Appendixes to "Emerging Market Currency Excess Returns" by Stephen Gilmore and Fumio Hayashi, February 2011 version

Appendix A: Documentation of the Monthly File

This appendix describes how we created the monthly file, on which all the results of the text (except for Figure 3, which is about daily bid/offer spreads) are based, from daily observations on spot and forward rates.

A.1. Daily Files

Our procedure for creating the monthly file utilizes two files of daily observations. One, to be referred to as the Delivery Date File, was provided to us by AIG-FP (AIG Financial Products International, Incorporated). It gives the delivery dates of spot and forward contracts against USD for all weekdays between January 1980 and December 2011 for a large number of currencies including EM20 (the 20 emerging market currencies) and G9 (the 9 major currencies) listed in Table 1 and legacy currencies DEM, FRF, ITL. We write DEL_{jt} for the delivery date of a j-month forward contract and DEL_{0t} for that of a spot contract, traded on observation date t. This DEL_{0t} will be referred to as the *spot delivery date*. We also write OBS_{jt} for the observation date whose spot delivery date coincides with DEL_{jt}.

To provide an example, here is an extract of the Delivery Date File for JPY:

t	DEL_{0t}	DEL_{1t}	DEL_{2t}	DEL_{3t}
Wed, March 25, 2009	Friday, March 27, 2009	Monday, April 27, 2009	Wed, May 27, 2009	Monday, June 29, 2009
Thursday, March 26, 2009	Monday, March 30, 2009	Thursday, April 30, 2009	Friday, May 29, 2009	Tuesday, June 30, 2009
Friday, March 27, 2009	Tuesday, March 31, 2009	Thursday, April 30, 2009	Friday, May 29, 2009	Tuesday, June 30, 2009
Monday, March 30, 2009	Wed, April 01, 2009	Friday, May 01, 2009	Monday, June 01, 2009	Wed, July 01, 2009
Tuesday, March 31, 2009	Thursday, April 02, 2009	Thursday, May 07, 2009	Tuesday, June 02, 2009	Thursday, July 02, 2009
...	...	...	...	...
Friday, April 24, 2009	Tuesday, April 28, 2009	Thursday, May 28, 2009	Monday, June 29, 2009	Tuesday, July 28, 2009
Monday, April 27, 2009	Thursday, April 30, 2009	Friday, May 29, 2009	Tuesday, June 30, 2009	Friday, July 31, 2009
Tuesday, April 28, 2009	Friday, May 01, 2009	Monday, June 01, 2009	Wed, July 01, 2009	Monday, August 03, 2009
Wed, April 29, 2009	Friday, May 01, 2009	Monday, June 01, 2009	Wed, July 01, 2009	Monday, August 03, 2009
Thursday, April 30, 2009	Thursday, May 07, 2009	Monday, June 08, 2009	Tuesday, July 07, 2009	Friday, August 07, 2009

For example, for t = Thursday, March 26, 2009 in the above delivery date schedule, we have: DEL_{1t} = Thursday, April 30, 2009 and OBS_{1t} = Monday, April 27, 2009. It is possible that multiple days qualify as OBS_{jt}: an observation date of $t =$ Monday, March 30, 2009 has DEL_{1t} = Friday, May 1, 2009, and two observation dates, April 28 and April 29, share the same spot delivery date of May 1. As this JPY example illustrates, it appears that national holidays of the country of the counter currency are not a delivery day (Wednesday, April 29, 2009 is a Japanese national holiday).

The other file is what we call the Price File, which has daily observations on the over-the-counter spot and forward rates against USD for EM20 and G9. There are two data sources for daily exchange rates. AIG-FP provided us with daily observations on spot, 1-, 2-, and 3-month forward mid rates for EM20 currencies, many of which date back to as early as the late 1990s. The last observation is for April 19, 2010. We also obtained, via *Datastream*, the WM/Reuters Historic Rate Data on spot and forward rates for a large set of countries including G9 since December 31, 1996 as well as EM20 (from December 31, 1996 for a small subset and from 2004 for the rest of the 20 EM currencies). Unlike the AIG-FP data, the WM/Reuters data have bid and offer rates in addition to mid rates[1] and can be updated to the latest date. Both sources provide daily observations for virtually all weekdays (literally all weekdays, in the case of WM/Reuters) including national holidays, because exchange rates can be sampled from multiple international financial centers. For example, there is an observation on the JPY/USD exchange rate for Wednesday, April 29, 2009 (a Japanese national holidy).

However, observations are available for (virtually) all weekdays, only because of repetitions. For example, the exchange rate values reported for December 25 can be the same as those reported for the most recent pre-Christmas weekday. The G9 in the WM/Reuters data have very few repetitions, about 1% of weekdays. Those repetitions are probably for weekdays that are not a business day, such as December 25 when global financial centers are all closed. Regarding EM20, for both AIG-FP and WM/Reuters, observations after excluding repetitions are relatively scarce for a small subset of currencies for several years. Also, although very rare except for IDR for January 14, 2003 through June 1, 2007 and TRY for November 29, 2000 through January 24, 2001 in WM-Reuters data, the forward rates are equal to the spot rate that is not constant over time. Appendix Table 1 reports the number of non-repetitive observations (observations after removing: repeated observations[2] and those with the forward rates being mere copies of the spot rate) by year for EM20. It shows that the two data sources, when both are available, provide similar coverage,

[1] In very rare cases, the bid rate is greater than the offer rate. For those cases we change the bid and offer rates so that the mid rate remains the same and the bid-offer spread as a ratio of the mid rate is some prescribed value (2 basis points for EM20 and 1 basis point for G9).

[2] An observation for the day is deemed a repetition if the values of the three forward rates (1-, 2- and 3-month) are the same as those from the previous weekday. The criterion would be stricter if we also required the spot rate to be the same as that from the previous weekday. But then the observation for the day would not be a repetition if (as occurs in the WM/Reuters data for, e.g., TRY for 2001) the spot rate is updated for the day but the forward rates are not. This leads to an erroneous calculation of the carry (the forward premium).

except for TRY in 1997-1999 and particularly 2002 (when WM/Reuters has more observations) and IDR (AIG-FP has more).

Since AIG-FP covers longer periods than WM/Reuters, we take the AIG-FP data to be the primary data source for EM20. There can be pros and cons about use of repeated observations. Exchange rate values in data are carried over from the previous business day, maybe because the market didn't show much movements (e.g., ARS and CNY under the (virtual) fixed exchange rate regime), or maybe because the market was closed or the liquidity was severely limited. Since it would be impossible or very time-consuming for us to go to each incidence of repeated observations and determine which is the case, we decided to exclude, for the most part, repeated observations. Exceptions are:

(a) (Importation from WM-Reuters) There are weekdays for which AIG-FP does not provide non-repetitive observations but WM/Reuters does. We assume that they are business days, with some financial centers providing the exchange rate information. We import those WM/Reuters observations for those weekdays. This occurs primarily for TRY for 1997-1999 and 2002.

(b) (Retention of repeated observations) All the daily observations from AIG-FP are kept for the following currencies and periods:

ARS under the (credible) fixed exchange rate regime (until the end of September 2000),
CNY until the end of August 2003 (when the spot rate was virtually fixed),
TRY from June to November 2001, and
CLP from January 1998 to May 2000.

TRY and CLP in AIG-FP have only one observation (in the case of TRY) or only several (CLP) for those indicated months. Even for those months, the last weekday of the month is sampled in data. For this reason we supposed that the reason for the infrequency of observations was not that the markets were closed.

The last day in the AIG-FP data on EM20 is April 19, 2010. To extend the period to the latest date, we append to the AIG-FP data the non-repetitive observations from WM/Reuters for observation dates after April 19, 2010. The daily observations created this way are our Price File for EM20.

For G9, the Price File is the non-repetitive daily observations from WM/Reuters.

A.2. A Matrix of Daily Observations

We write F_{jt} for the j-month forward rate and S_t for the spot rate on observation date t, stated in the foreign currency unit per USD. For each currency, the Price File provides a matrix of five columns whose typical row is $(t, S_t, F_{1t}, F_{2t}, F_{3t})$. The set of observation dates and hence the number of rows differ across currencies. From the Delivery Date File and the Price File we create a matrix for the same set of observation dates in the Price File. Its typical row is

$$t,\ DEL_{0t},\ S_t, (F_{jt}, DEL_{jt},\ OBS_{jt},\ S_{OBS_{jt}}),\ \ j = 1, 2, 3. \tag{A1}$$

The excess return from a j-month forward contract traded on date t is calculated as $F_{jt} / S_{OBS_{jt}} - 1$ and the carry on date t is $F_{jt} / S_t - 1$.

For each given observation t in the Price File, we can easily obtain (S_t, F_{jt}) from the Price File and (DEL_{0t}, DEL_{jt}) from the Delivery Date File (which covers all weekdays). Far less straightforward is to determine OBS_{jt}. We first obtain from the Price File the first and last observation dates for which the spot rate is available. Then turn to the Delivery Date File to find the associated first and last spot delivery dates (delivery dates for spot contracts). Hereafter we temporarily drop the subscript j for the forward contract in question. The following steps determine OBS_t for each observation date t in the Price File.

1. From the Delivery Date File, obtain DEL_t from the record corresponding to t.
2. If DEL_t is earlier than the first spot delivery date or later than the last spot delivery date just defined, we declare that OBS_t and S_{OBS_t} are not available, by assigning them the missing value. Otherwise, proceed as below.
3. From the Delivery Date File, we look for observation dates whose spot delivery date is DEL_t. The following exhausts all the possible cases.
   (a) There is only one such date in the Delivery Date File (i.e., the set $\{s \mid DEL_{0s} = DEL_t\}$ is a singleton). (An example in the JPY delivery schedule shown in Section 1 above is $t =$ March 26, 2009 with $DEL_{1t} =$ April 30. There is only one observation day, April 27, whose spot delivery date is April 30.) We turn to the Price File. There are two possibilities.
      i. If the Price File has an observation corresponding to that date, we determine OBS_t to be this date. (In the current example, if the Price File has April 27, then OBS_{1t} = April 27.)
      ii. Otherwise, we determine OBS_t to be the earliest observation date after that date in the Price File. (In the current example, if the Price File has April 28 but not April 27, then OBS_{1t} = April 28.) The underlying trading strategy is to receive the counter currency on DEL_t, hoard or lend the currency, and

(b) There are multiple such dates in the Delivery Date File. (An example in the JPY schedule shown in Section 1 is $t =$ March 30, 2009 with $DEL_{1t} =$ May 1. There are two observation dates, April 28 and April 29, whose spot delivery date is May 1.) From those multiple observation dates we select the set of dates, each of which has an observation in the Price File. There are two possibilities.

i. This set is not empty. OBS_t is the last date of this non-empty set. (In the current example, if the Price File has both April 28 and April 29, then OBS_{1t} = April 29.)

ii. This set is empty. We determine OBS_t to be the earliest observation date after the last of those multiple observation dates in the Price File. (In the current example, if the Price File has neither April 28 nor April 29 but has April 30, then OBS_{1t} = April 30). The underlying trading strategy is the same as in (a-ii).

(c) There is no such date in the Delivery Date File. (This occurs for IDR, PHP, CNY, TWD, MXN, ARS, and JPY a very few times in the periods shown in Table 1.) We turn to the earliest spot delivery date after DEL_t in the Delivery Date File such that the associated observation dates in the Delivery Date File have at least one corresponding observation in the Price File. We determine OBS_t to be the last date of those corresponding observations in the Price File. (If DEL_t is the last spot delivery date defined above, then this procedure is infeasible, but this did not arise in our data.) This procedure would correctly identify OBS_t if the true delivery date is not DEL_t (as given in the Delivery Date File) but the spot delivery date as determined above. If the true delivery date is before this spot delivery date, the underlying investment strategy is as described for case (a-ii) and (b-ii). Otherwise, the strategy involves borrowing the counter currency on the spot delivery date until the true delivery date.

The spot rate on OBS_t thus determined in cases (a)-(c) is available because DEL_t is between the first and the last spot delivery dates defined above.

The data challenges identified in (a-ii) and (b-ii) can occur because the Price File does not have observations on all business days. The date misalignment described in (c) can occur perhaps because there was an unscheduled holiday that was added between the initial establishment of the forward transaction or its delivery. In the case of IDR the delivery schedule is also complicated by the need to observe Singapore holidays for the NDF (non-deliverable forward) market.

A.3. The Monthly File

To create monthly observations on so-called end/end deals in which the delivery date for the forward contract is the last business day of the month, we extract, for each month in the matrix of daily observations just described, the row or observation date whose DEL_{jt} is the latest day of the month. (If there are multiple observation dates, we pick the row corresponding to the latest observation date.) The convention in the forward market is that this choice of the observation date does not depend on the tenor (spot, 1-, 2-, or 3-month forward) of the contract (although it can depend on the currency). The JPY example of Section 1 of this appendix illustrate this.

If the first daily observation of the spot and forward rate is, for example, December 31, 1996 (as in the WM/Reuters data), 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.

In the monthly file thus created, let $t(m)$ be the observation date of month m. To use the JPY example, $t(m)$ = March 27, 2009 for m = March 2009 and $t(m+1)$ = April 27, 2009, provided that the Price File has those observation dates. If the Delivery Date File had no date misalignment of the sort described in case (c) above and if the Price File had for each month an observation whose DEL_{1t} is the last business day of the month, then the way the monthly file is created ensures that, for any month m in the monthly file, we have:

$$DEL_{j,t(m)} = DEL_{0,t(m+j)} \quad \text{for} \quad j = 1, 2, 3. \tag{A2}$$

In the current JPY example, $DEL_{1,t(m)}$ =April 30 and $DEL_{0,t(m+1)}$ = April 30, as required by (A2). Under the procedure described in Section 2 of this appendix for determining OBS_{jt}, (A2) implies

$$OBS_{j,t(m)} = t(m+j) \quad \text{for} \quad j = 1, 2, 3. \tag{A3}$$

In the example, indeed, $OBS_{1,t(m)}$ = $t(m+1)$ = April 27, 2009.

To understand the role played by (A2) and (A3), consider an investor who opened a 1-month forward long position in month m (say, March 2009) on $t(m)$ (March 27, 2009), deliverable on $DEL_{1,t(m)}$ (April 30). To maintain (or "roll") the forward position, the investor must sell spot the counter currency she receives on $DEL_{1,t(m)}$ and buy forward the currency. The spot and forward legs of this transaction can be arranged on the same day ($OBS_{1,t(m)}$, April 27) if (A3) holds. (An FX swap can be used to execute both legs simultaneously.) (A2) ensures that a delivery of the counter currency promised in the spot leg is provided by the existing forward position created on $t(m)$ (March 27).

Because of the possible date misalignment in the Delivery Date File and missing business days in the Price File, conditions (A2) and (A3) can fail. (In the current JPY example with m = March 2009, if the Price File does not have April 27 but has April 24 (so case (a-ii) applies here), both (A2) and (A3) fail with $t(m+1)$ = April 24, and $D_{0,t(m+1)}$ = April 28, $OBS_{1,t(m)}$ = April 28.) For EM20, the conditions for $j=1$ fail in 90 cases (currency-months) out of 3,197 cases. For those problem cases, we redefine $OBS_{j,t(m)}$ ($j=1$, 2, 3) this time by (A3), so the spot and forward legs can still be arranged on the same day. However, since the delivery date $DEL_{j,t(m)}$ of the existing forward position is before or after the spot delivery date of $D_{0,t(m+j)}$, the investor needs to borrow or lend the forward currency to bridge the gap. The G9 monthly file has no such problem cases.

A.4. Variables in the Monthly File

An Excel file called "Gilmore_Hayashi_monthly_FX_file.xls" has been created by the procedure detailed above. It has 52 sheets grouped into three sets of currencies.

(a) 20 sheets bearing EM20's acronyms --- "TWD", "THB", "ZAR", "TRY", "PHP", "KRW", "CNY", "IDR", "PLN", "CZK", "CLP", "MXN", "SKK", "HUF", "COP", "ARS", "INR", "BRL", "ILS", and "RUB" --- have the following series. The data source is AIG-FP supplemented by WM-Reuters as described in Section 1 of this appendix.

column 1 (labelled "year-month"): year and month of the month (e.g., 201004),
column 2 ("date"): observation date for the end/end deal,
column 3 ("eom_obs"): 1 if "date" is the last observation day of the month in the Price File, 0 otherwise,
column 4 ("DEL0"): delivery date of spot contracts traded on "date",
column 5 ("S"): mid spot rate observed on "date",
column 6 ("F1"): mid one-month forward rate observed on "date",
column 7 ("F2"): mid two-month forward rate observed on "date",
column 8 ("F3"): mid three-month forward rate observed on "date",
column 9 ("DEL1"): delivery date of one-month forward contracts traded on "date",
column 10 ("OBS1"): observation date for spot contracts deliverable on "DEL1",
column 11 ("S_OBS1"): mid spot rate observed on "OBS1",

column 12 (“DEL2”): delivery date of two-month forward contracts traded on “date”,

column 13 (“OBS2”): observation date for spot contracts deliverable on “DEL2”,

column 14 (“S_OBS2”): mid spot rate observed on “OBS2”,

column 15 (“DEL3”): delivery date of three-month forward contracts traded on “date”,

column 16 (“OBS3”): observation date for spot contracts deliverable on “DEL3”,

column 17 (“S_OBS3”): mid spot rate observed on “OBS3”,

column 18 (“FLAG1”): flag for “OBS1”. 1 if case (a-i) described in Section 2 above, 2 if (a-ii), 3 if (b-i), 4 if (b-ii), 5 if (c), 999 if “DEL1” is after the last spot delivery date defined in Section 2,

column 19 (“FLAG2”): flag for “OBS2”,

column 20 (“FLAG3”): flag for “OBS3”,

column 21 (“signal_obs_date”): signal observation date defined in Section IV.B of the text, common to all constituent currencies,

column 22 (“too_early”): 1 if “date” is on or earlier than “signal_observation_date”, 0 otherwise,

column 23 (“actual_signal_date”): date the signal (i.e., the carry) is actually observed,

column 24 (“S_signal”): mid spot rate on “signal_date”,

column 25 (“F1_signal”): mid one-month forward rate on “signal_date”,

column 26 (“F2_signal”): mid two-month forward rate on “signal_date”,

column 27 (“F3_signal”): mid three-month forward rate on “signal_date”,

column 28 (“last_bus_date”): the last observation day of the month in the Price File, i.e., the date for which “eom_obs” equals 1,

column 29 (“S_eom”): mid spot rate on “last_bus_date”,

column 30 (“F1_eom”): mid one-month forward rate on “last_bus_date”,

column 31 (“F2_eom”): mid two-month forward rate on “last_bus_date”,

column 32 (“F3_eom”): mid three-month forward rate on “last_bus_date”.

The “eom” information (columns 28-32) is included only because the usual way in the academic literature to calculate the excess return utilizes them; the one-month excess return from month $m-1$ to m is usually calculated as: F1_eom for month $m-1$ less S_eom for month m.

(b) 12 sheets bearing G9’s acronyms --- “AUD”, “CAD”, “JPY”, “NZD”, “NOK”, “SEK”, “CHF”, “GBP”, “EUR”, “DEM”, “FRF”, and “ITL” --- have the following 54 series. The data source is WM-Reuters.

column 1 (“year-month”): year and month of the month (e.g., 201004),

column 2 (“date”): observation date for the end/end deal, column 3 (“eom_obs”): 1 if “date” is the last observation day of the month in the Price File, 0 otherwise,

column 4 (“DEL0”): delivery date of spot contracts traded on “date”,

column 5 (“S_mid”): mid spot rate observed on “date”,

column 6 (“F1_mid”): mid one-month forward rate observed on “date”,

column 7 (“F2_mid”): mid two-month forward rate observed on “date”,

column 8 (“F3_mid”): mid three-month forward rate observed on “date”,

column 9 (“S_bid”): bid spot rate observed on “date”,

column 10 (“F1_bid”): bid one-month forward rate observed on “date”,

column 11 (“F2_bid”): bid two-month forward rate observed on “date”,

column 12 (“F3_bid”): bid three-month forward rate observed on “date”,

column 13 (“S_offer”): offer spot rate observed on “date”,

column 14 (“F1_offer”): offer one-month forward rate observed on “date”,

column 15 (“F2_offer”): offer two-month forward rate observed on “date”,

column 16 (“F3_offer”): offer three-month forward rate observed on “date”,

column 17 (“DEL1”): delivery date of one-month forward contracts traded on “date”,

column 18 (“OBS1”): observation date for spot contracts deliverable on “DEL1”,

column 19 (“S_mid_OBS1”): mid spot rate observed on “OBS1”,

column 20 (“S_bid_OBS1”): bid spot rate observed on “OBS1”,

column 21 (“S_offer_OBS1”): offer spot rate observed on “OBS1”,

column 22 (“DEL2”): delivery date of two-month forward contracts traded on “date”,

column 23 (“OBS2”): observation date for spot contracts deliverable on “DEL2”,

column 24 (“S_mid_OBS2”): mid spot rate observed on “OBS2”,

column 25 (“S_bid_OBS2”): bid spot rate observed on “OBS2”,

column 26 (“S_offer_OBS2”): offer spot rate observed on “OBS2”,

column 27 (“DEL3”): delivery date of three-month forward contracts traded on “date”,

column 28 (“OBS3”): observation date for spot contracts deliverable on “DEL3”,

column 29 (“S_mid_OBS3”): mid spot rate observed on “OBS3”,

column 30 (“S_bid_OBS3”): bid spot rate observed on “OBS3”,

column 31 (“S_offer_OBS3”): offer spot rate observed on “OBS3”,

column 32 (“FLAG1”): flag for “OBS1”. 1 if case (a-i) described in Section 2 above, 2 if (a-ii), 3 if (b-i), 4 if (b-ii), 5 if (c), 999 if “DEL1” is after the last spot delivery date defined in Section 2,

column 33 (“FLAG2”): flag for “OBS2”,

column 34 (“FLAG3”): flag for “OBS3”,

column 35 (“signal_obs_date”): signal observation date defined in Section IV.B of the text, common to all constituent currencies,

column 36 (“too_early”): 1 if “date” is on or earlier than “signal_observation_date”, 0 otherwise,

column 37 (“actual_signal_date”): date the signal (i.e., the carry) is actually observed,

column 38 (“S_signal”): mid spot rate on “signal_date”,

column 39 (“F1_signal”): mid one-month forward rate on “signal_date”,

column 40 (“F2_signal”): mid two-month forward rate on “signal_date”,

column 41 (“F3_signal”): mid three-month forward rate on “signal_date”,

column 42 (“last_bus_date”): the last observation day of the month in the Price File, i.e., the date for which “eom_obs” equals 1,

column 43 (“S_mid_eom”): mid spot rate on “last_bus_date”,

column 44 (“F1_mid _eom”): mid one-month forward rate on “last_bus_date”,

column 45 (“F2_mid _eom”): mid two-month forward rate on “last_bus_date”,

column 46 (“F3_mid _eom”): mid three-month forward rate on “last_bus_date”,

column 47 (“S_bid_eom”): bid spot rate on “last_bus_date”,

column 48 (“F1_bid _eom”): bid one-month forward rate on “last_bus_date”,

column 49 (“F2_bid _eom”): bid two-month forward rate on “last_bus_date”,

column 50 (“F3_bid _eom”): bid three-month forward rate on “last_bus_date”,

column 51 (“S_offer_eom”): offer spot rate on “last_bus_date”,

column 52 (“F1_offer _eom”): offer one-month forward rate on “last_bus_date”,

column 53 (“F2_offer _eom”): offer two-month forward rate on “last_bus_date”,

column 54 (“F3_offer _eom”): offer three-month forward rate on “last_bus_date”.

For AUD, EUR, GBP, and NZD, the exchange rate is in USD per unit of the foreign currency.

(c) 20 sheets bearing EM20’s acronyms with “_WM” added --- “TWD_WM”, “THB_WM”, “ZAR_WM”, “TRY_WM”, “PHP_WM”, “KRW_WM”, “CNY_WM”, “IDR_WM”, “PLN_WM”, “CZK_WM”, “CLP_WM”, “MXN_WM”, “SKK_WM”, “HUF_WM”, “COP_WM”, “ARS_WM”, “INR_WM”, “BRL_WM”, “ILS_WM”, and “RUB_WM” --- have 54 series with the same definitions as in (b). The data source is WM-Reuters.

AppendixB: Incorporating Bid/offer Spreads

We argued in the text that the transactions cost due to bid/offer spreads is much lower than commonly supposed in the academic literature. In the first section of this appendix, we substantiate this claim by deriving a formula for the cumulative return from continued exposure to forward contracts via FX (foreign exchange) swaps. The second section of the appendix generalizes the formula to portfolios of currencies 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 III of the text, or they may be a function of the carry for currencies as in the active strategy considered in Section IV of the text. Throughout the appendix, we suppose that the duration of the forward contract is 1 month and that the unit period is a month. The base currency is taken to be USD (the U.S. dollar).

B.1. Excess Return Calculation for a Single Currency

In this appendix, we state the exchange rate in units of the foreign currency, because that is the practice of the foreign exchange market for all EM (emerging market) currencies and for most major currencies. So let S_t^b and S_t^o denote the bid and offer rates in date t against USD stated in units of the foreign currency in question. The spot bid/offer spread is $S_t^o - S_t^b > 0$. One gets to buy an amount S_t^b of the foreign currency for selling 1 unit of USD, and $1/S_t^o$ units of USD for selling 1 unit of the foreign currency. The mid rate is the arithmetic average of the bid and offer rates, i.e., $S_t \equiv (S_t^b + S_t^o)/2$. So we have $S_t^o > S_t > S_t^b$.

It is also a practice of the foreign exchange market to express the (outright) 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 forward bid and offer rates are $F_t^b \equiv S_t^b + P_t^b$ and $F_t^o \equiv S_t^o + P_t^o$. Since the offer forward points are always greater than the bid and since $S_t^o > S_t^b$, we have $F_t^o > F_t > F_t^b$ where $F_t \equiv (F_t^b + F_t^o)/2$ is the mid forward rate, and the bid/offer spread should be wider for the forward contract than for the spot contract.

An FX swap is a contract to buy spot an amount of currency at an agreed rate (the “spot leg”), and simultaneously resell the same amount of currency for a later date (1 month hence in our case) also at an agreed forward rate (the “forward leg”). There are “uneven” (or “mismatched” or “non-round”) swaps whereby the amounts vary on each leg of the swap. We assume that the amount is the same in both legs for the most part. Toward the end of this section, we consider uneven FX swaps. The rate in the spot leg is usually the current mid rate, which is what we assume in all our calculations. Therefore, the forward rate in the forward leg, which we denote $\tilde{F}_t$, is $\tilde{F}_t \equiv S_t + P_t^b$. It can be written as[3]

$$\tilde{F}_t = F_t - \frac{1}{2}\left[\left(F_t^o - F_t^b\right) - \left(S_t^o - S_t^b\right)\right] = \left(1 - \frac{1}{2}\frac{\left(F_t^o - F_t^b\right) - \left(S_t^o - S_t^b\right)}{F_t}\right)F_t. \qquad \text{(B1)}$$

By construction, we have $F_t^o > F_t > \tilde{F}_t > F_t^b$.

Consider a USD investor who takes long positions on 1-month forward contracts over n consecutive months from month 0 to n, with an initial wealth of USD A_0 (A_0 U.S. dollars). The position is "long" because the investor promises to *buy* the foreign currency or sell USD. We now describe the rolling operation involving FX swaps that underlies our calculation of the excess return with bid/offer spreads. Let r_t be the 1-month USD interest rate from the end of month t to $t+1$. For concreteness, let's say the foreign currency is ZAR (South African Rand).

(a) At the end of month 0, the investor opens a forward position by an outright forward contract. She buys 1 month forward ZAR (i.e., sells 1 month forward USD). The notional, i.e., the amount or volume of the position, measured in USD is chosen to be USD $A_0(1+r_0)$. The outright forward rate is the bid rate F_0^b (because the investor is promising to sell USD/buy ZAR), so the ZAR amount of the position is $X_0 \equiv A_0(1+r_0)F_0^b$. At the same time, the USD amount A_0 is invested in the USD 1-month money market instrument.

(b) At the end of month 1, the investor collects USD $A_0(1+r_0)$ from the money market investment. This USD amount matches the ZAR amount $X_0 = A_0(1+r_0)F_0^b$, that is, it is just enough to pay for the ZAR delivery. With this ZAR amount in hand, the investor carries out an FX swap. In the spot leg of the FX swap, the investor buys spot USD (sells spot ZAR) at the mid rate S_1 to obtain USD $A_1 = X_0 / S_1$, which is invested in the USD 1-month money market instrument. In the forward leg, the investor sells forward this USD amount X_0 / S_1 to create a forward position of ZAR $(X_0 / S_1)\tilde{F}_1$. Thus the current forward position has been rolled over via the FX swap. In addition, to take account of the interest income to be collected in the next month from the USD 1-month money market investment, the investor opens an additional and new forward position by an outright forward contract. As in the initial period, the outright forward rate is the bid rate F_1^b, not the more favourable rate of

[3] Since $F_t^b = S_t^b + P_t^b$, we have $\tilde{F}_t \equiv S_t + P_t^b = (1/2)(S_t^o + S_t^b) + (F_t^b - S_t^b) = (1/2)(S_t^o - S_t^b) + F_t^b$. This equals (B1) because $F_t = (1/2)(F_t^o + F_t^b)$ or $F_t^b = F_t - (1/2)(F_t^o - F_t^b)$.

$\tilde{F}_1$, because this is a newly opened position. So if Z_1 is the ZAR amount of this additional position, its USD amount is Z_1 / F_1^b. The total forward position carried over to the next period is ZAR $X_1 = (X_0 / S_1)\tilde{F}_1 + Z_1$. In order for the principal and the interest that the investor receives in the next period from the USD investment to match this ZAR amount, the size of the new ZAR position Z_1 must satisfy

$$(1+r_1)A_1 = \frac{X_0}{S_1} + \frac{Z_1}{F_1^b}. \qquad \text{(B2)}$$

(c) More generally, at the end of each interim month t $(=1,2,..,n-1)$, given the forward position of ZAR X_{t-1}, the investor repeats the same transaction described by three equations

$$A_t = \frac{X_{t-1}}{S_t},\ X_t = \frac{X_{t-1}}{S_t}\tilde{F}_t + Z_t,\ \text{and}\ (1+r_t)A_t = \frac{X_{t-1}}{S_t} + \frac{Z_t}{F_t^b}. \qquad \text{(B3)}$$

The first of these three equations describes the spot leg of the FX swap. The second equation says that the new position consists of the position created by the forward leg of the FX swap and a position due to a new outright forward contract. The third equation is a matching requirement that the size of the new position be equal to that of the current USD 1-month investment.

(d) In the final month $t = n$, the investor closes out or unwinds the forward position that was carried over from the previous month. That is, the investor receives a delivery of ZAR X_{n-1} and sell spot this amount for USD $A_n = X_{n-1} / S_n^o$. The spot rate is the offer rate S_n^o because the investor is selling ZAR/buying USD. The cumulative gross total (i.e., cum interest) USD return over the n period is A_n / A_0. This completes our description of the rolling operation.

The three equations in (B3) together yield a difference equation in X_t:

$$X_t = (1+r_t)\frac{X_{t-1}}{S_t}\tilde{F}_t - \left(\frac{\tilde{F}_t}{F_t^b} - 1\right)Z_t = (1+r_t)\frac{X_{t-1}}{S_t}\hat{F}_t, \qquad \text{(B3')}$$

where (with $\tilde{F}_t$ the forward rate in the forward leg defined in (B1)) the applicable forward rate $\hat{F}_t$ is defined as[4]

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[4] To derive (B3') with (B4), note that the last equation of (B3) implies $Z_t / F_t^b = r_t A_t$. Also, from the previous footnote, $\tilde{F}_t = (1/2)(S_t^o - S_t^b) + F_t^b$.

$$\hat{F}_t \equiv \tilde{F}_t - \left(\frac{\tilde{F}_t}{F_t^b} - 1\right)\frac{Z_t}{(1+r_t)A_t} = \left(1 - \frac{r_t}{1+r_t}\frac{\frac{1}{2}(S_t^o - S_t^b)}{\tilde{F}_t}\right)\tilde{F}_t. \qquad \text{(B4)}$$

By construction, we have $F_t^o > F_t > \tilde{F}_t > \hat{F}_t > F_t^b$.

With the initial condition of $X_0 = A_0(1+r_0)F_0^b$ and taking into account that in the final month the ZAR position X_{n-1} is converted into USD at the offer rate S_n^o, the cumulative gross total USD return, A_n / A_0, can be calculated by the recursion (B3') as[5]

$$A_n / A_0 = (1+r_0)\cdots(1+r_{n-1})\frac{F_0^b}{S_1}\times\frac{\hat{F}_1}{S_2}\times\cdots\times\frac{\hat{F}_{n-2}}{S_{n-1}}\times\frac{\hat{F}_{n-1}}{S_n^o}. \qquad \text{(B5)}$$

Therefore, the expression for the cumulative gross excess return with transactions costs that we have been seeking is

$$\text{Cumulative gross excess return with FX swaps} = \frac{F_0^b}{S_1}\times\frac{\hat{F}_1}{S_2}\times\cdots\times\frac{\hat{F}_{n-2}}{S_{n-1}}\times\frac{\hat{F}_{n-1}}{S_n^o}. \qquad \text{(B6)}$$

In the above foreign exchange operation, the forward position (excluding the portion corresponding to the interest) is rolled over in the interim months. If, as assumed in most of the academic literature, the forward position is closed and then newly opened in each month, the applicable forward rate (at which the investor buys ZAR forward) in the interim month is now the bid rate F_t^b for all months and the applicable spot rate (at which the investor sells spot ZAR for USD) in the interim month is the offer rate. Thus, the formula for the cumulative gross excess return becomes

$$\text{Cumulative gross excess return without FX swaps} = \frac{F_0^b}{S_1^o}\times\frac{F_1^b}{S_2^o}\times\cdots\times\frac{F_{n-2}^b}{S_{n-1}^o}\times\frac{F_{n-1}^b}{S_n^o}. \qquad \text{(B7)}$$

If we ignore transactions costs by setting the spot and forward bid/offer spreads to zero and thus assuming that all the transactions occur at mid rates, the cumulative gross excess return becomes

$$\text{Cumulative gross excess return without transactions costs} = \frac{F_0}{S_1}\times\frac{F_1}{S_2}\times\cdots\times\frac{F_{n-2}}{S_{n-1}}\times\frac{F_{n-1}}{S_n}. \qquad \text{(B8)}$$

We could define the *transactions cost per unit period* as the n-th root of the ratio of the cumulative gross excess return without bid/offer spreads to one with bid/offer spreads, less unity. If

[5] As mentioned in footnote 22 of the text, the formula has the mid rate S_n in place of the offer rate S_n^o if the rate is taken from the NDF (non-deliverable forward) market.

FX swaps is utilized, the ratio in the definition is the ratio of (B8) to (B6), so the per-unit period transactions cost is

$$\left[\text{ratio of (A2.8) to (A2.6)}\right]^{1/n} - 1 = \left[\left(\frac{F_0}{F_0^b}\right)\times\left(\frac{S_n^o}{S_n}\right)\times\prod_{t=1}^{n-1}\left(\frac{F_t}{\hat{F}_t}\right)\right]^{1/n} - 1. \qquad \text{(B9)}$$

A series of approximations yields that the transactions cost per unit period is approximately equal to[6]

$$\frac{1}{n}\left[\frac{1}{2}\left(\frac{F_0^o - F_0^b}{F_0} + \frac{S_n^o - S_n^b}{S_n}\right)\right] + \frac{n-1}{n}\left[\frac{1}{n-1}\sum_{t=1}^{n-1}\frac{1}{2}\frac{\left(F_t^o - F_t^b\right) - \left(S_t^o - S_t^b\right)}{F_t}\right]$$

$$+ \frac{n-1}{n}\left[\frac{1}{n-1}\sum_{t=1}^{n-1}\frac{r_t}{1+r_t}\frac{\frac{1}{2}\left(S_t^o - S_t^b\right)}{F_t}\right]. \qquad \text{(B10)}$$

The first term represents the entry and exit costs, each equalling half times the relevant bid/offer spread. It is divided by n (the investment horizon) because those costs are paid only once. The second term is the average cost of rolling the forward position. The third term comes about because the interest component of the position needs to be opened anew in every interim month.

We now consider the case in which "uneven" FX swaps are allowed. With uneven swaps, the formulas we have derived become simpler. Since the forward leg can be expanded to cover the interest component, there is no need to open a new position by an outright forward contract; the investor can take advantage of the more favourable rate $\tilde{F}_t$ in month t for the whole of the position. Therefore, $\tilde{F}_t$ replaces F_t^b in the last of the three equations in (B3). Consequently, $\tilde{F}_t$ replaces $\hat{F}_t$ in the difference equation (B3') and also in the cumulative returns formulas (B5) and (B6). Indeed, the formula (16) in the text reflects this substitution. The formula for the approximate transactions cost (B10) simplify as (17) of the text, with the interest term (the third term) in (B10) dropping out.

In all these discussions, special attention should be paid to CNY (Chinese Yuan). Since the local convention is to quote a single rate for the spot rate and to express the outright forward rate as the sum of this single spot rate (call that S_t) and forward points, $F_t^b = S_t + P_t^b$ instead of

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[6] To derive (B10), we use (B1), (B4), and the fact that $S_t^o - S_t = (1/2)(S_t^o - S_t^b)$ and $F_t - F_t^b = (1/2)(F_t^o - F_t^b)$. The approximations used are: for a and b close to each other, $c \approx \frac{1}{n}\log(a/b)$ if $c \equiv \left(\frac{a}{b}\right)^{1/n} - 1$, $\log(a/b) \approx \frac{a-b}{b}$, and $\frac{1}{a} \approx \frac{1}{b}$.

$F_t^b = S_t^b + P_t^b$ as in the second paragraph of this section. Recalling that the definition of $\tilde{F}_t$ (the forward rate in the forward leg of an FX swap and also the applicable rate when uneven FX swaps are allowed) is given by $\tilde{F}_t \equiv S_t + P_t^b$, we have $\tilde{F}_t = F_t^b$, which also means that $\hat{F}_t$, the applicable forward rate with swaps with even amounts, too reduces to F_t^b. Furthermore, since the spot exchange data on CNY is from the NDF (non-deliverable forward) market, the applicable spot rate is that single spot rate S_t. 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).

To close this section, we note for our data that the approximation for the per-period transactions cost — (B10) for the case of "even" FX swaps and (17) in the text for "uneven" swaps — is almost exact and that whether uneven swaps are allowed or not makes very little difference for the transactions cost. For each of the two cases (even and uneven swaps), there can be four different ways to calculate the transactions cost: (a) the exact formula (B9) (with $\tilde{F}_t$ replacing $\hat{F}_t$ in the case of uneven swaps), (b) the difference in the geometric mean of the gross excess return with and without transactions cost, (c) the difference in the arithmetic mean, and (d) the approximation formula (B10) (with the third term dropped for the uneven case). In our data, formulas (a)-(c) give virtually the same estimate of the annualized transactions cost, differing from each other in less than 1 basis point, for almost all of the EM and major currencies, particularly when the investment horizon n is more than a couple of years, and the basis point estimate does not depend on whether uneven swaps are allowed or not. Formula (d) sometimes gives somewhat different estimates, but the discrepancy gets very small when averaged across constituent currencies. As an illustration, for $n =$ 60 months, the annualized transactions cost estimate averaged across the 20 EM currencies is the same (42 basis points per year) for all eight formulas.

B.2. Portfolio Excess Returns

To handle portfolios that takes long positions in multiple foreign currencies, we add subscript j for currency $j = 1,2,...,J$, where J is the number of constituent currencies (J can depend on time t). So, for example, S_{jt} is the spot mid rate of currency j against the base currency, stated in units of currency j, at the end of month t. As before, the investment horizon is n. For interim month t ($t = 1,2,..., n-1$), the additional notation is

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

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

Z_{jt} = 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 portion Y_{jt} of the existing position in currency j is closed out, and the offer rate S_{jt}^{o} applies. The amount to roll for currency j is $X_{j,t-1} - Y_{jt}$. As in the case of a single currency, the favourable rate $\tilde{F}_{jt}$ applies to rolled positions, so the position in the foreign currency unit to be carried over to the next month $t+1$ is $(X_{j,t-1} - Y_{jt})\tilde{F}_{jt} / S_{jt}$. The three equations in (B3), which assume that uneven FX swaps are not allowed, can be extended to multiple currencies as

$$A_t = \sum_{j=1}^{J} \left(\frac{X_{jt} - Y_{jt}}{S_{jt}} + \frac{Y_{jt}}{S_{jt}^{o}} \right), \tag{B11a}$$

$$X_{jt} = \left(X_{j,t-1} - Y_{jt} \right) \frac{\tilde{F}_{jt}}{S_{jt}} + Z_{jt} \qquad \text{for} \qquad j = 1,2,\ldots,J\,, \tag{B11b}$$

$$(1 + r_t) A_t w_{jt} = \frac{X_{j,t-1} - Y_{jt}}{S_{jt}} + \frac{Z_{jt}}{F_{jt}^{b}} \qquad \text{for} \qquad j = 1,2,\ldots,J\,, \tag{B11c}$$

for $t = 1,2,\ldots,n-1$. Here, w_{jt} is currency j's weight in the portfolio of forward long positions. (B11) reduces to (B3) if $J = 1$, $Y_{jt} = 0$, and $w_{jt} = 1$.

In the interim month t, Given the portfolio carried over from month $t-1$ and given the exchange rates, the system (B11) has $3J+1$ unknowns $(A_t, Y_{1t}, \ldots, Y_{Jt}, Z_{1t}, \ldots, Z_{Jt}, X_{1t}, \ldots, X_{Jt})$ but only $2J+1$ equations. Because of the bid/offer spreads, it is not to the investor's advantage to close out some portion of the position and at the same time create a new position for the same currency. To be more precise, suppose (B11) has a solution $(A_t, Y_{1t}, \ldots, Y_{Jt}, Z_{1t}, \ldots, Z_{Jt}, X_{1t}, \ldots, X_{Jt})$ with $Y_{jt} > 0$ and $Z_{jt} > 0$ for some currency. Then it is possible to find an alternative solution $(A_t', Y_{1t}', \ldots, Y_{Jt}', Z_{1t}', \ldots, Z_{Jt}', X_{1t}', \ldots, X_{Jt}')$ with a dominating portfolio, that is, with $X_{jt}' > X_{jt}$ for all currency j. Therefore, either Y_{jt} or Z_{jt}

is zero, which furnishes additional J equality conditions.[7] This provides a difference equation, a mapping from $(X_{1,t-1}, X_{2,t-1}, ..., X_{J,t-1})$ to $(X_{1t}, X_{2t}, ..., X_{Jt})$.

In the initial month $t = 0$, the investor opens a position by an outright forward contract for each currency. If w_{j0} is the weight for currency j, the portfolio to be carried over to the first interim month $t = 1$ is

$$(X_{10}, X_{20}, ..., X_{J0}) = \left((1+r_0)A_0 w_{10} F_{10}^b, (1+r_0)A_0 w_{20} F_{20}^b, ..., (1+r_0)A_0 w_{J0} F_{J0}^b\right), \tag{B12}$$

where, as in the single-currency case, the scalar A_0 is the initial USD wealth. Taking this as the initial condition, we can use the recursion described in the previous paragraph to obtain $(X_{1,n-1}, X_{2,n-1}, ..., X_{J,n-1})$, the portfolio to be carried into the final investment month n when the position is closed out. The USD value of the portfolio when closed out is

$$A_n = \sum_{j=1}^{J} \frac{X_{j,n-1}}{S_{jn}^o}. \tag{B13}$$

Given the initial USD wealth A_0 and the terminal wealth A_n, we can define the cumulative gross total and excess returns and the transactions cost exactly as in the single-currency case of the previous section. We used the 1-month LIBOR rate at the end of month t for the interest rate r_t in the above formulas. The value of the interest rate hardly affects the excess return.

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[7] Finding the corner — which one, Y_{jt} or Z_{jt}, is zero for each j — is accomplished by solving a linear programming problem, in which the objective function is a weighted sum over j of X_{jt} and the constraints are (B11) and $Y_{jt} \geq 0$ and $Z_{jt} \geq 0$. We used the "linprog" function of Matlab (version R2010b) to find the solution. Different choices of the weight vector in the objective function should result in the same corner (and indeed they do in our computations) as long as the weight is positive for all j.

Appendix Table 1: Number of Non-Repetitive Daily Observations

	TWD		THB		ZAR		TRY		PHP		KRW		CNY		IDR		PLN		CZK		CLP		MXN		SKK		HUF		COP		ARS		INR		BRL		ILS		RUB	
1996	139	1	149	1	147	1	146	1	59	1	20	0	19	0	1	1	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1997	219	196	255	251	245	256	235	255	239	249	235	0	193	0	253	253	222	0	208	256	164	0	198	255	138	0	19	47	0	0	1	0	0	47	0	0	0	0	0	0
1998	243	252	256	258	247	258	237	255	216	256	232	0	201	0	255	258	252	0	249	258	53	0	249	258	246	0	250	258	249	0	169	0	159	251	124	0	0	0	0	0
1999	238	256	246	250	246	258	175	258	243	255	237	0	224	0	244	257	246	0	242	258	36	0	250	257	260	0	246	258	261	0	221	0	206	248	237	0	0	0	0	0
2000	237	253	251	257	244	258	240	236	237	257	217	0	206	0	245	254	245	0	244	258	168	0	253	257	260	0	246	258	260	0	217	0	207	252	246	0	36	0	0	0
2001	238	251	246	242	248	258	82	23	218	258	247	0	156	0	254	30	245	0	247	258	220	0	249	258	261	0	244	258	261	0	230	0	172	250	239	0	221	0	120	0
2002	243	249	245	249	247	258	35	256	222	258	249	220	211	222	257	0	246	230	249	258	227	0	252	255	261	230	250	258	261	0	201	0	173	251	238	0	189	0	252	0
2003	247	253	249	224	251	257	232	256	232	256	251	250	229	252	251	0	251	257	248	257	239	0	251	257	260	257	250	257	260	0	237	0	226	255	244	0	239	0	257	0
2004	253	257	256	235	260	259	259	259	243	259	255	253	253	254	257	0	261	259	260	259	243	195	248	259	261	259	260	259	260	197	199	185	248	254	249	196	253	197	255	192
2005	244	254	246	242	252	258	255	258	237	258	243	229	244	257	242	0	255	258	255	258	249	253	257	258	260	258	255	258	250	257	179	240	239	251	256	258	253	258	253	249
2006	249	253	250	252	253	257	252	257	246	256	249	249	250	253	250	0	253	257	253	257	248	252	253	257	254	257	253	257	246	251	201	234	246	255	251	256	252	257	245	249
2007	245	252	246	243	250	257	250	257	243	251	245	250	244	251	244	146	250	257	250	257	243	244	251	257	250	257	250	257	243	256	244	246	244	249	244	257	250	256	242	257
2008	245	257	247	247	255	259	255	259	244	258	245	243	245	250	247	244	255	259	255	259	241	258	255	259	255	259	255	259	244	258	244	258	245	243	242	258	255	259	243	259
2009	251	253	252	245	257	258	257	258	240	250	250	252	247	245	240	243	257	258	257	258	253	258	257	258	257	258	257	258	253	258	252	255	249	238	253	258	257	258	252	258
2010	68	251	71	239	73	259	73	259	71	242	71	249	68	241	68	248	73	259	73	259	73	259	73	259	73	259	73	259	73	259	73	253	73	246	73	259	73	259	74	259

Note: For each currency, the left column is for the daily data from AIG-FP and the right column is from WM/Reuters. AIG-FP has fewer observations for 2010 because the last observation of the AIG-FP data is for April 19, 2010.