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ABSTRACT

We discuss the foreign currency forward premium puzzle in the context of 20 internationally tradable emerging market currencies. We find that since the late 1990s the broad basket of emerging market currencies has provided significant equity-like excess returns against a number of major market currencies, but with low volatility. We also find that the forward premium, or carry, is significant in explaining that excess return but that excess returns would still have existed even in the absence of positive carry. Our calculation shows that transactions cost due to bid/offer spreads is substantially lower than commonly supposed in the academic literature.

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1. Introduction

This paper examines the excess return (the difference between the forward exchange rate and the spot rate at maturity) from taking long positions in 20 internationally tradable EM (emerging market) currencies. We find that since the late 1990s the basket of those EM currencies has provided equity-like excess returns in USD (U.S. Dollars) but with far less volatility and with Sharpe ratios well above unity. This is not just a USD story. The basket has also provided excess returns in EUR (the Euro) and JPY (the Japanese Yen), although with lower Sharpe ratios given the higher volatility of those currencies against EM currencies. By comparison, the excess return available from a basket of major currencies is, while positive, far lower in the mean and the Sharpe ratio. We also find that the forward premium, which equals the interest-rate differential or what is commonly called the *carry* by foreign exchange traders, is significant in predicting the excess return. Additionally, we note that the transactions cost due to bid/offer spreads is much lower than commonly supposed in the academic literature.

Our paper has two broad contributions. First, it contributes to the vast literature on the failure of Uncovered Interest Rate Parity (UIP)[1] by providing corroborating results and some new ones for EM currencies. There are two classes of tests of UIP. One, sometimes called the unconditional test, examines whether the mean excess return is significantly different from zero. The other, the conditional test, has attracted a lot more attention. The test can be performed by regressing the excess return on the carry or, equivalently, by regressing the rate of change of the spot exchange rate on the carry. This latter time-series regression is known as the Fama (1984) regression. The extensive literature reports that, while it survives the unconditional test, UIP fails spectacularly on the latter test, with the carry coefficient in the excess return regression far above the value of zero implied by UIP and often above two (or, equivalently, the carry coefficient in the Fama regression far less than the theoretical value of unity and often negative). This phenomenon is known as the *forward premium puzzle* --- at short time horizons higher yielding currencies tend to appreciate rather than depreciate as implied by UIP.

Those results found in the literature are mostly for major currencies. We find that the results of the unconditional test for EM currencies are very different: for many of the 20 EM currencies the mean excess return in USD is significantly different from zero. We also test for joint significance by asking whether the excess return from a *portfolio* of passive investments in currencies, consisting of equally-weighted long positions in forward contracts, is positive. For an investor seeking exposure to EM currencies as an asset class, this is the most relevant question. As already mentioned, the excess return from this asset class has historically generated an equity-like excess return in the mean.

[1] UIP states that the forward exchange rate is an unbiased predictor of the future spot rate at maturity. See Engel (1997) for an exhaustive survey. Lustig, Roussanov, and Verdelhan (2008) contain a concise survey of very recent empirical studies on UIP.

Our results on the conditional test for EM currencies, too, are different from those for majors. The effect of the carry on the excess return for EM currencies is weak in two respects. First, for each EM currency, the carry coefficient in the excess return regression is small, typically between 0 and 1. Second, and this is what we think is new, we find that the excess return from EM currencies as a whole (as measured by the return from the passive portfolio) is better explained by the carry for *major currencies* than by the EM currency carry. However, the portfolio-based conditional test gives a different picture. That is, for EM currencies, the excess return from an actively-managed portfolio of currencies that takes long positions only in those relatively high-yielding currencies (for which the carry is more positive than others) is substantially higher than that from the passive portfolio (which itself is comparable to U.S. equity excess returns in the mean) with a Sharpe ratio that is well above unity. We argue that one way to possibly reconcile these apparently conflicting results about the effect of the carry for EM currencies is to assume that the excess returns from individual currencies share a common factor related to the world real interest rate.

Very recently, several papers have examined EM currencies. Frankel and Poonawala (2006) confirm an earlier result in Bansal and Darlquist (2000) that the carry coefficient in the Fama regression is (still less than unity but) above zero for EM currencies. Burnside, Eichenbaum, and Rebelo (2007) show that high Sharpe ratios for the excess return can be obtained from carry-based, actively-managed portfolios of a large number of currencies. de Zwart, Markwat, Swinkels, and van Dijk (2008) report that various active strategies including the carry-based and chartist strategies generate Sharpe ratios above unity for EM currencies but not for currencies of developed countries. The exchange rates data used by these studies are quotes assembled by Reuters and disseminated by *Datastream*.[2] Besides providing the new evidence discussed above, our contribution relative to these studies is that we use a propriety dataset, which we deem is more reliable, covering longer time periods for EM currencies. We also examine passive portfolios which, curiously, these studies ignored.

The second broad contribution of our paper lies in its careful calculation of the excess return. To calculate the excess return, which is the difference between the forward rate and the spot rate at maturity, one needs to take into account the lag (zero, one, or two days depending on the currency) between the date when the spot rate is observed and the settlement date. Perhaps surprisingly, compared to the usual practice of matching the 1-month forward rate observed at the end of the month with the spot rate at the end of the following month, aligning dates correctly makes some difference especially for EM currencies (the mean absolute value difference in the excess return is 46 basis points if averaged over the EM

[2] Except possibly for Bansal and Darlquist (2000), which merely indicates that the data were obtained from *Datastream*. The Burnside *et. al.* study uses the WM/Reuters data available from *Datastream*. The de Zwart *et. al.* study states that their exchange rates correspond to Reuters 7am GMT mid rate fixings.

currencies). We explain, in an appendix, how to identify the observation date for the spot contract so that the forward rate and spot rate that go into the excess return calculation have the same settlement date. The alignment issue also has an implication for the date for observing the carry as a signal in implementing the active carry-based strategy. A casual choice of the signal observation date, such as equating the date with the observation date used for the excess return calculation, leads to an overstatement of the return from the strategy by several tens of basis points per annum.

We have also been careful when incorporating transactions costs due to bid/offer spreads in our excess return calculations. For a forward contract of, say, 1 month, a number of previous academic studies we are aware of assume that the investor opens a forward position and then closes or unwinds it one month later and repeats this operation during the investment period.[3] The transactions cost calculated this way is large: more than 100 basis points per annum for developed countries (see, e.g., Table 1 of Lustig, Roussanov, and Verdelhan (2008)) and large enough to turn a positive Sharpe ratio negative for EM currencies (see Burnside, Eichenbaum, and Rebelo (2007)). But in practice it is far cheaper to maintain, or "roll", the position, via foreign exchange swaps. Our calculation indicates that even for EM currencies the annual transactions cost due to bid/offer spreads has historically been well below 100 basis points, perhaps just several tens of basis points, per annum.[4] We extend this currency-by-currency calculation to encompass passively or actively managed portfolios in which the allocation of positions between currencies needs to be adjusted monthly by newly opening a position of a suitable size, unwinding another, and rolling the rest of the existing positions. The calculation, detailed in an appendix, indicates that even for actively-managed portfolios of EM currencies, the transactions costs would likely have historically been less than 100 basis points per annum.

The plan of the paper is as follows. By way of establishing our notation, Section 2 restates UIP and describes the two classes of tests (unconditional and conditional) of UIP. Section 3 describes the dataset and explains our method for calculating the excess return that takes into account the data alignment issue mentioned above and also bid/offer spreads. Section 4 reports our results of the unconditional tests for individual currencies and for passive portfolios. Our results of the conditional

[3] An exception is Burnside, Eichenbaum, Kleshchelski, and Rebelo (2008) who note that maintaining a long position in a forward contract is equivalent to investing in the underlying asset (a foreign short term bond) on an uncovered basis and paying bid/offer spreads upon entry and exit. However, they do not provide an explicit calculation of transactions costs from this investment strategy. Furthermore, unlike maintaining a forward position, this strategy involves credit risk on the full notional amount which may be important for EM currencies.

[4] Our estimate of the transactions cost, assuming that the bid/offer spreads available from the WM-Reuters data are representative, is about 30 basis points per annum for the EM currencies and less than 10 for majors. As the global financial system crisis has deepened during the fall of 2008, bid/offer spreads have widened dramatically, doubling our estimate of the transactions cost for EM currencies and tripling that for majors. It remains too early to make definitive statements on whether or not spreads will return to the average levels seen during recent years.

tests, one in the form of the excess return regression and the other in terms of actively-managed portfolios, are in Section 5. Section 6 briefly summarizes our main results.

2. Tests of UIP (Uncovered Interest Rate Parity)

A. Notation and Statement of UIP

By way of establishing the notation, we start with a restatement of UIP (Uncovered Interest-rate Parity). We express the exchange rates in units of the domestic currency (USD (the U.S. dollar) for the most part of our paper) per unit of the foreign currency in question.[5] So let S_t be the USD price of a unit of the foreign currency in question at the end of month *t*, and F_t be the associated 1-month forward rate for delivery in the next month. UIP can be stated as

$$\text{UIP: } \mathrm{E}_t(S_{t+1}) = F_t, \quad (1)$$

where E_t is the conditional expectations operator conditional on information available at time *t*. We define the *excess return* from a long position in the forward contract at time t, ER_{t+1}, as[6]

$$ER_{t+1} \equiv \frac{S_{t+1} - F_t}{F_t} = \frac{S_{t+1}}{F_t} - 1. \quad (2)$$

This is the return when the investor longs the currency and shorts USD. The return is an excess return because it accrues to an investment strategy that requires zero cost. Since F_t is known at time *t*, UIP can be stated equivalently as:

$$\text{UIP restated: } \mathrm{E}_t(ER_{t+1}) = 0. \quad (3)$$

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[5] Exchange rates for most currencies against USD are usually quoted in foreign currency units per USD (e.g., 108 Yen to the U.S. dollar). Our notation, which instead refers to 1 Yen being 1/108 USD, does not follow this convention because the exposition of UIP in terms of the excess return (to be defined in a moment) is more transparent when the exchange rate is stated as a price in USD. See, e.g., Burnside *et. al.* (2008, Section 2) for a statement of UIP using the notation the same as ours. However, later on when we report some calculations to incorporate bid/offer spreads, the formulas for calculations (to be displayed in Appendix 2.1) will adhere to the usual convention of stating the exchange rate in foreign currency units.

[6] More often, researchers state UIP and the excess return in terms of logs: $\mathrm{E}_t(\log(S_{t+1})) = \log(F_t)$ and $ER_{t+1} \equiv \log(S_{t+1}) - \log(F_t)$. Because the log difference approximately equals the percentage difference (i.e., $\log(x) - \log(y) \approx \frac{x-y}{y}$), all the results to be reported in the paper are virtually identical with the log version. We chose to use the non-log version because the exact expression for the excess return that the investor receives is (2) in the text, not the log difference.

The left hand side of this equation is the *(conditional) risk premium*. So UIP states that the risk premium is zero for all dates. As is well known, if the time t information includes past excess returns (ER_S for $s \leq t$), the excess return series should exhibit no serial correlation under UIP.

We define the *forward premium* to be the percentage difference between the spot and forward rates. Under CIP (covered interest rate parity), the forward premium equals what is called the carry, which is the interest rate differential between the two currencies (the interest rate in the foreign currency minus the domestic currency (USD) interest rate). In this paper we use the term "forward premium" and "carry" interchangeably. Thus,

$$carry_t \equiv \frac{S_t - F_t}{F_t} = \frac{S_t}{F_t} - 1. \quad (4)$$

From the definition of the excess return and the carry, it follows that[7]

$$1 + ER_{t+1} = \frac{S_{t+1}}{F_t} = \frac{S_{t+1}}{S_t}\frac{S_t}{F_t} \quad \text{or} \quad ER_{t+1} \approx \frac{S_{t+1} - S_t}{S_t} + carry_t, \quad (5)$$

That is, the excess return can be decomposed into the spot return and the carry.

We note two points here. First, by CIP, the excess return equals the return from a *carry trade* in which the investor borrows at the dollar short-term interest rate, invests the borrowed amount in the foreign currency, and then converts the return and the principal into USD, thus bearing the foreign exchange risk.[8] Second, even when the currency is pegged to USD (so the USD spot return is zero), the excess return may not be zero because the carry may not necessarily be zero. For example, if market participants anticipate an imminent devaluation (as occurred to Argentine Peso in weeks leading up to the eventual devaluation in Jaunary 2002), the carry (and hence the excess return prior to devaluation) is positive.

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[7] The derivation of (5) is as follows. $1 + ER_{t+1} = \left(1 + \frac{S_{t+1} - S_t}{S_t}\right)\left(1 + \frac{S_t - F_t}{F_t}\right)$. The right hand side is approximately equal to $1 + \frac{S_{t+1} - S_t}{S_t} + \frac{S_t - F_t}{F_t}$ if the second-order term $\left(\frac{S_{t+1} - S_t}{S_t}\right)\left(\frac{S_t - F_t}{F_t}\right)$ is ignored. If the excess return is defined as the log difference as in the previous footnote and if we define the carry as $carry_t \equiv \log(S_t) - \log(F_t)$, then the decomposition (5) becomes exact: $\log(S_{t+1}) - \log(F_t) = [\log(S_{t+1}) - \log(S_t)] + [\log(S_t) - \log(F_t)]$.

[8] The return from the carry trade is $(1 + r^*_{t+1})S_{t+1} / S_t - (1 + r_{t+1})$, where r^*_{t+1} is the foreign currency interest rate from date t to $t+1$ and r_{t+1} is the USD interest rate. CIP states that $S_t / F_t = (1 + r^*_{t+1})/(1 + r_{t+1})$. Eliminating S_t from these two equations, we obtain $(1 + r^*_{t+1})S_{t+1} / S_t - (1 + r_{t+1}) = (1 + r_{t+1})(S_{t+1} / F_t - 1)$. So the carry-trade return is proportional to the excess return defined in equation (2) of the text.

B. Tests of UIP

The null hypothesis in the *unconditional test* of UIP is

$$\text{the null in the unconditional test: } \mathrm{E}(ER_{t+1}) = 0\,, \quad (6)$$

which is implied by UIP by taking the unconditional expectation of both sides of (3). We will test the null hypothesis in two ways. First, we will conduct the usual *t* test for each currency. Second, to test for the risk premium for a group of currencies, we will examine the *index excess return*, defined as the excess return from a *portfolio* of currencies that is passively managed.

The *conditional test* examines whether the excess return from *t* to *t*+1 can be predicted by some variable whose value is known at time *t*. The variable most likely to be informative about the future excess return is the carry. Consider the excess-return regression

$$ER_{t+1} = \alpha + \gamma \cdot carry_t + u_t\,. \quad (7)$$

Under UIP, both α and γ are zero. As is well known (see, e.g., Hayashi (2000, Chapter 6)), UIP implies that those conditions under which the OLS (ordinary least squares) estimator is consistent (except the one requiring that the variables be ergodic stationary, which we assume here) are satisfied. We will also conduct a portfolio-based test of the predictive ability of the carry by examining the return from a portfolio that is actively managed based on the carry as the signal.

C. Relation to the Fama Regression

The more popular, and nearly equivalent, form of the conditional test in the literature is the "Fama regression" in Fama (1984):

$$\log(S_{t+1}) - \log(S_t) = \alpha + \beta \cdot (\log(F_t) - \log(S_t)) + u_t\,. \quad (8)$$

Since under UIP the forward premium is an optimal predictor (in the sense of minimizing the mean squared error) of the actual rate of change of the spot rate, we have $\alpha = 0$ and $\beta = 1$. The well-known *forward premium puzzle* is that the OLS estimate of β is far less than unity, often negative and more like -1 than 0.[9] Since $ER_{t+1} \equiv \dfrac{S_{t+1} - F_t}{F_t} \approx \log(S_{t+1}) - \log(F_t)$ and $carry_t \equiv \dfrac{S_t - F_t}{F_t} \approx \log(S_t) - \log(F_t)$, the excess-return regression (7) can be written approximately as

$$\log(S_{t+1}) - \log(F_t) \approx \alpha + \gamma \cdot (\log(S_t) - \log(F_t)) + u_t\,. \quad (9)$$

Subtracting $\log(S_t) - \log(F_t)$ from both sides of this equation, we obtain

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[9] Froot and Thaler (1990) carried out a survey of 75 such studies, finding that the carry coefficient was on average -0.9.

$$\log(S_{t+1}) - \log(S_t) \approx \alpha + (1-\gamma)\cdot(\log(F_t) - \log(S_t)) + u_t, \quad (10)$$

which is the Fama regression. That is, the α in the Fama regression is approximately equal to the α in the excess-return regression, and

$$\gamma \approx 1 - \beta. \quad (11)$$

Therefore, the forward premium puzzle in terms of the excess-return regression is that the OLS estimate of the carry coefficient γ is greater than unity, often above 2.

3. The Data

A. The Baskets of Currencies

We obtained daily data on over-the-counter spot and forward rates against USD (the U. S. dollar) as the base currency for 20 EM (emerging market) currencies and 9 major currencies. The 20 EM currencies (to be referred to as "EM20"), listed in Table 1A, are: ARS (Argentine Peso), BRL (Brazilian Real), CLP (Chilean Peso), CNY (Chinese Yuan), COP (Colombian Peso), CZK (Czech Koruna), HUF (Hungarian Forint), IDR (Indonesian Rupiah), ILS (Israeli Shekel), INR (Indian Rupee), KRW (Korean Won), MXN (Mexican Peso), PHP (Philippine Peso), PLN (Polish Zloty), RUB (Russian Ruble), SKK (Slovak Koruna), THB (Thai Baht), TRY (Turkish Lira), TWD (Taiwan Dollar), and ZAR (South African Rand). The 9 major currencies (to be referred to as "G9"), listed in Table 1B, are: AUD (Australian Dollar), CAD (Canadian Dollar), JPY (Japanese Yen), NZD (New Zealand Dollar) , NOK (Norwegian Krona), SEK (Swedish Krona) , CHF (Swiss Franc) , GBP (British Pound), and EUR (Euro). We will also use data on three EUR legacy currencies, DEM (Deutsche Mark), FRF (French Franc), and ITL (Italian Lira), that the Euro replaced.

The main criteria for choosing EM currencies for our study are the following. The first is existence of sufficient historical data on spot and forward rates, reflecting what could potentially have been traded by international counterparties. The second is liquidity. The assessment of this criterion is by necessity somewhat subjective, but the above set of currencies (plus exceptions noted below) approximates, but is not identical to, those identified by the BIS Triennial Survey as having the highest daily turnover. Third, some currencies that are occasionally classed as emerging market currencies have been deliberately excluded. The most notable are the Singapore Dollar and the Hong Kong Dollar. In both cases high per capita incomes and levels of development suggest they cannot comfortably be classified as emerging market currencies. Fourth, we excluded those currencies that were sustainably pegged to a major currency over the entire sample period of from the late 1990s to 2008. Perhaps the most prominent in this category is the Saudi Arabian Riyal.

ARS (Argentine Peso) and CNY (Chinese Yuan), two of our 20 EM currencies, were pegged to USD for only part of the sample period. ARS was pegged to the USD until January 4, 2002. For CNY, the authorities intervened to maintain the spot rate within a very narrow range until July 20, 2005. We will include those periods with (near) constant exchange rates in our excess return calculation because the excess return, which equals the carry (i.e., the forward premium) when the spot rate is constant (see (5)), fluctuated in anticipation of potential future moves in the spot rate.

B. Data Source

The dataset for EM20 was prepared by AIG-FP (AIG Financial Products International, Incorporated) using its own proprietary database. For some emerging market currencies, the series on the spot and forward rates start as early as May 1996. Where gaps or deficiencies existed, a combination of additional sources was used with the aim of preparing a dataset that represented prices that were tradable by international or offshore market participants. As a result, where significant capital controls or other restrictions exist in a particular country, rates observed in non-deliverable forward (NDF) markets have been used.[10] AIG-FP has used this proprietary data to construct a family of investible emerging market indexes (called the AIG-EMFXI^{SM} family) in a way similar to --- but not identical to --- our EM20 index to be explained later in Section 4B. We have taken some comfort in the knowledge that the series derived from the underlying spot and forward observations in the AIG-FP dataset correspond closely to those derived independently by JP Morgan in its short-dated local currency emerging market index (the ELMI+ index). We have not attempted to access the underlying spot and forward rate data used by JP Morgan.

We also examined the data compiled by WM/Reuters and by Barclays Bank, both publicly available from *Datastream*. WM/Reuters spot rates, covering a large number of currencies including EM20 and G9, are widely used by fund managers, custodians and index compilers.[11] In more recent years they have compiled intraday spot rates and also forward rates. Their forward rate series start from December 31, 1996, for some currencies and later (from 2004) for most others. For EM20, comparing AIG-FP with WM/Reuters (as available via *Datastream*), we judge that the former is a superior data source, because for most EM currencies the series starts earlier in AIG-FP (with all the six East Asian currencies starting earlier than the East Asian currency crisis of mid 1997 to January 1998)[12] and because WM/Reuters (as available via *Datastream*) contains a couple of currencies (IDR and TRY), for which

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[10] As at June 2008 data on eleven of the 20 EM currencies comes from the NDF market which is cash settled. They are: KRW, IDR, PHP, CNY, TWD, INR, BRL, CLP, COP, ARS and RUB. International market participants actively trade RUB in both non-deliverable and deliverable markets.

[11] For details, see a WM/Reuters document entitled *Spot & Forward Rates Guide* available from the web.

[12] For example for KRW, the daily forward rate data are available from November 29, 1996 in AIG-FP and from February 11, 2002 in WM/Reuters.

there were significant missing or repeated observations. As shown in Appendix Table 1, however, both data sources when available provide similar numbers. On the other hand, AIG-FP provides only mid rates (the arithmetic average of bid and offer rates) while WM/Reuters has both bid and offer rates. This is not a problem for the AIG-FP data because for the most part our excess return calculation uses mid rates (for a good reason to be mentioned shortly). The Barclays Bank data, whose forward rate series cover longer time periods, include only a very small subset of EM20. For these reasons, we decided not to use those publicly available datasets for EM20.

For G9, our data source is the G9 component of the WM/Reuters data. The G9 component of the Barclays Bank series start as early as October 1983 for some currencies, but the data seem far less reliable than WM/Reuters. For example, for JPY, the carry (forward premium) at the end of June 1998 implied by the spot and 1-month forward rate is 2.26% (or 27.1% per annum) and for NOK, there are repeated observations of forward rates for late August 1998. We did not attempt to ascertain whether this was simply a problem with the data downloaded to *Datastream* or with the underlying dataset.

C. Calculation of Excess Returns

There are two practical issues related to the calculation of the excess return from daily data that seem to have been ignored in most previous academic studies. The first is about a date alignment needed to take account of the lag, which exists even for spot contracts, between the observation date (the date when the contract is traded and the exchange rate is observed) and the settlement date.[13] As we will note later, a one or two day difference can make a difference to average excess returns for EM currencies. The second issue is treatment of transactions costs in the form of bid/offer spreads. To calculate the average excess return over an extended period of time, many of the previous studies assume that the investor opens the foreign exchange position and then unwinds it every month, thus paying the bid/offer spread on the forward outright repeatedly. In practice, it is customary to maintain (or "roll") the position much more cheaply by the use of foreign exchange swaps. For this reason, when the investment period is long enough, the excess return we calculate using mid rates (and thus ignoring transactions costs bid/offer spreads) is a better approximation to the excess return that the investor in the real world could enjoy, provided that the mean excess return is large relative to the roll cost. These two issues are discussed in detail in Appendixes 1 and 2. Here in the text we provide a summary focusing on the case of 1-month forward over-the-counter transactions.

C.1. Date Alignment

[13] The lag is zero or one business day for TRY, one business day for CAD, PHP, and RUB and two business days for other currencies.

We define the 1-month excess return to be the return on 1-month forward contracts whose settlement date is the end (the last business day) of the month. This means that both the forward rate F_t and the corresponding spot rate S_{t+1} that go into the excess return formula (2) are for the same settlement date of the last business day of month *t*+1, and we need to identify the observation date for F_t in month *t* and the observation date for S_{t+1} in month $t+1$. For example for JPY, the 1-month forward rate for settlement on Monday, June 30, 2008 is observed on Wednesday, May 28, 2008, to be about 104.6 yen to the dollar. The spot rate for the June 30 settlement is observed on Thursday, June 26 and is 107.2 yen to the dollar. The USD excess return on JPY 1-month forwards from May to June 2008 is calculated as (1/107.2 – 1/104.6)/(1/104.6). The monthly return series thus calculated is non-overlapping in that the observation date for S_t needed to calculate ER_t (the excess return from month *t*-1 to *t*) is also the observation date for the 1-month forward rate F_t for settlement on the last business day of month $t+1$.

An obvious alternative in defining the monthly excess return is take the F_t in (2) to be the forward rate observed at the end of month *t* (the last business day of the month) and the S_{t+1} to be the spot rate observed at the end of month *t*+1. The problem is the discrepancy in the settlement date. For example for JPY, the settlement date for the 1-month forward contract traded on Friday, May 30, 2008 is Thursday, July 3, while the settlement day for the spot contract traded on June 30 is July 2. Our calculation shows that the difference in the settlement day makes some difference for the mean excess return and that the discrepancy in the settlement day between the spot and forward contracts raises the volatility of the excess return for high volatility currencies.[14] This example also shows that the same problem arises in a magnified way if the last Friday of each month is sampled. The last Friday of June 2008 is June 27, which is four business days prior to the settlement date of July 3.

C.2. Transactions Costs

Consider an investor who, instead of opening a new position and unwinding the old one every month, opens a long position via a 1-month forward outright contract in month 0, maintains the position for n successive months via foreign exchange swaps, and then unwinds in month n. Relative to the excess

[14] This problem makes fairly big differences for high volatility currencies. The mean of the absolute value of the difference in the excess return per annum between the values calculated by our procedure (shown in Table 1) and those calculated from end-of-month record is about 46 basis points if averaged over EM20. The absolute-value difference is 306 basis points for IDR and 190 for ARS. For G9, the average absolute-value difference is about 32 basis points. These numbers are substantially smaller for G9 if the third quarter of 2008 is not included (the EM20 average is about 46 basis points and the G9 average is 9 if the sample ends in June 2008). For the annualized volatility, the mean absolute value difference is 84 basis points for EM20 (the maximum is 815 basis points for IDR) and 25 basis points for G9.

return without transactions costs calculated from mid rates throughout, the investor pays the difference between the bid and mid rates (which equals half times the bid/offer spread) when opening the position in month 0, the difference between the offer and mid rates when unwinding the position in month n, and a monthly "roll cost" in between. The roll cost is the difference between the bid and mid of the foreign exchange forward points of foreign exchange swaps. This will be less than the difference between the bid and mid of the forward outright rate.

To be more succinct, *in this paragraph*, we temporarily adopt the convention of stating the exchange rate in units of the foreign currency per domestic currency (USD). Let S_t be the spot mid rate at the end of month t (e.g., 108 JPY = 1 USD), F_t the (outright) forward mid rate, and F_t^b the forward bid rate. We have $F_t > F_t^b$. Appendix 2.1 shows that the forward rate applicable when the position is being rolled, denoted $\tilde{F}_t$, is given by (A2.3). The low roll cost means that $\tilde{F}_t$ is much closer to the mid rate F_t than to the bid rate F_t^b. The cumulative gross (i.e., 1 plus) excess return from continuous exposure to the currency between dates 0 and n, derived in Appendix 2.1 as (A2.3), is

$$\frac{F_0^b}{S_1}\times\frac{\tilde{F}_1}{S_2}\times\cdots\times\frac{\tilde{F}_{n-2}}{S_{n-1}}\times\frac{\tilde{F}_{n-1}}{S_n^o}, \qquad (12)$$

where S_t^o is the spot offer rate for USD.[15]

It is then easy to see that the transactions cost per annum, defined as the difference in the mean excess return per annum over n successive months with and without bid/offer spreads, is approximately equal to

$$12\times\left[\frac{1}{n}\left(\frac{\text{forward bid/offer spread } + \text{ spot bid/offer spread}}{2}\right)\right]+12\times\bar{x}, \quad \text{where}$$

$$\bar{x}\equiv\frac{1}{n-1}\sum_{t=1}^{n-1}x_t, \quad x_t\equiv\frac{\text{forward bid/offer spread } - \text{ spot bid/offer spread}}{2} \quad \text{in month } t, \qquad (13)$$

where the bid/offer spread is relative to the mid rate. (The exact expression for the transactions cost is (A2.6).) The variable x_t is the roll cost that has to be incurred every month. The expression in the

[15] If the NDF (non-deliverable forward) market is used, the applicable spot rate when unwinding is not the offer spot rate but the mid rate. So for NDFs (those currencies whose exchange rate data are taken from the NDF market) mentioned in footnote 10, the offer spot rate S_n^o should be replaced by the mid rate S_n, and the term labeled "spot bid/offer spread" in (13) below should be set to zero.

brackets is the entry and exit costs. It is divided by n because the investor incurs these costs only once. Obviously, if n is sufficiently large, the spot bid/offer spreads are insignificant and the annual transactions cost is about $12\bar{x}$ (the annualized average roll cost).

How big are those components of the transactions cost? Appendix Table 2 has the spot and forward bid/offer spread and the annualized roll cost calculated from the WM/Reuters data. Judged from the WM/Reuters data and also the Barclays Bank data, the bid/offer spreads for spot and forward contracts have been declining slowly but steadily over recent several years, until the onset in 2007 of the global financial crisis. The table shows averages only since March 2004, because (as can be surmised from Appendix Table 1) the coverage of EM currencies by WM/Reuters becomes comprehensible only since then. The table shows that transactions costs are far higher for EM currencies, and within EM currencies there is a great deal of heterogeneity. Nevertheless, if we focus on averages, the annualized roll cost --- excluding the entry and exit costs --- was about 30 basis points per annum during the four and half year period to September 2008. For G9, it was almost negligible, about 5 basis points. However, as the global financial crisis deepened during September and October 2008, the number of active market participants and the willingness of those participants to transact with one another declined. As a result bid/offer spreads widened and roll costs increased. Appendix Figure graphs daily values of the annualized roll cost for EM20 and G9. In September and early October 2008, the roll cost more than doubled for EM20 and more than quadrupled for G9.

If (as most previous academic studies assume) the investor repeats the operation of opening a new position and unwinding the old one, the annualized transactions cost does not depend on the length of the investment period and is approximately equal to

$$12\times\left(\frac{\text{forward bid/offer spread} + \text{spot bid/offer spread}}{2}\right). \qquad (14)$$

If the averages shown in Appendix Table 2 are to be used, the approximate annualized transaction cost equals about 160 basis points for EM20 and about 60 basis points for G9.

We hasten to add, though, that these historical transactions cost estimates should be viewed as providing only indicative orders of magnitude for the marginal cost faced by entities that have direct access to the over-the-counter interbank foreign exchange market. In practice there are several reasons why the actual costs faced by a market participant might be different from these estimates, although we expect that on average the differences between the costs we derive from WM/Reuters data and the costs actually faced by a market participant would be relatively small. First, the reported bid/offer spreads might not be accessible for a specific market participant. This can occur for instance when a market participant does not have available credit lines or a dealing relationship with the bank making the quote to a broker (or WM/Reuters) --- something that is likely to be more of an issue for emerging market currencies where the bank making the quote might be located in one of the EM countries. Second, even if prices are accessible they may only be accessible in relatively small volumes --- again a factor that is likely to be more relevant for EM than the major markets. (This is likely to be less of a problem when rolling positions than with spot transactions, though.) Third, market participants may not necessarily face the full bid/offer. Fourth, bid/offer costs will vary with market liquidity and the time of the day. For instance the bid/offer spread will be wider on Latin American currencies in Asian hours or in European hours prior to the opening of the US markets. Our conversation with foreign exchange traders leads us to suspect that the roll costs calculated from the WM/Reuters data (shown in Appendix Table 2) have historically appeared too low for some currencies, e.g., IDR, COP, ARS, INR, PHP and CLP and too high for others e.g., TRY, KRW, HUF and ILS.

4. Unconditional Tests of UIP

A. Simple Statistics of the Excess Return, the Carry, and the Spot Return

Having shown that the transactions cost due to bid/offer spreads is much smaller than commonly assumed in the academic literature, we present our calculations using mid rates. Simple statistics for non-overlapping monthly excess return are reported in Table 1 along with those for the carry (i.e., the forward premium) and the spot return. Panel A of the table has EM20 (the 20 emerging market currencies) ordered by the time of data availability. Panel B has G9 (the 9 majors). The following are noteworthy.[16]

- For EM20, as indicated by its *t*-value, the mean excess return is significantly different from zero at the 5% level for half the currencies. In sharp contrast, *no* G9 currency exhibits a mean excess return that is significant, even at 10%.[17] That is, the null hypothesis (6) can be rejected for a number of EM currencies but not for majors.

- The volatility of the excess return for EM20, ranging from 1% for CNY to nearly 40% for IDR, is on average *not* much higher than that for G9.

[16] The mean excess returns and the volatilities reported in de Zwart *et. al.* (2008) are similar, although the sample periods are somewhat different. It is not possible to judge from their tables whether the mean excess return is significantly different from zero or not.

[17] This *t*-value is based on the standard error that is conventionally calculated ignoring serial correlation. As can be surmised from the low serial correlation coefficients, incorporating serial correlation doesn't change the standard error substantially. The *t*-values that incorporate serial correlation for monthly non-overlapping series (as well as for weekly and daily overlapping series) are reported in Appendix Table 5.

- Consistent with UIP, there is no strong evidence for serial correlation, both for EM20 and G9.[18]
- The average cross-currency correlation shows that the excess returns are correlated less among EM20 than among G9.
- Turning to the carry, except for CNY and TWD, it has on average been positive and generally much higher for EM20 than for G9. The range of variation, too, is far wider for EM20 than for G9.
- Looking across currencies, we note that the mean excess return is positively associated with the mean carry (a point we come back to in the next section). Volatility has no clear association with the mean excess return.

These points about EM currencies emerge more strongly if the sample period excludes the 1997 East Asian crisis (as seen in Appendix Table 3). They hold true if the 3-month forward rate is used to calculate the excess return, as shown in Appendix Table 4. Ditto when the sampling interval is finer: in Appendix Table 5, we calculate the excess return using the 1-month forward rate, but the sampling interval is either daily or weekly. Again, the conclusion --- that the premium for USD investors is significantly different from zero for EM20 but not for G9 (majors) --- remains true.

B. The Unconditional Test on Passive Portfolios

It is of interest to see if the risk premium is positive for EM20 as a whole. We could calculate the *t*-value for a pooled sample of the 20 currencies. However, to investors seeking exposure to emerging market currencies as an asset class, a far more interesting way to test for joint significance is to look at the return from a *portfolio* of those currencies. For this purpose, we created excess return indexes, one for EM20 and the other for majors. The index takes a long position in an equally-weighted basket of 1-month forward contracts versus USD. The trading rule used to form the portfolio is therefore *passive*. At the end of each month, the portfolio is rebalanced. To be more precise, let $Y_t^{(i)}$ be the index value at the end of month *t*, with $i = 1$ for EM20 and $i = 2$ for G9. Then calculate the index values as a cumulative excess returns by the formula

$$\frac{Y_{t+1}^{(i)} - Y_t^{(i)}}{Y_t^{(i)}} = \frac{1}{\# B(i,t)} \sum_{j \in B(i,t)} ER_{j,t+1}\,, \quad i = 1 \text{ for EM20 and } i = 2 \text{ for G9}, \quad (15)$$

[18] The high first-order serial correlation coefficient of 0.31 for KRW drops to 0.05 if the sample excludes the East Asian crisis and starts in June1998 (see Appendix Table 3). CNY shows a significant positive serial correlation because, with the spot rate moving very slowly, the excess return is mostly the carry. The negative serial correlation for ARS is partly due to large swings in the spot rate during months after the peg was terminated. For INR and RUB, the serial correlation coefficient is smaller if the third quarter of 2008 is not included in the sample: 0.19** for INR and 0.14 for RUB.

where $ER_{j,t+1}$ is the USD excess return from time t to $t+1$ for currency j, $B(i,t)$ is the basket of constituent currencies for which data on $ER_{j,t+1}$ are available, and $\#B(i,t)$ is the cardinality (the number of constituent currencies) of $B(i,t)$.

The basket $B(i,t)$ for EM20 can be read off from Table 1A for each month *t*. We have, for example,

B(EM20, June 96) = {TWD, THB, ZAR, TRY},

B(EM20, January 97) = {TWD, THB, ZAR, TRY, PHP, KRW, CNY, IDR},

B(EM20, May 97) = {TWD, THB, ZAR, TRY, PHP, KRW, CNY, IDR, PLN, CZK, CLP, MXN},

B(EM20, June 98) = {20 EM currencies except ILS and RUB}.

Therefore, during the East Asian currency crisis of the second half of 1997, there were twelve constituent currencies in the EM basket and as many as half of them were East Asian currencies. As a result the basket is not as diversified as for later periods and so may not be as reflective of emerging market foreign exchange as an asset class. Indeed, it would be reasonable to assume that given that the basket includes a high exposure to currencies that were directly affected by the crisis it might be a negatively biased sample. It also goes almost without saying that there will have been severe liquidity constraints during the crisis itself, again with a potential impact on the quality of the data.

For G9, for the pre-Euro period, we use DEM, FRF, and ITL as the legacy currencies that EUR replaced, so the "G9" actually consists of eleven currencies before the introduction of the Euro:

B(G9, *t*) = {AUD, CAD, JPY, NZD, NOK, SEK, CHF, GBP, DEM, FRF, ITL} for $t <$ January 1999,

B(G9, *t*) = {AUD, CAD, JPY, NZD, NOK, SEK, CHF, GBP, EUR} for $t \geqq$ January 1999.

Therefore, for example, the last observation of the DEM excess return used for the G9 index is from the end of December 1998 to the end of January 1999, and the first EUR excess return observation is from January to February 1999.

As can be surmised from Table 1, the return from the G9 excess return index would be substantially lower than that from EM20. We can also expect that the two excess returns are positively correlated, because a USD appreciation (depreciation) works to depress (raise) the excess return for each currency. Therefore, it is of interest to consider a portfolio in which the investor goes long in EM currencies (therefore shorting USD) *and* shorts G9 currencies (hence going long USD), thus mitigating the impact of USD fluctuations by using low risk-premium currencies as a hedge. This long-short index, denoted $Y_t^{(3)}$, is calculated as

$$\frac{Y_{t+1}^{(3)} - Y_t^{(3)}}{Y_t^{(3)}} = \frac{1}{2}\frac{Y_{t+1}^{(1)} - Y_t^{(1)}}{Y_t^{(1)}} - \frac{1}{2}\frac{Y_{t+1}^{(2)} - Y_t^{(2)}}{Y_t^{(2)}}$$

$$= \frac{1}{2}\left(\frac{1}{\# B(1,t)} \sum_{j \in B(1,t)} ER_{j,t+1} - \frac{1}{\# B(2,t)} \sum_{j \in B(2,t)} ER_{j,t+1} \right). \qquad (16)$$

The size of the bet is $1 because the sum of the absolute values of the weights is unity, as in the passive long-only strategies considered above. This is a "genuine" long-short index in that the weights add up to zero. By construction, 2 times the sample mean equals the difference in the mean excess return between EM20 and G9. A USD appreciation or depreciation uniform against all currencies is completely offset.

Figure 1 plots the three indexes thus defined --- the passive long-only EM20, the passive long-only G9, and the long-EM20/short-G9 index defined by (16) --- all normalized to 100 at June 1998. The EM20 excess return index shows a sharp drop from November 1997 to January 1998 (the monthly excess return is about -5% from November to December 97 and -7% from December 97 to January 98) followed by a rebound in February and March 1998. This swing took place when the basket size is 13 to 16 currencies. It is interesting to note that the G9 index declined almost in parallel to EM20 during 1997, underscoring the common USD factor. The Brazilian devaluation of early 1999, the Turkish devaluation of early 2001 and the Argentine crisis of early 2002 hardly affect the performance of EM20, thanks in part to the increased basket size. The sharp deterioration of the global financial crisis in September and October 2008, which depressed the value of almost all currencies against USD, did affect both EM20 and G9 indexes. On the other hand, the LS (long EM20, short G9) index shows steady movements even during the global financial crisis.

Table 2 displays summary statistics of the three indexes. We examine three subsamples differing in the starting date. Although the index for EM20 can be calculated from June 1996, the earliest starting date is taken to be January 1997, because over several months from June 1996 the index covers just four currencies, (TWD, THB, ZAR, TRY) and also because it is the earliest starting date for the G9 index using WM/Reuters data. The next starting date is June 1998 because by then a more diversified 18 currency basket that we think is more representative of the asset class was available (the next EM currency, ILS, is not available until September 2000). As an aside, the effects of the East Asian crisis were declining by mid-1998 with the losses in the second half of 1997 being partially reversed in the first half of 1998 (if we started in January 1998, without BRL, rather than June 1998, the mean excess return would be higher). The third subsample is determined by the introduction of EUR in January 1999. The following are noteworthy features of the table.

- The mean excess return is positive for both the EM20 and G9 indexes, although it is statistically significant only for the EM20. That is, USD investors would have earned a positive risk premium from both EM currencies and majors, but only the EM risk premium is large relative to the volatility.

- The EM20 index exhibits *less* volatility than G9. Consequently, the Sharpe ratio is much higher for EM20. The constituents are larger in number for EM currencies, but still this finding should be surprising to many. The low volatility is due in part to the relative lack of co-movements in the individual excess returns among E20 (shown in Table 1). The EM currencies benefit from diversification across regions. EM volatility is also likely to have been lower because a number of EM central banks have intervened actively to smoothen currency movements against USD.
- For both long-only and long-short indexes, there is little evidence of non-normality in skewness or kurtosis, as indicated by the Jarque-Bera statistic, except when the sample period includes the East Asian crisis of 1997. A plot of empirical density (not shown) indicates that the high value of kurtosis is due to fat tails at both ends of the distribution.
- As expected, going long EM20 and shorting G9 reduces volatility. (The correlation between the EM20 and G9 indexes is about 0.6.) The mean excess return for the long EM20/short G9 index (16) of about 2% means that the extra risk premium of EM20 over and above the G9 risk premium (which too is positive) is about 4% per annum. The *t*-value indicates that the difference is statistically significant.

These conclusions also hold true if the sample ends in June 2008, rather than September 2008, thus excluding the sharp deterioration of the global financial crisis in the fall of 2008. This is shown in Appendix Table 6. We also calculated the indexes with *annual* rebalancing to equal weights rather than the monthly rebalancing discussed above. The simple statistics in Appendix Table 7, which assumes rebalancing in every January, shows that less frequent rebalancing generally raises the mean excess return slightly (a sign of weak but positive momentum in returns), raises volatility slightly, and makes the departure from normality slightly more pronounced.

In Table 3, we calculate the index excess returns (with monthly rebalancing to equal weights as in Table 2) when the base currency is EUR and JPY.[19] To make the sample period uniform across the base currency, the sample period starts in January 1999. As the table shows, the mean excess return from the EM20 index has been positive and generally statistically significant in both JPY and EUR. Its volatility is higher when the base currency is EUR or JPY rather than USD. A possible reason is that, as was

[19] To change the base currency from USD to, say, EUR, we perform two operations. First, for each currency in the basket, the USD gross (1 plus) excess return from month t to $t+1$ is multiplied by S_{t+1}^{*} / F_{t}^{*}, where S_{t+1}^{*} is the spot rate, stated in USD per unit of EUR, on the observation date for settlement on the last business day of month $t+1$ and F_{t}^{*} is the forward rate on the observation date for settlement on the last business day of month t. Second, for the G9 index, which includes EUR when the base currency is USD, EUR is replaced by USD. For USD in the G9 basket, the EUR gross excess return is S_{t+1}^{*} / F_{t}^{*}.

mentioned above, most EM currencies trade against USD and a number of EM central banks have actively intervened to smooth currency volatility against USD.

C. Transactions Costs

We argued above in the context of individual foreign currencies that the transactions cost is modest because to long-term investors the entry and exit costs become small relative to the roll cost which itself is low. Here, the indexes being considered assume monthly rebalancing to equal weights, which requires opening additional long positions or unwinding a portion of existing positions every month. The investor has to pay bid/offer spreads for those monthly transactions. Although those incremental costs due to rebalancing over and above the roll cost should be modest compared to the level of excess returns, it is nevertheless of interest to verify that.

More fundamentally, with transactions costs, we have to be clear about what is meant by equal weights. Without transactions costs, the equal weight (in USD) strategy is equivalent to requiring that the long position in the currency be proportional to the forward rate stated in the units of the currency per USD. With transactions costs, we define the equal weight strategy to be one in which the position is proportional to the applicable forward rate when the position is being rolled (namely, $\tilde{F}_t$ in formula (12) above), except that for the initial month the position is required to be proportional to the bid rate (F_0^b in (12)) which is what the investor has to pay when opening a new long position.

Table 4 displays our calculations of excess returns under this definition of equal weights with bid/offer spreads (for now, ignore Rows 5-8). The period is from March 2004 to September 2008 (the same as in Appendix Table 2 on bid/offer spreads) because WM/Reuters provides bid/offer rates for only 13 of the 20 EM currencies before then. Our calculation assumes that the investor newly opens the positions in March 2004 and closes out 54 months later, in September 2008. For the intervening months, the calculation takes into account the bid/offer spreads as well as roll costs that the investor has to pay when adjusting the portfolio monthly to equal weights. Appendix 2.2 explains how to determine what portion of the existing positions to roll, what proportion to unwind, and the size of new positions to open. It also explains how to allocate the cumulative gross excess return between intervening months. The results in Table 4 show that, if the data on bid/offer spread provided by WM/Reuters are representative, or at least close to being representative, the cost of rebalancing is indeed very small because the transactions cost (defined as the difference in the mean excess return with and without bid/offer spreads and roll costs) of 32 basis points (6.64% - 6.32%) for EM20 and 4 basis points (3.00% - 2.96%) for G9 are only slightly higher than the annualized average roll costs displayed in Appendix Table 2 (of about 30 basis points for EM20 and about 3 basis points for G9).

5. Conditional Tests

A. The Regression-Based Test

Turning to the conditional UIP test, we first consider the excess return regression (7). Using the data that include recent years and that we deem reliable, we find that the carry coefficient is statistically significant, thus confirming the forward premium puzzle. The extent of the puzzle is less for EM20 in that the coefficient is closer to zero for EM20 than for G9. This corroborates the recent findings by Bansal and Darlquist (2000) and Frankel and Poonawala (2006).

Table 5 displays the OLS estimates for EM20 in Panel A and for G9 in Panel B. For each currency, the sample period is the same as in Table 1.[20] Looking at Panel B first, we confirm the forward premium puzzle for G9. For all G9 currencies except JPY, the estimated carry coefficient γ in the excess return regression (7) is above 2. This implies that the β in the Fama regression, which should be 1 under UIP, would be less than -1 (recall from Section 2 that the β in the Fama regression (8) is about equal to $1-\gamma$). This is indeed the case, as shown in Appendix Table 8B which displays the corresponding results for the Fama regression. Now consider EM20 by turning to Panel A of Table 5. The carry coefficient γ for most currencies is between 0 and 1.[21] There is a great deal of heterogeneity across currencies in the estimated values of α and γ. We do not report results from pooled OLS estimation, because the equality of regression coefficients across currencies can be decisively rejected by the Wald statistic. Results (not shown) for the post-East Asian crisis period are similar except for THB and KRW, the two currencies hit hard by the crisis.

B. Conditional Test on Actively-Managed Portfolios

A more interesting conditional test is to see whether the investor can earn a significantly higher return from a portfolio that is actively managed to exploit the predictive power of the carry. The strategy widely practiced in financial markets is the carry trade in high-yielding currencies. Since, as noted in Section 2, the forward contract excess return equals the carry trade return and the carry equals the interest rate differential, the carry-based strategy is equivalent to taking long positions in only those currencies with a positive carry.

However, for EM20, the carry is positive for most currencies (as seen in Table 1A). We therefore consider a strategy based on the *relative*, rather than absolute, value of the carry, within the universe of

[20] Therefore, for ARS and CNY, for part of the sample period in which the spot rate is constant, the excess return equals the carry. Consequently, the carry coefficient is unity. This period should be included in the sample period; otherwise the OLS estimate of the carry coefficient would be biased downwards.

[21] For ARS, a carry of 600% for December 2001 is a clear outlier. If this single month is excluded, the carry coefficient for ARS increases from 0.01 to 0.38 (and highly significant).

available EM currencies and also within majors. That is, at the end of each month (see below for how we determine the date of the month), the investor sorts the currencies by the carry and takes equally-weighted long positions in only those currencies in the top half. We will call this strategy the *relative long-only strategy*.[22] More precisely, the index representing this strategy is defined by

$$\text{relative long-only:}\quad \frac{Y_{t+1}-Y_t}{Y_t}=\frac{1}{\#B^+(t)}\sum_{j\in B^+(t)} ER_{j,t+1}\,, \qquad (17)$$

where

$$B^+(t)=\left\{j\in B(t)\,|\,carry_{jt}>\text{Median}(carry_{it}, i\in B(t))\right\},$$

$B(t)$ is the basket of constituent currencies for which data on the excess return from the end of month *t* to *t*+1 is available, and $\#B^+(t)$ is the cardinality (the number of constituent currencies) of $B^+(t)$.[23] The passive long-only strategy considered earlier in Section 4B obtains if we replace $B^+(t)$ by $B(t)$ in (17):

$$\text{passive long-only:}\quad \frac{Y_{t+1}-Y_t}{Y_t}=\frac{1}{\#B(t)}\sum_{j\in B(t)} ER_{j,t+1}\,. \qquad (18)$$

We also consider, for EM20 and G9 separately, the long-short version, called the *relative long-short strategy*, which takes long positions in the top half of the currencies (hence shorts USD) sorted by the carry and short position in the bottom half (long USD). The associated index is defined by

$$\text{relative long-short:}\quad \frac{Y_{t+1}-Y_t}{Y_t}=\frac{1}{\#B^+(t)+\#B^-(t)}\left(\sum_{j\in B^+(t)} ER_{j,t+1}-\sum_{j\in B^-(t)} ER_{j,t+1}\right), \qquad (19)$$

where

$$B^-(t)=\left\{j\in B(t)\,|\,carry_{jt}<\text{Median}(carry_{it}, i\in B(t))\right\}.$$

Thus the size of the bet is still \$1 because the absolute values of the weights add up to unity. This is a long-short index because the weights sum to zero.

[22] The idea of creating portfolios based on these sorts by signals has been around for decades in foreign exchange. That is what CTAs do. For recent academic studies on sorted portfolios, see Gorton and Rouwenhorst (2006) who apply the idea to commodities and Lustig and Verdelhan (2007) who look at foreign exchange.

[23] The median of a set of numbers is the middle number when the numbers are sorted. If there is an even amount of numbers, the median is the arithmetic mean of the two middle numbers. Therefore, if *n* is the number of constituent currencies, the strategy goes long on *n*/2 currencies for even *n* and (*n*-1)/2 currencies for odd *n*.

If the number of constituent currencies in $B(t)$ is even, then $B^{+}(t) \cup B^{-}(t) = B(t)$ and $\# B^{+}(t) = \# B^{-}(t) = \# B(t)/2$. A simple algebra utilizing (17)-(19) shows that the difference in the excess return between the relative long-only strategy and the passive strategy numerically equals the excess return from the long-short strategy for each *t*. If the number of constituents is odd, this algebraic relation holds approximately, if not exactly. Therefore, the mean excess return of the relative long-short index should be almost equal to the difference in the mean excess return between the relative long-only index and the passive index, and we can judge from the significance of the long-short index whether the long-only index performs significantly better than the passive index.

These active strategies use the carry as a signal to pick currencies. For them to be feasible in practice, the signal must be observed before taking positions. This is a non-trivial practical issue because the date when the forward rate F_t is observed for settlement at the end of month *t*+1 differs across currencies. For the set of constituent currencies $B(t)$ as a whole, we identify the earliest observation date among them.[24] The signal is the carry observed on the *previous* business day (which for later reference will be referred to as the *signal observation day*). We do so because the foreign exchange rates data are obtained at different times of the day and some foreign exchange markets are very illiquid by the time Latin American currency rates are observed.[25] Ignoring this feasibility issue introduces upward biases in the excess return, and the size of the bias is rather substantial, especially for EM20. If we use as the signal the carry observed on the day the forward rate is observed (so the date differs across currencies), the mean excess returns from long-only and long-short strategies are about 70 to 80 basis points higher for EM20 and 20 to 30 basis points higher for G9 depending on the sample period.

Table 6 displays simple statistics for those two active strategies for EM20 and G9 separately, for the three periods considered in Table 2. The table's main message is that the active strategies could outperform the passive strategy, especially for EM20. More specifically,

- Relative to the passive strategy, the active, carry-based long-only strategy has historically raised the excess return by about 450 basis points for EM20. This improvement is highly statistically significant as indicated by the significance of the long-short strategy. For majors, the effect, while significant at 5%, is much smaller in magnitude.

[24] For example, for the end of June 2008 settlement, the 1-month rate is observed on Wednesday, May 28 for most currencies and on May 29 for CAD, PHP, and RUB (which are also the currencies for which the lag between the spot observation date and the spot settlement date is one, not two, business day) and May 29 or 30 for TRY depending on the time of the day. So the earliest observation date is May 28 for June 2008 settlement.

[25] If for some currencies the spot and forward rates are not available on the signal observation date, we turn to the latest business day before that date for which the data are available.

- Relative to the passive strategy, the active long-only strategy, whose constituent currencies are only half as numerous, raises the volatility only modestly and the Sharpe ratio is higher. The diversification benefit seems to taper off after inclusion of only several currencies in the basket. This is true for both EM20 and G9 for all sub-samples.
- The high Sharpe ratio for the long-short strategy for EM20 should be taken with care because of fat tails indicated by the high value of kurtosis even for periods excluding the East Asian crisis.
- Currency turnover is low due to a high degree of persistence in the ranking by the carry. About 11-12% of those whose carry is relatively high for the month cease to be so in the following month for EM20. The percentage for G9 is even lower, about 4%.[26]

The excess return calculation for the table uses mid rates and thus ignores transactions costs. With rule-based active strategies, which would regularly require the investor to unwind the whole position of some currencies and open new positions for others depending on the configuration of the signal, bid/offer spreads weigh in more heavily. Using the methodology of Appendix 2.2, which was used to calculate the transactions cost for passive strategies and which works just as well for active strategies, we calculated the excess returns for the relative long-only strategies with bid/offer spreads. The results are reported in Rows 5-8 of Table 4. Again, if the WM/Reuters bid/offer spreads are representative, the transactions cost is surprisingly low, with about 50 basis points for EM20 and less than 10 basis points for G9. That these transaction cost estimates are not much higher than those for the passive strategies shown in Rows 1-4 of the table is due to the low turnover noted above. If the rule underlying the active strategies required a high monthly turnover of currencies, the transactions cost would have been much higher; it should be as high as when (as has been assumed in the literature) the investor closes and reopens the positions monthly (about 160 basis points for EM20 and about 60 for majors, as mentioned in Section 3.C.1) if the underlying rule required the set of invested currencies to change completely from month to month.

C. Reconciling Conflicting Evidence about EM20

Why does the carry-based, relative long-only strategy raise the mean index excess return for EM20 in spite of the low carry coefficient in the excess return regression for individual currencies? To explore the mechanism behind it, we draw a cross-section plot of the time-series mean excess return against the

[26] For EM20, the top half of the currencies when ranked by the carry was (THB, TRY, PHP, KRW, IDR, PLN, MXN, COP, INR) for the June to July 1998 excess return, and (TRY, BRL, ZAR, COP, MXN, HUF, ARS, IDR, INR, PHP) for the August to September 2008 excess return.

time-series mean carry for each currency in Figure 2, for two subsample periods.[27] March 2004 is used to break the whole sample, because the average CPI inflation rate for EM20 counties stabilized at around 4% since 2004[28] and also because we have provided simple statistics for the period starting March 2004 in an earlier table. For both EM20 and G9, there is a fairly strong cross-section association between the excess return and the carry. The difference is that for EM20 the range for the mean carry is far more compressed in more recent years. One explanation might be a possible decline in the inflation premium in the nominal interest rates. The high persistence in the ranking noted above implies that the compression took place while preserving the ranking by the carry. If the real interest rate differential is a predictor of the subsequent excess return, this would help explain why the *relative* long-only strategy was able to pick currencies with high risk premium. The nominal interest rate differential (i.e., the carry) has a small coefficient in the excess return regression because it is a noisy measure of the real interest rate differential for EM currencies.

So far, in predicting the excess return from the currency in question, we have considered the carry of that currency only. However, as noted by, e.g., Lustig *et. al.* (2008), the carry of other currencies may also help predict the excess return. Here, we address this issue of cross effects in the context of two passive long-only indexes (one for EM20, the other for G9) considered in Section 4. For the two indexes, Figure 3 provides a time-series plot of the index excess return (which is the cross-section mean excess return for each month) on the mean carry (the cross-section mean for the constituent currencies of the carry).[29] For EM20, there is no time-series correlation between the index return and the associated carry. This is consistent with the possible contamination by the inflation premium just noted. Regressions #1, #3, and #5 in Table 7 confirm the lack of correlation for the three subsamples considered in Table 2. In contrast, regressions #7, #9, and #11 show that for G9 the G9 mean carry has a strong influence on the G9 index excess return. Now, to examine the cross effect, in regressions #2, #4, and #6, we regress the EM20 index excess return on the EM20 carry *and* the G9 carry. Surprisingly, the G9 carry, not the EM20 carry, shows up with a significant coefficient. One possible explanation is that the excess return

[27] The carry here is on the signal observation day (defined in Section 5B) as in the carry used in the active carry-based indexes, not on the last business day of the month as in the excess return regression. This difference makes very little difference for the plot.

[28] The source is IMF's *World Economic Outlook*. The inflation measure is the rate of change of the CPI for the average of the year (the WEO code PCPIPCH). The EM average inflation rate was above 10% per annum for 1996-1999, followed by about 8% for 2000-2002, and about 6% for 2003.

[29] The index return from month t to $t+1$ is given by (15) for $i = \text{EM20}$ and G9. The mean carry for month t is the average over $B(i,t)$ of $carry_{jt}$ where $carry_{jt}$ is the carry for currency j at the end of month t (more precisely, on the signal observation day of month t). Use of the carry on the last business day of the month makes very little difference.

for individual currencies has a common global real-interest factor and the G9 carry, with less contamination by the inflation premium, is a better predictor of this factor.

We have seen in Table 2 that USD investors earned a positive (but not statistically significant) risk premium in major currencies and an additional premium over majors in EM currencies. Looking at the intercepts in even-numbered regressions in Table 7, we see that these positive risk premiums and the extra premium of EM currencies would still have existed even in the absence of positive carry.

6. Conclusions

The paper has three major findings. First, USD investors have historically earned a positive risk premium by taking long forward positions in emerging market currencies. The risk premium would have existed even in the absence of carry. Second, the carry of other currencies (particularly the carry of major currencies), not just the currency's own carry, help predict the currency's excess return. Third, according to our calculations, the transactions cost due to bid/offer spreads is substantially lower than previously supposed.

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Appendix 1: Calculation of the Excess Return and the Carry

This appendix describes how we calculated daily data on the excess return on forward contracts of a given maturity (e.g., 1 month or 3 months) and the carry. Monthly data can be created from daily data simply by extracting end-of-month (the last business day of the month) records. Weekly data can be created by extracting Friday (or the last business day of the week) records.

We need some notation to account for the fact, often ignored in academic research, that the settlement date for the spot contract is two business days (for most currencies, and either zero or one business day for TRY, one business day for CAD, PHP, RUB) after the *spot observation date*, the date on which the spot contract is traded and the spot rate is observed. Aligning dates correctly can make a difference to the measured returns, especially for EM currencies. For the forward contract in question (e.g., a 1-month forward contract) traded on business date *t*, we write F_t for the forward rate and $SETTLE_t$ for the settlement day. Also, we write OBS_t for the spot observation date when the spot rate for settlement on $SETTLE_t$ is observed. For most currencies, $SETTLE_t$ comes two business days after OBS_t. We write S_t for the spot rate observed on date t. The excess return from the forward contract traded on date t is $(S_{OBS_t} - F_t)/F_t = S_{OBS_t}/F_t - 1$ and the carry or the forward premium on date *t* is $(S_t - F_t)/F_t = S_t/F_t - 1$.[30] The non-trivial part of the calculation of the excess return is to identify OBS_t for each business day t.

Our calculation utilizes two files holding daily data. The first file is the *price file*, which holds S_t and F_t for each observation day t for the currency in question. As explained in the text, the source for daily price data depends on the currency. For the 20 emerging market currencies, the source is AIG-FP, while for majors it is WM/Reuters. The other file is the *settlement-day file* provided by AIG-FP. It gives the settlement days for the spot and forward contracts for each observation day for a large number of currencies including EM20 and G9.

For each observation day t in the price file, we obtain (S_t, F_t) from the price file. So the carry can be calculated for each business day. To calculate the excess return, we need to determine OBS_t. We proceed in two steps.

1. From the settlement-day file, obtain $SETTLE_t$ from the record corresponding to t. For example, for CNY and for observation $t =$ Friday, February 22, 2008, the settlement date for a 1-month contract is Wednesday, March 26, 2008. So $SETTLE_t$ = March 26, 2008 for $t =$ February 22, 2008.

[30] In the data, for most currencies, the exchange rates are stated in units of the foreign currency per USD. For those currencies, the formulas we use to calculate the excess return and the carry are: $F_t / S_{OBS_t} - 1$ and $F_t / S_t - 1$, respectively, where the spot and forward rates are mid rates (the mid rate is the arithmetic average of the bid and offer rates).

2. Identify the spot observation date whose spot settlement date is $SETTLE_t$. This is accomplished as follows. From the settlement-day file, we look for the observation dates whose spot settlement date is $SETTLE_t$. There are several possibilities.
   a. There is only one such day, and the price file has the spot rate observed on that day. We define OBS_t to be this day.
   b. There is only one such day, but the price file has no spot rate observed on that day. We define OBS_t to be the next business day in the price file for which the spot rate is available.
   c. There is no such day in the settlement-day file. This occurs for IDR, PHP, CNY, TWD, MXN, and ARS for periods shown in Table 1. We turn to the next spot settlement date and look for observation dates whose spot settlement day is this spot settlement day. It turned out that there is a unique observation day in the settlement-day file and the price file has a record for the spot rate. OBS_t is defined to be this unique day.

(The data challenges identified in b. and c. can occur when AIG-FP has not stored spot data because the date in question is an AIG-EMFXI^{SM} index holiday or perhaps because there is was an unscheduled holiday that was added between the initial establishment of the forward transaction or its settlement. In the case of IDR the observation process is also complicated by the need to observe Singapore holidays for the NDF market.)

   d. There are multiple such days. This can happen because the settlement-day file gives, for non-business days, the spot settlement day for the most recent observation day. From those multiple observation dates we select the set of dates in the price file for which the spot rate is available. There are two possibilities.
      i. This set is not empty. OBS_t is the last day of this non-empty set.
      ii. This set is empty. This would happen, as in (b) above, on those multiple observations days the market is closed. We define OBS_t to be the next business day in the price file for which the spot rate is available.

By this procedure, we created a matrix whose rows correspond to business days available in the price file. The row corresponding to business day t has: t, (S_t, F_t), ($SETTLE_t$, OBS_t, S_{OBS_t}) for the forward contract in question. Each row has enough information to calculate the excess return and the carry for the business day t corresponding to the row. There are very few rows (i.e., business days) falling in the problematic cases of (b), (c), or (d-ii). In the case of the 1-month forward contract, for the currencies and periods shown in Table 1, there are none for G9 and very few for EM20 (254 rows out of the total of 57,428 currency-days for EM20).

Weekly data can be created from this daily file by extracting rows whose t is the last business day of the week.

To create monthly data, we extract rows whose $SETTLE_t$ is the last business day of the month. If there are multiple such records (this can happen if on consecutive business days the forward contract traded settle on the last business day of the month), we pick the row corresponding to the latest business day. For the 1-month forward contract and the periods shown in Table 1, there are no problem months for EM20 except the following. BRL, CLP, and COP have one month with (b), due to the missing price information for December 26, 2007 in the price file (an AIG-EMFXI index holiday). IDR had two months falling in case (c). CNY had one month falling in case (c).

For the monthly data thus created, the excess return is non-overlapping because for each row of the extracted matrix (except for the first row) the date t equals OBS_t (if available) of the immediately preceding row. This is true for EM20 as well as G9.

Appendix 2: Incorporating Bid/offer Spreads

We argued in the text that the return calculation using mid rates provides a good approximation to the return from continued exposure to foreign exchange forward contracts over an extended period of time given the relatively low cost of rolling transactions. In the first half of this appendix, we substantiate this claim by deriving, for a given single currency in question and for 1-month forward contracts, a formula for the excess return that explicitly incorporates bid/offer spreads. The latter part of the appendix generalizes the formula to the excess return from a portfolio of 1-month forward contracts that is rebalanced monthly to arbitrarily given weights. The weights may be the same across constituent currencies as in the passive, equally-weighted strategy considered in Section 4 of the text, or they may be a function of the carry for currencies as in the active strategy considered in Section 5.

2.1. Excess Return Calculation for a Single Currency

Although in the text, for expositional clarity, we stated the exchange rate as the USD price of a unit of the foreign currency (e.g., 1/105 USD per JPY). We state the exchange rate in units of the foreign currency (e.g., 105 yen to the dollar), because that is the convention for all EM (emerging market) currencies and for most major currencies (except GBP, EUR, AUD, NZD, and SDR). Therefore, if S_t^b and S_t^o denote the bid and offer rates against USD stated in units of the foreign currency in question, we have $S_t^o > S_t > S_t^b$ where $S \equiv (S_t^b + S_t^o)/2$ is the mid rate. The spot bid/offer spread is $S_t^o - S_t^b$.

It is the practice of the FX (foreign exchange) market to express the forward rate as the sum of the spot rate and the forward premium. The latter is called the "forward points". If P_t^b and P_t^o denote the bid and offer values of the forward points, the (outright) forward bid and offer rates are $F_t^b = S_t^b + P_t^b$ and $F_t^o = S_t^o + P_t^o$. Since the offer forward points are always greater than the bid and since $S_t^o > S_t^b$, we have that $F_t^o > F_t > F_t^b$ where $F_t \equiv (F_t^b + F_t^o)/2$ is the mid forward rate, and that the bid/offer spread should be wider for the forward outright rate than for the spot rate.[31]

If we ignore the bid/offer spreads and use the mid rates only, the gross (i.e., one plus) excess return in USD from taking long positions on the 1-month forward contract over n consecutive months from month 0 to n is

$$1 + ER_{0,n}^{(1)} \equiv \frac{F_0}{S_1} \times \frac{F_1}{S_2} \times \cdots \times \frac{F_{n-2}}{S_{n-1}} \times \frac{F_{n-1}}{S_n}. \quad \text{(A2.1)}$$

[31] The forward points can be negative (as when the interest rate on the emerging market currency is less than that on USD). Even in this case, the forward offer points will be larger (i.e., less negative) than the forward bid points.

(Note that the exchange rates are in units of the foreign currency here.) For concreteness, let's say the foreign currency is ZAR (South African Rand). The formula (A2.1) can be derived as follows. Let r_{t+1} be the 1-month USD interest rate from the end of month t to $t+1$ (the interest rate factor will drop out at the end). Consider a U.S. investor with an initial investment of \$ A at the end of month 0.[32]

- At the end of month 0, the investor sells 1-month ZAR forward for \$ $A(1+r_1)$ (this is possible because r_1 is known at the end of month 0) and at the same time invests \$ A in the USD 1-month money market instrument.
- At the end of month 1 the investor collects \$ $A(1+r_1)$, buys ZAR at the 1-month forward rate F_0 to obtain $A(1+r_1)F_0$ in ZAR
- Then, still at the end of month 1, the investor goes into the FX spot market to sell ZAR of the amount $A(1+r_1)F_0$ for USD. The investor ends up with \$ $A(1+r_1)F_0 / S_1$. Thus the forward position has been opened and then closed or unwound.
- At the end of month 1, the investor repeats the same strategy, this time with a 1-month forward rate of F_1 and a spot rate of S_2, and with the initial investment of amount \$ $A(1+r_1)F_0 / S_1$ instead of \$ A. This yields \$ $A(1+r_1)(F_0 / S_1)(1+r_2)(F_1 / S_2)$.
- Repeating this operation of opening and then closing or unwinding the forward position n times, at the end of month n, the investor collects \$ $A(1+r_1)(F_0 / S_1)(1+r_2)(F_1 / S_2)\times\cdots(1+r_n)(F_{n-1} / S_n)$.
- Therefore, the gross excess return --- the return over and above what the investor would obtain without exposure to the FX forward market --- is what is given in (A2.1).

Now we incorporate bid/offer spreads. In the above operation, at the end of every month, the investor unwinds the forward position by going into the spot market and then at the same time reopens a new forward position. With bid/offer spreads, the applicable forward rate is the bid rate and the applicable spot rate is the offer rate. Thus, the formula for the cumulative gross excess return (A2.1) becomes:

$$1+ER_{0,n}^{(2)} \equiv \frac{F_0^b}{S_1^o}\times\frac{F_1^b}{S_2^o}\times\cdots\times\frac{F_{n-2}^b}{S_{n-1}^o}\times\frac{F_{n-1}^b}{S_n^o}. \quad \text{(A2.2)}$$

Therefore, after one month and every month hence, relative to the mid rate, the investor gets hit by the difference between the bid and the mid when opening a forward position and by the difference between offer

[32] Note that the investor need not actually have the cash, but for ease of exposition we will assume he does and again for ease of exposition will further assume that the rate derived in the US money market is equivalent to the implied yield on US dollars derived from the foreign exchange market.

and mid when unwinding. If the spot bid/offer spread (as a percentage fraction of mid) is 15 basis points and the forward bid/offer spread is 17 (those figures are for ZAR recently, as shown in Appendix Table 2), the investor pays ((0.15/2)+(0.17/2))×12 = 192 basis points per annum.

Much of this heavy transactions cost can be avoided if the position is *rolled*, that is, if the position is not unwound, but is extended over consecutive months. The investor can roll a position immediately prior to maturity by entering into what is called an FX swap. In an FX swap, the investor will "buy and sell USD" or "sell and buy ZAR". This is equivalent to selling spot the ZAR amount, buying USD, and then selling those USD 1 month forward to buy ZAR 1 month forward. The spot legs of the transactions cancel out (recall that the forward rate is the sum of the spot and the forward points) so there should be no bid/offer to pay on the spot. The spread is on the forward points. The formula for the cumulative gross excess return under this "rolling" operation is

$$1+ER_{0,n}^{(3)} \equiv \frac{F_0^b}{S_1}\times\frac{\tilde{F}_1}{S_2}\times\cdots\times\frac{\tilde{F}_{n-2}}{S_{n-1}}\times\frac{\tilde{F}_{n-1}}{S_n^o}, \quad \text{(A2.3)}$$

where

$$\tilde{F}_t \equiv S_t + P_t^b. \qquad \text{(A2.4)}$$

By a simple algebra utilizing the identities stated in the second paragraph of this section to (A2.3),[33] we obtain

$$\tilde{F}_t = F_t(1-x_t) \;\text{ with }\; x_t \equiv \frac{1}{2}\frac{\left(F_t^o - F_t^b\right)-\left(S_t^o - S_t^b\right)}{F_t}. \quad \text{(A2.5)}$$

Thus, under this rolling operation, the investor pays the difference between the bid and mid upon entry (at the end of month 0), pays half times the bid/offer in the forward points in between, and then pays the difference between offer and mid when exiting (at the end of month n). More precisely,

$$\text{Ratio of (A2.3) to (A.2.1)} = \left(\frac{F_0^b}{F_0}\right)\times\left(\frac{S_n}{S_n^o}\right)\times\prod_{t=1}^{n-1}(1-x_t). \quad \text{(A2.6)}$$

It then follows that transactions cost reduces the (arithmetic or geometric) mean excess return per annum by an amount approximately equal to

$$12\times\left[\frac{1}{2n}\left(\frac{F_0^o - F_0^b}{F_0}+\frac{S_n^o - S_n^b}{S_n}\right)\right]+12\times\frac{n-1}{n}\bar{x} \quad \text{with} \quad \bar{x}\equiv\frac{1}{n-1}\sum_{t=1}^{n-1}x_t. \quad \text{(A2.7)}$$

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[33] Since $F_t^b = S_t^b + P_t^b$, we have $\tilde{F}_t \equiv S_t + P_t^b = (1/2)(S_t^o + S_t^b) + (F_t^b - S_t^b) = (1/2)(S_t^o - S_t^b) + F_t^b$. By the definition of x_t, this equals $F_t - x_t F_t$. Solve this for $x_t F_t$, taking into account that $F_t = (1/2)(F_t^o + F_t^b)$.

In (A2.3), the applicable spot rate for exiting is the offer rate S_n^o. This is not true for currencies whose data come from the NDF (non-deliverable forward) market. The NDF contract settles against a specified spot rate and the difference between this specified rate and the forward rate is settled in one currency, usually USD. That specified spot rate is usually the mid rate. Therefore, in our calculation for NDFs, the formula (A2.3) has the mid rate S_n in place of the offer rate S_n^o.

To use the above illustrative example of ZAR (which is not an NDF), as mentioned above, the spot bid/offer spread as a fraction of mid is 15 basis points and the forward spread is 17. The mean of x times 12 is about 7 basis points for ZAR lately. For an investment horizon of 5 years (so $n = 60$ months), the transactions cost (the value of (A2.7)) is about 13 basis points per year, which is far lower than the transaction costs of 192 basis points calculated above for the case in which the forward position is opened and closed every month. The cost of rolling different currencies can vary considerably. Nevertheless it does not invalidate the point that it will typically be substantially cheaper to roll a position than to close it and then reopen it.

2.2. Portfolio Excess Returns

To handle portfolios invested in multiple currencies, we add subscript j for currency j. So, for example, S_{jt} is the spot mid rate of currency j against the domestic currency (USD), stated in units of currency j, at the end of month t. The additional notation is

$x_{j,t-1}$ = position in currency j, stated in the foreign currency unit, determined at the end of month $t-1$ and thus carried over to month t,

y_{jt} = the amount, stated in the foreign currency unit, to unwind at the end of month t,

z_{jt} = the amount, stated in the foreign currency unit, to newly open at the end of month t.

y_{jt} and z_{jt} are required to be nonnegative. The amount to roll is $x_{j,t-1} - y_{jt}$. As shown in Section 1 of this appendix, the rolled position to be carried over to the next month $t+1$ is $(x_{j,t-1} - y_{jt})\tilde{F}_{jt} / S_{jt}$. Therefore, the evolution of the position is governed by

$$x_{jt} = \left(x_{j,t-1} - y_{jt}\right)\frac{\tilde{F}_{jt}}{S_{jt}} + z_{jt}. \qquad \text{(A2.8)}$$

If we define

$$\hat{x}_{j,t-1} \equiv \frac{x_{j,t-1}}{S_{jt}}, \quad \hat{y}_{jt} \equiv \frac{y_{jt}}{S_{jt}}, \quad \hat{z}_{jt} \equiv \frac{z_{jt}}{\tilde{F}_{jt}}, \qquad \text{(A2.9)}$$

then (A2.8) can be written as

$$x_{jt} = \left(\hat{x}_{j,t-1} - (\hat{y}_{jt} - \hat{z}_{jt})\right)\tilde{F}_{jt} . \qquad \text{(A2.10)}$$

This $\hat{v}_{jt}$ can be interpreted as the net deduction, stated in the domestic currency unit, from investment in currency j. $\hat{z}_{jt}$ is the gross addition and $\hat{y}_{jt}$ is the gross deduction, both stated in the domestic currency unit.

Since the portfolio returns are reinvested continuously and no new funds are added to the portfolio, it must be that

$$\sum_{j=1}^{J} \frac{y_{jt}}{S_{jt}^{o}} = \sum_{j=1}^{J} \frac{z_{jt}}{F_{jt}^{b}} , \qquad \text{(A2.11)}$$

where J is the number of constituent currencies. Using the "hat" notation just introduced, this self-sufficiency condition can be rewritten as

$$\sum_{j=1}^{J} \frac{S_{jt}}{S_{jt}^{o}} \hat{y}_{jt} = \sum_{j=1}^{J} \frac{\tilde{F}_{jt}}{F_{jt}^{b}} \hat{z}_{jt} . \qquad \text{(A2.12)}$$

In (A2.12), the ratio multiplying $\hat{y}_{jt}$ is less than unity because $S_{jt} < S_{jt}^{o}$, and the ratio multiplying $\hat{z}_{jt}$ is greater than unity because $\tilde{F}_{jt} > F_{jt}^{b}$. So if both $\hat{y}_{jt}$ and $\hat{z}_{jt}$ were positive, we can economize on the net trade $\hat{y}_{jt} - \hat{z}_{jt}$ by reducing $\hat{y}_{jt}$ by a small amount, say ε, and reducing $\hat{z}_{jt}$ by $\varepsilon(S_{jt} / S_{jt}^{o})/(\tilde{F}_{jt} / F_{jt}^{b})$ (which is less than ε), while meeting the self-sufficiency condition. Therefore, to maximize returns from the portfolio, it is necessary that $\hat{y}_{jt} \times \hat{z}_{jt} = 0$ (that is, both $\hat{y}_{jt}$ and $\hat{z}_{jt}$ cannot be positive).[34]

Despite the self-sufficiency condition, the total net deduction, $\sum_{j} (\hat{y}_{jt} - \hat{z}_{jt})$, is positive because

$$\sum_{j=1}^{J} \hat{y}_{jt} - \sum_{j=1}^{J} \hat{z}_{jt} > \sum_{j=1}^{J} \frac{S_{jt}}{S_{jt}^{o}} \hat{y}_{jt} - \sum_{j=1}^{J} \frac{\tilde{F}_{jt}}{F_{jt}^{b}} \hat{z}_{jt} = 0 . \qquad \text{(A2.13)}$$

(The strict inequality holds if for some currency j either $\hat{y}_{jt} > 0$ or $\hat{z}_{jt} > 0$. The last equality is due to (A2.11).) This positive sum can be interpreted as the rebalancing cost.

[34] The only exception is CNY (Chinese Yuan). Since the local convention is to quote a single rate for the spot rate (much as the way e.g., the S&P500 index is quoted) and to express the outright forward rate as the sum of this single spot rate (call that S_{jt}) and forward points, $F_{jt}^{b} = S_{jt} + P_{jt}^{b}$ for $j = \text{CNY}$. So by (A2.4) we have $F_{jt}^{b} = \tilde{F}_{jt}$. Furthermore, since the data on CNY is from the NDF (non-deliverable forward) market, the applicable spot rate is that single spot rate S_{jt}. Therefore, both S_{jt} / S_{jt}^{o} and $\tilde{F}_{jt} / F_{jt}^{b}$ should be set to zero for CNY. Put differently, for CNY, rolling and opening/unwinding a position cost the same in data (although in practice, their costs could differ because the spot rate and forward points are determined at different times on the day).

Let $\{w_{jt}\}$ be the portfolio weights. By definition, $\sum_j w_{jt} = 1$ and $w_{jt} \geq 0$. We say that the portfolio $(x_{1t}, x_{2t}, ..., x_{nt})$ is balanced to $(w_{1t}, w_{2t}, ..., w_{nt})$ if

$$\frac{x_{jt}}{\tilde{F}_{jt}} = w_{jt} \times \left(\frac{x_{1t}}{\tilde{F}_{1t}} + \frac{x_{2t}}{\tilde{F}_{2t}} + \cdots + \frac{x_{nt}}{\tilde{F}_{nt}} \right) \quad \text{for} \quad k = 1,2,..., J. \qquad \text{(A2.14)}$$

Only $n-1$ of these n equations are linearly independent because the weights add up to unity. Using (A2.10), this balancing requirement can be written as

$$\hat{x}_{j,t-1} - (\hat{y}_{jt} - \hat{z}_{jt}) = w_{jt} \times \left(\sum_{i=1}^{J} \hat{x}_{i,t-1} - \sum_{i=1}^{J} (\hat{y}_{it} - \hat{z}_{it}) \right) \quad \text{for} \quad k = 1,2,..., J. \qquad \text{(A2.15)}$$

To minimize the rebalancing cost, we need to identify, for each t, a set of constituent currencies such that $\hat{y}_{jt} > 0$ and a disjoint set such that $\hat{z}_{jt} > 0$. This can be accomplished by solving, for each t, the following linear programming problem:

$$\min \sum_{j=1}^{J} (\hat{y}_{jt} - \hat{z}_{jt}) \quad \text{s.t.} \quad \text{(A2.12), (A2.15)}, \ \hat{y}_t \geq 0, \ \hat{z}_t \geq 0, \qquad \text{(A2.16)}$$

where $\hat{y}_t \equiv (\hat{y}_{1t}, ..., \hat{y}_{Jt})'$, $\hat{z}_t \equiv (\hat{z}_{1t}, ..., \hat{z}_{Jt})'$, and the minimization is over $(\hat{y}_t, \hat{z}_t)$.

To see that (A2.16) is indeed a linear programming problem, define

$$\xi_t \equiv \begin{bmatrix} \hat{y}_t \\ \hat{z}_t \end{bmatrix}, H \equiv [I_J, -I_J], a \equiv \left[\frac{S_{1t}}{S_{1t}^o}, ..., \frac{S_{Jt}}{S_{Jt}^o}, -\frac{\tilde{F}_{1t}}{F_{1t}^b}, ..., -\frac{\tilde{F}_{Jt}}{F_{Jt}^b} \right], \iota \equiv \begin{bmatrix} 1 \\ \vdots \\ 1 \end{bmatrix}, w_t \equiv \begin{bmatrix} w_{1t} \\ \vdots \\ w_{Jt} \end{bmatrix}, \hat{x}_{t-1} \equiv \begin{bmatrix} \hat{x}_{1,t-1} \\ \vdots \\ \hat{x}_{J,t-1} \end{bmatrix}$$

(A2.17)

Then, (A2.12) can be written as $a\xi_t = 0$ and (A2.15) can be written as $(I_J - w_t\iota')H\xi_t = (I_J - w_t\iota')\hat{x}_{t-1}$. The objective function can be written as $(H'\iota)'\xi_t$.

Consider an investor who invests a notional of \$ A in month 0. Since the relevant forward rate is the bid rate, the initial position in foreign currency units, $x_0 = (x_{10}, ..., x_{J0})$, is given by

$$(x_{10}, ..., x_{J0}) = (Aw_{10}F_{10}^b, ..., Aw_{J0}F_{J0}^b). \qquad \text{(A2.18)}$$

Conversely, if the initial position in foreign currency units is $(x_{10}, ..., x_{J0})$, the required initial dollar investment must have been

$$\sum_{j=1}^{J} \frac{x_{j0}}{F_{j0}^b} = A. \qquad \text{(A2.19)}$$

By the definition of $\hat{x}_{jt}$, $(\hat{x}_{10}, ..., \hat{x}_{J0})$ is given by

$$(\hat{x}_{10},...,\hat{x}_{J0}) = (w_{10}F_{10}^{b} / S_{11},...,w_{J0}F_{J0}^{b} / S_{J1}) . \qquad \text{(A2.20)}$$

In month 1, the investor solves (A2.16) for $t = 1$ to obtain $(\hat{y}_{j1}, \hat{z}_{j1})$ and hence $\hat{v}_{j1}$ for $j = 1,2,..., J$. Then the difference equation (A2.10) spits out the position in foreign currency units to be carried over to month 2. This process repeats until the final period $t = n$ when the investor's position in foreign currency units is $(x_{1,n-1},..., x_{J,n-1})$. The position is converted into USD for the offer spot rate, yielding

$$\sum_{j=1}^{J} x_{j,n-1} / S_{jn}^{o} . \qquad \text{(A2.21)}$$

The cumulative gross excess return over the n month horizon, therefore, is given by

$$\frac{\sum_{j=1}^{J} x_{j,n-1} / S_{jn}^{o}}{\sum_{j=1}^{J} x_{j0} / F_{j0}^{b}} . \qquad \text{(A2.22)}$$

Finally, we consider the issue of how to allocate this cumulative excess return between the months comprising the investment horizon $[0, n]$. This becomes an issue if the arithmetic, rather than geometric, mean of monthly excess return is to be calculated. If there were no transactions costs, the gross excess return from t to $t+1$ can be calculated as

$$\frac{\sum_{j=1}^{J} x_{jt} / S_{j,t+1}}{\sum_{j=1}^{J} x_{jt} / F_{jt}} = \sum_{j=1}^{J} w_{jt} \frac{S_{j,t+1}}{F_{jt}} , \qquad \text{(A2.23)}$$

where use has been made of (A2.14) with $\tilde{F}_{jt}$ replaced by the mid rate F_{jt} . This suggests the following decomposition of the cumulative excess return under transactions costs:

$$\frac{\sum_{j} x_{j0} / S_{j1}}{\sum_{j} x_{j0} / F_{j0}^{b}} \times \frac{\sum_{j} x_{j1} / S_{j2}}{\sum_{j} x_{j1} / \tilde{F}_{j1}} \times \cdots \times \frac{\sum_{j} x_{jt} / S_{j,t+1}}{\sum_{j} x_{jt} / \tilde{F}_{jt}} \times \cdots \times \frac{\sum_{j} x_{j,n-2} / S_{j,n-1}}{\sum_{j} x_{j,n-2} / \tilde{F}_{j,n-2}} \times \frac{\sum_{j} x_{j,n-1} / S_{jn}^{o}}{\sum_{j} x_{j,n-1} / \tilde{F}_{j,n-1}} .$$

(A2.24)

This takes into account the fact that when the position was opened anew in month 0, the applicable forward rate is the bid rate and when the position is closed in month n the applicable spot rate is the offer rate. This, however, is not a decomposition of the cumulative gross excess return (A2.22) because

$$\sum_{j=1}^{J} x_{j,t-1} / S_{jt} = \sum_{j=1}^{J} x_{j,t} / \tilde{F}_{jt} + \sum_{j=1}^{J} (\hat{y}_{jt} - \hat{z}_{jt}) . \qquad \text{(A2.25)}$$

(This equality can be derived from (A2.10) and the definition $\hat{x}_{j,t-1} \equiv x_{j,t-1} / S_{jt}$ in (A2.9).) A valid decomposition, therefore, adds the balancing cost $\sum_j (\hat{y}_{jt} - \hat{z}_{jt})$ to the denominator $\sum_j x_{jt} / \tilde{F}_{jt}$:

$$\frac{\sum_j x_{j0} / S_{j1}}{\sum_j x_{j0} / F_{j0}^b} \times \frac{\sum_j x_{j1} / S_{j2}}{\sum_j x_{j1} / \tilde{F}_{j1} + \sum_j (\hat{y}_{j1} - \hat{z}_{j1})} \times \cdots \times \frac{\sum_j x_{jt} / S_{j,t+1}}{\sum_j x_{jt} / \tilde{F}_{jt} + \sum_j (\hat{y}_{jt} - \hat{z}_{jt})} \times \cdots$$
$$\times \frac{\sum_j x_{j,n-2} / S_{j,n-1}}{\sum_j x_{j,n-2} / \tilde{F}_{j,n-2} + \sum_j (\hat{y}_{j,n-2} - \hat{z}_{j,n-2})} \times \frac{\sum_j x_{j,n-1} / S_{jn}^o}{\sum_j x_{j,n-1} / \tilde{F}_{j,n-1} + \sum_j (\hat{y}_{j,n-1} - \hat{z}_{j,n-1})} .$$

(A2.26)

This provides an allocation of the cumulative gross excess return between months.

Table 1: Summary Statistics (Sample ending September 2008)

Panel A: EM20 (Data Source: AIG-FP)

Currency	Start Date	#Obs	Excess Return $\equiv (S_{t+1} - F_t)/F_t$						Carry $\equiv (S_t - F_t)/F_t$ (% p.a.)			Spot Return $(S_{t+1} - S_t)/S_t$
			Mean (% p.a.)	Annualized Volatility	Sharpe Ratio	*t*-value for Mean	rho(1)	average correlation	Mean	Max	Min	Mean (% p.a.)
TWD (Taiwan Dollar)	Jun-96	147	-1.6%	5.5%	-0.29	-1.01	0.19**	0.25	-0.5%	18.1%	-15.5%	-1.1%
THB (Thai Baht)	Jun-96	147	2.0%	14.6%	0.14	0.48	0.11	0.22	3.4%	36.4%	-3.2%	-1.3%
ZAR (South African Rand)	Jun-96	147	3.8%	16.3%	0.24	0.83	-0.03	0.17	7.7%	20.8%	2.1%	-3.9%
TRY (Turkish Lira)	Jun-96	147	19.5%****	16.4%	1.19	4.15	-0.05	0.11	41.1%	127.3%	7.4%	-20.5%
PHP (Philippine Peso)	Oct-96	143	4.1%	10.7%	0.38	1.31	-0.02	0.20	8.5%	104.9%	-21.8%	-4.4%
KRW (Korean Won)	Dec-96	141	2.4%	13.5%	0.18	0.62	0.31***	0.21	4.3%	71.3%	-6.2%	-1.6%
CNY (Chinese Yuan)	Dec-96	141	0.8%**	1.1%	0.73	2.49	0.25**	0.03	-0.9%	13.0%	-11.7%	1.7%
IDR (Indonesian Rupiah)	Jan-97	140	8.1%	38.9%	0.21	0.71	0.02	0.17	11.6%	64.0%	-2.0%	-3.8%
PLN (Polish Zloty)	Feb-97	139	10.4%**	11.5%	0.91	3.10	0.02	0.30	7.3%	23.0%	-1.4%	3.1%
CZK (Czech Koruna)	Mar-97	138	7.3%**	12.4%	0.59	2.00	-0.04	0.27	1.7%	44.0%	-3.3%	5.6%
CLP (Chilean Peso)	Mar-97	138	0.4%	9.3%	0.05	0.16	0.08	0.19	2.5%	19.3%	-0.6%	-2.0%
MXN (Mexican Peso)	Mar-97	138	6.8%**	8.4%	0.81	2.74	-0.01	0.11	9.1%	34.3%	1.6%	-2.3%
SKK (Slovak Koruna)	Jun-97	135	9.5%**	10.1%	0.94	3.14	0.11	0.27	4.8%	29.3%	-2.1%	4.8%
HUF (Hungarian Forint)	Dec-97	129	9.3%**	11.0%	0.84	2.76	-0.01	0.29	6.7%	21.9%	0.8%	2.6%
COP (Colombian Peso)	Jan-98	128	3.6%	10.9%	0.33	1.08	0.15*	0.15	7.4%	30.0%	-1.1%	-3.8%
ARS (Argentine Peso)	Jan-98	128	12.5%**	15.2%	0.82	2.68	-0.25**	0.02	23.9%	600.0%	-2.1%	-8.2%
INR (Indian Rupee)	Mar-98	126	4.1%**	4.9%	0.83	2.69	0.21**	0.20	5.5%	17.5%	-3.2%	-1.4%
BRL (Brazilian Real)	Jun-98	123	9.3%	19.8%	0.47	1.50	0.15*	0.15	11.9%	41.0%	-25.1%	-2.5%
ILS (Israeli Shekel)	Sep-00	96	4.6%*	7.8%	0.60	1.69	0.10	0.10	2.2%	8.0%	-1.6%	2.4%
RUB (Russian Ruble)	Jun-01	87	5.1%***	3.9%	1.29	3.48	0.24**	0.29	3.0%	18.4%	-4.4%	2.0%

Panel B: G9 (Data Source: WM/Reuters)

Currency	Start Date	#Obs	Excess Return $\equiv (S_{t+1} - F_t)/F_t$						Carry $\equiv (S_t - F_t)/F_t$ (% p.a.)			Spot Return $(S_{t+1} - S_t)/S_t$
			Mean (% p.a.)	Annualized Volatility	Sharpe Ratio	*t*-value for Mean	rho(1)	average correlation	Mean	Max	Min	Mean (% p.a.)
AUD (Australian Dollar)	Jan-97	140	2.8%	11.3%	0.24	0.83	0.03	0.51	1.5%	4.9%	-1.0%	1.3%
CAD (Canadian Dollar)	Jan-97	140	2.3%	7.2%	0.32	1.10	0.04	0.32	-0.2%	2.2%	-2.6%	2.5%
JPY (Japanese Yen)	Jan-97	140	-2.0%	10.7%	-0.19	-0.66	0.01	0.30	-3.8%	-1.0%	-6.8%	1.8%
NZD (NZ Dollar)	Jan-97	140	3.2%	11.6%	0.27	0.94	0.05	0.50	2.6%	6.2%	-1.2%	0.6%
NOK (Norwegian Krona)	Jan-97	140	2.7%	10.8%	0.25	0.84	-0.02	0.58	0.8%	6.0%	-2.6%	1.8%
SEK (Swedish Krona)	Jan-97	140	0.8%	10.2%	0.08	0.26	0.04	0.62	-0.6%	2.8%	-3.2%	1.3%
CHF (Swiss Franc)	Jan-97	140	0.3%	9.8%	0.03	0.11	0.04	0.56	-2.5%	0.0%	-5.1%	2.8%
GBP (British Pound)	Jan-97	140	2.6%	7.6%	0.35	1.19	-0.09	0.47	1.2%	3.6%	-0.8%	1.4%
EUR (Euro)	Jan-99	116	2.5%	9.2%	0.27	0.83	0.16*	0.64	-0.4%	2.0%	-3.3%	2.9%

Note: Monthly data. The base currency is USD. The sample ends in September 2008 for all currencies. "rho(1)" is the sample first-order autocorrelation coefficient. "average correlation" is the average of the time-series correlation coefficients in the monthly excess return with the other currencies (19 others for EM20, 8 others for G9). The significance for the mean excess return and rho(1) are indicated by stars with * = significant at 10%, ** = 5%, *** = 1%, **** = 0.1%. Recall: ER_{t+1} = excess return $\equiv (S_{t+1} - F_t)/F_t$, $carry_t \equiv (S_t - F_t)/F_t$, where S_t and F_t are spot and 1-month forward rates at the end of month t, stated in U.S. Dollars per unit of foreign currency. See Appendix 1 for details on the calculation of monthly excess returns and the carry from daily data. The excess return and the carry are at annual rates, with monthly values multiplied by 12. The mean excess return is the average of ER_{t+1} ($t = t_1, t_1$+1,..., t_2-1), or equivalently, the average of ER_t ($t = t_1$+1 t_1+1,..., t_2), where t_1 is the start date and t_2 is September 2008. So, for example for TWD, the first observation of the excess return is from June to July 96 and the last observation is from August to September 2008. The mean carry is the average of $carry_t$ ($t = t_1, t_1$+1,..., t_2-1). Therefore, ER_{t+1} is paired with $carry_t$. The annualized volatility of the excess return is defined as the standard deviation (calculated as the square root of: the sum of squared deviations from the sample mean divided by the number of observations minus 1) of monthly excess returns at annual rates divided by the square root of 12 (or, equivalently, the standard deviation of monthly excess returns at monthly rates multiplied by the square root of 12). The Sharpe ratio is the ratio of the mean annualized excess return to the annualized volatility. To determine the significance of rho(1), we calculate the *t*-value as the square root of the number of observations times the point estimate. If the first observation of the spot and forward rate is, for example, December 31, 1996, the first monthly excess return observation is from January to February 1997. This is because to calculate the December 1996 to January 1997 return we need to observe the 1-month forward rate on one or two business days prior to December 31, 1996. This is why the first month for monthly excess returns based on WM/Reuters data (which starts on December 31, 1996) is from January to February 1997, not from December 1996 to January 1997.

Table 2: Index Returns

Index	Data Source	Start Date	End Date	#Obs	Simple Statistics of Index Excess Return: Mean (% p.a.)	Annualized Volatility	Sharpe Ratio	*t*-value for Mean	Skewness	Kurtosis	Jarque-Bera	rho(1)
EM20 (long-only defined by (15))	AIG-FP	Jan-97	Sep-08	140	5.5%**	6.6%	0.83	2.84	-0.18	6.12	57.4****	0.16 *
		Jun-98	Sep-08	123	7.3%****	5.3%	1.36	4.37	0.14	3.63	2.4	0.16 *
		Jan-99	Sep-08	116	6.6%****	4.9%	1.34	4.16	-0.12	3.23	0.5	0.13
G9 (long-only defined by (15))	WM/Reuters	Jan-97	Sep-08	140	1.6%	7.4%	0.22	0.76	0.49	3.05	5.7*	0.13
		Jun-98	Sep-08	123	3.2%	7.6%	0.42	1.36	0.41	2.86	3.5	0.11
		Jan-99	Sep-08	116	2.8%	7.4%	0.39	1.20	0.37	2.70	3.1	0.16 *
long-EM20/short-G9 defined by (16)	AIG-FP for EM20, WM/Reuters for G9	Jan-97	Sep-08	140	1.9%**	3.3%	0.58	1.98	-0.06	5.42	34.2****	0.01
		Jun-98	Sep-08	123	2.0%**	2.9%	0.71	2.28	-0.48	2.54	5.8*	0.00
		Jan-99	Sep-08	116	1.9%**	2.7%	0.68	2.13	-0.53	2.63	6.1**	0.03

Note: Monthly data. The base currency is USD. "rho(1)" is the sample first-order autocorrelation coefficient. The significance for the mean excess return, the Jarque-Bera statistic (a function of skewness and kurtosis, distributed chi-squared with two degrees of freedom under the null of normality), and rho(1) are indicated by stars with * = significant at 10%, ** = 5%, *** = 1%, **** = 0.1%. It is stated at an annual rate, with monthly values multiplied by 12. See Note to Table 1 for how the annualized volatility, the Sharpe ratio, the *t*-value, and the significance of rho(1) are calculated. The constituents of "G9" before January 1999 (when the Euro started to trade) are (AUD, CAD, JPY, NZD, SEK, NOK, CHF, GBP, DEM, FRF, ITL). The legacies (DEM, FRF, ITL) are replaced by EUR when the Euro is introduced. For the reason stated in Note to Table 6, ILS enters the constituents of the EM20 index in October 2000, not September 2000.

Table 3: Index Returns in USD, EUR, and JPY

The Sample Period is January 1999 – September 2008 (Sample Size is 116)

Index	Base Currency	Index Excess Return							
		Mean (% p.a.)	Annualized Volatility	Sharpe Ratio	*t*-value for Mean	Skewness	Kurtosis	Jarque-Bera	rho(1)
EM20 (long-only defined by (15) for EM20)	USD	6.6%****	4.9%	1.34	4.16	-0.12	3.23	0.5	0.13
	EUR	4.7%*	7.6%	0.62	1.92	-0.15	3.20	0.6	0.04
	JPY	9.6%**	9.6%	1.00	3.10	-0.21	2.78	1.1	-0.03
G9 (long-only G9 defined by (15) for G9)	USD	2.8%	7.3%	0.38	1.19	0.40	2.81	3.3	0.18*
	EUR	0.5%	4.9%	0.09	0.29	0.04	3.74	2.7	-0.06
	JPY	5.9%**	9.0%	0.66	2.04	-0.06	3.79	3.1	-0.06
long-EM20/short-G9 defined by (16)	USD	1.9%**	2.7%	0.68	2.13	-0.53	2.63	6.1 **	0.03
	EUR	2.1%**	2.4%	0.89	2.78	-0.45	2.61	4.7 *	-0.01
	JPY	1.8%**	2.5%	0.73	2.28	-0.48	2.71	4.9 *	0.00

Note: Monthly data. "rho(1)" is the sample first-order autocorrelation coefficient. The significance for the mean excess return, the Jaque-Bera statistic, and rho(1) are indicated by stars with * = significant at 10%, ** = 5%, *** = 1%, **** = 0.1%. For the reason stated in Note to Table 6, ILS enters the constituents of the EM20 index in October 2000, not September 2000.

Table 4: Long-Only Index Returns With and Without Transactions Costs

The Sample Period is March 2004 – September 2008 (Sample Size is 54)

Row No.	Index	Bid/offer Spreads Incorporated?	Simple Statistics of Index Excess Return: Mean (% p.a.)		Annualized Volatility	Sharpe Ratio	*t*-value for Mean	Skewness	Kurtosis	Jarque-Bera	rho(1)	Geometric Mean (% p.a.)
			Passive Portfolios (Equally-Weighted Long-only Strategies)									
1	EM20 (defined by (15))	No	6.64%	**	5.4%	1.22	2.59	-0.29	3.26	0.91	0.00	6.50%
2		Yes	6.32%	**	5.4%	1.16	2.46	-0.29	3.27	0.92	0.01	6.17%
3	G9 (defined by (15))	No	3.00%		7.0%	0.43	0.91	0.03	2.61	0.34	0.11	2.76%
4		Yes	2.96%		7.0%	0.42	0.90	0.03	2.61	0.35	0.11	2.72%
			Actively-Managed Portfolios (Relative Long-Only Strategies)									
5	EM20 (defined by (17))	No	8.33%	**	6.8%	1.22	2.60	-0.57	3.35	3.21	-0.06	8.10%
6		Yes	7.87%	**	6.8%	1.16	2.45	-0.57	3.35	3.25	-0.06	7.64%
7	G9 (defined by (17))	No	4.50%		7.6%	0.59	1.25	-0.29	3.32	0.99	0.03	4.21%
8		Yes	4.43%		7.6%	0.58	1.23	-0.29	3.31	1.00	0.03	4.15%

Note: Monthly data. The base currency is USD. The data source for the mid rates is AIG-FP for EM20 and WM/Reuters for G9. The data on bid/offer spreads (whose averages are reported in Appendix Table 2) are from WM/Reuters. "rho(1)" is the sample first-order autocorrelation coefficient. The significance for the mean excess return, the Jarque-Bera statistic and rho(1) are indicated by stars with * = significant at 10%, ** = 5%, *** = 1%, **** = 0.1%. For both EM20 and G9, the passive index excess return is defined by (15) (or (18)) and the active index is the relative long-only index defined by (17). See Note to Table 2 for more details on the definition of the statistics reported here.

Table 5: Excess-Return Regression: $ER_{t+1} = \alpha + \gamma \cdot carry_t + u_t$

Panel A: EM20 (Data Source: AIG-FP)

Currency	#Obs	α (% p.a.)	Std. Error (% p.a.)	*t*-value for α	γ	Std. Error	*t*-value for γ=0	R^2	*SER* (% p.a.)
TWD (Taiwan Dollar)	147	-1.5%	1.6%	-0.96	0.10	0.47	0.21	0.00	5.5%
THB (Thai Baht)	147	3.7%	4.9%	0.76	-0.50	0.73	-0.68	0.00	14.7%
ZAR (South African Rand)	147	-17.0%	10.6%	-1.60	2.70**	1.24	2.18	0.03	16.1%
TRY (Turkish Lira)	147	11.5%	8.7%	1.33	0.19	0.18	1.10	0.01	16.4%
PHP (Philippine Peso)	143	-4.3%	3.4%	-1.26	0.99****	0.22	4.58	0.13	10.0%
KRW (Korean Won)	141	6.6%	4.1%	1.59	-0.97**	0.35	-2.76	0.05	13.2%
CNY (Chinese Yuan)	141	1.2%***	0.3%	3.89	0.43****	0.08	5.47	0.18	1.0%
IDR (Indonesian Rupiah)	140	-37.2%**	15.0%	-2.48	3.90****	0.90	4.32	0.12	36.6%
PLN (Polish Zloty)	139	10.1%*	5.2%	1.95	0.05	0.53	0.09	0.00	11.5%
CZK (Czech Koruna)	138	6.0%	3.8%	1.57	0.77	0.69	1.10	0.01	12.4%
CLP (Chilean Peso)	138	1.9%	3.5%	0.54	-0.59	0.87	-0.68	0.00	9.3%
MXN (Mexican Peso)	138	-4.0%	4.0%	-1.01	1.18***	0.35	3.40	0.08	8.1%
SKK (Slovak Koruna)	135	8.5%**	3.8%	2.26	0.21	0.47	0.45	0.00	10.2%
HUF (Hungarian Forint)	129	2.8%	6.5%	0.44	0.96	0.83	1.16	0.01	11.0%
COP (Colombian Peso)	128	2.9%	5.0%	0.59	0.09	0.50	0.17	0.00	10.9%
ARS (Argentine Peso)	128	12.3%**	4.9%	2.50	0.01	0.06	0.11	0.00	15.2%
INR (Indian Rupee)	126	0.4%	2.6%	0.17	0.67*	0.37	1.78	0.02	4.9%
BRL (Brazilian Real)	123	2.8%	10.8%	0.26	0.55	0.74	0.74	0.00	19.9%
ILS (Israeli Shekel)	96	3.7%	3.7%	1.01	0.42	1.10	0.38	0.00	7.8%
RUB (Russian Ruble)	87	4.3%**	1.7%	2.49	0.24	0.31	0.79	0.01	3.9%

Panel B: G9 (Data Source: WM/Reuters)

Currency	#Obs	α (% p.a.)	Std. Error (% p.a.)	*t*-value for α	γ	Std. Error	*t*-value for γ=0	R^2	*SER* (% p.a.)
AUD (Australian Dollar)	140	-3.4%	4.3%	-0.79	4.10**	1.85	2.22	0.03	11.1%
CAD (Canadian Dollar)	140	3.0%	2.1%	1.42	3.67*	1.95	1.88	0.02	7.1%
JPY (Japanese Yen)	140	4.3%	7.7%	0.56	1.67	1.85	0.90	0.01	10.7%
NZD (NZ Dollar)	140	-4.6%	5.7%	-0.80	3.03*	1.79	1.69	0.02	11.6%
NOK (Norwegian Krona)	140	0.2%	3.3%	0.06	2.96**	1.27	2.32	0.04	10.7%
SEK (Swedish Krona)	140	2.8%	3.1%	0.91	3.63**	1.59	2.28	0.04	10.1%
CHF (Swiss Franc)	140	11.3%**	5.5%	2.04	4.45**	1.92	2.31	0.04	9.7%
GBP (British Pound)	140	0.2%	3.2%	0.06	1.97	1.86	1.06	0.01	7.6%
EUR (Euro)	116	4.4%	3.0%	1.47	4.55**	1.84	2.46	0.05	9.0%

Note: The base currency is USD. Estimation by OLS on monthly data. The sample period is the same as in Table 1 for each currency. For α and γ, * = significant at 10%, ** = 5%, *** = 1%, **** = 0.1%. Recall: ER_{t+1} = excess return $\equiv (S_{t+1} - F_t)/F_t$, $carry_t \equiv (S_t - F_t)/F_t$, where S_t and F_t are spot and 1-month forward rates at the end of month *t*, stated in U.S. Dollars per unit of foreign currency. See Appendix 1 for how the monthly excess return and the carry are calculated. The excess return and the carry are at annual rates, with monthly values multiplied by 12. "*SER*" is the standard error of the regression, defined as the square root of: the sum of squared residuals divided by *n*-2 where *n* is the sample size. This is annualized by further dividing it by the square root of 12.

Table 6: Conditional Tests on Actively Managed Portfolios based on Carry

Row No.	Constituent Currencies	Strategy	Start Date	#Obs	Turnover	Simple Statistics of Excess Return from the Strategy							
						Mean (% p.a.)	Annualized Volatility	Sharpe Ratio	*t*-value for Mean	Skewness	Kurtosis	Jarque-Bera	rho(1)
1	EM20 (source: AIG-FP)	relative, long-only (defined by (17))	Jan-97	140	12%	10.2%****	8.7%	1.17	3.99	0.21	9.20	225.3****	0.12
2			Jun-98	123	11%	11.8%****	7.0%	1.69	5.42	-0.21	4.08	6.9**	0.09
3			Jan-99	116	11%	11.1%****	6.3%	1.77	5.49	-0.40	3.58	4.8*	0.07
4		relative, long-short (defined by (19))	Jan-97	140		4.7%****	3.6%	1.30	4.43	0.70	10.74	360.7****	-0.02
5			Jun-98	123		4.5%****	2.7%	1.67	5.33	-0.55	5.12	29.4****	-0.03
6			Jan-99	116		4.6%****	2.5%	1.79	5.57	-0.39	4.78	18.2****	0.00
7	G9 (source: WM/Reuters)	relative, long-only (defined by (17))	Jan-97	140	4%	3.0%	8.3%	0.36	1.24	0.21	3.12	1.2	0.07
8			Jun-98	123	4%	4.8%*	8.6%	0.56	1.78	0.08	2.94	0.2	0.04
9			Jan-99	116	4%	4.8%*	8.4%	0.57	1.76	0.09	2.79	0.4	0.09
10		relative, long-short (defined by (19))	Jan-97	140		1.7%**	3.0%	0.58	1.97	-0.53	3.10	6.7**	-0.13
11			Jun-98	123		2.0%**	3.1%	0.63	2.01	-0.56	2.98	6.4**	-0.13
12			Jan-99	116		2.3%**	3.0%	0.77	2.38	-0.65	3.26	8.4**	-0.10

Note: The base currency is USD. The sample ends in September 2008 for all indexes. The two strategies, “relative, long-only” and “relative, long-short”, are based on the ranking of currencies by the carry at the end of each month. The “relative, long-only” strategy, defined by (17) of the text, goes long in those currencies in the top half of the ranking and no position in the rest of the currencies. The “relative, long-short” strategy, defined by (19), longs those currencies in the top half of the ranking and shorts the rest of the currencies. “rho(1)” is the sample first-order autocorrelation coefficient. The significance for the mean excess return, the Jarque-Bera statistic of normality, and rho(1) are indicated by stars with * = significant at 10%, ** = 5%, *** = 1%, **** = 0.1%. See Note to Table 2 for how the statistics shown (except the item labeled “Turnover”) here are calculated. “Turnover” is the average over the sample period of the fraction of currencies in the basket under the long-only strategy for the month that depart from the basket in the following month. The AIG-FP dataset has daily data on ILS from September 27, 2000. This starting date is early enough to observe the 1-month forward rate for settlement on October 31 and the excess return from September to October 2000 can be calculated. This is why the start date in Table 1 for ILS is September 2000. However, the observation date for October 2000 settlement is September 27, which requires data on the spot and forward rates observed on September 26, 2000. For this reason, in the active trading strategies studied in Rows 1-8, ILS enters the constituents in October 2000, not September 2000.

Table 7: Time-Series Regression of Index Returns on Average Carry

Regression No.	Index	Start Date	End Date	#Obs	Mean Excess Return (% p.a.)	Constant (% p.a.)	*t*-value	Coefficient of EM20 Carry	*t*-value	Coefficient of G9 Carry	*t*-value	R^2
1	EM20 passive long-only	Jan-97	Sep-08	140	5.5%	7.1%**	2.26	-0.19	-0.66	--------	--------	0.00
2						7.6%**	2.45	-0.20	-0.70	2.64**	2.02	0.03
3		Jun-98	Sep-08	123	7.3%	5.0%*	1.93	0.31	1.16	--------	--------	0.01
4						5.4%**	2.08	0.25	0.94	1.36	1.20	0.02
5		Jan-99	Sep-08	116	6.6%	6.1%**	2.53	0.07	0.24	--------	--------	0.00
6						6.9%**	2.83	-0.07	-0.25	1.89*	1.74	0.03
7	G9 passive long-only	Jan-97	Sep-08	140	1.6%	2.3%	1.08	--------	--------	3.95**	2.74	0.05
8						2.9%	0.83	-0.07	-0.22	3.95**	2.73	0.05
9		Jun-98	Sep-08	123	3.2%	3.2%	1.38	--------	--------	3.38**	2.15	0.04
10						2.0%	0.54	0.17	0.45	3.26**	2.04	0.04
11		Jan-99	Sep-08	116	2.8%	2.6%	1.12	--------	--------	3.62**	2.34	0.05
12						3.1%	0.87	-0.08	-0.19	3.71**	2.29	0.05

Note: The base currency is USD. Estimation by OLS on monthly data. The passive long-only indexes are defined by (15). The significance for the regression coefficients is indicated by stars with * = significant at 10%, ** = 5%, *** = 1%, **** = 0.1%.

Appendix Table 1: Comparison of Monthly Excess Return from Two Data Sources, AIG-FP and WP/Reuters

Currency	Common Period	#Obs	AIG-FP		WM/Reuters	
			Mean (% p.a)	Annualized Volatility (%)	Mean (% p.a)	Annualized Volatility (%)
TWD (Taiwan Dollar)	Jan-97 to Sep-08	140	-0.14%	5.59%	-0.17%	5.70%
THB (Thai Baht)	Jan-97 to Sep-08	140	0.17%	15.00%	0.10%	14.68%
ZAR (South African Rand)	Jan-97 to Sep-08	140	0.32%	16.59%	0.32%	16.44%
TRY (Turkish Lira)	Jan-97 to Nov-00, Jan-02 to Sep-08	127	1.76%	13.17%	1.86%	13.35%
PHP (Philippine Peso)	Jan-97 to Sep-08	140	0.34%	10.82%	0.08%	10.12%
KRW (Korean Won)	Feb-02 to Sep-08	79	0.29%	7.93%	0.28%	7.94%
CNY (Chinese Yuan)	Feb-02 to Sep-08	79	-0.02%	1.29%	-0.02%	1.35%
IDR (Indonesian Rupiah)	Jan-97 to Feb-01, Jun-07 to Sep-08	64	0.30%	55.69%	0.44%	57.27%
PLN (Polish Zloty)	Feb-02 to Sep-08	79	1.05%	11.71%	1.04%	11.39%
CZK (Czech Koruna)	Mar-97 to Sep-08	138	0.61%	12.38%	0.60%	12.27%
CLP (Chilean Peso)	Mar-04 to Sep-08	54	0.33%	9.91%	0.35%	10.32%
MXN (Mexican Peso)	Mar-97 to Sep-08	138	0.56%	8.38%	0.56%	8.47%
SKK (Slovak Koruna)	Feb-02 to Sep-08	79	1.27%	10.71%	1.26%	10.49%
HUF (Hungarian Forint)	Dec-97 to Sep-08	129	0.77%	11.02%	0.77%	10.85%
COP (Colombian Peso)	Mar-04 to Sep-08	54	0.77%	12.70%	0.81%	12.67%
ARS (Argentine Peso)	Mar-04 to Sep-08	54	0.25%	4.50%	0.28%	4.51%
INR (Indian Rupee)	Mar-98 to Sep-08	126	0.34%	4.95%	0.19%	4.91%
BRL (Brazilian Real)	Mar-04 to Sep-08	54	1.76%	13.69%	1.77%	13.51%
ILS (Israeli Shekel)	Mar-04 to Sep-08	54	0.60%	7.84%	0.62%	7.87%
RUB (Russian Ruble)	Mar-04 to Sep-08	54	0.29%	4.47%	0.30%	4.54%

Note: Monthly data. The base currency is USD. See Note to Table 1 for how the monthly excess return is calculated from daily data and how the annualized volatility is defined. For each EM (emerging market) currencies, the mean and the annualized volatility are for the common period in which data are available from both sources, AIG-FP and WM/Reuters. WM/Reuters has repeated or missing observations between November 2000 and January 2002 for TRY and between February 2001 and June 2007 for IDR.

Appendix Table 2: Bid/offer Spreads and Roll Costs in Basis Points

EM20

Currency	Spot	1-month Outright Forward	
	Bid/offer Spread as Fraction of Mid	Bid/offer Spread as Fraction of Mid	Annualized Roll Cost
TWD (Taiwan Dollar)	11.5	16.4	29.1
THB (Thai Baht)	10.6	16.1	33.4
ZAR (South African Rand)	15.2	16.5	7.9
TRY (Turkish Lira)	30.5	37.2	42.0
PHP (Philippine Peso)	14.2	20.1	35.5
KRW (Korean Won)	5.6	18.8	79.1
CNY (Chinese Yuan)	0.0	4.9	29.4
IDR (Indonesian Rupiah)	9.8	14.1	25.9
PLN (Polish Zloty)	13.0	13.7	4.3
CZK (Czech Koruna)	12.9	13.7	4.8
CLP (Chilean Peso)	6.8	9.2	14.2
MXN (Mexican Peso)	4.6	5.3	4.6
SKK (Slovak Koruna)	14.7	17.6	17.1
HUF (Hungarian Forint)	13.9	16.7	17.0
COP (Colombian Peso)	9.3	20.8	69.0
ARS (Argentine Peso)	9.3	21.8	75.7
INR (Indian Rupee)	7.3	9.9	15.7
BRL (Brazilian Real)	10.2	19.7	57.3
ILS (Israeli Shekel)	17.7	20.8	18.7
RUB (Russian Ruble)	2.8	9.9	42.3
Average over Currencies	11.0	16.2	31.2

G9

Currency	Spot	1-month Outright Forward	
	Bid/offer Spread as Fraction of Mid	Bid/offer Spread as Fraction of Mid	Annualized Roll Cost
AUD (Australian Dollar)	5.5	6.0	2.3
CAD (Canadian Dollar)	4.5	5.8	3.4
JPY (Japanese Yen)	2.7	2.8	1.8
NZD (NZ Dollar)	7.6	5.8	5.7
NOK (Norwegian Krona)	7.1	7.1	4.0
SEK (Swedish Krona)	5.4	5.3	3.5
CHF (Swiss Franc)	5.0	4.6	2.4
GBP (British Pound)	2.3	2.7	1.4
EUR (Euro)	2.2	2.1	0.9
Average over Currencies	4.7	4.7	2.8

Note: In basis points. The base currency is USD. The source is WM/Reuters. Averages of end-of-month values. The sample period is March 2004-September 2008 (except for IDR whose sample period is June 2007-September 2008). The roll cost equals 0.5 times the difference between the forward bid/offer spread and the spot bid/offer spread multiplied by 12. The spot bid/offer spread for CNY is zero because for CNY only a single rate is quoted.

Appendix Table 3: Post East Asian Crisis Summary Statistics for EM20 (Sample ending September 2008)

Currency	Start Date	#Obs	Excess Return $\equiv (S_{t+1} - F_t)/F_t$						Carry $\equiv (S_t - F_t)/F_t$ (% p.a.)			Spot Return $(S_{t+1} - S_t)/S_t$
			Mean (% p.a.)	Annualized Volatility	Sharpe Ratio	*t*-value for Mean	rho(1)	average correlation	Mean	Max	Min	Mean (% p.a.)
TWD (Taiwan Dollar)	Jun-98	123	-0.1%	5.0%	-0.01	-0.04	0.19**	0.25	-0.9%	18.1%	-15.5%	0.9%
THB (Thai Baht)	Jun-98	123	4.5%	9.0%	0.50	1.60	0.00	0.20	2.1%	22.5%	-3.2%	2.4%
ZAR (South African Rand)	Jun-98	123	5.3%	17.2%	0.31	0.99	-0.05	0.18	7.1%	20.8%	2.1%	-1.8%
TRY (Turkish Lira)	Jun-98	123	21.3%***	17.8%	1.20	3.83	-0.06	0.11	35.2%	127.3%	7.4%	-13.2%
PHP (Philippine Peso)	Jun-98	123	6.3%**	8.0%	0.78	2.49	-0.06	0.19	7.1%	104.9%	-21.8%	-0.8%
KRW (Korean Won)	Jun-98	123	4.0%	9.6%	0.42	1.33	0.05	0.21	1.8%	29.0%	-4.4%	2.2%
CNY (Chinese Yuan)	Jun-98	123	0.7%*	1.2%	0.61	1.95	0.24**	0.03	-1.2%	13.0%	-11.7%	1.9%
IDR (Indonesian Rupiah)	Jun-98	123	18.5%**	24.7%	0.75	2.40	0.18**	0.13	11.3%	64.0%	-2.0%	6.9%
PLN (Polish Zloty)	Jun-98	123	10.7%**	11.9%	0.90	2.87	0.01	0.31	5.8%	19.4%	-1.4%	4.8%
CZK (Czech Koruna)	Jun-98	123	8.0%**	12.3%	0.65	2.07	-0.01	0.28	0.4%	10.2%	-3.3%	7.6%
CLP (Chilean Peso)	Jun-98	123	0.9%	9.7%	0.09	0.30	0.07	0.20	2.3%	19.3%	-0.6%	-1.3%
MXN (Mexican Peso)	Jun-98	123	6.9%**	8.5%	0.81	2.60	0.00	0.12	8.3%	34.3%	1.6%	-1.4%
SKK (Slovak Koruna)	Jun-98	123	9.1%**	10.4%	0.88	2.80	0.10	0.28	3.4%	29.3%	-2.1%	5.7%
HUF (Hungarian Forint)	Jun-98	123	9.8%**	11.2%	0.87	2.80	-0.01	0.30	6.4%	21.9%	0.8%	3.4%
COP (Colombian Peso)	Jun-98	123	3.2%	11.0%	0.29	0.92	0.16*	0.16	7.0%	30.0%	-1.1%	-3.7%
ARS (Argentine Peso)	Jun-98	123	12.9%**	15.4%	0.83	2.67	-0.26**	0.02	24.8%	600.0%	-2.1%	-8.5%
INR (Indian Rupee)	Jun-98	123	4.7%**	4.8%	0.98	3.12	0.20**	0.20	5.4%	17.5%	-3.2%	-0.7%
BRL (Brazilian Real)	Jun-98	123	9.3%	19.8%	0.47	1.50	0.15*	0.15	11.9%	41.0%	-25.1%	-2.5%
ILS (Israeli Shekel)	Sep-00	96	4.6%*	7.8%	0.60	1.69	0.10	0.10	2.2%	8.0%	-1.6%	2.4%
RUB (Russian Ruble)	Jun-01	87	5.1%***	3.9%	1.29	3.48	0.24**	0.29	3.0%	18.4%	-4.4%	2.0%

Note: Monthly data. The base currency is USD. See Note to Table 1 for how the statistics are defined and calculated. The difference from Table 1 is that, except for ILS and RUB, the start date is moved to June 1998 (so that the first excess return observation is from June to July 1998 and the first carry observation is for the end of June 1998).

Appendix Table 4: Summary Statistics with 3-Month Forward Rates (Sample Ending September 2008)

Panel A: EM20 (Data Source: AIG-FP)

Currency	#Obs	Excess Return $\equiv (S_{t+3} - F_t)/F_t$				Carry $\equiv (S_t - F_t)/F_t$ (% p.a.)		
		Mean (% p.a.)	Annualized Volatility	Sharpe Ratio	*t*-value for Mean	Mean	Max	Min
TWD (Taiwan Dollar)	145	-1.5%	3.7%	-0.40	-1.09	-0.6%	11.5%	-9.2%
THB (Thai Baht)	145	1.8%	8.9%	0.20	0.55	3.0%	34.6%	-2.2%
ZAR (South African Rand)	145	4.0%	9.5%	0.42	1.15	7.4%	17.4%	2.0%
TRY (Turkish Lira)	145	19.6%****	10.2%	1.92	5.34	42.7%	137.4%	7.5%
PHP (Philippine Peso)	141	3.3%	6.6%	0.50	1.38	7.4%	66.0%	-6.6%
KRW (Korean Won)	139	2.4%	8.9%	0.27	0.73	3.2%	36.0%	-5.0%
CNY (Chinese Yuan)	139	0.9%**	1.0%	0.92	2.41	-0.8%	14.0%	-12.1%
IDR (Indonesian Rupiah)	138	8.0%	23.5%	0.34	0.97	11.6%	64.0%	0.7%
PLN (Polish Zloty)	137	10.8%****	6.5%	1.67	4.65	7.2%	21.0%	-1.4%
CZK (Czech Koruna)	136	7.9%**	6.8%	1.15	3.15	1.4%	18.3%	-3.3%
CLP (Chilean Peso)	136	1.1%	5.7%	0.20	0.52	2.6%	13.3%	-0.2%
MXN (Mexican Peso)	136	7.2%****	4.9%	1.48	4.06	9.3%	35.5%	1.6%
SKK (Slovak Koruna)	133	10.4%****	6.3%	1.64	4.36	5.0%	29.4%	-1.6%
HUF (Hungarian Forint)	127	9.6%****	6.3%	1.51	3.97	6.4%	19.0%	0.8%
COP (Colombian Peso)	126	5.0%*	6.8%	0.74	1.92	7.9%	28.7%	0.3%
ARS (Argentine Peso)	126	11.4%**	12.9%	0.88	2.22	22.7%	333.3%	-0.1%
INR (Indian Rupee)	124	4.1%**	3.2%	1.29	3.25	4.8%	15.2%	-1.8%
BRL (Brazilian Real)	121	11.3%**	12.0%	0.94	2.43	12.7%	37.9%	-8.9%
ILS (Israeli Shekel)	94	4.6%**	4.7%	0.99	2.21	2.2%	7.8%	-1.6%
RUB (Russian Ruble)	85	6.2%****	2.6%	2.41	5.17	3.6%	15.9%	-1.7%

Panel B: G9 (Data Source: WM/Reuters)

Currency	#Obs	Excess Return $\equiv (S_{t+3} - F_t)/F_t$				Carry $\equiv (S_t - F_t)/F_t$ (% p.a.)		
		Mean (% p.a.)	Annualized Volatility	Sharpe Ratio	*t*-value for Mean	Mean	Max	Min
AUD (Australian Dollar)	138	3.1%	6.4%	0.49	1.31	1.4%	5.0%	-1.0%
CAD (Canadian Dollar)	138	2.5%	4.3%	0.57	1.55	-0.2%	2.1%	-2.5%
JPY (Japanese Yen)	138	-2.1%	6.4%	-0.34	-0.90	-3.8%	-1.1%	-6.8%
NZD (NZ Dollar)	138	3.4%	7.1%	0.48	1.28	2.5%	6.2%	-1.1%
NOK (Norwegian Krona)	138	3.1%	6.2%	0.51	1.41	0.8%	5.6%	-2.5%
SEK (Swedish Krona)	138	1.3%	5.8%	0.22	0.61	-0.6%	2.7%	-3.1%
CHF (Swiss Franc)	138	0.6%	5.8%	0.11	0.30	-2.5%	0.1%	-4.6%
GBP (British Pound)	138	2.7%*	3.9%	0.71	1.95	1.2%	3.4%	-0.8%
EUR (Euro)	114	3.2%	5.9%	0.55	1.36	-0.5%	1.8%	-2.9%

Note: Monthly data. The base currency is USD. The sample period same as in Table 1. "rho(1)" is the sample first-order autocorrelation coefficient. The significance for the mean excess return and rho(1) are indicated by stars with * = significant at 10%, ** = 5%, *** = 1%, **** = 0.1%. ER_{t+3} = excess return $\equiv (S_{t+3} - F_t)/F_t$, $carry_t \equiv (S_t - F_t)/F_t$, where S_t and F_t are spot and 3-month forward rates, stated in U.S. Dollars per unit of foreign currency. See Appendix 1 for how the monthly data on 3-month excess return series and the carry are calculated. The excess return and the carry are at annual rates, with 3-month rates multiplied by 4. The annualized volatility of the excess return is defined as the standard deviation (calculated as the square root of: the sum of squared deviations from the sample mean divided by the number of observations minus 1) of monthly excess returns at annual rates divided by the square root of 12. The mean excess return is the average of ER_{t+3} ($t = t_1, t_1+1, ..., t_2-3$), or equivalently, the average of ER_t ($t = t_1+3\ t_1+1, ..., t_2$), where t_1 is the start date indicated in Table 1 for each currency and t_2 is September 2008. So for example for TWD, the first excess return observation is from June to September 97 and the last observation is from March to September 2008. The mean carry is the average of $carry_t$ ($t = t_1, t_1+1, ..., t_2-3$). Therefore, ER_{t+3} is paired with $carry_t$. Because returns are overlapping (the return is over 3 months but the sampling interval is a month), the monthly returns are serially correlated, with autocorrelation possibly non-zero up to the second order. The *t*-value for the mean here incorporates this serial correlation structure with the Bartlett kernel allowing for serial correlation up to 2 lags. The first-order serial correlation coefficient is not reported because for the present case of overlapping returns (3-montn returns on monthly sampling intervals) the return is serially correlated under the null of Uncovered Interest Parity.

Appendix Table 5: Effect of Sampling Interval

Panel A: EM20 (Data Source: AIG-FP)

Currency	Monthly			Weekly			Daily		
	#Obs	Mean (% p.a.)	*t*-value for Mean	#Obs	Mean (% p.a.)	*t*-value for Mean	#Obs	Mean (% p.a.)	*t*-value for Mean
TWD (Taiwan Dollar)	147	-1.6%	-0.99	639	-1.8%	-1.42	3,175	-1.5%	-1.47
THB (Thai Baht)	147	2.0%	0.49	639	2.4%	0.84	3,176	2.0%	0.83
ZAR (South African Rand)	147	3.8%	0.76	639	4.0%	1.17	3,186	3.8%	1.32
TRY (Turkish Lira)	147	19.5%****	4.06	640	19.7%****	5.62	3,187	18.2%****	5.89
PHP (Philippine Peso)	143	4.1%	1.42	623	3.2%	1.57	3,090	3.3%*	1.85
KRW (Korean Won)	141	2.4%	0.60	613	2.0%	0.63	3,045	2.1%	0.79
CNY (Chinese Yuan)	141	0.8%	1.56	613	0.8%**	3.27	3,045	0.8%***	3.62
IDR (Indonesian Rupiah)	140	8.1%	0.76	609	7.1%	0.98	3,023	5.4%	0.88
PLN (Polish Zloty)	139	10.4%***	3.47	604	10.8%****	4.31	3,011	10.2%****	4.87
CZK (Czech Koruna)	138	7.3%**	2.09	600	7.5%**	2.74	2,991	7.2%**	3.23
CLP (Chilean Peso)	138	0.4%	0.16	601	-0.3%	-0.13	2,979	0.0%	0.01
MXN (Mexican Peso)	138	6.8%**	2.72	601	6.7%***	3.40	2,990	6.1%***	3.84
SKK (Slovak Koruna)	135	9.5%**	2.89	587	9.3%***	3.86	2,926	9.5%****	4.74
HUF (Hungarian Forint)	129	9.3%**	2.62	561	8.9%***	3.40	2,795	9.0%****	4.11
COP (Colombian Peso)	128	3.6%	1.01	558	3.2%	1.19	2,761	3.0%	1.37
ARS (Argentine Peso)	128	12.5%**	2.24	558	11.5%****	4.03	2,761	13.0%****	4.92
INR (Indian Rupee)	126	4.1%**	2.33	548	3.5%**	2.90	2,719	3.6%***	3.54
BRL (Brazilian Real)	123	9.3%	1.50	536	8.9%*	1.89	2,655	8.6%**	2.19
ILS (Israeli Shekel)	96	4.6%	1.59	415	4.6%**	2.20	2,060	4.6%**	2.62
RUB (Russian Ruble)	87	5.1%***	3.44	376	4.5%***	3.63	1,853	4.7%****	4.38

Panel B: G9 (Data Source: WM/Reuters)

Currency	Monthly			weekly			daily		
	#Obs	Mean (% p.a.)	*t*-value for Mean	#Obs	Mean (% p.a.)	*t*-value for Mean	#Obs	Mean (% p.a.)	*t*-value for Mean
AUD (Australian Dollar)	140	2.8%	0.75	610	2.0%	0.78	3,052	2.2%	1.04
CAD (Canadian Dollar)	140	2.3%	1.07	611	2.0%	1.38	3,053	2.1%*	1.70
JPY (Japanese Yen)	140	-2.0%	-0.67	611	-3.0%	-1.23	3,053	-2.1%	-1.04
NZD (NZ Dollar)	140	3.2%	0.79	610	2.6%	1.02	3,052	2.8%	1.29
NOK (Norwegian Krona)	140	2.7%	0.81	610	2.1%	0.88	3,052	2.1%	1.08
SEK (Swedish Krona)	140	0.8%	0.23	610	-0.4%	-0.16	3,052	0.1%	0.07
CHF (Swiss Franc)	140	0.3%	0.10	610	-0.4%	-0.17	3,052	-0.1%	-0.06
GBP (British Pound)	140	2.6%	1.18	610	1.8%	1.04	3,052	2.2%	1.54
EUR (Euro)	116	2.5%	0.71	506	2.0%	0.83	2,530	2.1%	1.05

Note: The base currency is USD. The sample period is the same as in Table 1 for each currency. The significance for the mean excess return is indicated by stars with * = significant at 10%, ** = 5%, *** = 1%, **** = 0.1%. The weekly overlapping 1-month excess return is defined as $(S_{OBS_t} - F_t)/F_t$ with t indicating the last business day of the week, where OBS_t is the observation date for the spot contract whose settlement date is the same as the settlement date for F_t. For daily returns, t is the business day. See Appendix 1 for details. Because returns are overlapping (the return is over one month but the sampling interval is a week or a day), the return is serially correlated. The *t*-value for the mean here incorporates serial correlation in the series with the Bartlett kernel that allows for serial correlation up to 11 lags for monthly series, 5 for weekly series, and 22 for daily series.

Appendix Table 6: Index Returns (Sample Period Ending in June 2008)

Index	Data Source	Start Date	End Date	#Obs	Simple Statistics of Index Excess Return							
					Mean (% p.a.)	Annualized Volatility	Sharpe Ratio	*t*-value for Mean	Skewness	Kurtosis	Jarque-Bera	rho(1)
EM20 (long-only defined by (15))	AIG-FP	Jan-97	Jun-08	137	6.0%**	6.5%	0.93	3.14	-0.15	6.52	71.3****	0.16 *
		Jun-98	Jun-08	120	7.9%****	5.1%	1.55	4.90	0.35	3.58	4.1	0.14
		Jan-99	Jun-08	113	7.2%****	4.6%	1.56	4.79	0.13	2.96	0.3	0.10
G9 (long-only defined by (15))	WM/Reuter s	Jan-97	Jun-08	137	2.3%	7.3%	0.31	1.06	0.55	2.97	6.9**	0.11
		Jun-98	Jun-08	120	4.0%*	7.5%	0.53	1.69	0.46	2.77	4.6	0.09
		Jan-99	Jun-08	113	3.7%	7.2%	0.50	1.55	0.44	2.57	4.4	0.14
long-EM20/short-G9 defined by (16)	AIG-FP for EM20, WM/Reuter s for G9	Jan-97	Jun-08	137	1.9%*	3.3%	0.56	1.91	-0.05	5.56	37.4****	0.01
		Jun-98	Jun-08	120	2.0%**	2.8%	0.70	2.21	-0.50	2.58	5.9*	-0.01
		Jan-99	Jun-08	113	1.8%**	2.7%	0.67	2.04	-0.56	2.68	6.4**	0.02

Note: See note to Table 2.

Appendix Table 7: Index Returns with Annual Rebalancing

Index	Start Date	End Date	#Obs	Simple Statistics of Index Excess Return							
				Mean (% p.a.)	Annualized Volatility	Sharpe Ratio	*t*-value for Mean	Skewness	Kurtosis	Jarque-Bera	rho(1)
EM20 (long-only defined by (15) for EM20)	Jan-97	Sep-08	140	5.2%**	7.4%	0.70	2.40	-0.47	7.29	112.8****	0.24**
	Jun-98	Sep-08	123	7.6%****	5.6%	1.36	4.36	0.30	4.45	12.6***	0.18*
	Jan-99	Sep-08	116	6.8%****	5.0%	1.36	4.23	-0.15	3.21	0.6	0.13
G9 (long-only G9 defined by (15) for G9)	Jan-97	Sep-08	140	1.6%	7.3%	0.22	0.74	0.50	3.06	5.8*	0.13
	Jun-98	Sep-08	123	3.2%	7.6%	0.42	1.35	0.41	2.85	3.5	0.12
	Jan-99	Sep-08	116	2.8%	7.3%	0.39	1.20	0.37	2.69	3.1	0.17*
long-EM20/short-G9 defined by (16)	Jan-97	Sep-08	140	2.1%**	3.5%	0.61	2.10	-0.02	5.17	27.4****	0.06
	Jun-98	Sep-08	123	2.5%**	2.9%	0.84	2.70	-0.40	2.86	3.4	-0.04
	Jan-99	Sep-08	116	2.2%**	2.7%	0.84	2.61	-0.50	2.68	5.4*	-0.02

Note: Monthly data. The base currency is USD. "rho(1)" is the sample first-order autocorrelation coefficient. The significance for the mean excess return, the Jarque-Bera statistic (a function of skewness and kurtosis, distributed chi-squared with two degrees of freedom under the null of normality), and rho(1) are indicated by stars with * = significant at 10%, ** = 5%, *** = 1%, **** = 0.1%. If rebalancing occurred monthly, the index excess return would be defined by (15) for EM20 and G9, and the long-short index defined by (16). With annual rebalancing, the basket of constituent currencies is determined by the availability of the excess return from January to February and is fixed over the 12 month cycle. So if data on a currency become available during a cycle, the currency is included in the next January. During the 12-month cycle, no rebalancing between the currencies within the fixed basket takes place. If the start date is not January, the basket of constituent currencies until January of the following year is those whose excess return is available from the start date to the next month. The excess return is stated at an annual rate, with monthly values multiplied by 12. See Note to Table 1 for how the annualized volatility, the Sharpe ratio, the *t*-value, and the significance of rho(1) are calculated. The constituents of "G9" before January 1999 (when the Euro started to trade) are (AUD, CAD, JPY, NZD, SEK, NOK, CHF, GBP, DEM, FRF, ITL). The legacies (DEM, FRF, ITL) are later replaced by EUR. For the reason stated in Note to Table 6, ILS enters the constituents of the EM20 index in October 2000, not September 2000.

Appendix Table 8: "Fama Regression": $\log(S_{t+1}) - \log(S_t) = \alpha + \beta \cdot (\log(F_t) - \log(S_t)) + u_t$

Panel A: EM20 (Data Source: AIG-FP)

Currency	#Obs	α (% p.a.)	Std. Error (% p.a.)	*t*-value for α	β	Std. Error	*t*-value for $\beta=1$	R^2	*SER* (% p.a.)
TWD (Taiwan Dollar)	147	-1.7%	1.6%	-1.06	0.93	0.47	-0.16	0.03	5.5%
THB (Thai Baht)	147	3.5%	4.8%	0.74	1.76	0.73	1.05	0.04	14.4%
ZAR (South African Rand)	147	-17.4%	10.7%	-1.63	-1.59	1.25	-2.06	0.01	16.1%
TRY (Turkish Lira)	147	10.0%	9.2%	1.09	0.80	0.19	-1.03	0.11	17.2%
PHP (Philippine Peso)	143	-4.3%	3.5%	-1.23	0.07	0.23	-4.12	0.00	10.1%
KRW (Korean Won)	141	6.4%	4.1%	1.54	2.15	0.36	3.20	0.20	13.2%
CNY (Chinese Yuan)	141	1.2%***	0.3%	3.88	0.57	0.08	-5.48	0.27	1.0%
IDR (Indonesian Rupiah)	140	-40.3%**	17.2%	-2.34	-2.49	1.06	-3.31	0.04	41.9%
PLN (Polish Zloty)	139	9.4%*	5.2%	1.81	0.95	0.53	-0.10	0.02	11.5%
CZK (Czech Koruna)	138	5.3%	3.8%	1.41	0.29	0.70	-1.02	0.00	12.3%
CLP (Chilean Peso)	138	1.4%	3.5%	0.41	1.58	0.87	0.67	0.02	9.3%
MXN (Mexican Peso)	138	-4.2%	4.0%	-1.06	-0.17	0.35	-3.32	0.00	8.1%
SKK (Slovak Koruna)	135	7.9%**	3.8%	2.11	0.78	0.47	-0.47	0.02	10.1%
HUF (Hungarian Forint)	129	2.0%	6.5%	0.30	0.00	0.83	-1.21	0.00	11.0%
COP (Colombian Peso)	128	2.3%	5.0%	0.46	0.91	0.50	-0.19	0.03	11.0%
ARS (Argentine Peso)	128	11.6%**	4.9%	2.38	1.02	0.07	0.22	0.60	15.0%
INR (Indian Rupee)	126	0.4%	2.6%	0.15	0.34	0.38	-1.75	0.01	4.9%
BRL (Brazilian Real)	123	1.7%	11.6%	0.15	0.54	0.81	-0.57	0.00	21.4%
ILS (Israeli Shekel)	96	3.4%	3.7%	0.92	0.58	1.10	-0.39	0.00	7.8%
RUB (Russian Ruble)	87	4.2%**	1.7%	2.43	0.75	0.31	-0.81	0.06	3.9%

Panel B: G9 (Data Source: WM/Reuters)

Currency	#Obs	α (% p.a.)	Std. Error (% p.a.)	*t*-value for α	β	Std. Error	*t*-value for $\beta=1$	R^2	*SER* (% p.a.)
AUD (Australian Dollar)	140	-4.0%	4.3%	-0.94	-3.12	1.85	-2.22	0.02	11.2%
CAD (Canadian Dollar)	140	2.7%	2.1%	1.29	-2.60	1.94	-1.85	0.01	7.1%
JPY (Japanese Yen)	140	4.0%	7.6%	0.52	-0.73	1.82	-0.95	0.00	10.5%
NZD (NZ Dollar)	140	-5.3%	5.7%	-0.93	-2.04	1.80	-1.69	0.01	11.6%
NOK (Norwegian Krona)	140	-0.3%	3.3%	-0.10	-1.89	1.27	-2.28	0.02	10.6%
SEK (Swedish Krona)	140	2.2%	3.1%	0.73	-2.57	1.59	-2.25	0.02	10.0%
CHF (Swiss Franc)	140	10.7%*	5.5%	1.95	-3.39	1.91	-2.30	0.02	9.6%
GBP (British Pound)	140	0.0%	3.2%	-0.01	-0.93	1.86	-1.04	0.00	7.6%
EUR (Euro)	116	4.0%	3.0%	1.33	-3.49	1.84	-2.45	0.03	9.0%

Note: Estimation by OLS on monthly data. The base currency is USD. The sample period is the same as in Table 5 for each currency. For α, * = significant at 10%, ** = 5%, *** = 1%, **** = 0.1%. S_t and F_t are spot and 1-month forward rates, stated in U.S. Dollars per unit of foreign currency. The spot return (the log difference in the spot rate, which is the dependent variable) and the (negative) carry (here the log difference between forward and spot rates, which is the regressor) are at annual rates, with monthly values multiplied by 12. See Note to Table 5 for how the statistics shown here are calculated.

Figure 1: Cumulative USD Excess Returns, EM 20 and G9, June 1998=100

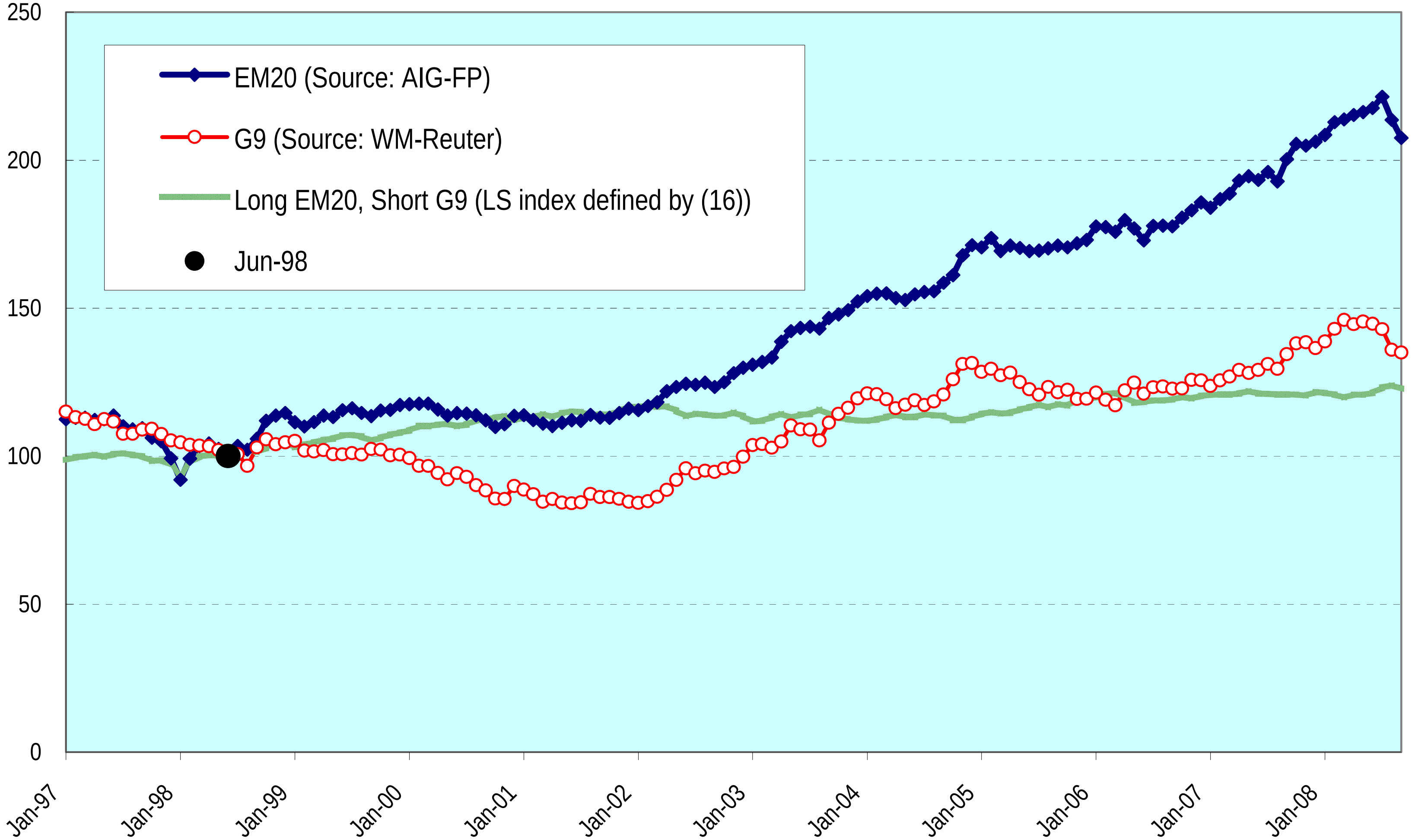


Figure 2A: Cross-Section Plot of Mean ER against Mean Carry

January 1997-March 2004

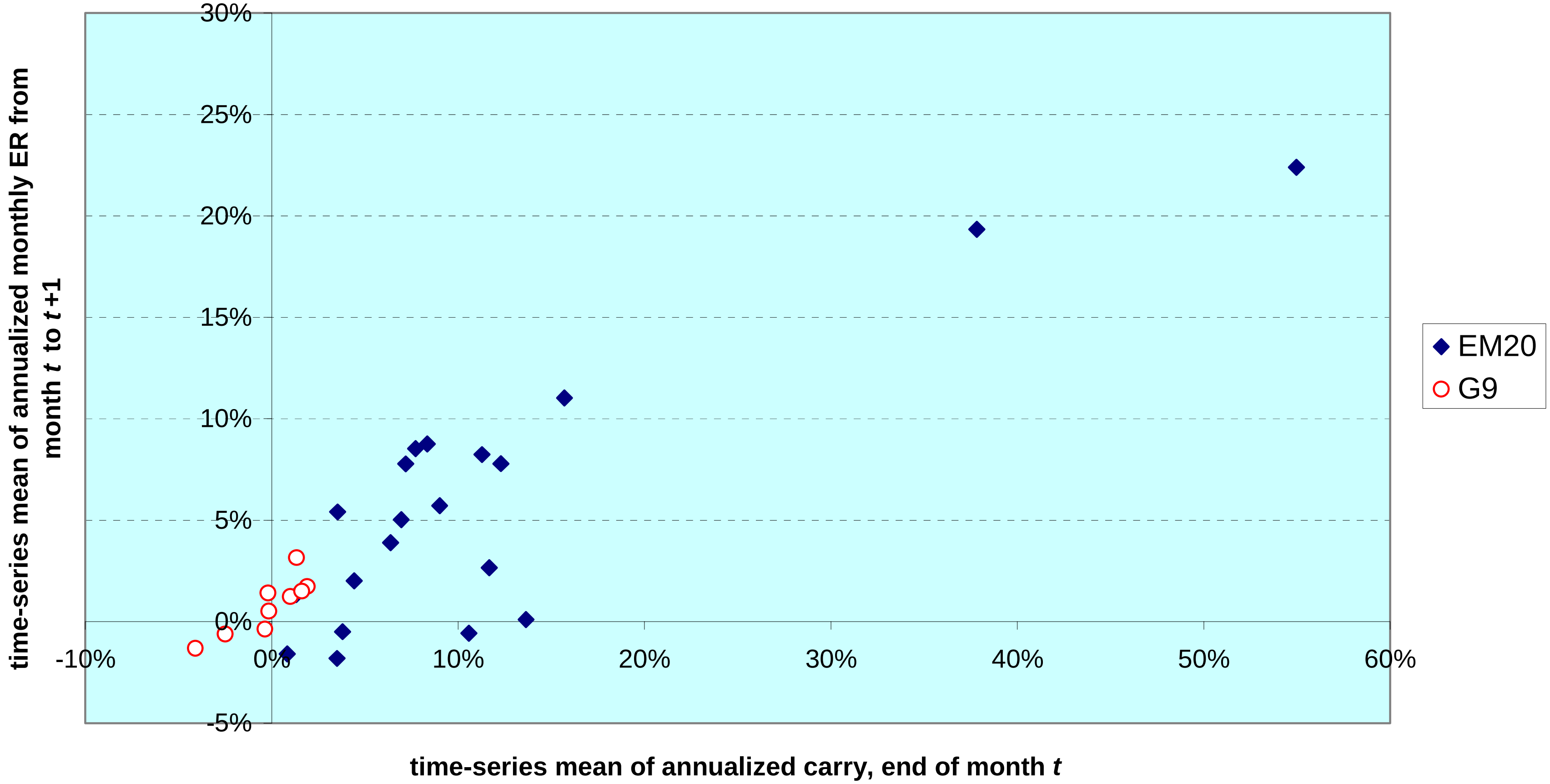


Figure 2B: Cross-Section Plot of Mean ER against Mean Carry

March 2004-September 2008

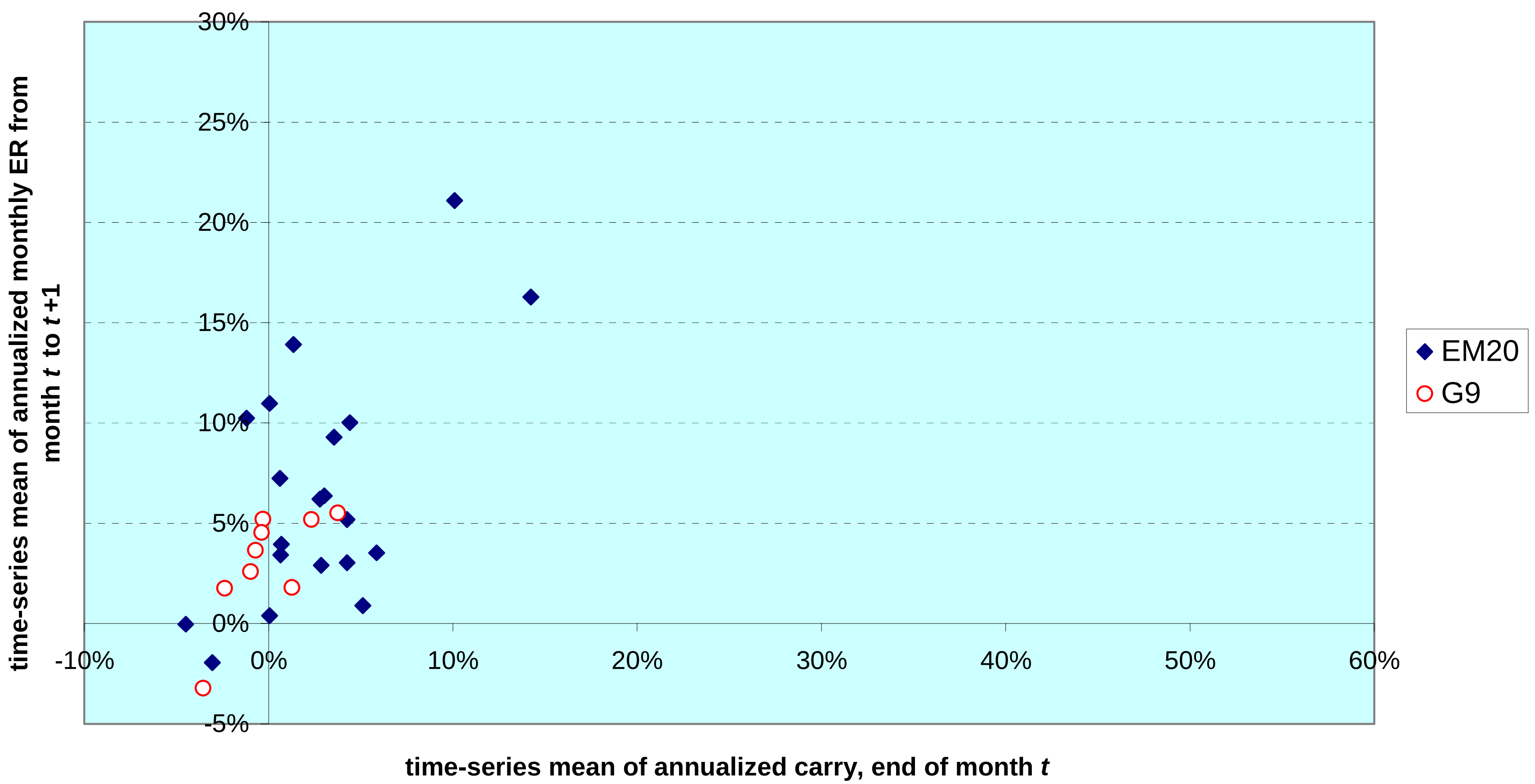
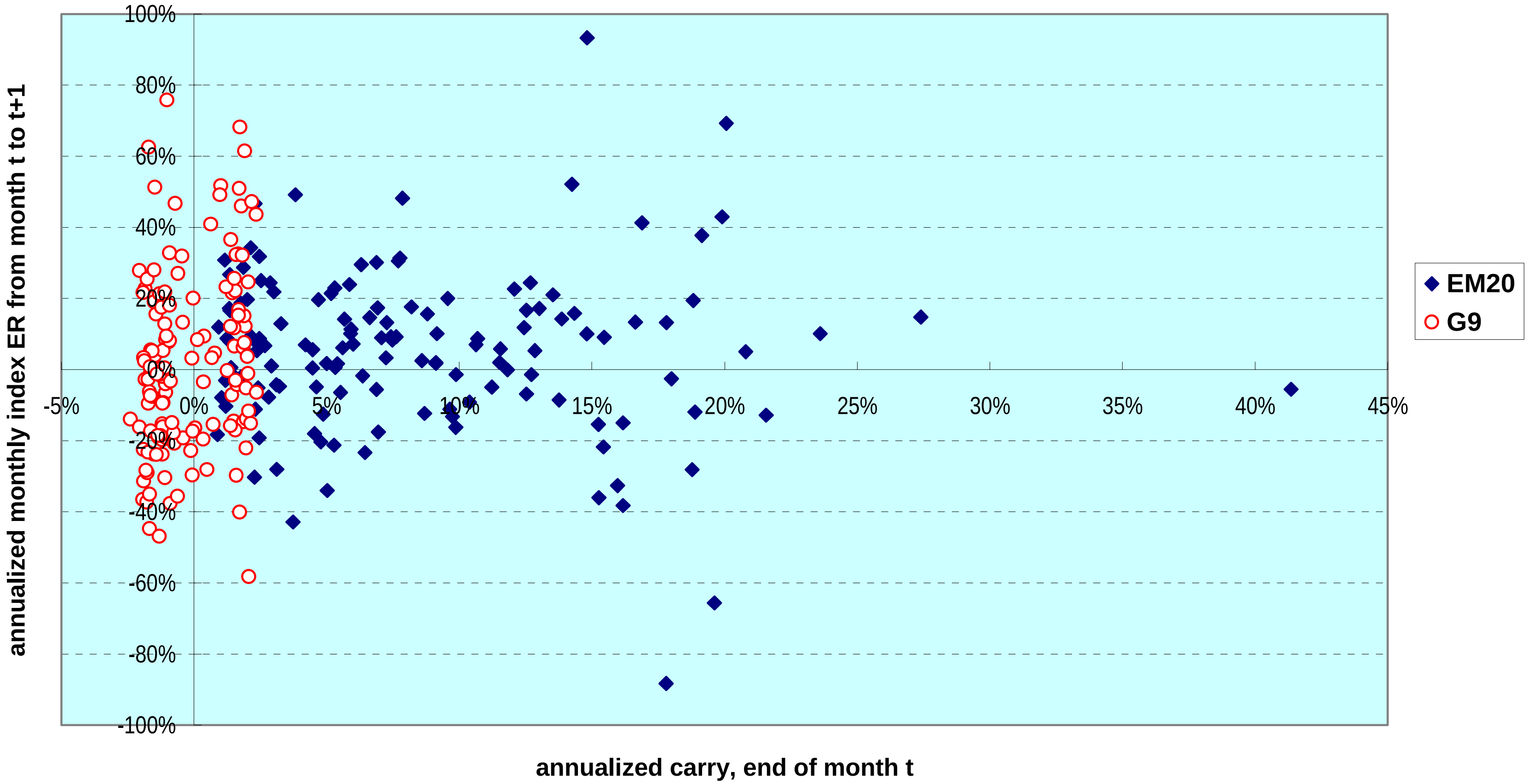
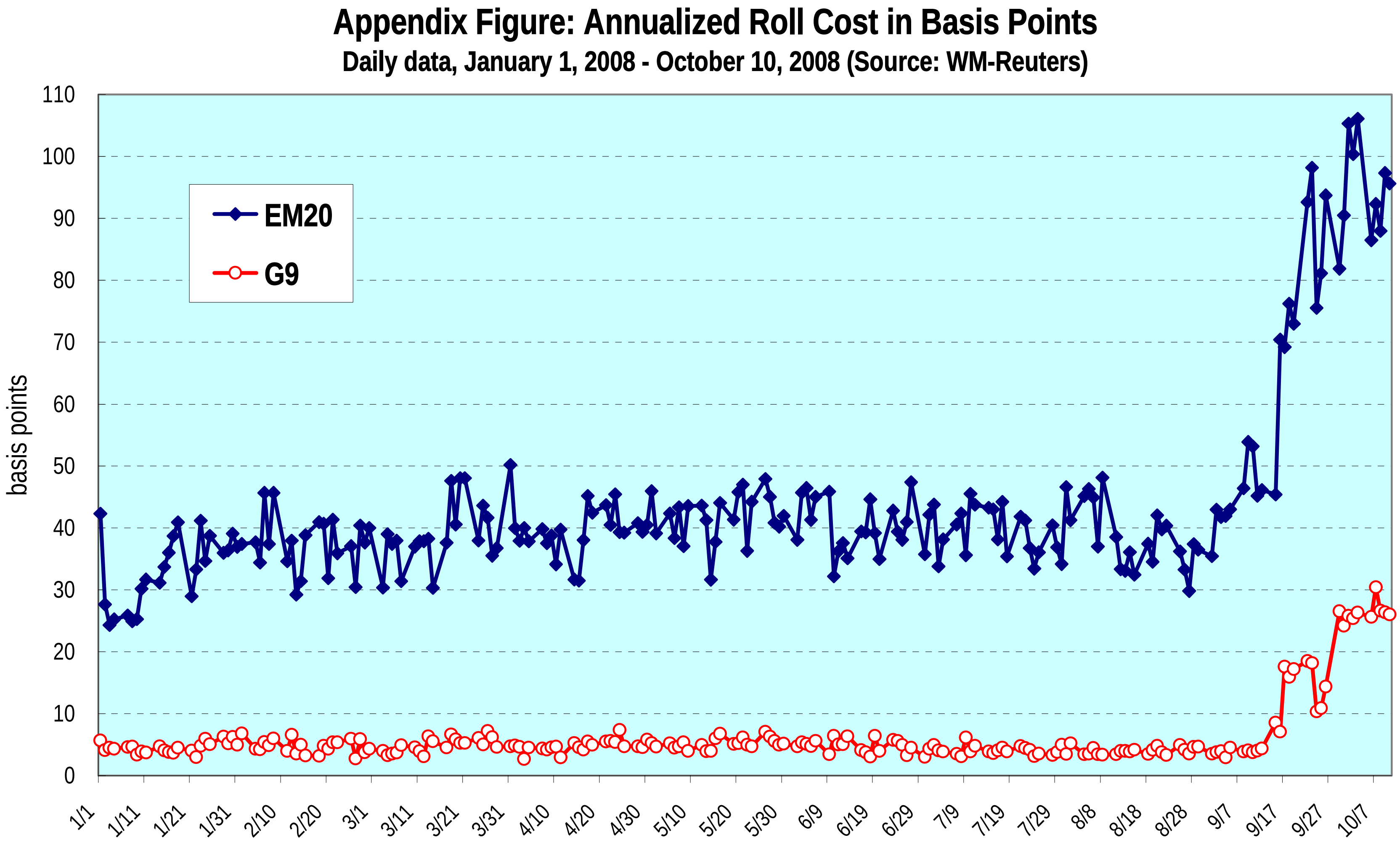


Figure 3: Time-Series Plot of Index ER against Carry

January 1997-September 2008





Appendix Figure: Annualized Roll Cost in Basis Points
Daily data, January 1, 2008 - October 10, 2008 (Source: WM-Reuters)
basis points
EM20
G9
0
10
20
30
40
50
60
70
80
90
100
110
1/1
1/11
1/21
1/31
2/10
2/20
3/1
3/11
3/21
3/31
4/10
4/20
4/30
5/10
5/20
5/30
6/9
6/19
6/29
7/9
7/19
7/29
8/8
8/18
8/28
9/7
9/17
9/27
10/7