Exchange Rates

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ABSTRACT

This study documents substantial disparity in currency volatility and crash incidents between emerging markets and industrialized countries. Under the same flexible exchange rate regime, currencies in emerging markets are more volatile and experience more crashes. The paper investigates whether international financial investments attracted to higher interest rate in emerging markets contribute to the disparity. Using Vector Autoregression (VAR) models and data from 23 countries, the study confirms that the relative higher interest rate accounts for a large part of the more volatilities and crashes in currencies of emerging countries. The results imply that emerging economies may not necessarily benefit from a flexible exchange rate regime, which was thought to be a shock absorber that could avert large crashes in currency.

**Keywords:** Monetary Policy, Flexible Exchange Rate, Currency Crash, Carry Trade, Vector Autoregression

## INTRODUCTION

A flexible exchange rate regime has been growing popular in recent decades among emerging countries. It can be either in the form of floating or free-floating in exchange rates as defined by the International Monetary Fund (Klein & Shambaugh, 2010). The historical background of this transition is the many financial crises in developing countries in the past 30 years. Mexico experienced a severe collapse of its peso, banking system and economy in December 1994. Several Asian economies (South Korea, Indonesia, Thailand, Malaysia, and the Philippines) had similar events in 1997. Most of these crises were caused by a crawl pegging exchange rate policy (Fankel & Rose, 1996)—fixing the value of the very currency to dollar at a target number within a narrow range. A large capital outflow could be triggered by loss of confidence in the government's ability to maintain such a target value. Since then, most of developing countries have abandoned the pegging in favor of flexible exchange rates after crisis.

In this paper, we want to address the issue whether it is wise for emerging countries to adopt a flexible exchange rate regime under an environment of high capital mobility. The exchange rate regime choice is an unsettled issue. There is no clear guidance on choosing a proper exchange rate for an economy. Countries have much of the freedom to decide an exchange rate policy. In the recent decade, countries have been under heavy influence of such "two-corner solutions," i.e., either a flexible floating exchange rate or a hard peg is viable under high capital mobility. Facing only these two possible options, since the 1997 Asian financial crisis, majority have transitioned into a floating or free floating exchange rate policy, because a hard peg requires much more resources. The purpose of this transition is to remove the exchange rate of a currency as a trigger of financial crisis (Frankel & Rose, 1996; Gopinath, 2004; Kaminsky & Rienhart, 1999; Schneider &

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Tornell, 2004). But the new type of exchange rate policy exposes the country's financial markets to foreign portfolio investments, which have high mobility and could cause sudden exchange rate movements. Majority of these foreign portfolios are in the form of currency investments, chasing higher interest rates or returns in the developing countries. Thus it is important to understand whether a flexible exchange rate policy could prevent sudden outflows of capital, as well as a financial crisis in the future. Particularly, we examine how a flexible regime fares in emerging markets compared with that in the industrialized countries, from the angle of exchange rate stability.

Statistics from our sample data show that emerging markets experienced more tumultuous episodes than industrialized nations, while both are under the flexible exchange rate regime. Currency in an emerging country shows much more volatility and negative skewness than one in a major industrialized country. In addition, an emerging currency would crashes three percent or more at a higher frequency than an industrialized currency over the period of flexible rate regime.

We then investigate the possible cause for such discrepancy in volatility and skewness. We ask if carry (interest rate differential) or carry trade, a major type of currency investments across border, induces more volatile and downside currency changes, particularly in emerging markets (Vistese, 1996). We choose to carry trade as a proxy for foreign portfolio investment because almost all foreign portfolio investments are attracted to the higher interest rates or returns in the host countries. Since the mid-1990s, we have seen the rise of carry trade, a simple investment recipe of borrowing a currency with a low interest rate and investing in another currency with a high interest rate. The low-interest-rate currency is called the funding currency and the high-interest-rate currency the target currency. The funding currency of the carry trade is mostly the Japanese yen, due to its super-low interest rate since the mid-1990s.[1] Increasingly, emerging markets with floating exchange rates become targets of carry trade because they tend to have a higher interest rate.

Carry trade is associated with currency movement because it involves buying the higher-interest-rate currency first, and unwinding it later. The investment horizon typically is limited within a year (Brunnermeier et al., 2008). In its nature, carry trade would only increase volatility in the target currency, because it is a type of temporary shocks to a target currency. Numerous studies have shown asset appreciation by temporary or short-term shocks would necessarily induce longer-term depreciation due to unwinding (Froot & Ramadorai, 2005; Campbell, 1991; Campbell & Ammer, 1993; Vuolteenaho, 2002). A quick reversal results in more volatile exchange rates when a large unwinding of carry trade hits.

We define carry as the interest rate differential between a country and the U.S., while carry trade is defined as carry plus currency return in the local currency. We document that carry or carry trade is highly associated with currency movements in all countries. But the association is much stronger in emerging markets. We use a VAR model to investigate quantitatively how much carry or carry trade contributes to currency volatility and crash. Finally, we test the hypothesis that the volatility or crash count discrepancy between emerging markets and industrialized nations is caused by carry trade, using impulse response of exchange rates to carry (or carry trade).

The paper is organized as follows. The first section presents statistics of volatility and crash counts. After that, a preliminary analysis between carry (trade) and currency

[1] Galati, Heath, & McGuire (2007) claim that the yen accounted for about eighty percent of funding currency for carry trades in 2007.

volatility (crashes) is performed. In the last two sections we discuss the VAR set-up and perform hypothesis testing.

## EMPIRICAL FACTS ON CURRENCY RETURNS AND CRASHES

Using monthly exchange rate data from the IMF International Financial Statistics (IFS), we compute exchange rate volatility and number of crashes in eight industrialized and 15 emerging countries. We use only exchange rate data for the period when a floating or free-floating exchange rate regime was in place, but limit the beginning time at January 1973, when the Bretton Woods System ended. So the longest possible data run from January 1973 to April 2016 for 524 months.

### Measuring Currency Crashes

There are various indicators of currency crashes existing in the literature. Based on Kaminsky and Reinhart (1996, 1998), Milesi-Ferretti and Razin (1998) and Frankel and Rose (1996), a currency crash is defined as more than $x$ depreciation and to the former one plus two percent; at the same time the preceding depreciation should have been less than two percent.[2]

$$indicator = 1 \qquad \Delta s_t < -x\%, |\Delta s_t| > |\Delta s_{t-1}| + 2\% \text{ and } \Delta s_{t-1} > -2\%$$
$$indicator = 0 \qquad \text{otherwise}$$

### Volatility and Crashes Comparison

Table 1 shows that emerging markets as a group experienced both higher volatility and more crashes in their currencies than industrialized countries. At the monthly level, the emerging currencies had an average of five percent volatility in contrast to the three percent volatility in industrialized countries. Currencies in emerging countries also had higher skewness, a measurement of severe downside movement, than those in industrialized countries. It implies that emerging countries were more likely to see their currencies crash although both were under the same type of exchange rate regime.

Table 2 presents the number of times (months) of currency crashes countries experienced during the flexible regime. Consistent with higher volatility and skewness in emerging currencies, numbers of currency crashes were higher in emerging currencies too. Considering that most of emerging countries had a shorter history of floating exchange rate policy, the actual probability of crashes should be higher. The average count per country per year is calculated as "All." For example, an emerging currency depreciated five percent or more for almost ten times on average per year, much higher than an industrialized currency, which crashed 6 times. For depreciation greater than nine percent in a month, emerging currencies crashed almost 2.8 times of industrialized currencies.

### Naïve Explanation

One tentative explanation is that under floating or free floating exchange rate arrangement, emerging markets, typically with a high interest rate, attract foreign capitals flows, which causes the higher volatility, hence more crashes in exchange rates (Galati & McGuire, 2007; Gourinchas & Rey, 2007). To explore this venue, the correlation between

[2] We found that two percent is not a critical parameter. The crash counts in emerging countries are always greater than those in industrialized countries when two percent is replaced by any number up to eight percent.

the carry (or carry trade) and the exchange rates is calculated. Table 3 shows the correlation between exchange rate returns and lag carry (trade) by levels of carry. Countries with high carry, mostly emerging ones, showed very strong correlations, in contrast to countries with low carry, mostly industrialized countries. In the group of highest carry, top 20% quantile, the currency movement was 39% (37%) correlated with carry (trade), while the currency crashed most (20 times). It shows that emerging countries, which usually had an interest rate (carry), were the most prone to currency crashes. Table 4 shows such correlation for each emerging and industrialized nation. In general, relationship between currency movement and interest rate (carry) in industrial countries was mute, at about one percent for each lag, while that was much higher in emerging countries.

Therefore, we may conclude that in emerging markets, where a floating or free-floating exchange rate policy is in place, higher carry, hence high expected carry trade profit, contributes to the higher volatility and more crashes in currencies.

TABLE 1

Volatility and Skewness Comparison

| Group A. Industrialized Country | Time of float | Min | Max | Std. Dev. | Skewness |
|---|---|---|---|---|---|
| Euro | 1999.01 | -0.11 | 0.09 | 0.03 | -0.24 |
| Australia | 1983.12 | -0.21 | 0.09 | 0.03 | -1.05 |
| Canada | 1970.01 | -0.17 | 0.08 | 0.02 | -1.47 |
| Japan | 1985.01 | -0.11 | 0.15 | 0.03 | 0.48 |
| New Zealand | 1985.03 | -0.15 | 0.10 | 0.03 | -0.58 |
| Norway | 1992.12 | -0.15 | 0.08 | 0.04 | -0.57 |
| Sweden | 1992.11 | -0.16 | 0.09 | 0.03 | -0.67 |
| U.K. | 1971.08 | -0.12 | 0.08 | 0.03 | -0.95 |
| All | | -0.15 | 0.10 | 0.03 | -0.63 |
| Group B. Emerging Country | | | | | |
| Brazil | 1999.01 | -0.51 | 0.17 | 0.06 | -3.66 |
| Chile | 1999.09 | -0.18 | 0.10 | 0.03 | -0.89 |
| Czech Republic | 1993.01 | -0.11 | 0.10 | 0.04 | -0.30 |
| Hungary | 2001.01 | -0.19 | 0.09 | 0.05 | -1.11 |
| India | 1992.03 | -0.12 | 0.08 | 0.02 | -0.97 |
| Mexico | 2011.11 | -0.07 | 0.07 | 0.03 | -0.17 |
| Mongolia | 1993.01 | -0.29 | 0.15 | 0.10 | -4.54 |
| Peru | 2011.04 | -0.06 | 0.05 | 0.01 | -0.13 |
| Philippines | 1964.01 | -0.15 | 0.08 | 0.03 | -1.64 |
| Poland (04/2000) | 2012.11 | -0.17 | 0.10 | 0.05 | -0.91 |
| Romania (01/1997) | 2005.07 | -0.33 | 0.12 | 0.04 | -2.59 |
| South Africa | 1961.02 | -0.20 | 0.11 | 0.04 | -0.60 |
| South Korea | 1997.12 | -0.39 | 0.15 | 0.05 | -3.61 |
| Thailand | 1998.01 | -0.25 | 0.23 | 0.03 | -0.96 |
| Turkey | 2005.01 | -0.24 | 0.10 | 0.04 | -0.85 |
| All | | -0.22 | 0.11 | 0.05 | -2.06 |

Note: Numbers in a pair of parentheses indicate the month/year when the floating or free-floating exchange rate regime was officially adopted. Time of float is from various IMF reports.

TABLE 2

Crash Incident Counts

| Group A. Industrialized Countries | x>3% | x>5% | x>7% | x>9% |
|---|---|---|---|---|
| Euro | 14 | 7 | 3 | 1 |
| Australia | 13 | 7 | 4 | 2 |
| Canada | 7 | 1 | 1 | 1 |
| Japan | 13 | 6 | 6 | 0 |
| New Zealand | 20 | 8 | 8 | 3 |
| Norway | 18 | 4 | 4 | 0 |
| Sweden | 16 | 6 | 6 | 0 |
| U.K. | 13 | 9 | 3 | 2 |
| All (Average) | 14.2 | 6.0 | 4.4 | 1.1 |
| Group B. Emerging Countries | | | | |
| Brazil | 22 | 11 | 6 | 3 |
| Chile | 19 | 12 | 3 | 1 |
| Czech Republic | 22 | 18 | 8 | 4 |
| Hungary | 16 | 13 | 8 | 5 |
| India | 11 | 8 | 2 | 1 |
| Mexico | 2 | 1 | 1 | 0 |
| Mongolia | 10 | 7 | 7 | 6 |
| Peru | 2 | 1 | 1 | 0 |
| Philippines | 15 | 5 | 3 | 2 |
| Poland | 21 | 15 | 12 | 8 |
| Romania | 22 | 7 | 4 | 1 |
| South Africa | 39 | 20 | 13 | 2 |
| South Korea | 15 | 6 | 5 | 4 |
| Thailand | 14 | 4 | 2 | 2 |
| Turkey | 22 | 20 | 8 | 3 |
| All (Average) | 16.8 | 9.9 | 5.5 | 2.8 |

TABLE 3

Exchange Rate and Carry (Interest Rate Differential) Correlations

| | Number of months | | $\rho_{,carry}$ | | | $\rho_{,carry\ trade}$ | | | Currency Crash |
|---|---|---|---|---|---|---|---|---|---|
| Carry quintiles | Industrial | Emerging | lag 1 | lag 2 | lag 12 | lag 1 | lag 2 | lag 12 | >9% |
| Highest 20% | 27 | 1,742 | 0.39 | 0.31 | -0.12 | 0.37 | 0.29 | -0.11 | 20 |
| 60%-80% | 224 | 1,543 | 0.03 | 0.03 | 0.04 | 0.06 | 0.01 | -0.01 | 17 |
| 40%-60% | 724 | 1,047 | -0.04 | -0.04 | 0.01 | 0.01 | 0.02 | -0.02 | 9 |
| 20%-40% | 859 | 913 | 0.03 | 0.02 | 0.02 | -0.02 | 0.00 | -0.02 | 5 |
| 0-20% | 1,139 | 631 | 0.08 | 0.08 | 0.03 | 0.05 | 0.03 | 0.06 | 2 |

Note: The correlations are between currency returns and previous carry (trade).

TABLE 4

Exchange Rate and Carry Correlations

| Group A. Industrial Country | | $P_{,carry}$ | | | $P_{,carry\ trade\ profit}$ | |
|---|---|---|---|---|---|---|
| | lag 1 | lag 2 | lag 12 | lag 1 | lag 2 | lag 12 |
| Euro | 0.34 | 0.35 | 0.28 | 0.16 | -0.03 | -0.15 |
| Australia | 0.00 | 0.00 | 0.06 | 0.05 | 0.02 | -0.08 |
| Canada | -0.03 | -0.02 | 0.00 | -0.06 | 0.02 | 0.03 |
| Japan | 0.09 | 0.09 | 0.07 | 0.08 | 0.06 | 0.05 |
| New Zealand | 0.06 | 0.05 | 0.08 | 0.02 | 0.01 | -0.05 |
| Norway | -0.02 | -0.02 | 0.01 | 0.14 | 0.06 | -0.08 |
| Sweden | 0.12 | 0.12 | 0.20 | 0.00 | 0.09 | -0.04 |
| U.K. | 0.15 | 0.12 | 0.02 | 0.10 | 0.02 | -0.01 |
| All | 0.01 | 0.01 | 0.01 | 0.02 | 0.00 | 0.00 |
| Group B. Emerging Country | | | | | | |
| Brazil | 0.49 | 0.39 | -0.13 | 0.48 | 0.38 | -0.12 |
| Chile | 0.20 | 0.17 | -0.09 | -0.04 | 0.02 | -0.02 |
| Czech Republic | 0.06 | 0.07 | -0.07 | 0.01 | -0.02 | -0.02 |
| Hungary | 0.09 | 0.10 | -0.11 | 0.01 | -0.02 | 0.01 |
| India | 0.02 | 0.02 | -0.01 | -0.09 | -0.02 | -0.08 |
| Mexico (11/11) | 0.30 | 0.29 | -0.19 | -0.01 | 0.00 | 0.02 |
| Mongolia | 0.01 | 0.03 | -0.05 | -0.04 | -0.03 | -0.02 |
| Peru (04/11) | 0.77 | 0.54 | -0.18 | 0.82 | 0.56 | -0.15 |
| Philippines | 0.02 | 0.01 | 0.01 | -0.02 | -0.06 | 0.15 |
| Poland (12/11) | 0.27 | 0.27 | -0.14 | -0.01 | 0.13 | -0.08 |
| Romania | 0.25 | 0.26 | -0.25 | -0.26 | -0.04 | 0.01 |
| South Africa | -0.02 | -0.03 | 0.06 | -0.05 | -0.05 | 0.03 |
| South Korea | 0.01 | 0.00 | 0.02 | -0.04 | -0.02 | -0.06 |
| Thailand | 0.01 | 0.00 | -0.04 | -0.15 | 0.07 | -0.06 |
| Turkey | 0.19 | 0.21 | -0.10 | -0.08 | 0.00 | 0.03 |
| All | 0.32 | 0.26 | -0.11 | 0.30 | 0.24 | -0.10 |

## CURRENCY RETURNS AND THE VAR

### The Exchange Rate and the VAR

The first step is to set up a proper model of exchange rate. Following literature in international finance (Lewis, 1995; Kilian & Tylor, 2003; Mark & Sul, 2001; Engel & West, 2003), the standard monetary exchange rate model is used in this analysis.

$$\Delta s_t = \beta_0 + \beta_y(y_t - y_t^*) + \beta_\pi(\pi_t - \pi_t^*) + \beta_i(i_t - i_t^*) + \varepsilon_t \qquad (1)$$

where $s_t$ is the log exchange rate expressed as units of yen per unit of the target currency and $\Delta s_t = s_t - s_{t-1}$. An increase in $s_t$ indicates appreciation of the target currency and depreciation of the yen, and vice versa. Variable $i_t$ is the interest rate of the local currency and $i_t^*$ is the interest rate of the U.S. dollar. An asterisk denotes variables in the U.S. Variables $y$ and $\pi$ are the GDP growth rate and inflation rate respectively.

The interest rate differential $i_t - i_t^*$ is defined as the carry. The carry trade profit (CTP) therefore is defined as $(i_t - i_t^*) + \Delta s_t$. The interest rate parity states that the current spot rate is expected to depreciate/appreciate by the amount of the interest rate differential (carry) ex ante. If the interest parity holds, CTP is zero on average. Most empirical studies have invalidated such prediction (Meese & Rogoff, 1983a, 1983b; Corte et al., 2009).

Money supply is not included in the equation because lack of data in emerging countries. Numerous studies also have found that money supply has little or no predicting power on exchange rate returns (Baxter, 1994; Engel & West, 2003; Frankel & Valesco, 2012).

The VAR system is designed to include the exchange rate returns $\Delta s_t$, the carry $(i_t - i_t^*)$, the economic growth rate differential $(y_t - y_t^*)$, and the inflation rate differential $(\pi_t - \pi_t^*)$. The specification makes sure that proper analysis between exchange rate returns and carry (or CTP) can be performed:

$$z_t = Az_{t-1} + u_t$$

where $z_t = [\Delta s_t, i_t - i_t^*, y_t - y_t^*, \pi_t - \pi_t^*]$. The coefficient matrix $A$ is assumed to be constant across currencies in the same group, whether emerging or industrialized countries. The covariance matrix $\mathrm{E}(u_t u_t') = \Omega$ for the error term $u_t$ is constant and allows correlations among errors.

The covariance matrix $V(z_t) = \Pi$ is equal to $\Pi = \mathrm{A}\Pi\mathrm{A}' + \Omega$, which can be solved as

$$vec\Pi = (I_{16} - A \otimes A)^{-1} vec\Omega$$

where $vec$ is the stacking operator that stacks columns of a matrix and operator $\otimes$ is the Kronecker product. We use this formula to compute the covariance matrix.

The variance of exchange rate returns $\sigma_s^2$ is the first element in $\Pi$. It is picked out by pre-multiplying by an appropriate selection vector. Vector $1_1' = [1,0,0..,0]$, i.e. $\sigma_s^2 = 1_1'\Pi 1_1$. We can solve for $\sigma_s^2$ from equation $\Pi = \mathrm{A}\Pi\mathrm{A}' + \Omega$:

$$\sigma_s^2 = (1 - a^2{}_{11})^{-1}\left(\textstyle\sum_i \sum_j a_{ij}\pi_{ij} + 1_1'\Omega 1_1\right)$$

The variance can be further decomposed into the covariance from carry (or CTP)

$$\sum_j a_{2j}\pi_{2j} + \sum_i a_{i2}\pi_{i2}$$

and others

$$\sigma_s^2 = (1 - a_{11}^2)^{-1}(\sigma_c^2 + \sigma_v^2)$$

where $\sigma_c^2 = \sum_j a_{2j}\pi_{2j} + \sum_i a_{i2}\pi_{i2}$ and $\sigma_v^2 = \sum_{i\neq 2}\sum_{j\neq 2} a_{ij}\pi_{ij} + 1_1^{'}\Omega 1_1$. We use this decomposition to analyze the effect of carry on the exchange rate volatility.

To identify the effect of carry trade (profit), we rewrite the first exchange rate equation from

$$\Delta s_t = a_{11}\Delta s_{t-1} + a_{12}(i_{t-1} - i_{t-1}^*) + a_{13}(y_{t-1} - y_{t-1}^*) + a_{14}(\pi_{t-1} - \pi_{t-1}^*) + u_t$$

into

$$\Delta s_t = (a_{11} - a_{12})\Delta s_{t-1} + a_{12}(i_{t-1} - i_{t-1}^* + \Delta s_{t-1}) + a_{13}(y_{t-1} - y_{t-1}^*) + a_{14}(\pi_{t-1} - \pi_{t-1}^*) + u_t$$

The corresponding VAR is modified as

$$z_t = Bz_{t-1} + u_t$$

where $z_t = [\Delta s_t, i_t - i_t^* + \Delta s_t, y_t - y_t^*, \pi_t - \pi_t^*]$ with $b_{11} = a_{11} - a_{12}$ and $b_{12} = a_{12}$, etc. The variance decomposition is now

$$\sigma_s^2 = (1 - b_{11}^2)^{-1}(\sigma_c^2 + \sigma_v^2)$$

where $\sigma_c^2 = \sum_j b_{2j}\pi_{2j} + \sum_i b_{i2}\pi_{i2}$ and $\sigma_v^2 = \sum_{i\neq 2}\sum_{j\neq 2} b_{ij}\pi_{ij} + 1_1^{'}\Omega 1_1$.

**Data and Estimation**

The Federal Reserve Economic Data (FRED) is the source for the end-of-month exchange rates. We sampled end-of-month exchange rates from daily exchange rates. IFS CD-ROM is the source for all the fundamental economic variables: GDP (or industrial production), consumer prices, and interest rates. Some of these fundamentals are quarterly or annual data. We assumed monthly values from the previous quarterly or annual data. Any missing data were imputed with the "cubic spline" method in MATLAB.

The original data consist of monthly series of all variables, from January 1973 to April 2016. We kept the data only when a country was in a floating or free-floating regime, defined by the IMF.[3] The date when a country started floating its currency is listed in Table 1. The longest sample size is 500 for countries such as for U.K., Canada, and South Africa, which have traditionally not involved much currency fixing. Tables 5 and 6 present some basic statistics of the whole sample. Variables are all very volatile because their relatively large sample deviations are compared to their sample means.

Each group of countries, emerging or industrialized countries fit their own VAR model. We pooled data from countries within the same group. During the estimation, data from each country in the same group were stacked together to produce only one set of parameters. The following equation illustrates the regression technique.

$$Z = AZ_{-1} + u_t$$

where $Z = [z_{11}\ z_{21} \ldots z_{T_1 1}, z_{12} \ldots z_{T_2 2}, \ldots z_{1I} \ldots z_{T_I I,}]$ is a 4 by $T = \sum_{i=1}^{I} T_i$ matrix, and $T_i$ is the number of observation minus one in country $i$ within group $I$.

[3] Please see IMF, Annual Report on Exchange Arrangements and Exchange Restrictions, 2008-2013.

TABLE 5

Descriptive Statistics for Industrialized Countries

| | Euro Zone | Australia | Canada | Japan | New Zea- | Norway | Sweden | United | All |
|---|---|---|---|---|---|---|---|---|---|
| 1.$\Delta s$ | 0.08 | 0.01 | -0.02 | 0.25 | 0.02 | 0.18 | -0.07 | -0.07 | 0.04 |
| | (3.00) | (3.35) | (1.87) | (3.14) | (3.08) | (3.53) | (3.40) | (2.91) | (3.00) |
| 2.$i-i^*$ | -3.79 | 0.39 | -2.98 | -5.67 | -2.10 | 0.72 | -4.18 | -1.51 | -2.16 |
| | (1.72) | (3.64) | (1.88) | (2.14) | (2.52) | (2.68) | (2.24) | (2.94) | (3.39) |
| 3.$y-y^*$ | -1.29 | -0.26 | -0.72 | -1.28 | -2.00 | -2.30 | -0.65 | -1.65 | -1.32 |
| | (4.35) | (3.85) | (2.81) | (6.10) | (6.37) | (3.95) | (5.66) | (4.26) | (4.81) |
| 4.$\pi-\pi^*$ | -0.41 | 0.81 | 0.03 | -2.26 | -0.43 | 1.00 | -1.03 | 0.04 | -0.23 |
| | (0.83) | (2.15) | (1.61) | (1.25) | (1.34) | (3.97) | (1.30) | (1.51) | (2.28) |

Note: The number in parentheses under each variable is the standard deviation of the indicated variable. An asterisk indicates a U.S. value; $\Delta s$ is the percentage change in the exchange rate (a higher value indicates appreciation against the dollar); i is the money market rate or government bond yield; $\Delta y$ is the growth rate of the industrial production index or GDP; $\pi$ is the rate of inflation.

TABLE 6

Descriptive Statistics for Emerging Countries

| | Brazil | Chile | Czech Republic | Hungary | India | Mexico | Mongolia | Peru | Philippines | Poland | Romania | South Africa | South Korea | Thailand | Turkey | All |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.$\Delta s$ | -0.33 | -0.08 | 0.12 | 0.11 | -0.31 | 0.03 | -1.48 | 0.01 | -0.37 | 0.03 | -0.10 | -0.52 | 0.07 | 0.20 | -0.41 | -0.30 |
| | (6.19) | (3.34) | (3.53) | (4.51) | (2.25) | (2.83) | (10.32) | (1.16) | (2.71) | (4.73) | (3.80) | (4.15) | (4.55) | (2.93) | (4.16) | (4.71) |
| 2.$i-i^*$ | 0.09 | -0.41 | -2.77 | 1.88 | 6.66 | -2.10 | 3.09 | -0.01 | 1.45 | -5.67 | 2.00 | 2.87 | -0.23 | -2.57 | 5.69 | 1.44 |
| | (0.05) | (2.17) | (2.06) | (2.44) | (2.18) | (0.20) | (7.65) | (0.00) | (4.10) | (0.51) | (3.61) | (4.80) | (2.04) | (2.10) | (0.92) | (4.60) |
| 3.$y-y^*$ | -1.30 | -1.17 | 0.67 | -0.88 | -1.11 | -3.35 | -4.36 | -3.27 | -2.22 | -0.91 | -0.82 | -2.22 | 5.12 | -1.45 | -1.17 | -0.94 |
| | (4.34) | (4.39) | (6.47) | (4.48) | (4.94) | (0.73) | (1.45) | (0.71) | (4.15) | (5.21) | (5.23) | (4.57) | (9.61) | (4.34) | (5.02) | (5.60) |
| 4.$\pi-\pi^*$ | 0.14 | 0.08 | 1.75 | 2.63 | 5.20 | 0.70 | 26.97 | 0.04 | 5.48 | 0.05 | 0.32 | 5.60 | 0.74 | 0.46 | 1.24 | 4.90 |
| | (0.10) | (0.21) | (3.39) | (2.39) | (3.85) | (0.26) | (64.19) | (0.03) | (8.90) | (0.20) | (0.23) | (4.04) | (1.93) | (2.10) | (0.34) | (20.23) |

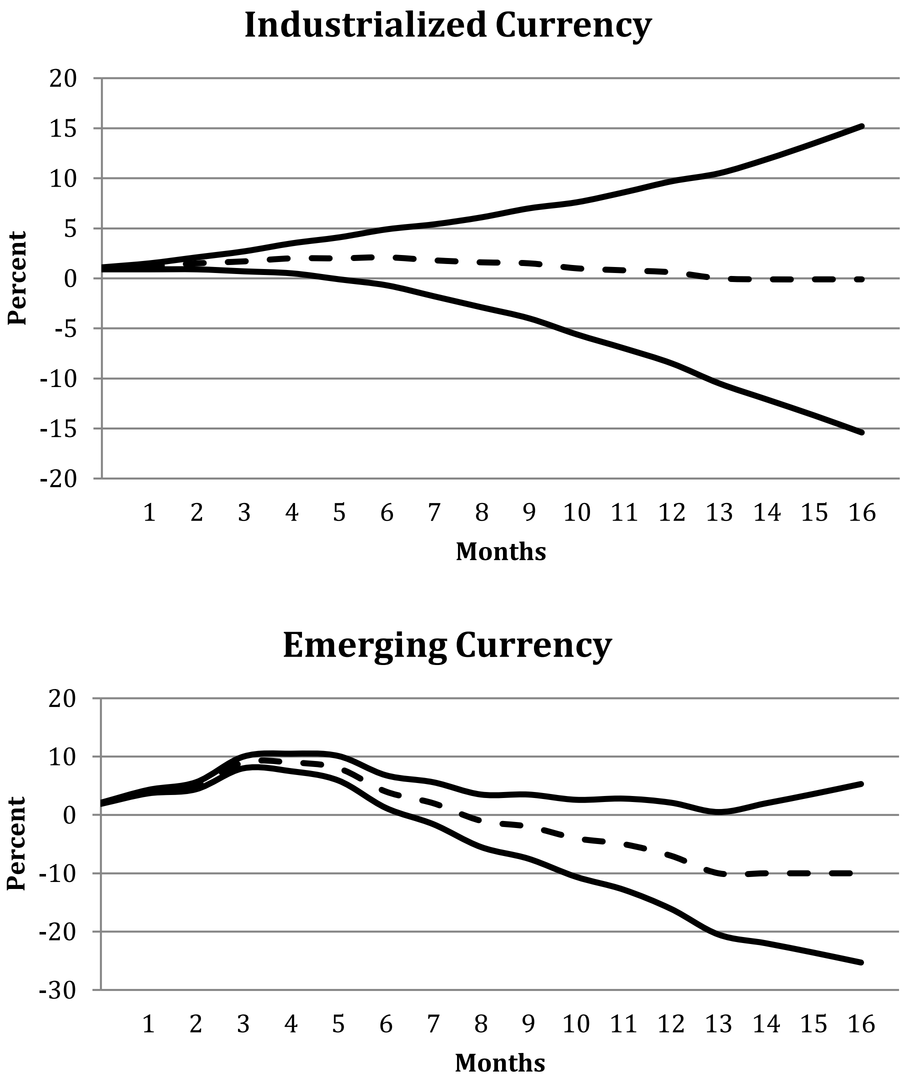


FIGURE 1
Exchange Rate Returns Response to an Unexpected Increase in Carry

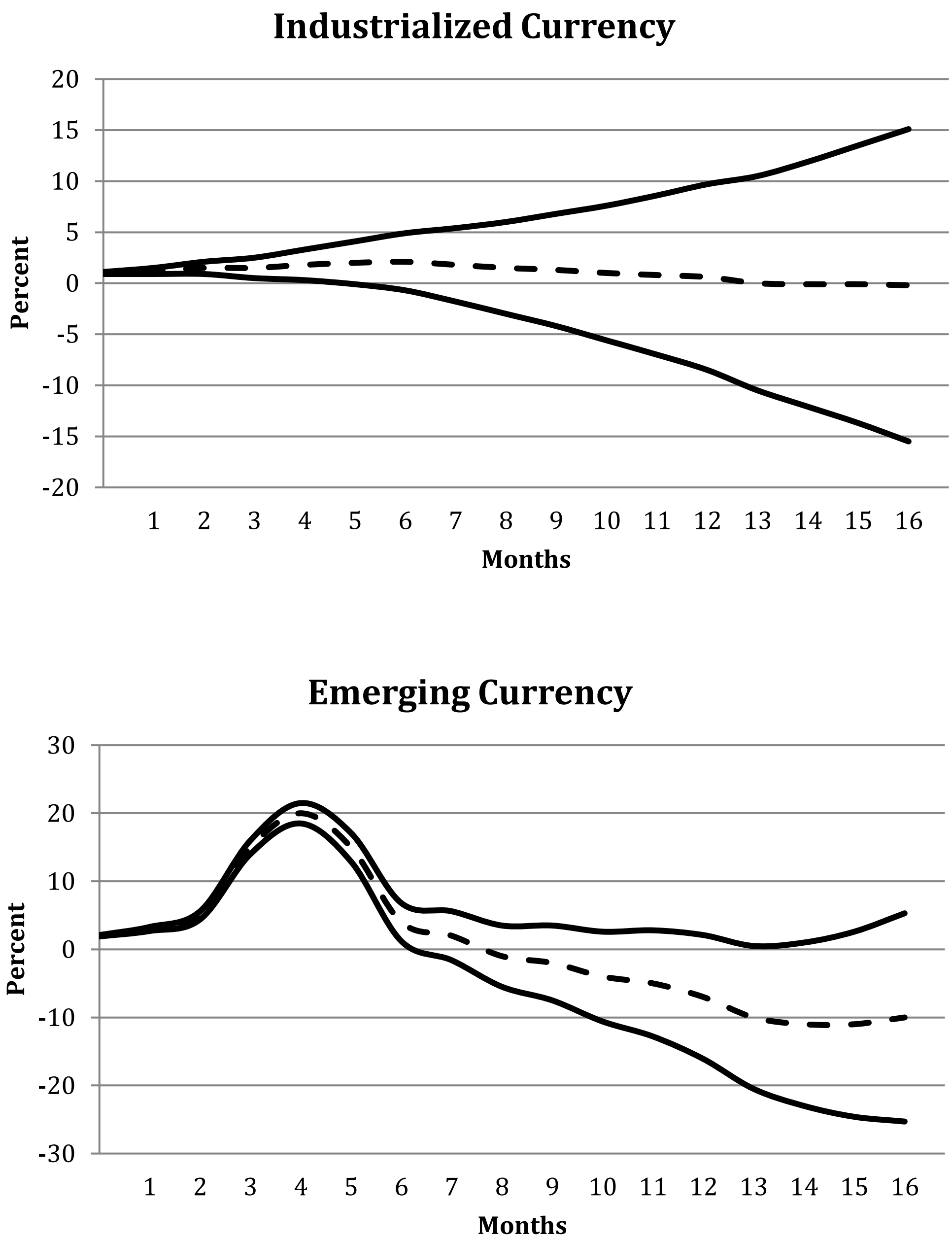


FIGURE 2
Response to Carry Trade Caused by a Unit Shock

## RESULTS FROM THE VAR

### Currency Returns and Carry Trade Relationship: Impulse Responses

First, we explored the currency returns response to carry (trade) shocks. We used the impulse response function from estimates to compute how the exchange rate moves in the following 16 months after a unit shock to carry(trade). Figure 1 shows the exchange rate returns response to an unexpected increase in carry. The upper and lower curves are the 95% confidence intervals of the impulse response. They were estimated using the delete-one jackknife method of Shao and Wu (1989) and Shao (1989). In the emerging currencies, immediately after a positive unit shock to carry (trade), there were strong subsequent appreciations (momentum) over the first 7 months, after that at longer horizons, depreciation (reversal). This pattern lined up with the positive correlations in the shorter horizon and negative ones in the longer horizon between the exchange rate returns and carry (trade), shown in Tables 3 and 4. In industrialized currencies, the appreciation was in much lower rates and depreciation in the long horizon was muted. This was also consistent with the lower correlations between exchange rate returns and carry.

Figure 2 shows the response to carry trade caused by a unit shock. The responses to carry trade shocks were stronger in the first eight months in emerging countries. Reponses in the industrialized currencies were again dampened. The hump-shape movement in exchange rates increased volatility. Momentum and reversal were mostly likely caused by short-term or transitory shocks, which only added noise to the exchange rate movement. We rationally concluded that emerging currencies were more likely subject to transitory shocks in interest rate than persistent shocks, which normally only caused muted movement in exchange rate returns, as mostly the cases in industrialized currencies.

### Variance Discrepancy Test

Using the variance decomposition equation for the exchange rate returns, we were able to test whether the carry (trade) contributes to larger volatility in the emerging currencies. To do so, we denoted $\lambda$, the proportion of volatility caused by carry (trade) caused to the total returns volatility as following

$$\lambda = \frac{\sigma_c^2}{\sigma_s^2} = (1 - a_{11}^2)\frac{\sigma_c^2}{\sigma_c^2 + \sigma_v^2}$$

We tested the null hypothesis that the ratio in industrialized currencies was less that in emerging currencies, i.e. $H_0\colon ln(\lambda_I/\lambda_E) < 0$. Since there was not test statistics available at this moment, we used bootstrapping technique to compute the $p$-value and confidence interval. We bootstrapped the time series data by generating residuals from the original estimation residuals, then computing the time series recursively as

$$z_t^* = Az_{t-1}^* + u_t^*$$

where $u_t^*$ is the re-sampled residual. For every bootstrapping, we computed $\lambda_I$, $\lambda_E$ and $ln(\lambda_I/\lambda_E)$. In Table 7, the proportions of carry (trade) volatility in total returns volatility in emerging currencies were overwhelmingly larger than those in industrialized currencies. The result was consistent with the much higher correlations between returns and carry(trade) in emerging markets. It implied that larger volatility in emerging currencies was caused by carry (trade), not others.

TABLE 7

Exchange Rate and Carry (Interest Rate Differential) Correlations

| Country Group | Carry | Carry Trade |
|---|---|---|
| Industrialized ($\lambda_I$ ) | 0.05 | 0.08 |
| | (0.021) | (0.035) |
| Emerging ($\lambda_E$) | 0.29 | 0.31 |
| | (0.091) | (0.075) |
| Probability that alternative $H_1$ is true, $p$-value | | |
| $H_0 : \ln(\lambda_I/\lambda_E)<0$ | 0.001 | 0.002 |

**Crash Discrepancy Test**

The probability of a currency crash with more than $a$ percentage is defined as $Pr(\Delta s < -a)$. We wanted to test the null hypothesis that the probability in industrialized currencies is less than that in emerging. Ideally, the test should be designed in way that only carry(trade) shocks occur while other macroeconomic variables remain the same. To isolate the effect of other variables, we computed the probability based on the impulse response of returns to carry(trade) shocks:

$$\theta = Pr(\Delta s_k < -a\% | u_c, \text{ and other } u = 0)$$

where $k$ is the months into the future after the shocks. This conditional probability is the probability of a currency crash when the carry(trade) changes, all else unchanged. The null hypothesis is then, $H_0: ln(\theta_I/\theta_E) < 0$.

To perform the test, we again resorted to bootstrapping. We first bootstrapped the carry (trade) shocks $u_c$ from the estimation residual $\hat{u}_c$. The impulse responses of returns to the shocks were then computed in each $k$-month horizon. The probability and its standard errors were then calculated from the large number of impulses responses at each $k$.

Table 8 shows probabilities of crashes at several levels of $a$ for each group of countries. The probability of crashes of currency in emerging markets was higher than that in industrialized countries across all horizons and magnitudes. Table 9 shows the test results of the null hypothesis on crash probability between the two groups of nations. Except for one-month horizon, at 95% or more confidence level, all future responses of exchange rates in emerging markets were having a higher chance of crashes than those in industrialized nations.

TABLE 8

Probability of Currency Crash from Carry (Trade) Shock

| Currency crash> | Months | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Industrialized Countries | | | | | | | | | | | | | |
| 3% | | 0.0100 | 0.0140 | 0.0152 | 0.0161 | 0.0162 | 0.0271 | 0.0289 | 0.0342 | 0.0503 | 0.0516 | 0.0592 | 0.0598 |
| 5% | | 0.0080 | 0.0110 | 0.0149 | 0.0155 | 0.016 | 0.0245 | 0.0266 | 0.0299 | 0.0455 | 0.0488 | 0.0512 | 0.0533 |
| 7% | | 0.0050 | 0.0090 | 0.0112 | 0.0134 | 0.0153 | 0.0171 | 0.0189 | 0.0276 | 0.0395 | 0.0487 | 0.0491 | 0.0499 |
| 9% | | 0.0001 | 0.0001 | 0.0015 | 0.0016 | 0.0016 | 0.0017 | 0.0021 | 0.0023 | 0.0032 | 0.0044 | 0.0059 | 0.0137 |
| Emerging Countries | | | | | | | | | | | | | |
| 3% | | 0.0247 | 0.0287 | 0.0339 | 0.0414 | 0.0490 | 0.0634 | 0.0665 | 0.0922 | 0.1009 | 0.1411 | 0.1750 | 0.1806 |
| 5% | | 0.0163 | 0.0218 | 0.0304 | 0.0356 | 0.0394 | 0.0544 | 0.0577 | 0.0792 | 0.0951 | 0.1219 | 0.1521 | 0.1569 |
| 7% | | 0.0132 | 0.0195 | 0.0274 | 0.0336 | 0.0345 | 0.0362 | 0.0403 | 0.0566 | 0.0852 | 0.1137 | 0.1329 | 0.1379 |
| 9% | | 0.0002 | 0.0003 | 0.0032 | 0.0034 | 0.0034 | 0.0043 | 0.0046 | 0.0067 | 0.0075 | 0.0118 | 0.0151 | 0.0375 |

TABLE 9

Test of Emerging Currencies Crash More than Industrialized Currencies

| Currency crash> | Months | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3% | | 0 | * | ** | ** | *** | *** | *** | *** | *** | *** | *** | *** |
| 5% | | 0 | * | ** | ** | *** | *** | *** | *** | *** | *** | *** | *** |
| 7% | | 0 | * | ** | *** | *** | *** | *** | *** | *** | *** | *** | *** |
| 9% | | 0 | * | ** | ** | *** | *** | *** | *** | *** | *** | *** | *** |

## CONCLUSION

In this paper we documented important facts on the exchange rate volatility for countries with flexible exchange rate regime. Emerging countries, hoping to absorb shocks in their currency with free market exchange rates, had experienced a higher chance of crashes in their monetary currency than their peer advanced countries. International community should learn from such experience to design a currency regime that limits capital mobility, in order to stabilize exchange rate.

This study can be extended to include other financial markets in emerging countries. Although the carry (trade) causes currency crashes, we cannot ignore its effect on the stock market or bond market. In this study, we focus only on the currency market because financial crisis typically starts at currency crisis in emerging countries. Understanding currency crisis is half way through understanding financial crisis in developing countries. A complete study would require understanding the dynamics among various financial markets and macroeconomic fundamentals.

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