Systematic Intervention and Currency Risk Premia*

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Abstract

Using data for the trades of 19 central banks intervening in currency markets, we show that stabilization policies by individual central banks lead to "systematic intervention" patterns. This systematic intervention is driven by and impacts on the same factors that drive currency excess returns: carry, momentum, value, and a dollar factor. The sensitivity of an individual central bank's intervention to these factors differs markedly across countries, with developed countries making a profit from intervention and emerging markets incurring large losses.

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1. Introduction

A large literature has documented that the cross section of currency excess returns is predictable, and that currency risk premia can be summarized by a few key risk factors. These include, *inter alia*, carry trades that buy high interest rate currencies and sell low interest rate currencies, dollar strategies that short the US dollar (USD) and buy a diversified portfolio of foreign currencies, momentum strategies that buy currencies that appreciated in the recent past and short those that depreciated in the recent past, and value strategies that buy undervalued currencies and sell overvalued currencies; see, e.g., Asness et al. (2013), Lettau et al. (2014), Lustig and Verdelhan (2007), Lustig et al. (2011), Menkhoff et al. (2012a,b, 2017), Koijen et al. (2018). Asset managers and other global investors in the foreign exchange (FX) market routinely engage in these currency strategies to earn the associated risk premia. However, the FX market is populated by a large and diverse set of players, some of which are not necessarily motivated by profiting through FX trading, most notably central banks.

In this paper we investigate the *systematic* nature of FX interventions across central banks and provide a number of new stylized facts about interventions in the cross-section of central banks and for the central banking sector on aggregate. Specifically, we address the following questions: First, are aggregate central bank interventions driven by the same set of factors that drive exchange rates? Second, do the trading actions of central banks, i.e., their FX intervention flows, affect currency risk premia and, if so, do they increase or decrease excess returns from popular currency strategies? Third, do central banks profit or lose money from their intervention operations? We tackle these questions empirically using the data on daily sterilized interventions in the FX market collected by Fratzscher et al. (2018), and study a cross-section of sterilized central bank interventions in 19 exchange rates (all against the USD) from 1995 to 2011.[1]

The stylized facts about systematic intervention we document in this paper are as

[1] It is important to note that central banks trade in FX markets for a variety of reasons unrelated to intervention designed to affect the evolution of exchange rates, for example for reserve management purposes. The focus in this paper is on sterilized intervention operations whereby central banks buy or sell foreign currencies while taking offsetting actions such that the domestic monetary base is unchanged.

follows: (i) there is a factor structure in interventions, which we call "systematic intervention", that is closely related to the factor structure in exchange rates; (ii) central banks tend to intervene in support of a factor (e.g., carry) when returns to that factor are low and vice versa; (iii) as a corollary, central bank interventions are significantly different across different market states; (iv) there are significant differences across country subgroups (developed versus emerging markets, high versus low interest rate countries, high versus low net foreign asset positions); (v) emerging countries lose money on their intervention activity and the bulk of these losses is driven by the hefty interest rate differential they face when they sell their currencies to buy the USD; (vi) a simple price impact analysis suggests that global, systematic interventions by the aggregate central banking sector are large enough to move exchange rates by a significant amount and, for example, interventions to support carry in the aftermath of the global financial crisis lifted carry returns by about five percent.

Why are these results important? The literature in international macro-finance has studied the effect of central banks' intervention on exchange rates, mainly for the purpose of understanding optimal exchange rate policy. A traditional view in international finance is that sterilized central bank interventions – whereby central banks buy or sell in FX markets while keeping the amount of money in circulation unchanged – do not matter for exchange rates. For example, Backus and Kehoe (1989) use a simple arbitrage condition to show that the FX composition of the central bank balance sheet is irrelevant for exchange rates and that sterilized intervention is ineffective both in complete and incomplete markets. Standard theory, therefore, interprets the observed currency composition of the central bank balance sheet as just one of infinitely many possible combinations with no special role for asset pricing in FX markets. Recent theoretical work has challenged this view and shown the limitation of this argument. In the presence of financial frictions FX interventions matter: following Gabaix and Maggiori (2015) a new class of models shows that the FX composition of the central bank balance sheet impacts on exchange rates and currency risk premia (e.g. Amador et al., 2017; Fanelli and Straub, 2017; Cavallino, 2018).[2] Moreover,

[2]See also Vitale (2003), Pasquariello (2010), Basu et al. (2016), Hassan et al. (2017) for theoretical arguments implying that FX intervention can be effective. A separate literature examines the impact of government intervention on mispricing in international financial markets (e.g., Pasquariello, 2017; Pelizzon

recent empirical work has successfully taken on the challenge of documenting the effects of FX intervention on the level, path, and volatility of exchange rates. For example, Blanchard et al. (2015) look at the response of different countries to capital inflows and explore whether FX intervention dampens the effect of inflows across countries. Fratzscher et al. (2018) employ a panel approach to study FX intervention and document its success in affecting exchange rate outcomes using a large cross-section of confidential data of FX intervention.[3] Our results provide a further challenge to the traditional view that FX intervention is irrelevant for asset pricing and that the observed FX intervention is a random pattern in the data. In turn, our findings suggest that interventions across central banks are *not* random and it would indeed strain credibility, in our opinion, for models to simply generate it as one of infinitely many possible outcomes. Rather, the evidence seems more in line with models in which this type of systematic FX intervention emerges as an optimal policy.

This paper uses the same dataset as Fratzscher et al. (2018) but, whereas Fratzscher et al. (2018) focus on testing the effectiveness of interventions on the level and/or volatility of exchange rates conditional on different exchange rate regimes, this paper focuses on the systematic nature of interventions and its drivers. More importantly, this paper has a distinct focus on the link between official intervention and systematic currency risk factors as opposed to bilateral spot exchange rates, which are the main object of interest in the existing literature. This is important for several reasons. First, from a finance perspective, central bank intervention is only relevant for asset pricing if it impacts on FX excess returns and, hence, currency risk premia. The effectiveness of central bank trades in moving spot exchange rates, documented by Fratzscher et al. (2018) on these data, does not necessarily imply systematic patterns in central bank activity since central banks tend to react solely to developments in their own currency, except for cases where intervention activities are coordinated internationally. Second, the ability to affect spot exchange rates does not imply an impact on currency risk premia since interest rate differentials may offset changes in spot exchange rates caused by intervention trades, in which case trades

et al., 2017).

[3]See also Pasquariello (2007) for earlier evidence that intervention can be an effective policy tool of central banks under certain circumstances.

of central banks have no relevance for systematic risk factors. Third, measuring the profits and losses to central banks trading in FX markets requires careful calculation of interest rate differentials, and indeed our analysis below shows that estimates of the profits and losses of the central banking sector would be quantitatively and qualitatively different if one ignores interest rate differentials.

Our finding of a strong factor structure in interventions means that central banks *on aggregate* intervene in a systematic way and that interventions are at least partly driven by the same factors that also drive currency returns. We argue that such systematic intervention arises quite naturally, because the global financial system is centered around the USD as the world's reserve currency and most central banks care about the value of their currency in relation to the USD. If each individual central bank simply tries to stabilize its own currency by "leaning against the wind" (e.g., Frankel, 2017), systematic factors that move the USD will have a systematic impact on the intervention activity of all central banks even if there is no coordinated global intervention.[4]

As an empirical illustration of such a systematic factor, we now focus on carry trades. We know from previous research that high (low) interest rate currencies systematically depreciate (appreciate) in bad states of the world (Ranaldo and Söderlind, 2010; Lustig et al., 2011; Menkhoff et al., 2012a). Hence, in bad times, e.g., in times of high global FX volatility, central banks associated with safe, low interest rate currencies will sell their own currency to curb the appreciation whereas central banks associated with risky, high interest rate currencies will buy their own currency to mitigate the depreciation. An intervention pattern like this would naturally lead to a "systematic intervention" in support of the carry trade in bad times and, hence, exposure to the carry trade by the aggregate central banking sector even if central banks do not coordinate their policies globally.

To illustrate this mechanism empirically, we run a simple experiment and compute intervention-volatility betas and return-volatility betas for all currencies in our sample,

[4] In a recent paper, Frankel (2017) studies so-called "systematic managed floating", a regime in which central banks regularly respond to pressure on the exchange rate by partially intervening against it and partially letting the exchange rate depreciate. Our notion of systematic intervention is different from systematic managed floating primarily because we are interested in intervention related to currency factors. Moreover, the recent literature has documented forcefully that systematic factors related to the USD strongly affect exchange rates (Verdelhan, 2018) and recent theoretical work has shown that such a structure will affect the incentives for intervening and outcome of FX interventions (Hassan et al., 2017).

and plot these betas for five groups of countries in Figure 1. Intervention-volatility betas are obtained from time-series regressions of intervention amounts on a proxy for global FX volatility risk (Menkhoff et al., 2012a), whereas return-volatility betas are obtained from time-series regressions of exchange rate changes on global FX volatility risk.[5] A positive (negative) intervention-volatility beta means that a central bank buys (sells) its own currency in bad times on average. A high (low) return-volatility beta means that the exchange rate of a country tends to appreciate (depreciate) in bad times, i.e., countries with high (low) return-volatility betas are safe (risky). Figure 1 shows a highly negative correlation (-85 percent) between these two betas across countries, which suggests that central banks of countries with risky, high-interest rate currencies do indeed tend to buy their home currency in bad times whereas central banks of safe, low-interest rate currencies tend to sell their currency in bad times. Overall, Figure 1 suggests that interventions across different central banks are driven by the same common, systematic factor underlying carry trades. This is what we call "systematic intervention".

While the above example is based on carry trades, we define several measures of systematic intervention to characterize intervention-related trading of central banks around the globe more broadly. A first benchmark measure is global intervention activity, which is simply the sum of the absolute amount of intervention across all countries in our sample. While one might think of intervention as a rare occurrence, especially with the experience of major economies and floating exchange rate regimes in mind, global intervention activity appears to be a steadfast feature in FX markets, and displays strong time variation, with activity reaching peaks during times of market turmoil and especially since the onset of the global financial crisis. We also construct measures of "signed" systematic intervention that inform us about whether, on aggregate, central banks are net buyers or net sellers in a particular currency strategy; we do this for each of the dollar factor, carry, momentum, and value. We find that the central banking sector tends to intervene, on average, against carry and momentum, and in support of (against) undervalued (overvalued) currencies. It also tends to be a net buyer of US dollars.

[5]Global volatility has been used as a measure of "bad times" in Menkhoff et al. (2012a), who show that return-volatility betas capture a large share of the cross-sectional variation in currency risk premia. Currencies with high return-volatility betas tend to be low interest rate currencies and vice versa.

However, this unconditional analysis masks an important feature of the link between systematic intervention and currency excess returns. A conditional analysis reveals that central banks trade against carry in calm market periods, whereas in volatile times there is systematic intervention in support of carry. These effects are particularly strong for emerging markets, countries with high interest rates, and countries with low net foreign asset positions. In essence, the “leaning against the wind” nature of intervention activities curbs carry profits during good times, but helps reducing carry losses in bad times, effectively smoothing fluctuations in carry returns. Similarly, the central banking sector is a net buyer of USD but even more so during times of crisis. Finally, systematic intervention tends to lean against momentum and against exchange rate misalignments (i.e., in support of value strategies), and this effect is much more pronounced during times of market turmoil.

After characterizing the link between systematic intervention and currency excess returns arising from these popular currency investment strategies, we investigate the profits and losses of the central banking sector by building portfolios that mimick the intervention flows for our sample of countries, which resembles the way in which FX order flow strategies are constructed in the literature (e.g., Menkhoff et al., 2016). This analysis shows that systematic intervention is associated with substantial costs across the aggregate central banking sector. However, central banks of major developed economies tend to make a small profit from their FX intervention trades, whereas central banks of emerging markets incur large losses. We also find that these losses are not driven by the exchange rate component of the excess return since systematic intervention appears to move exchange rates in the desired direction, but the carry (interest rate differential) component of excess returns more than offsets the gain from the spot exchange rate component. This is the key reason why costs of intervention for emerging markets with high interest rates tend to be particularly high.

Finally we estimate the price impact of interventions on currency returns and use a range of price impacts to estimate the effect of interventions by the aggregate central banking sector on each of the four currency strategies analyzed here. This analysis shows that the price impact of interventions can be very large at times, especially during the global financial crisis, when systematic intervention in support of high interest rate currencies and undervalued currencies pushed up the returns from carry and value by some 2.5-7.5 percent relative to a counterfactual scenario without any interventions. More generally, value strategies would have delivered much lower returns and the dollar would have been much weaker over our sample period in the absence of systematic intervention.

The rest of the paper is structured as follows. Section 2 describes the data, the construction of the currency factors, and the measures of systematic intervention used in the empirical analysis. Section 3 presents empirical results on the link between systematic intervention and currency excess returns, both unconditionally and conditional on market states. Section 4 reports evidence on the profits and losses on systematic intervention, and Section 5 provides a measure of the price impact of systematic intervention on currency excess returns. Finally, Section 6 concludes. The Appendix provides further details on some of the methods employed, and an Internet Appendix reports a number of further results and robustness analysis.

2. Data

2.1. Sample countries and currency returns

Intervention data. The intervention data employed in this paper comprise daily sterilized interventions in the FX market and are the same data used in Fratzscher et al. (2018). The main difference with the paper by Fratzscher et al. (2018) is that we focus on interventions against USD only and that we limit the sample of currencies to countries with (relatively) flexible exchange rate regimes and few or no capital controls. Specifically, we use the intersection of countries with available intervention data and countries in the sample of Menkhoff et al. (2012b), as currencies in the latter paper are generally tradable in meaningful size according to their survey conducted among market participants. The latter feature is important as we are interested in examining the link between interventions and the excess returns to currency strategies commonly used by investors, and therefore we need to ensure that our sample comprises currencies that are actually tradable. This sample selection choice results in the following set of 19 countries: Australia, Canada, Czech Republic, Croatia, Denmark, EMU, Hong Kong, Iceland, Israel, Japan, Mexico, New Zealand, Norway, Poland, Slovakia, South Africa, Sweden, Switzerland and the United Kingdom. We employ exchange rates against the USD for all 19 countries and define all exchange rates such that they measure the amount of foreign currency units per USD, i.e. a higher number for the exchange rate implies a depreciation of the foreign currency. All data on forward and spot exchange rates are obtained from BBI and Reuters (via Datastream).

Denote the exchange rate of country i against USD on day t by $S_{i,t}$. We compute log exchange rate changes as

$$\Delta s_{t+1} = s_{t+1} - s_t \tag{1}$$

which correspond to depreciation rates of foreign currencies against USD. Log currency excess returns are given by

$$rx_{i,t+1} = fds_{i,t} - \Delta s_{i,t+1} = f_{i,t} - s_{i,t+1} \tag{2}$$

where fds denotes the forward discount $fds_{i,t} = f_{i,t} - s_{i,t}$. If covered interest parity (CIP) holds, the forward discount is identical to the interest rate differential between the foreign currency and USD. In the period before the global financial crisis, CIP held closely (Akram et al., 2008), so using forwards versus short-term interest rates to compute excess returns was inconsequential. However, we use forward data to compute excess returns (as in the extant recent literature) instead of short-term interest rates as there have been large deviations from CIP since the global financial crisis (e.g., Baba and Packer, 2009; Du et al., 2018; Rime et al., 2017) that render the use of, e.g., LIBOR rates unreliable.

2.2. Currency factors

We now describe the daily currency factors used in the empirical analysis. The recent literature has identified a number of systematic risk factors in FX markets which are natural candidates in our context. We use these factors to measure systematic currency returns as well as systematic currency intervention (defined more formally in Section 2.3 below).

First, we know from Lustig et al. (2011) that two factors suffice to capture the cross-section of carry trade returns: a "dollar" factor and a "carry" (or slope) factor. The dollar factor (DOL) is the average excess return on holding an equally-weighted basket of foreign currencies against USD. We employ the same setup and compute the excess return to the dollar factor as the cross-sectional average of currency excess returns on each day, i.e., $rx^D_{t+1} = 1/N_{t+1} \sum_i rx_{i,t+1}$, where i indexes currencies and N_t denotes the number of currencies with available data on day t.

The carry factor (CAR) is based on going long or short currencies based on their (lagged) interest rate differential over the previous 22 trading days, so the weight on currency i in the carry portfolios is

$$w^C_{i,t} = \begin{cases} N_t^{-1} & , \text{ if } \overline{fd}_{i,t-21;t} > 0, \\ -N_t^{-1} & , \text{ if } \overline{fd}_{i,t-21;t} \leq 0, \end{cases} \tag{3}$$

where fd is the interest rate differential of currency i at time t. We employ average forward discounts over the previous month to make sure that our carry measure is not driven by outliers on a particular trading day and the sorting variable is the same as in the vast literature studying the properties of carry trade strategies with monthly rebalancing since Lustig et al. (2011). Carry portfolio returns are then given by $rx^C_{t+1} = \sum_i w^C_{i,t} rx_{i,t+1}$.[6]

Moreover, we also compute returns to momentum (MOM) and value (VAL) strategies (Asness et al., 2013; Menkhoff et al., 2012b, 2017). The momentum strategy is based on lagged one month excess returns, which Menkhoff et al. (2012b) find to be the most profitable currency momentum strategy. Value is based on 5-year exchange rate depreciation rates. We construct returns to momentum and value strategies in the same way as for carry, and simply replace the forward discount-based signal with one-month lagged excess returns (momentum) or 5-year depreciation rates (value).

Whereas our signal for momentum is fairly standard in the currency literature, a few comments on the value signal are in order. Our measure of value is based on the long-term reversal of (nominal) exchange rates. The literature has employed different ways of

[6] We focus on carry *timing strategies* as in Burnside et al. (2011) and Koijen et al. (2018) because it seems more natural to study the link between interventions and carry in the time series dimension and also because the literature on currency interventions largely deals with time series aspects. For example, Mark and Moh (2007) examine how interventions affect the forward premium anomaly in a time-series context.

measuring currency value signals. A common way of approximating currency value is to use 5-year real exchange rate changes as in Asness et al. (2013). Since we are working with daily data, for which price levels are not available and where publication lags of macro data are especially severe, we look at reversal in nominal exchange rates instead. This measure was used in an earlier version of Asness et al. (2013), and Menkhoff et al. (2017) show that the nominal exchange rate component of real exchange rate changes drives all of the profitability of currency value trades, so using nominal or real FX rates makes little difference empirically.

Descriptive statistics. Table I, Panel A, shows descriptive statistics for daily factor returns. As can be seen, all four factors have positive returns on average. For carry and momentum, these mean excess returns are significantly different from zero and have Sharpe Ratios of 0.64 and 0.48, respectively. These numbers are in the same ballpark as Sharpe Ratios in earlier literature. Dollar returns are not significantly different from zero, which is to be expected from the earlier literature (e.g., Lustig et al., 2011). Somewhat more suprisingly, value returns are low (0.50 percent p.a.) and not statistically significant. Relative to earlier papers that found significantly positive returns on average, this is most likely driven by the set of countries and especially the relatively short sample period employed here. Since value strategies bet on convergence to fundamental values, which can take a long time in FX markets, it seems that we are not estimating value returns precisely enough (see, e.g., Taylor and Taylor, 2004). Nevertheless, value returns have the expected sign and they are negatively correlated with carry and momentum (Panel B), which is a well-known feature from earlier studies (e.g., Asness et al., 2013; Menkhoff et al., 2017) so that our measure of value returns seems reliable.

To further understand the behavior of factor returns, we plot rolling mean excess returns for one-year windows for the four factors in Figure IA.2 in the Internet Appendix. Even though the value and dollar factor do not deliver significant returns on average, it is clear from these plots that there are extended periods of time when these strategies were significantly profitable. More generally, there is strong time-variation in average excess returns and all four strategies experience times of positive (and negative) returns. This variation in returns over time is essential to the empirical analysis that follows, which focuses on establishing the link between systematic intervention and currency excess returns not just unconditionally but also conditional on good or bad states of the world.

2.3. Measures of systematic intervention

We are interested in *systematic* global intervention, i.e., net interventions of the aggregate central banking sector, and will thus use several different measures of aggregate interventions across central banks. Specifically, we are interested in the following measures of systematic intervention:

1. *Global intervention activity*:
$$I_{ABS,t} = \sum_i |I_{i,t}| \tag{4}$$
which is just the sum of absolute intervention amounts $I_{i,t}$ for each country i on any day t, where $I_{i,t}$ denotes purchases of foreign currency against USD by country i on day t in million USD. This intervention measure is informative about the absolute amount of intervention across all central banks.

2. *Carry-specific signed intervention flows*: $I_{\text{carry},t} = \sum_i \pi^C_{i,t} I_{i,t}$ which are signed intervention flows in the direction of the carry trade, i.e., $\pi^C_{i,t}$ equals one (minus one) if currency i had a positive (negative) interest rate differential against the USD on average from $t-22$ to $t-1$, where t denotes days.

3. *Momentum-specific signed intervention flows*: $I_{\text{mom},t} = \sum_i \pi^M_{I,t} I_{i,t}$ which are signed intervention flows in the direction of the momentum trade, i.e., $\pi^M_{i,t}$ equals one (minus one) if the lagged excess return from $t-22$ to $t-1$ of currency i against the USD is positive (negative).

4. *Value-specific signed intervention flows*: $I_{\text{value},t} = \sum_i \pi^V_{I,t} I_{i,t}$ which are signed intervention flows in the direction of the value trade, i.e., $\pi^V_{i,t}$ equals one (minus one) if the exchange rate of currency i depreciated (appreciated) over the previous 5 years from $t-1-5y$ to $t-1$. Hence, this measure is based on long-term reversal of exchange rates.

5. *Dollar-specific flows*: $I_{\text{Dollar},t} = \sum_i I_{i,t}$ which is just the sum of intervention amounts across all countries. This measure basically treats all currencies the same way (all against USD) and is directly related to the "dollar factor" by Lustig et al. (2011) and Verdelhan (2018), which is the average return of foreign currencies (against the USD). Hence, we will refer to global signed intervention flows as dollar-specific interventions later in the paper.

Table II shows descriptive statistics for these five intervention measures. Panel A of this Table reports results for all days in the sample, where we find an average global intervention amount ($I_{ABS,t}$) of about 80 million USD with a standard deviation of 204 million USD. The maximum intervention amount on a single day is 3,322 million USD. Interestingly, only 20.76 percent of all days in our sample have no interventions at all. Turning to the factor-specific flows, we find negative average intervention flows for the carry, momentum, and dollar factors and a positive average flow for the value factor. This means that the central banking sector as a whole tends to intervene, *on average*, against the carry trade (t-stat -1.59), against momentum (t-stat -2.26), in support of undervalued currencies (t-stat 4.02), and that it tends to sell foreign currency to buy USD (t-stat of -8.64).

Next, to further characterize systematic intervention, we plot global intervention activity in Figure 2. As might be expected, there was a surge of interventions in 2008/2009 during the global financial crisis. Other spikes of interventions can be observed in the late 90s (Asian crisis, LTCM crisis) and around 2004 when some emerging countries changed their exchange rate regime. Overall, intervention activity seems to have slowed down from 2001 to 2007 (relative to the second half of the 90s) and then increased again with the start of the global financial crisis.[7]

Figure 3 plots cumulative factor-specific flows for the carry, momentum, value, and dollar factors. On average, central banks traded heavily against carry from the late 1990s until 2008. In 2009, there is a large positive shift in cumulative flows which reduced the negative cumulative flows by more than 60 percent (from almost -80 billion USD to about

[7]Figure IA.1 in the Internet Appendix shows average interventions against USD over time (for rolling windows of 3 months) and the cross-sectional standard deviation of average intervention flows. The figure shows that the size of interventions is positively correlated with the cross-sectional dispersion in interventions across countries, which is another stylized fact of the data.

-30 billion USD). This strong shift to interventions that buy (sell) high (low) interest rate currencies during the crisis seems responsible for the low statistical significance of average carry intervention flows documented in Table II (t-stat of -1.56). Hence, a fair conclusion seems to be that central banks trade against carry in normal times but intervene in support of carry when carry trades tend to perform worst, i.e., they lean against the wind.

Figure 3 also shows that central banks tend to trade against momentum consistently throughout the sample period. Contrary to carry, there is no significant change during the global financial crisis. If anything, anti-momentum interventions increased in 2008/2009 when cumulative flows quickly dropped from about -30 billion USD to less than -50 billion USD. This result is intuitively clear as central banks tend to lean against the wind in an attempt to slow down or reverse sharp trends in exchange rates (Sarno and Taylor, 2001; Fratzscher et al., 2018).

For value-specific interventions there is a consistently positive flow throughout the sample period, which strongly increased after 2004 when central banks started to increasingly buy undervalued currencies and sell overvalued currencies. In 2010, the cumulative flow in the direction of value was about 100 billion USD.

Finally, for dollar-specific flows, Figure 3 shows a consistently negative pattern, i.e., central banks sold foreign currencies to buy USD during the sample. As for other factors, this pattern intensified during the crisis and cumulative intervention flows decreased from -100 billion to less than -200 billion since the onset of the crisis.[8] Figure IA.3 in the Internet Appendix shows the same plots for developed and emerging countries separately. We find that a large share of the time-variation in cumulative intervention flows comes from emerging countries, whereas developed countries have less volatile intervention patterns. For example, developed countries always trade against carry, against momentum, in the direction of value, and they basically do not buy or sell the dollar in significant quantities. Emerging countries, however, switch from trading against and in the direction of carry, momentum and value at different points in time. For the dollar factor, emerging countries

[8] For robustness, we also show a similar result in the Internet Appendix, Figure IA.4, which plots cumulative flows for a broader sample of 32 currencies. This broader sample includes smaller currencies, and non-tradeable currencies of tightly managed exchange rate regimes with strict capital controls.

account for almost all of the USD buying in our sample.[9]

In sum, there are rich patterns in interventions of the aggregate central banking sector that point to the existence of a systematic component in interventions, i.e., *systematic intervention*. Central banks tend to curb carry and momentum on average, trade in the direction of value, and sell their currencies to buy USD. Importantly, these effects seem to reverse (carry) or intensify (momentum, value, dollar) during crisis periods.[10]

3. Systematic interventions and currency excess returns

3.1. Interventions and currency excess returns in good and bad states

The results in the previous section suggest a potentially close link between interventions and times of market turmoil or crisis. To gain a more thorough understanding of the link between currency factor returns and factor-specific intervention, we first conduct a simple exercise and split the sample period into three buckets (for each currency factor separately), depending on the factor-specific intervention amount. More specifically, the first bucket is comprised of days with intervention amounts below the 30th percentile of all interventions (over the full sample), the second bucket is made up of days on which factor-specific intervention amounts are between the 30th and 70th percentile, and the third bucket consists of days with the 30 percent highest intervention amounts.

Table III reports average factor excess returns and average intervention amounts for these three buckets. The results show that there is a consistent pattern across carry-,

[9] One reason for this behavior could be a precautionary motive (e.g., Jeanne, 2016) where emerging countries accumulate reserves as insurance against bad shocks. However, this strong pattern could also be driven, at least partly, by our sample period which ends in 2011. Central banks of several emerging but also some important developed economies like Japan have stopped accumulating reserves after 2011.

[10] An alternative approach to quantify the importance of systematic factors in intervention data would be to run a principal components analysis on these interventions. If we assume that currency-day combinations with missing data represent 'no intervention' we can construct a balanced sample and extract such common factors from the cross-section of individual currencies. Doing so generates a strong factor structure where the first three PCs capture 65% of the overall variance of intervention flows, which is broadly similar to results reported in, e.g., Lustig et al. (2011) for six forward discount-sorted portfolio returns. However, since the confidentiality of the data do not allow us to report loadings on individual currencies and because our assumption of no intervention for days with missing data cannot be tested empirically, we prefer to work with the intervention factors discussed in this section. These factors also allow us to speak directly to currency return factors discussed in the literature.

momentum-, value-, and dollar-specific interventions and returns: Days with low interventions (upper panel), i.e., interventions against the strategy, are characterized by high and positive returns. On the contrary, days with high interventions (lower panel), i.e., interventions that support the strategy, are characterized by highly negative returns. This pattern in returns across the three buckets is monotonic for carry, momentum, and the dollar factor, and the economic significance is quite substantial. For example, carry returns are 7.46 percent on average (annualized) when carry-specific interventions are low (i.e., central banks trade against carry), whereas carry trade returns average -5.93 percent during times of high carry-specific interventions (i.e., when central banks intervene in support of carry). We find similarly strong results for the other three currency factors, and when we look at Sharpe Ratios instead of excess returns. Figure 4 plots the Sharpe Ratios of the four factors for the three different intervention buckets and clearly shows that all four strategies have high and positive Sharpe Ratios when central banks trade against these factors, whereas all four strategies have highly negative Sharpe Ratios when central banks intervene in support of these strategies.

A natural interpretation of this finding is that central banks try to stabilize the exchange rate and thus try to curb exchange rate movements. As discussed earlier, if central banks of high interest rate countries buy their currencies during bad times (when these currencies typically depreciate strongly) and central banks of low interest rate countries sell their currencies during bad times (when these currencies typically appreciate strongly), one would naturally find a pattern as the one documented for carry in Table III and Figure 4. Our results suggest that a similar mechanism is at work for the other systematic currency factors as well.

We take a closer look at this mechanism in Table IV where we report annualized intervention amounts for the four factors in different market states. As above, we split the sample into three buckets based on the 30th percentile and the 70th percentile but now use different measures of market conditions to do so: Global FX volatility (based on a GARCH(1,1) model of dollar factor returns), strategy-specific returns over the previous week, strategy-specific returns over the previous month, country risk (based on the cross-country average financial risk rating by ICRG), and the average forward discount (based on the cross-country average of forward discounts as in Lustig et al. (2014)). For each conditioning variable, we then report average intervention amounts (annualized) for the low and high bucket and the difference between these two buckets.

Several interesting results emerge. Specifically, we find that central banks intervene significantly more in the direction of carry and value in bad times, when global FX volatility is high. They also intervene significantly more against the dollar factor (i.e., they buy more USD) in bad times. Conditioning on prior five-day or one-month returns shows that central banks intervene significantly more against the dollar factor (i.e., they buy more USD) when the dollar factor has performed well over the recent past (i.e., when foreign currencies appreciated against the USD). High country risk is accompanied by more intervention in support of carry, more intervention against momentum, and more intervention in support of the dollar factor (i.e., more purchases of foreign currencies). Finally, a high average forward discount is accompanied by more intervention in support of carry.

3.2. Dissecting central bank intervention flows at the country level

The results discussed above are informative about the drivers of factor-specific interventions and their state dependence. In this section, we complement these findings by focusing on interventions at the country level. To do so, we first run panel regressions of the form

$$I_{i,t+1} = \alpha_i + \rho I_{i,t} + \gamma \text{Factor signals}_{i,t} + \delta x_{i,t} + \varepsilon_{i,t+1} \tag{5}$$

where I denotes intervention amounts (purchase of currency i versus USD) of country i on day t, and α_i denotes country fixed effects. We include lagged intervention amounts ($I_{i,t}$) to account for the persistence in interventions. Furthermore, we run specifications of this panel regression where we include factor *signals* (i.e., lagged forward discounts for carry, lagged one-month returns for momentum, lagged 5-year depreciation rates for value) as well as further control variables in x. We employ double-clustered standard errors (clustered by currency and month). Note that, while all variables in this regression are country-specific, we estimate common coefficients in the panel at this stage.

Table V reports regression results. We find that interventions are indeed persistent with an AR(1) parameter of 0.47 (first column, labelled ALL). This finding seems to make sense as Figure 2 already suggests interventions tend to take place in clusters during bad times. We also find that lagged carry signals (forward discounts) enter with a statistically significant positive coefficient, which suggests that countries tend to intervene more in support of their own currency (against USD) when the interest rate differential against the US is high. The estimates further show that a high momentum is accompanied by sales of foreign currency for USD (negative and statistically significant coefficient), whereas a high value signal (i.e., currency i is undervalued) is accompanied by purchases of currency i (versus USD) although the positive coefficient on value is only significant at the 10 percent level. We allow for various control variables in the regression, namely global FX volatility, the (cross-currency) average forward discount (AFD), the (cross-currency) average country financial risk rating (CFR), as well as lagged one-month average returns of the dollar factor. We find that none of these additional control variables is significant. Overall, these findings suggest that the same factors that drive currency excess returns are also strongly related to currency interventions across central banks.

Then, we run the same regressions for subgroups of countries and report the results in Table V (columns 2-7). To be precise, we still run panel regressions as above, but now only use a subset of countries in each regression. The country groups we consider are: developed and emerging countries, countries with high or low average forward discounts, and countries with high or low average net foreign assets (NFA).[11] The split into developed and emerging countries also serves to (roughly) resemble the distinction into small and large countries in Hassan et al. (2017). Results for country groups show a few key differences relative to the results for all countries. First, interventions are less persistent for developed countries than for emerging countries (AR(1) coefficient of 0.32 versus 0.49). Second, the strong effects of lagged carry, momentum, and value on future interventions are especially pronounced for emerging markets, high interest rate countries and countries with low net foreign assets but

[11] Note that the sensitive nature of the information in our data does not allow us to present results for individual countries but only for subsets of countries. Hence, we focus on economically interesting and relevant groups defined in terms of their development (real per-capita GDP), (average) interest rate level, and (average) net foreign asset levels. While these country groupings are not independent (e.g., countries with low NFA also tend to have high interest rates) they are useful to inform us about heterogeneity across countries with different economic conditions.

insignificant for basically all other country groups. For developed countries and countries with high NFA, we find that country financial risk ratings enter significantly (higher country risk is associated with more USD purchases), whereas for low interest rate countries, higher global FX volatility is associated with more USD purchases (and, equivalently, sales of their home currency).

3.3. Discussion and summary of results

Our results are consistent with a mechanism in which leaning against the wind of central banks generates systematic responses to exchange rate developments across countries. This mechanism is also consistent with the basic implications of theories of exchange rate determination in the presence of financial frictions, such as Gabaix and Maggiori (2015). While we do not provide a formal model here, let us describe further why central banks might care about currency risk premia and the basic ingredients of a model that accounts for our empirical findings using the example of carry trades.

Suppose household investors know that the carry trade is profitable in equilibrium. This seems sensible given the vast body of evidence that the currency risk premium is positive when estimated over long periods of time. These investors want to capture this currency risk premium by following a simple trading rule – for example they might invest in a currency fund that follows this rule – rather than solving a complicated investment problem so that:

$$X_{i,t} = a + b(f_{i,t} - s_{i,t}) + \epsilon_{i,t} \tag{6}$$

where $X_{i,t}$ denotes the flow of money into currency i at time t, $b > 0$ implies that flows depend positively on the interest rate differential, and $\epsilon_{i,t}$ is a random taste shock for the carry trade.

In this simple setting, the country with the higher interest rate experiences a currency appreciation because of the carry-induced flow from households. Suppose that the currency appreciation is considered too strong by the central bank. Then the central bank will want to intervene against the carry trade, taking the other side of the trade and smoothing the appreciation. Similarly, if the carry trade suddenly pulls funds out of a country, the central bank might want to intervene in the direction of the carry trade to limit domestic fire sales of assets that the foreigners are liquidating. In the model of Gabaix and Maggiori (2015) the carry trade return depends on a stochastic (Gamma) parameter that captures the risk-bearing capacity of financial intermediaries and is related to time-varying FX volatility; in bad states of the world, when FX volatility is high and risk-bearing capacity is low, the carry trade performs poorly. The evidence in this paper suggests that the carry trade would perform even worse in bad states of the world had the central banking sector not intervened to take the other side of the trade and effectively curbed the drop in risk-bearing capacity. If these flows are large, because the trading strategy is popular, then this mechanism will account for a lot of variation in the exchange rate, and the central bank intervention will be very responsive to it. Of course, this need not be the only mechanism to digest our empirical results but it is perhaps the most natural.

Summing up, the results in this section suggest that systematic intervention flows move in support or against a factor differently across states: in bad times, central banks trade in the direction of carry, whereas normally they trade against it, and they also trade more strongly in the direction of value, against momentum, and to buy the USD in bad times than they do in normal times. These effects are generally much stronger for emerging markets and countries with higher interest rates and/or lower NFA positions. In light of these findings, the logical next questions that arise are: First, do central banks profit or lose from trading in FX markets, and what factor exposures drive their profits/losses? Second, do their intervention flows impact on exchange rates? We address each of these questions in the next two sections.

4. Intervention profits and losses

Having established that there is a strong systematic component in FX interventions around the globe, an important follow-up question is what the costs of interventions are for central banks and how these costs relate to systematic risk factors. Our results have shown that central banks trade against carry and momentum on average; an obvious conjecture is that central banks should lose from trading against these (profitable) factors relative to earning the domestic money market rate.[12]

To answer this question, we first plot daily cumulative aggregate profits (measured in billion USD) for all countries in Figure 5.[13] The solid (black) line is the overall cumulative excess return based on cumulative dollar purchases over the sample period, the dashed (blue) line shows the exchange rate component of the overall profit, and the dotted (red) line shows the interest rate differential component of excess returns. The key message of this figure is that all countries on aggregate lost a bit more than 30 billion USD from 1995 to 2011. Virtually all of this loss comes from the interest rate differential component, i.e., countries lose money by buying low interest rate currencies (mostly USD) and selling high interest rate currencies. By comparison, the exchange rate component part of profits is slightly positive at the end of the sample period (about 5 billion USD) and was substantially higher (around 30 billion USD) in 2008-2009.[14]

We also provide a more detailed breakdown in Figure 6, where we plot profits for different country subgroups (as in Table V above). We find significant differences across different groups of countries. Developed markets made a positive, albeit small, profit from their intervention activity of about seven billion USD over the full sample period, which stems from both the exchange rate (dashed line) and the carry component (dotted line). In contrast, emerging market countries lost about 40 billion USD during our sample period, which is fully driven by the carry component. In other words, emerging market

[12] Central banks do not trade in the FX market to make profits but to moderate or reverse undesirable exchange rate developments, and therefore if the welfare gain arising from effective intervention is associated with a loss for central banks, this is not necessarily problematic. Yet, we know little about the actual profits and losses of the central banking sector from trading in the FX market since intervention data are not readily available, so the estimates in the literature generate from variation in FX reserves rather than intervention flows (e.g., Taylor, 1982; Adler and Mano, 2016; Domanski et al., 2016). However, it is well known that FX reserves can be a poor proxy for intervention flows (e.g., Sarno and Taylor, 2001), and therefore knowledge of the actual, realized costs of intervention is largely anecdotal or limited to short sample periods and individual developed countries (e.g. Leahy, 1995; Sweeney, 2000).

[13] To compute profits, we compute the total excess return to holding the cumulative amount of USD (which can be positive or negative) for each central bank and we also split up the total return into the component due to exchange rate changes and interest rate differentials. To do so, we assume that reserves for each central bank are zero at the beginning of the sample period in 1995, i.e., we only take the actual intervention amounts during our sample period into account.

[14] The spike in profits during the global financial crisis is due to the strong appreciation of safe haven currencies such as the USD. As our results above show, many central banks intervened by selling their home currencies for USD; this induced a loss on the carry component but yielded a large profit when USD appreciated during the crisis.

countries tend to lose more money because they tend to sell their own currencies, which have relatively higher interest rates, and buy the USD which has a relatively lower interest rate. Overall, the results in Figure 5 for all countries discussed above seem mainly driven by emerging markets.[15]

As might be expected, we find that high carry countries and low NFA countries show a similar pattern as the emerging market subgroup, whereas low carry countries and high NFA countries show a pattern that is closer to the developed country subgroup. In general, developed countries, low interest rate countries, and high NFA countries make money from the carry component of profits whereas emerging countries, high interest rate countries, and low NFA countries lose money on the carry component. Hence, the carry component seems to be the main driver of the costs of interventions.[16]

Decomposing intervention profits. The analysis of intervention profits above suggests that some countries systematically lose money whereas others do not. A large share of these profits seems to be related to the dollar factor, i.e., the buying of low-yielding USD and selling higher-yielding home currency. To explore this issue in more depth, we now focus purely on the direction of interventions and build *intervention-mimicking* portfolios analogous to the order flow-mimicking portfolios used in Menkhoff et al. (2016). More precisely, we use the same procedure as described in Section 2.2 to build currency portfolios and go long (short) a currency, if the average intervention amount over the previous 22 trading days – approximately one month – is positive (negative), i.e., we use weights

$$w_{i,t}^{I} = \begin{cases} N_t^{-1} & , \text{ if } \overline{I}_{i,t-21;t} > 0 \\ -N_t^{-1} & , \text{ if } \overline{I}_{i,t-21;t} \leq 0 \end{cases} \tag{7}$$

[15]Similarly, we show profits and losses separately for all purchases of USD vs all sales of USD in Figure IA.5 in the Internet Appendix. This figure is similar to the one for developed markets (which closely resembles the figure for USD sales) and emerging markets (which closely resembles the figure for USD purchases).

[16]Table IA.2 reports profits/losses for different countries for the full sample period as well as for two subsamples: A pre-crisis sample from 1 January 1995 to 30 June 2007 and a crisis/post-crisis sample from 1 July 2007 to the end of our sample in August 2011. For comparison, we also report the same results in Table IA.1 in the Internet Appendix for a larger sample of currencies, that includes illiquid currencies and currencies in tightly managed exchange rate regimes (see Fratzscher et al., 2018).

so that each long and short position is scaled by the number of currencies with available data (N) on day t. Returns to these intervention-mimicking portfolios are then given by $rx^I_{t+1} = \sum_i w^I_{i,t} rx_{i,t+1}$.

Table VI reports regressions of these intervention-mimicking portfolio returns on a constant and the other systematic currency factors:

$$rx^I_{t+1} = \alpha + \beta^C rx^C_{t+1} + \beta^M rx^M_{t+1} + \beta^V rx^V_{t+1} + \beta^D rx^D_{t+1} + \varepsilon_{t+1} \tag{8}$$

where C, M, V, D denote carry, momentum, value, and the dollar factor, respectively. Panel A reports results for all countries. Specification (1) shows that the unconditional return is negative but not significantly different from zero (t-stat -0.96). The next specifications add the carry, momentum, value, and dollar factors in univariate specifications whereas specification (6) adds all four factors in a multivariate regression. We find that carry alone explains about 15 percent of the variation in intervention-mimicking portfolio returns, momentum explains virtually nothing, value alone captures about 7.5 percent of the overall variation in intervention-mimicking portfolio returns, and the dollar factor captures a hefty 83 percent. For the full specification, we find that returns are positively exposed to carry and highly negatively exposed to the dollar. Interestingly, the exposure to carry switches signs from specification (2) to specification (6), i.e., when netting out the dollar factor (unconditional buying/selling of USD), interventions are in the direction of the carry trade.

Panels B and C of Table VI report the same exercise for developed and emerging countries separately.[17] For developed countries, we find that intervention-mimicking portfolios have an α that is not significantly different from zero. The exposure to carry and value is positive whereas the exposure to momentum and the dollar is negative (specification (6)). Hence, developed countries buy USD, intervene in support of carry and value, and intervene against momentum in currency returns. For emerging markets (Panel C), we find a significantly negative α, i.e., interventions lose money on average even after netting out the factors, and a significantly negative exposure to carry and dollar, whereas the exposure to momentum is significantly positive. In sum, emerging countries lose money on

[17] We focus on these two groups here as they are similar to the subgroups of high vs low interest rate countries and high vs low NFA countries, as discussed above.

their interventions, trade against carry and their own currencies (i.e., buy USD), and tend to buy winner currencies (momentum).[18]

Overall, this analysis shows that systematic currency factors are closely related to systematic interventions, especially the dollar factor, and that developed and emerging countries follow very different intervention styles which result in different profits and losses. Importantly, our results have nothing to say about welfare implications, because we do not know what the costs of not intervening are for the different groups of countries.

5. The price impact of interventions

As a final step in the empirical analysis, we ask how important systematic intervention is for the return of currency factors, i.e., how much does intervention affect the return of carry, momentum, and value trades and the dollar factor. To do so, we need to measure the impact of interventions on currency returns. A large literature deals with the effectiveness of interventions based on various channels such as signalling, portfolio balance effects, and the coordination channel (e.g., Dominguez and Frankel, 1993; Fatum and Hutchinson, 2003; Blinder et al., 2008; Fratzscher, 2008; Fratzscher et al., 2018). The main challenge in this literature is that interventions are obviously not random so that regressions of exchange rate changes on intervention amounts will suffer from an endogeneity problem.

5.1. Empirical approach

Since it is beyond the scope of this paper to provide a detailed investigation of the price impact of FX intervention, we proceed in two steps: First, we borrow price impact estimates from earlier literature. Second, we perform a simple (propensity-score) matching exercise to alleviate concerns about endogeneity and estimate price impacts from our intervention data ourselves. We then report results based on both sets of price impact estimates to provide a reasonable range of the likely impact of interventions on currency returns.

With regard to the first approach, Mancini et al. (2013) and Karnaukh et al. (2015)

[18] Table IA.3 in the Internet Appendix reports results for the same regressions using spot exchange rate changes as dependent variable. We find essentially identical results, which shows that the effects discussed above are driven by the spot rate component of excess returns.

show that the price impact of a trade is about 0.6 basis points on average for a recent time period and for major currency pairs. This estimate is based on high-frequency data from the interbank market on electronic brokerage systems. The standard trade size on these systems is between one and five million USD so we assume a price impact of 0.6 basis points per three million USD intervention. Moreover, we assume a price impact of 0.6 basis points for all currencies in our sample and for the full sample period. This assumption seems conservative, because smaller currency pairs have higher price impacts, and the price impact is likely to be much higher in the earlier part of our sample period as well (when trading volume in the FX market was lower).

With respect to the second approach, we use propensity-score matching and match currency-day combinations with interventions ("treated") to currency-day combinations without interventions ("non-treated"). The matching criteria for the treated and non-treated samples are as follows. We require an exact match of currency and exchange rate regime (based on the coarse classification by Reinhart and Rogoff (2004)). In addition, we use propensity-score matching based on a global factor (the VIX), and currency-specific factors, i.e., the foreign country's financial risk rating, the exchange rate change over the previous day, the previous week, and the previous quarter, as well as the interest rate differential (against USD).[19] While this approach cannot rule out endogeneity issues entirely, it should at least alleviate these concerns. The downside of this strict matching approach is that it drastically reduces the number of observations (currency-day combinations) from 21,107 in the full sample to 1,094 observations in the matched sample.

Based on this matched sample, we find a price impact of about 0.2 basis points per three million USD intervention (see Table IA.4 in the Internet Appendix).[20] This number is much lower than the 0.6 basis points referenced above and there are at least two potential (economic) reasons for this difference. First, the frequency is different. We look at

[19] These criteria serve to make sure that we are capturing the same currency, in the same exchange rate regime, with a similar country risk rating, on days that are characterized by similar global and local market conditions. In other words, the matched observations should largely differ only by the fact that there was an intervention or no intervention. We provide more details on the approach in the Appendix.

[20] For example, we find the impact coefficient is 0.079 basis points or 0.066 basis points per *one* million USD in specifications (iii) and (iv) in Table IA.4 depending on whether we include systematic currency factors (carry, momentum, value, dollar) as controls in the regression. Per three million USD intervention volume, these numbers roughly imply a price impact of 0.2 basis points.

daily exchange rates whereas the studies referenced above typically examine high-frequency changes. Over the course of a day, some of the initial price impact might be reversed, which could lead to a lower price impact in our regressions. Second, interventions typically "lean against the wind" so that buying (selling) a depreciating (appreciating) exchange rate might generate a systematically lower price impact.

5.2. Factor-specific price impacts

Finally, we now compute the price impact of all intervention flows and aggregate these price impacts for the four factors (i.e., using the same weights as for the factors). This gives us a rough measure of how much interventions move factor-specific returns on any given day and we label this the "intervention-related return". We do so for a price impact of 0.6 basis points per three million USD trade (based on the literature) and for a price impact of 0.2 basis points per three million USD trade (based on our own estimate).

We report results from this procedure in Figure 7, where we plot rolling three-month factor returns (solid, blue line) along with rolling three-month intervention-related returns (dashed, red line and shaded area). For the intervention-related returns, the shaded area covers the region implied by price impacts of 0.2 and 0.6 basis points per three million USD trades. The dashed (red) line marks the average of these two price impacts (0.4 basis points per three million USD trade).

As Figure 7 shows, intervention-related returns are typically small. However, there are several periods where aggregate interventions by central banks are large enough to imply a significant price impact. For example, during the global financial crisis, large interventions in the direction of carry and value factors pushed the returns to these two factors up by 2.5-7.5 percent. For carry, intervention-related returns are highly negative in the post-crisis window (up to -2.5 percent around the end of 2010). For momentum, we find a large positive spike (about 5 percent) in early 2010 and several negative spikes of about 2.0–2.5 percent (e.g., at the end of 1998 and in early 2009).

In order to put these findings in context, we plot cumulative factor returns in Figure 8. Along with these realized factor returns, we also plot cumulative "factor returns net of interventions", which are computed as cumulative realized factor returns minus cumulative intervention-related returns. We use the same range of price impacts (from 0.2 to 0.6 basis points per three million USD trade) as above. In other graphs, we plot cumulative realized returns (solid lines) and counterfactual returns that an investor would have earned in the absence of any interventions (dashed lines and shaded area).

Figure 8 shows that realized returns for carry are lower than returns net of interventions up until the global financial crisis. This is intuitive since central banks intervened against carry on average before the crisis and curbed carry profits. The maximum difference in cumulative returns before the carry crash in 2008 is about 10 percent which suggests that carry returns from 1995 to 2008 were 10 percent lower than they would have been in the absence of interventions. Effectively, central banks curbed carry returns by about 0.75 percent per year. After the carry crash in 2008, central banks intervened in support of carry, so that carry returns net of interventions switched to being lower than realized carry trades. Put differently, during and after the carry crash, central bank interventions led to significantly higher carry profits than what would have been observed without interventions. In early 2010, the maximum difference in cumulative returns was close to 10 percent, which suggests a substantial stabilization of carry returns.

For momentum, we find that interventions reduce momentum returns by a few percentage points during most of our sample period.[21] However, momentum profits are much less affected by interventions than the other three factors. Value returns show a clear and consistent pattern throughout the full sample period. In the absence of interventions, value trades would have delivered a much lower return than what was observed in the data. Simply cumulating price impacts suggests a spread in cumulative returns over the full sample period of about 30 percent (20 percent with our own price impact estimate). Finally, for the dollar factor, we find that foreign currencies would have delivered a 15 percentage points higher return over the sample from 1995 to 2011 in the absence of interventions, i.e., interventions have contributed to the appreciation of the dollar relative to all other foreign currencies in our sample.

An obvious caveat in interpreting the above results is that we are imposing a permanent

[21] An earlier literature investigates whether central bank interventions are responsible for momentum profits (e.g., LeBaron, 1999; Neely, 2002). Our results suggest that central banks lean against momentum and that momentum would have been slightly more profitable in the absence of interventions.

price impact in this analysis. In reality, interventions by central banks could attract trades in the opposite direction by other market participants, which would reduce the impact of interventions as measured in our analysis. Hence, these results, even though they are based on rather conservative price impacts, have to be interpreted cautiously. However, the implication of this result for asset managers is that value strategies are likely to perform better in cross-sections of countries that intervene more in currency markets, while the opposite is true for dollar and momentum strategies, whose performance is hampered by systematic intervention. For carry trades the implication is less clear cut since interventions reduce carry returns in good times, but the downside risk of carry losses in bad times is much lower if the currencies traded are issued by central banks which intervene more in FX markets.

6. Conclusions

This paper empirically addresses a set of related questions on the relationship between the trading actions of central banks that intervene in the foreign exchange market and currency risk premia. What drives global central bank intervention? Are intervention flows around the globe exposed to the risk factors that drive popular currency investment strategies? Do intervention flows support or reduce the returns to currency investing? Do central banks profit or lose money in FX trading? We are able to address these questions for the first time using a broad panel of daily sterilized intervention flows for 19 countries over the period from 1995 to 2011 and we are the first to provide a set of new stylized facts regarding the drivers and effects of systematic intervention in foreign exchange markets.

The large panel of countries allows us to uncover the existence of "systematic interventions" by the central banking sector, i.e., systematic factors in global intervention activity. Global, systematic intervention follows a pattern that is closely related to the factor structure in exchange rates. Central banks generally tend to lean against the wind and their interventions are driven by and impact on the same factors that drive currency excess returns: carry, momentum, value, and/or dollar. This relationship between systematic intervention and currency factors is state dependent. For example, with respect to the currency carry trade, interventions reduce carry returns in good times, but mitigate the downside risk of carry losses in bad times. In this sense, FX systematic intervention operates as a partial hedge for the carry trade: like a hedge, it has costs and reduces profits at times of low risk, but also contains the losses when risk materializes.

We also detect significant differences in behavior across country subgroups such as developed and emerging markets, countries with high versus low interest rates, and countries with high versus low net foreign asset positions. These different intervention styles also manifest themselves in intervention profits and losses: Emerging countries lose money on their intervention activity, mainly due to negative interest rate differentials, whereas developed countries make a (small) profit. Finally, we provide baseline estimates of the price impact of systematic intervention on currency excess returns arising from various investment strategies, which suggest that aggregate interventions are sometimes large enough to affect currency risk premia by an economically significant amount.

A number of implications arise from this analysis. First, even if individual central banks only try to stabilize their own currency, the strong factor structure in exchange rates spills over into aggregate interventions and, in effect, interventions have a strong global component which arises even if there is no formal global coordination of interventions. Second, our analysis of profits and losses highlights the different challenges faced by different central banks. Whereas for developed countries intervention profits are positive, FX intervention can be very costly for emerging markets and we are the first to quantify these costs quite precisely over a large sample. These differences reflect both differences in intervention styles and heterogeneity in key fundamental conditions, such as the level of interest rates and net foreign assets. Third, our analysis of price impacts suggests that central banks on aggregate are large enough to affect currency risk premia, and this impact varies across currency strategies and over time. While for policy makers this finding suggests that coordinated interventions (e.g., in times of crisis) are an effective tool to stabilize exchange rates, for currency managers it means that the choice of the currency universe they trade (not just the choice of trading strategy) can have first-order implications for their risk-return tradeoff.

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Appendix

A. Estimating price impacts via matching

We employ a propensity-score matching procedure in Section 5 which matches observations based on a country's propensity to intervene in the foreign exchange market. The propensity to intervene is based on a logit model where the dependent variable equals one if an intervention takes place ("treated") and zero otherwise ("non-treated").

The matching criteria for the treated and non-treated samples are based on a combination of exact matching and propensity-score matching.

First, we require an exact match of currency and exchange rate regime (based on the coarse classification by Reinhart and Rogoff (2004)), i.e., we only match observations within the same currency and within the same exchange rate regime. For example, for the AUD/USD exchange rate, there could be a match for day t with interventions by the Reserve Bank of Australia with a day without interventions s. On both days t and s Australia would have to be in the same currency regime.

The exact matching alone obviously does not ensure a matching of sufficiently comparable days. Hence, second, we additionally use propensity-score matching based on a logit model with a global and some currency-specific factors. We employ the VIX as a global factor and the foreign country's financial risk rating (from ICRG), the exchange rate change over the previous day, the previous week, and the previous quarter, as well as the interest rate differential (against USD) as currency-specific factors. Based on the resulting matched sample, we run regressions of exchange rate changes on interventions (and controls) to estimate the price impact of interventions.

Table IA.4 reports results for four different specifications. We start with the full (non-matched) sample of all days and run a univariate regression of spot exchange rate changes on interventions (in million USD), labeled specification(i). In specification (ii), we additionally control for the four factors, carry, momentum, value, and dollar. The coefficient on interventions is 0.014 in specification (i) and basically zero in specification (ii). The estimated coefficient of 0.014 translates into a price impact of 0.042 (3×0.014) basis points per three million USD trade. Specification (ii) suggests no price impact at all. However, these results are not based on the matched sample, all standard caveats about the endogeneity of interventions apply, and are thus hard to interpret.

We re-estimate the same specifications, now based on the matched sample, and report results in columns (iii) and (iv) of Table IA.4. Compared to the full sample, these results are based on only 1,094 observations (compared to 21,2107 for all days). This reduction in observations is driven by the fact that we require exact matches for country and exchange rate regime. The estimated coefficient for interventions range from 0.066 to 0.079 and imply a price impact of 0.2 basis points per three million USD trade ($0.066 \times 3 \approx 0.2$).

In our empirical analysis, we employ a range of price impacts from 0.2 basis points to 0.6 basis points per three million USD trade based on the analysis described above and results in Karnaukh et al. (2015).

Table I: Descriptive statistics: Factor returns

This table reports descriptive statistics for currency factor returns in Panel A. The mean excess return, standard deviation of excess returns, and Sharpe Ratios (SR) are annualized (assuming 252 trading days per year). Panel B reports excess return correlations. The frequency is daily and the sample is from 1995/01 – 2011/08.

Panel A. Descriptive statistics					Panel B. Return correlations				
	Carry	Mom	Value	Dollar		Carry	Mom	Value	Dollar
Mean	3.20	2.79	0.50	1.98	Carry	1.00	0.01	-0.29	0.55
t	[2.58]	[2.05]	[0.39]	[1.10]	Mom		1.00	-0.19	-0.04
Stdev	5.04	5.75	5.05	7.21	Value			1.00	-0.30
Skew	0.02	-0.19	0.21	0.26	Dollar				1.00
SR	0.64	0.48	0.10	0.27					

Table II: Descriptive statistics: Factor-specific intervention flows and global intervention activity

This table reports descriptive statistics for intervention flows. We report results for a measure of global intervention activity ($|I|$), which is the sum of absolute intervention amounts across all currencies on a given day. We also report descriptive statistics for carry-, momentum-, value-, and dollar-specific intervention flows where a positive number means that intervention is in the direction of the trading strategy underlying the factor. For example, a positive number for carry-specific intervention flows on a given day means that central banks as a whole bought high interest rate currencies and sold low interest rate currencies. We report mean intervention amounts (in million USD), the t statistic for a test that interventions are zero on average (based on Newey and West (1987) standard errors), the standard deviation of intervention flows (Stdev), the minimum (min) and maximum (max) daily intervention amount, as well as the 25 percentile (p_{25}), median (p_{50}), and 75 percentile (p_{75}) of intervention flows. The last row (% 0) denotes the percentage of days with zero interventions. The frequency is daily and the sample is from 1995/01 – 2011/08.

	$\|I\|$	Carry	Mom	Value	Dollar
Mean	79.90	-8.66	-11.25	22.30	-50.68
t	[13.61]	[-1.59]	[-2.26]	[4.02]	[-8.64]
Stdev	204.41	185.40	187.38	187.40	202.29
Min	0	-2,504	-2,683	-1,640	-3,318
p_{25}	0.67	-16.89	-4.98	-0.12	-50.00
p_{50}	20.61	0.00	0.00	0.00	-11.29
p_{75}	65.00	0.00	0.00	11.35	0.00
Max	3,322	3,282	3,322	3,278	2,678
% 0	20.76	49.27	49.30	41.30	20.81

Table III: Strategy-specific interventions

This table reports average strategy-specific returns (rx) and average strategy-specific intervention amounts (I) conditional on strategy-specific interventions being low, medium, or high. The three buckets of observations are based on the quantiles of intervention amounts where $q(I_x, p)$ denotes the p% quantile of strategy-specific interventions for strategy x with x ={Carry, Momentum, Value, Dollar}. Numbers in squared brackets are t-statistics based on Newey and West (1987) standard errors. Intervention amounts are in million USD (annualized assuming 252 trading days per year). The frequency is daily and the sample is from 1995/01 – 2011/08.

	Carry	Momentum	Value	Dollar
	$I_x \leq q(I_x, 0.3)$			
rx	7.46	10.28	3.21	10.16
	[3.48]	[3.79]	[1.34]	[3.22]
I_x	-3,160.77	-3,592.61	-2,041.88	-5,426.43
	[-12.46]	[-11.69]	[-9.21]	[-12.72]
	$I_x > q(I_x, 0.3)$ and $I_x \leq q(I_x, 0.7)$			
rx	4.08	2.07	5.34	3.86
	[2.79]	[1.07]	[2.94]	[1.77]
I_x	-63.27	-20.03	0.64	-243.09
	[-13.04]	[-9.01]	[4.54]	[-21.72]
	$I_x > q(I_x, 0.7)$			
rx	-5.93	-4.53	-8.96	-23.48
	[-1.34]	[-1.57]	[-3.32]	[-3.90]
I_x	6,023.26	3,635.73	4,746.20	2,240.72
	[9.47]	[8.53]	[10.00]	[7.31]

Table IV: Strategy-specific intervention in different market states

This table reports average strategy-specific interventions amounts for different market states (measured in million USD and annualized assuming 252 trading days per year). For each market state, we distinguish between a "High" and a "Low" bucket depending on whether conditioning variable is at or above its 70%-tile ("High") and at or below its 30%-tile ("Low"), respectively. The market states we consider are high or low global foreign exchange return volatility, strategy-specific returns over the previous week (5 trading days), strategy-specific returns over the previous month (22 trading days), country financial risk (based on the average of financial risk ratings across all countries), and the average forward discount over the previous five days. Numbers in squared brackets are t-statistics based on Newey and West (1987) standard errors and test for a significant difference between the high versus low market state. The frequency is daily and the sample is from 1995/01 – 2011/08.

	Carry	Momentum	Value	Dollar
	Global FX volatility			
Low	-171.36	-20.16	448.56	-1,043.28
High	1,396.08	362.88	1,877.40	-2,716.56
High – Low	1,567.44	383.04	1,428.84	-1,673.28
	[3.02]	[0.78]	[2.78]	[-3.52]
	Prior one-week returns			
Low	216.72	-25.20	1,257.48	-952.56
High	544.32	-267.12	567.00	-2,383.92
High – Low	327.60	-239.40	-690.48	-1,433.88
	[0.84]	[-0.69]	[-1.90]	[-3.78]
	Prior one-month returns			
Low	103.32	219.24	1,030.68	-723.24
High	637.56	-317.52	597.24	-2,328.48
High – Low	534.24	-536.76	-433.44	-1,605.24
	[1.24]	[-1.21]	[-1.10]	[-3.90]
	Country financial risk ratings			
Low	-171.40	672.84	670.32	-2,371.32
High	1,396.10	-385.56	773.64	-652.68
High – Low	1,567.40	-1,058.40	103.32	1,718.64
	[3.02]	[-2.29]	[0.18]	[4.11]
	Average forward discount			
Low	-171.40	88.20	360.36	-758.52
High	1,396.10	-277.20	957.60	-1,285.20
High – Low	1,567.40	-365.40	597.24	-526.68
	[3.02]	[-0.98]	[1.45]	[-1.49]

Table V: Systematic intervention by country group

This table reports results for panel regressions for different groups of countries with country fixed effects and two-way clustered standard errors (by country and year×month) of intervention amounts on potential (lagged) drivers of interventions. Intervention amounts are measured in billion USD and a positive number means that a country is buying home currency against USD. I_{-1} denotes lagged interventions, CAR denotes the forward discount (a positive number means a positive interest rate differential against the U.S.) as a measure of currency carry, MOM denotes returns over the previous 22 trading days (i.e., one month) as a measure of currency momentum, VAL denotes long-term (5-year) spot exchange rate changes as a measure of currency value (or long-term reversal), $\log(\sigma^2)$ denotes the log of a variance estimate from a GARCH(1,1) model for dollar factor returns, $\overline{AFD}$ denotes the average forward discount, CFR denotes country financial risk ratings, and DOL denotes lagged one-month average returns of the dollar factor. ALL comprises all countries, DEV denotes developed countries, EM denotes emerging countries, HIGH fd denotes high carry countries, LOW fd denotes low carry countries, HIGH NFA denotes countries with high net foreign assets, LOW NFA denotes countries with low net foreign assets.The frequency is daily.

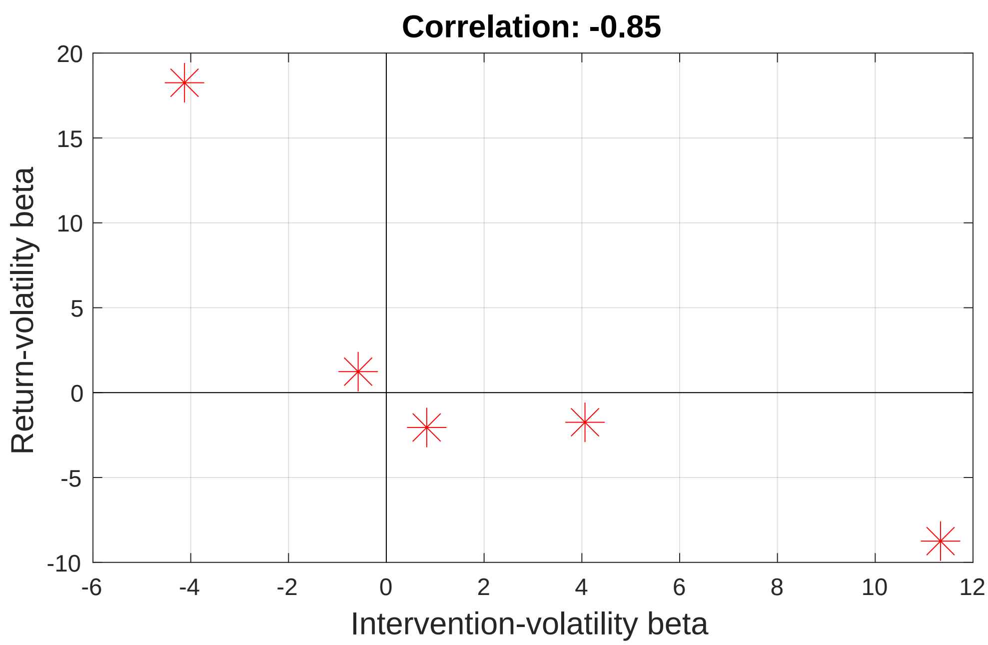
	ALL	DEV	EM	HIGH fd	LOW fd	HIGH NFA	LOW NFA
I_{-1}	0.47	0.32	0.49	0.30	0.30	0.34	0.29
	[9.72]	[14.82]	[18.90]	[18.94]	[2.77]	[95.32]	[32.21]
CAR_{-1}	9.69	-91.70	14.16	22.21	-1.07	-74.57	20.23
	[2.00]	[-1.14]	[1.65]	[48.29]	[-0.07]	[-1.04]	[4.77]
MOM_{-1}	-7.76	-4.12	-16.71	-13.01	-1.87	1.08	-14.44
	[-2.13]	[-1.06]	[-2.24]	[-12.19]	[-1.94]	[0.38]	[-11.76]
VAL_{-1}	43.73	29.90	92.81	75.99	5.56	-17.64	82.64
	[1.72]	[0.96]	[3.05]	[2.04]	[0.36]	[-0.69]	[2.70]
$\log \sigma^2_{-1}$	-5.61	0.45	-14.35	2.50	-0.18	0.47	0.30
	[-1.08]	[0.52]	[-1.18]	[1.47]	[-2.69]	[0.68]	[0.14]
AFD_{-1}	15.39	-0.44	20.79	-4.72	-11.79	17.16	-2.15
	[1.17]	[-0.01]	[1.54]	[-2.37]	[-1.40]	[0.69]	[-0.82]
CFR	-0.27	-0.69	0.97	-0.51	-0.22	-0.74	-0.57
	[-0.73]	[-3.06]	[0.92]	[-1.40]	[-1.12]	[-2.08]	[-1.85]
$\overline{DOL}_{-22;-1}$	3.10	3.20	5.10	10.79	-5.68	-0.08	5.20
	[0.42]	[0.43]	[0.34]	[0.62]	[-1.60]	[-0.02]	[0.39]
R^2	24.68	11.27	27.48	18.50	9.72	12.33	14.51

Table VI: Intervention-mimicking portfolios and currency factors

This table reports results for regressions of intervention-mimicking portfolio excess returns on currency factors (carry, momentum, value, and dollar). IR denotes the information ratio (annualized assuming 252 trading days per year). For specification (1), the information ratio equals the Sharpe Ratio. The regression intercept (α) is annualized and in percent. Numbers in squared brackets are t-statistics based on Newey/West standard errors. The frequency is daily and the sample is from 1995/01 – 2011/08.

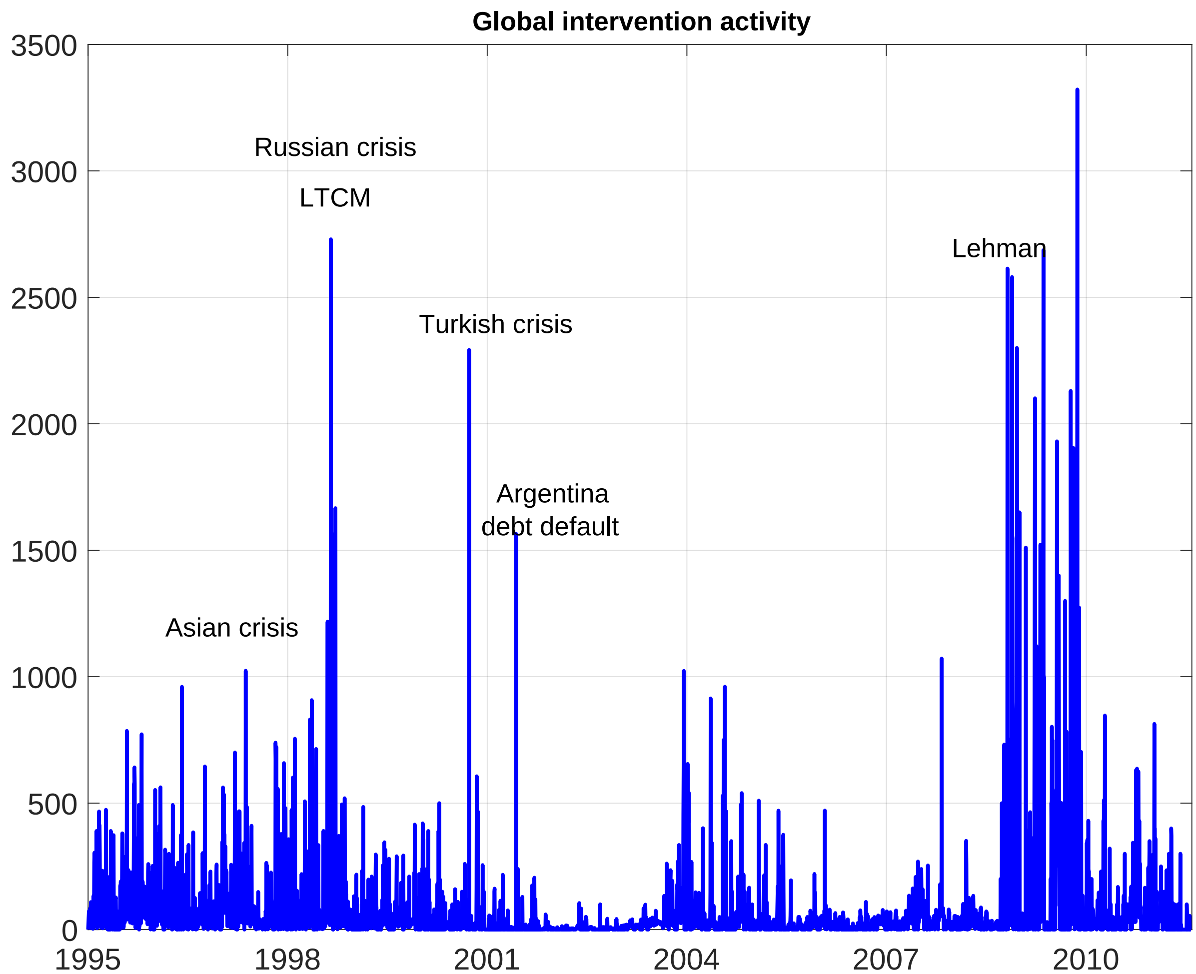
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A. All countries						
α	-1.62	-0.02	-1.65	-1.80	0.00	-0.45
	[-0.96]	[-0.01]	[-1.01]	[-1.11]	[0.00]	[-0.72]
β_{Carry}		-0.50				0.21
		[-11.04]				[8.51]
β_{Momentum}			0.01			-0.03
			[0.17]			[-1.42]
β_{Value}				0.35		0.03
				[6.46]		[1.24]
β_{Dollar}					-0.82	-0.90
					[-46.79]	[-50.51]
adj. R^2 (%)		15.12	-0.01	7.47	82.71	84.50
IR	-0.25	0.00	-0.25	-0.29	0.00	-0.17
Panel B. Developed countries						
α	-0.28	1.06	-0.12	-0.48	1.44	0.70
	[-0.15]	[0.60]	[-0.06]	[-0.27]	[1.79]	[0.88]
β_{Carry}		-0.42				0.39
		[-7.87]				[13.57]
β_{Momentum}			-0.06			-0.10
			[-0.98]			[-3.41]
β_{Value}				0.41		0.07
				[6.52]		[2.28]
β_{Dollar}					-0.87	-1.01
					[-30.73]	[-44.93]
adj. R^2 (%)		8.24	0.19	7.76	72.96	78.47
IR	-0.04	0.15	-0.02	-0.07	0.38	0.21
Panel C. Emerging countries						
α	-5.15	-2.74	-5.46	-5.20	-3.26	-3.01
	[-2.55]	[-1.56]	[-2.75]	[-2.65]	[-2.46]	[-2.25]
β_{Carry}		-0.73				-0.21
		[-19.42]				[-7.03]
β_{Momentum}			0.12			0.08
			[1.66]			[2.71]
β_{Value}				0.28		-0.03
				[5.55]		[-0.98]
β_{Dollar}					-0.72	-0.63
					[-35.06]	[-24.63]
adj. R^2 (%)		25.33	0.81	3.64	49.00	50.68
IR	-0.66	-0.41	-0.71	-0.68	-0.59	-0.55

Figure 1: Systematic intervention in the cross-section of currencies



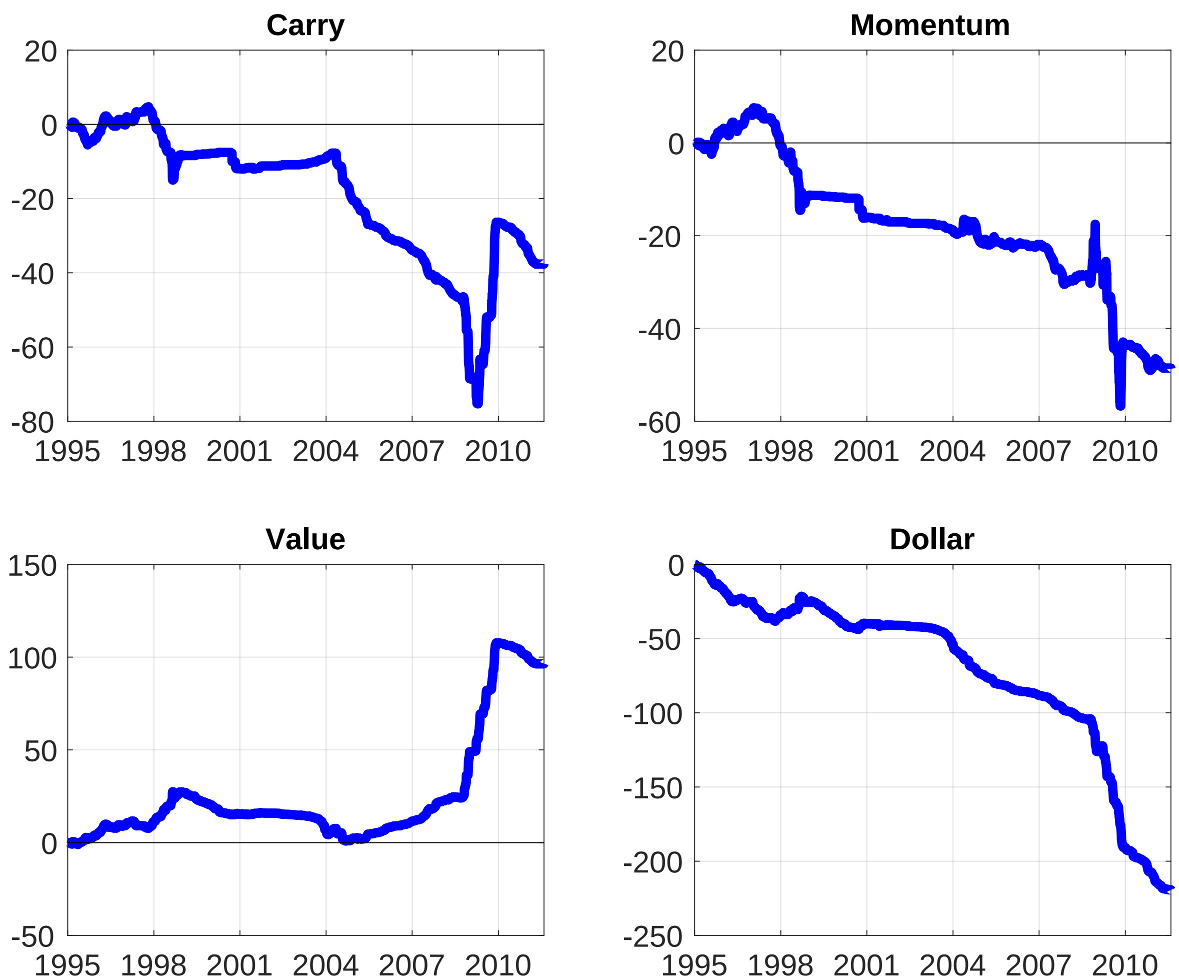
This figure shows scatter plots of intervention-volatility betas (horizontal axis) and return-volatility betas (lower plot) on the vertical axis. Intervention-volatility betas are obtained from time-series regressions of intervention amounts on volatility whereas return-volatility betas are obtained from regressions of (log) spot exchange rate changes on changes in global foreign exchange rate volatility. We run these regressions for each individual country and then form five groups of countries by averaging their betas and mean returns within each group. These five groups correspond to the stars shown in each plot. A higher intervention-volatility beta means that a country tends to buy its own currency (against) USD in bad times (i.e., times of high volatility) whereas a high return-volatility beta means that a country's currency tends to appreciate in bad times.

Figure 2: Global intervention activity across central banks



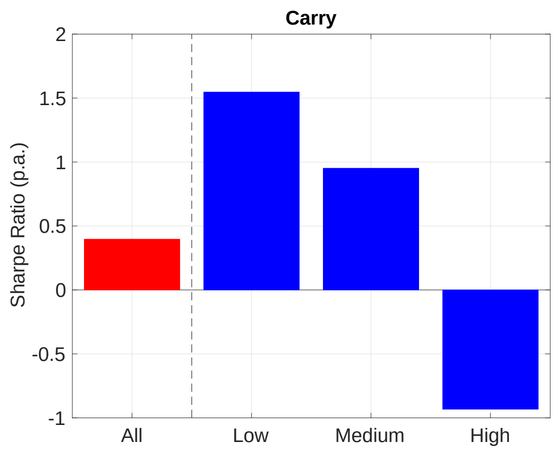
This figure shows global intervention activity, i.e., the sum of absolute intervention amounts across all central banks on a given day. Intervention amounts are measured in million USD. The frequency is daily and the sample is from 1995/01 – 2011/08.

Figure 3: Cumulative strategy-specific intervention flows

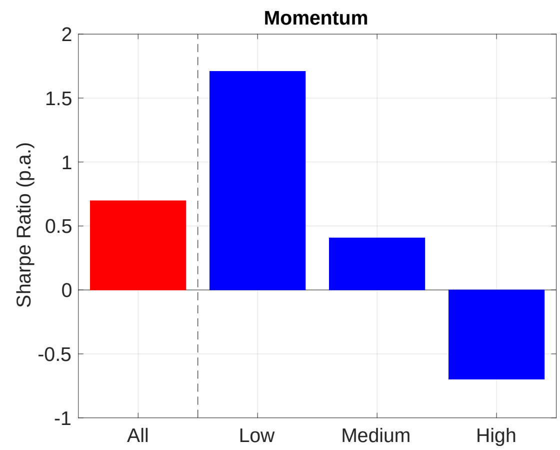


This figure shows cumulative strategy-specific intervention flows (vertical axis) in billion USD. The frequency is daily and the sample is from 1995/01 – 2011/08.

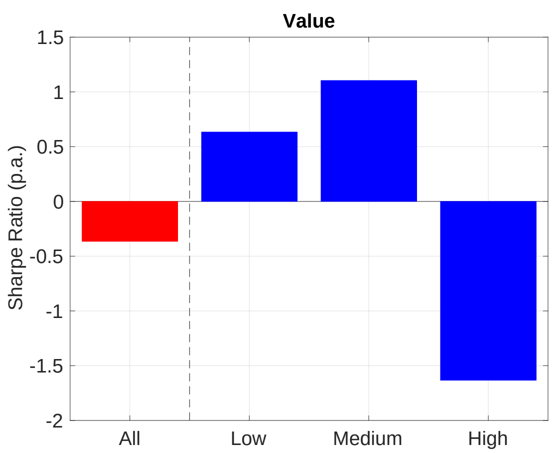
Figure 4: Strategy Sharpe Ratios conditional on strategy-specific interventions



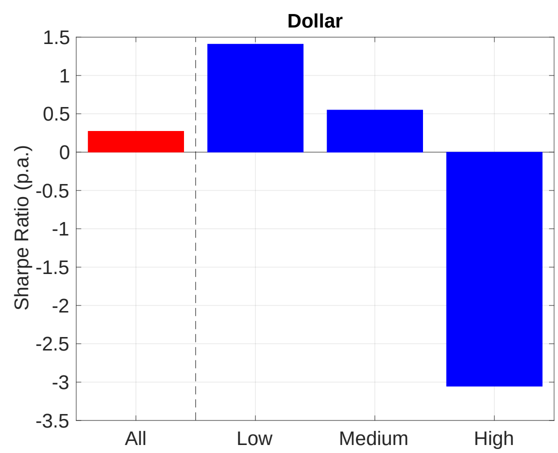
(a)



(b)



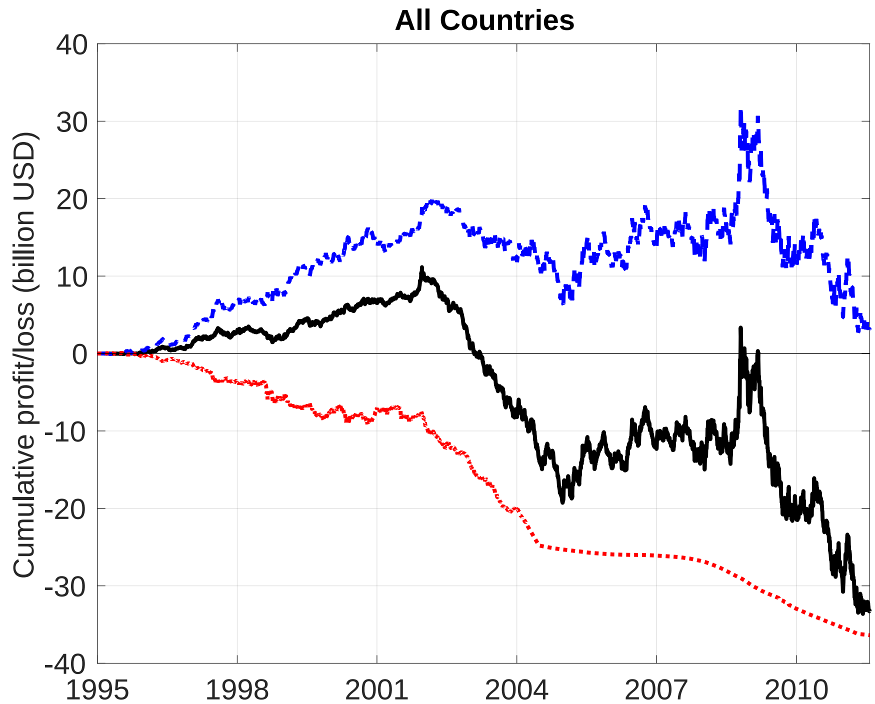
(c)



(d)

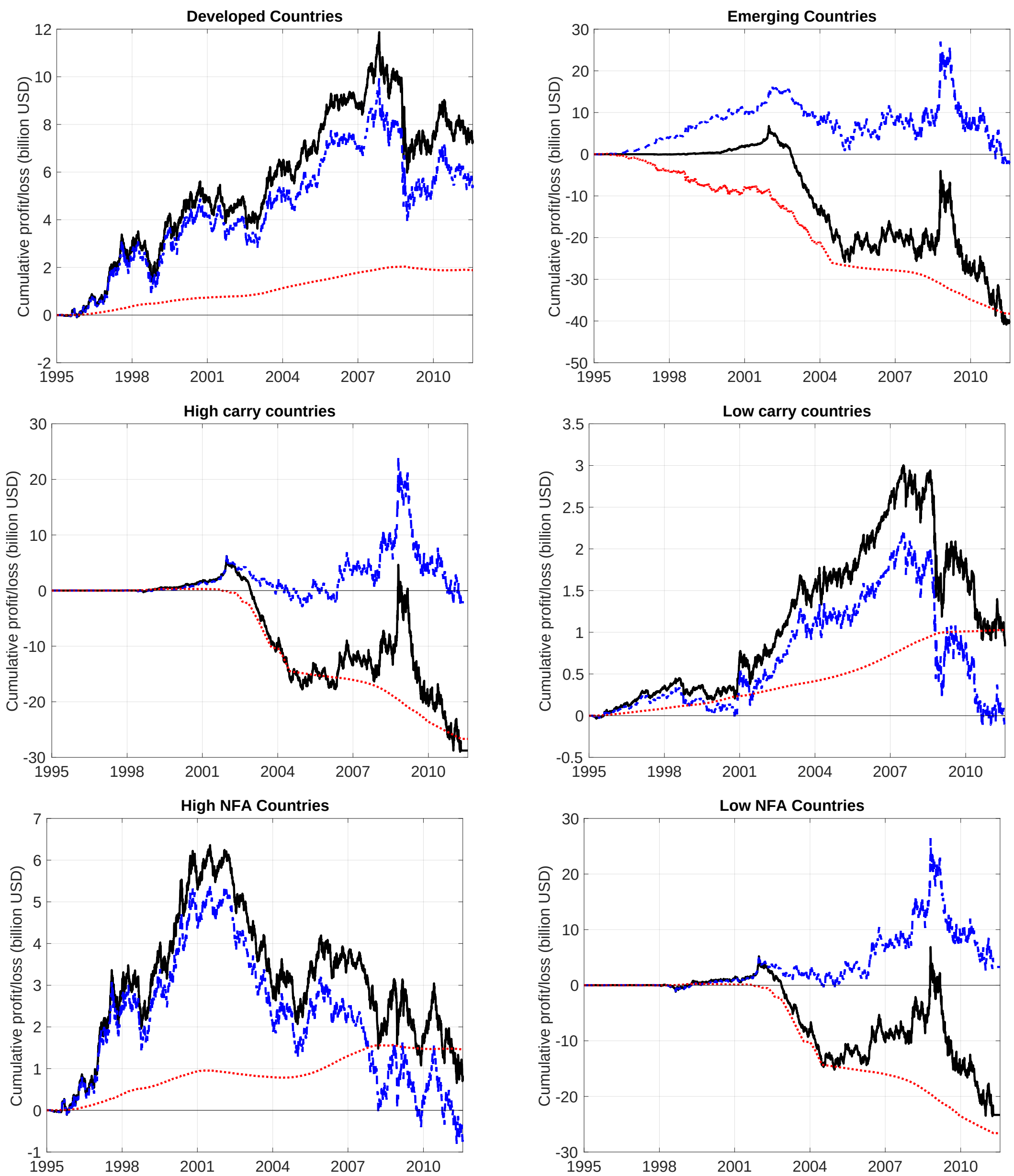
This figure shows mean Sharpe Ratios (p.a.) for carry, momentum, value and dollar factor returns for the full sample (All) and for three buckets of factor-specific intervention flows ("Low", "Medium", "High"), which are based on interventions (I_x) being below the 30%-tile, between the 30%-tile and 70%-tile, and above the 70%-tile . Strategy-specific signed intervention flows are the intervention amounts in the direction of the strategy (x = carry, momentum, value or dollar). For example, a positive carry-specific intervention flow means that interventions sell currencies with low interest rates and buy currencies with high interest rates. The frequency is daily and the sample is from 1995/01 – 2011/08.

Figure 5: Intervention profits/losses



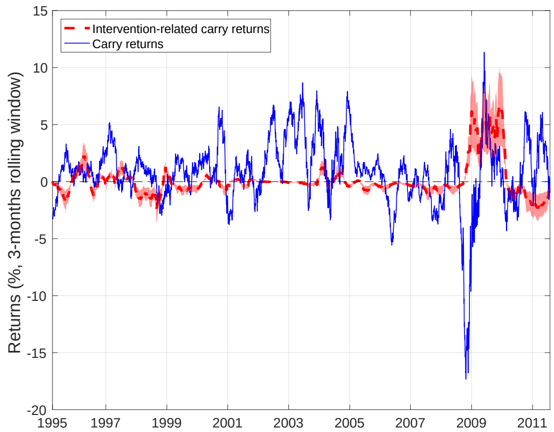
This figure shows cumulative profits/losses based on intervention flows by central banks. The solid line (black) shows overall profits/losses, the dashed line (blue) shows the exchange rate component of the overall p/l, and the dotted line (red) shows the interest rate differential component of the overall p/l. The frequency is daily and the sample is from 1995/01 – 2011/08.

Figure 6: Intervention profits/losses: Country groups

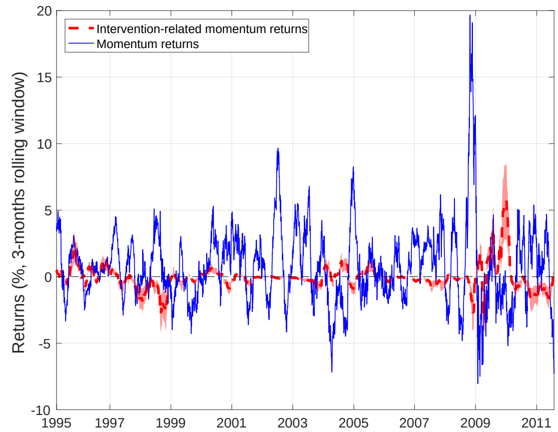


This figure shows cumulative profits/losses based on intervention flows by central banks. The solid line (black) shows overall profits/losses, the dashed line (blue) shows the exchange rate component of the overall p/l, and the dotted line (red) shows the interest rate differential component of the overall p/l. The frequency is daily and the sample is from 1995/01 – 2011/08.

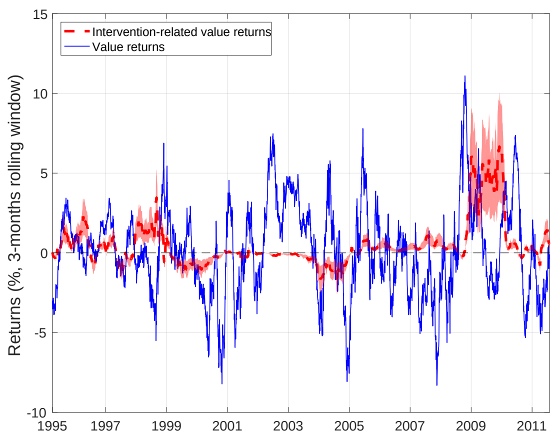
Figure 7: Factor returns and intervention-related returns



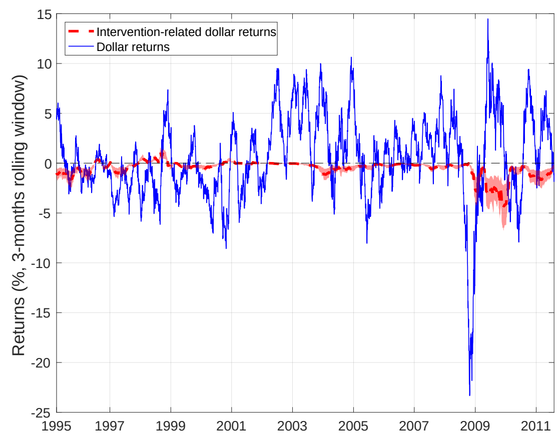
(a) Carry



(b) Momentum



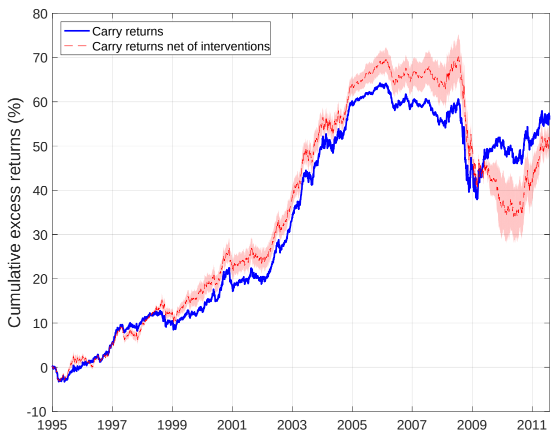
(c) Value



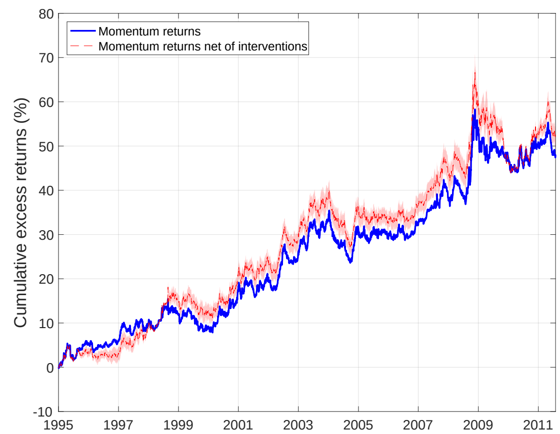
(d) Dollar

This figure shows 3-month rolling averages of factor returns (blue, solid) and interventional-related factor returns (red, dashed). Intervention-related factor returns are based on the price impact of intervention flows. We assume a price impact of 0.2–0.6 basis points for a USD 3 million trade size which is based on our own calculations in Appendix A and the average effective cost in Karnaukh et al. (2015). The shaded areas show results for costs of 0.2 to 0.6 basis points per trade and the dashed line shows the average of the two (0.4 basis points). The frequency is daily and the sample is from 1995/01 – 2011/08.

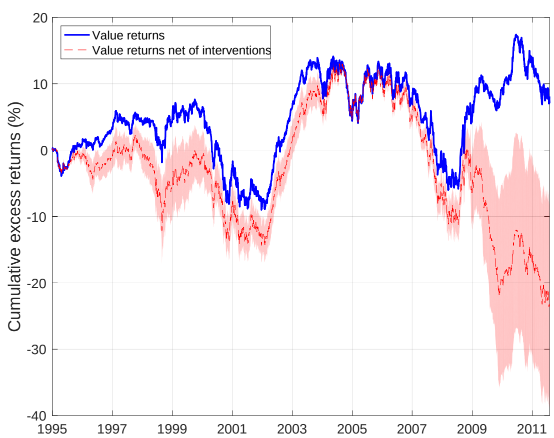
Figure 8: Factor returns net of interventions



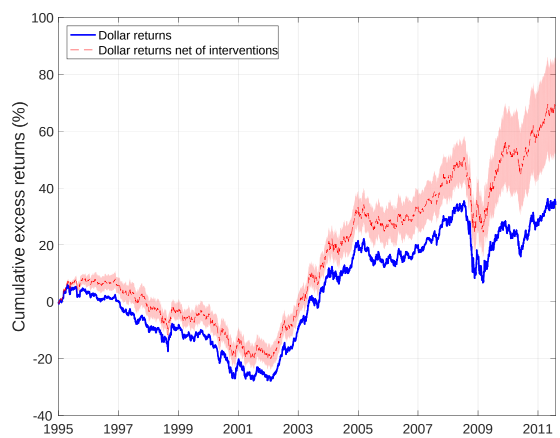
(a) Carry



(b) Momentum



(c) Value



(d) Dollar

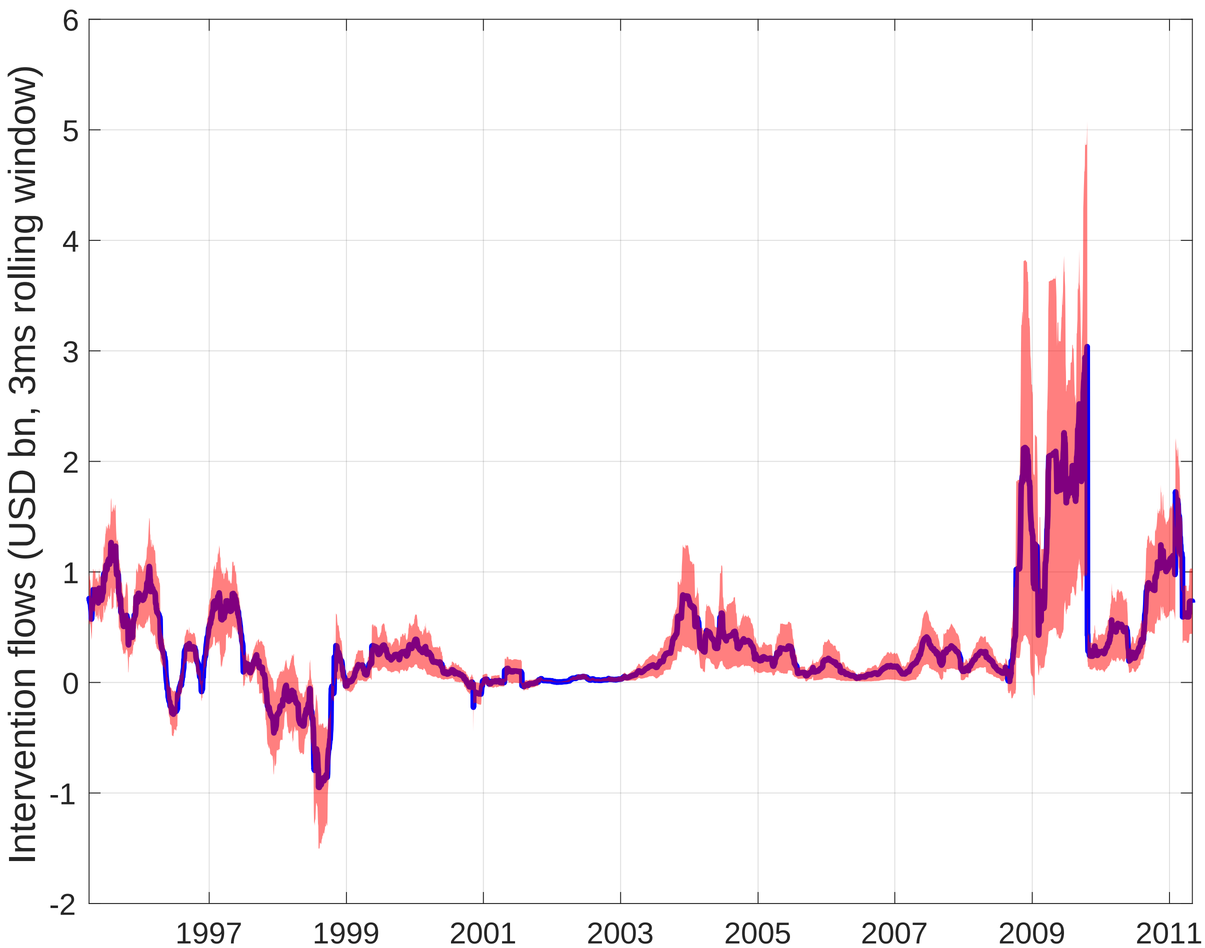
This figure shows cumulative factor returns (solid) and factor returns net of intervention activity (dashed). "Factor returns net of interventions" are computed as realized factor minus intervention-related factor returns. Intervention-related factor returns are based on the price impact of intervention flows. We assume a price impact of 0.2–0.6 basis points for a USD 3 million trade size which is based on our own caculations in Appendix A and the average effective cost in Karnaukh et al. (2015). The shaded areas show results for costs of 0.2 to 0.6 basis points per trade and the dashed line shows the average of the two (0.4 basis points). The sample period runs from 1995 to 2011 and the frequency is daily.

Internet Appendix for

Systematic Intervention and Currency Risk Premia

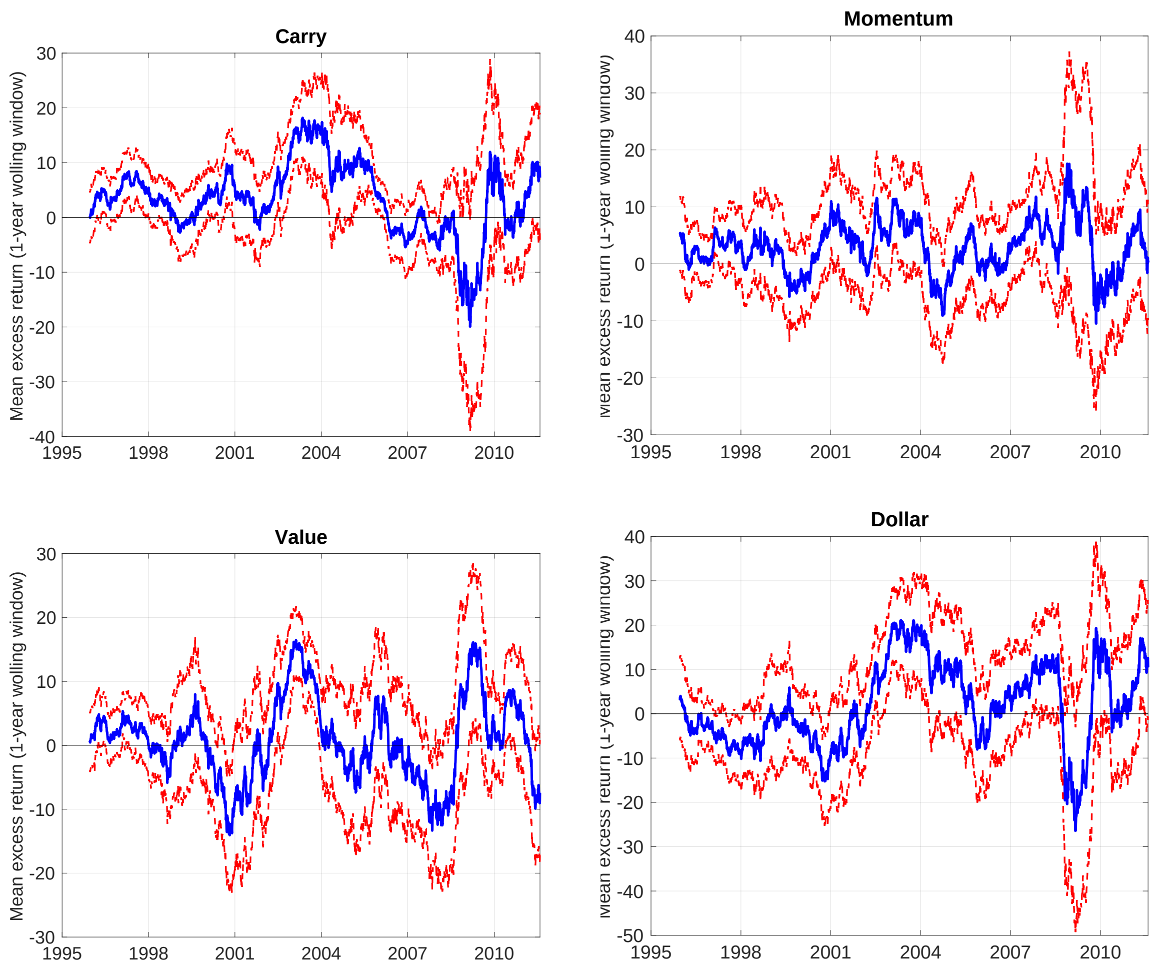
(not for publication)

Figure IA.1: Dispersion in intervention flows



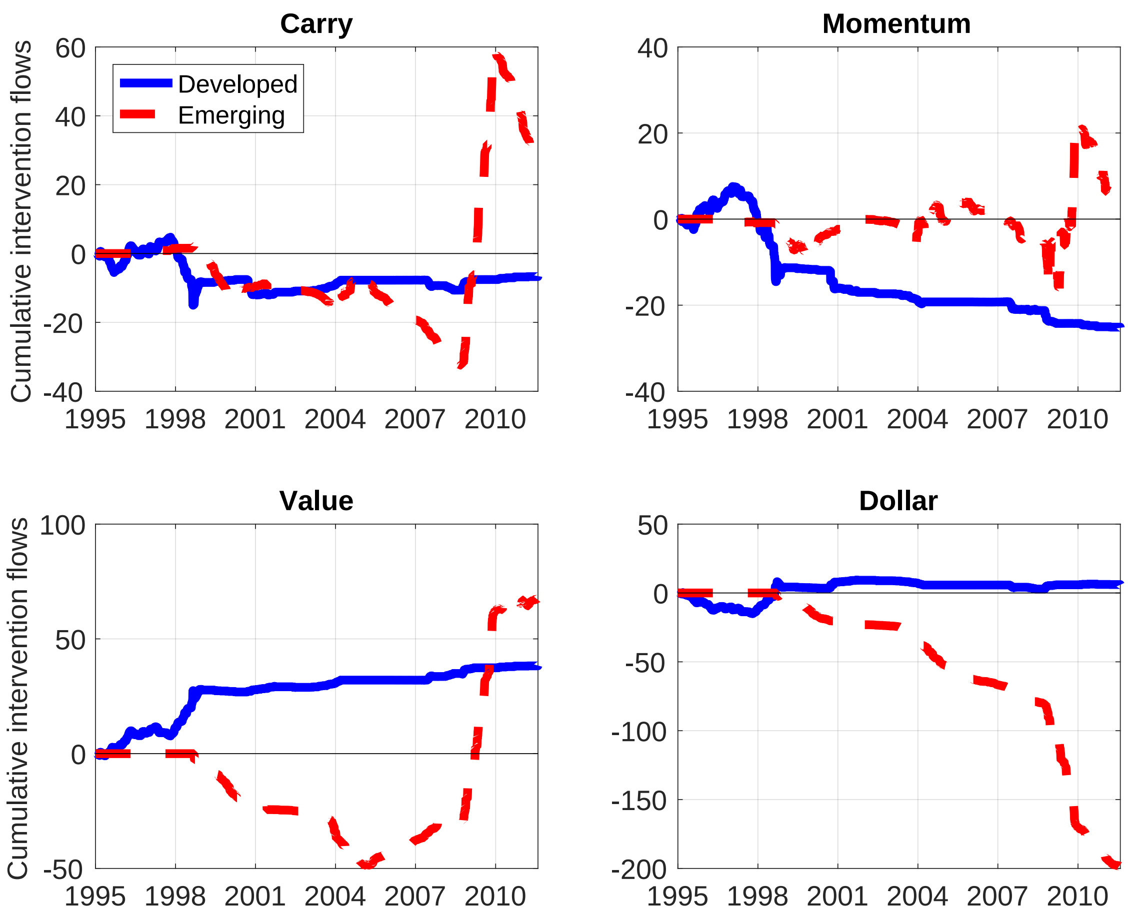
This figure shows (cross-sectional) average intervention flows (blue, solid line) measured in USD billions and the (cross-sectional) dispersion of mean intervention flows (±2 standard deviations, red shaded area) for rolling windows of three months (66 trading days). The frequency is daily and the sample is from 1995/01 – 2011/08.

Figure IA.2: Rolling strategy returns



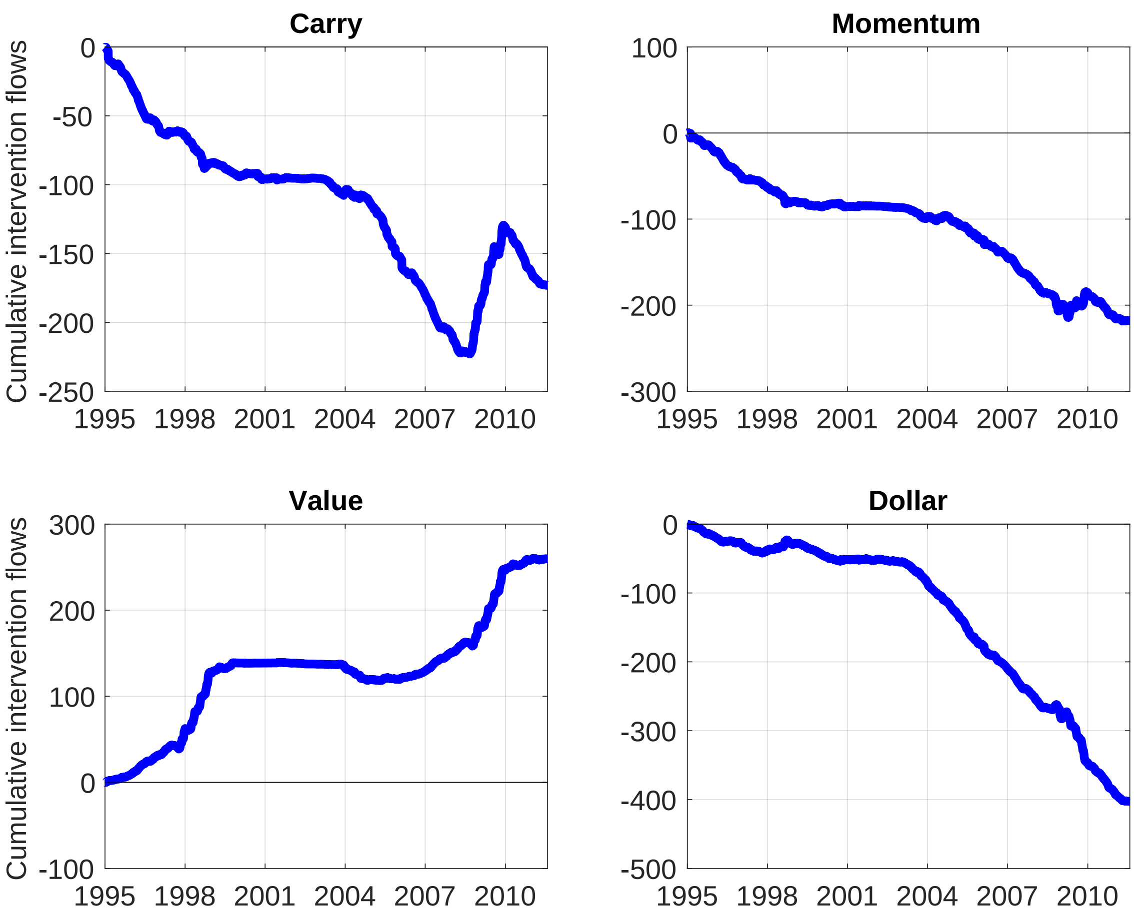
This figure shows rolling one-year excess returns of the carry, momentum, value, and dollar factor. The frequency is daily and the sample is from 1995/01 – 2011/08.

Figure IA.3: Cumulative strategy-specific intervention flows: Developed and emerging countries



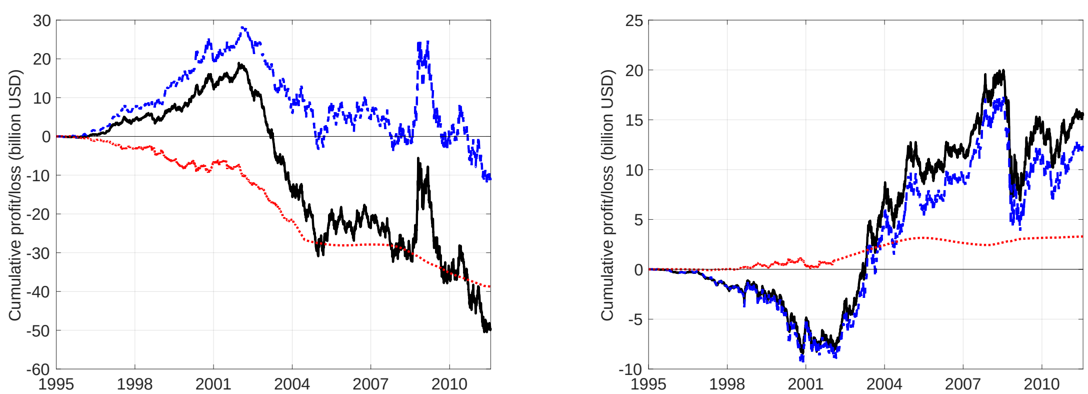
This figure shows cumulative strategy-specific intervention flows (vertical axis) in billion USD as in Figure 3 in the main text but here we show cumulative flows for developed (solid, blue line) and emerging (dashed, red line) separately. The frequency is daily and the sample is from 1995/01 – 2011/08.

Figure IA.4: Cumulative strategy-specific intervention flows: Broader sample



This figure shows cumulative strategy-specific intervention flows (vertical axis) in billion USD for a broader sample of currencies (compared to Figure 3 in the main text) that includes pegged or tightly managed currencies and/or currencies with substantial capital controls. The frequency is daily and the sample is from 1995/01 – 2011/08.

Figure IA.5: Intervention profits/losses: USD purchases vs. sales



(a) USD purchases

(b) USD sales

This figure shows cumulative profits/losses based on intervention flows by central banks as in Figure 5 but here we show profits and losses separately for USD purchases (left side) and USD sales (right side). The frequency is daily and the sample is from 1995/01 – 2011/08.

Table IA.1: Intervention profits/losses by country group: Broader sample

This table reports average daily profits/losses (in million USD) for different country groups and sample periods for a broader sample of currencies (compared to Table IA.2 in the main text) that includes pegged or tightly managed currencies and/or currencies with substantial capital controls. DEV (EM) denotes developed (emerging) countries, "carry" denotes the forward discount (i.e., the interest rate differential between a foreign country and the U.S.), and NFA denotes net foreign assets. rx denotes the overall excess return, Δs denotes the FX spot rate component of excess returns, and fd denotes the interest rate differential component of excess returns. Numbers in squared brackets are t-statistics based on Newey and West (1987) standard errors. The frequency is daily and the sample is from 1995/01 – 2011/08.

	All	DEV	EM	High carry	Low carry	High NFA	Low NFA
			Full sample (1995/01 – 2011/08				
rx	-7.66	1.70	-10.94	-8.17	0.22	0.19	-5.51
	[-1.51]	[1.33]	[-1.78]	[-1.47]	[0.57]	[0.21]	[-1.33]
Δs	0.74	1.26	-0.52	-0.60	-0.02	-0.14	0.78
	[0.14]	[0.99]	[-0.10]	[-0.11]	[-0.04]	[-0.15]	[0.19]
fds	-6.06	0.44	-7.59	-7.58	0.24	0.34	-6.30
	[-12.32]	[20.64]	[-14.34]	[-14.64]	[29.51]	[13.75]	[-13.59]
			Pre-crisis (1995/01 – 2007/06				
rx	-3.02	3.19	-7.66	-5.10	0.91	1.13	-2.62
	[-0.87]	[2.69]	[-1.89]	[-1.53]	[3.07]	[1.12]	[-1.00]
Δs	5.05	2.62	2.44	1.45	0.67	0.69	2.49
	[1.38]	[2.21]	[0.70]	[0.46]	[2.25]	[0.69]	[0.98]
$i^* - i$	-4.95	0.57	-6.82	-6.56	0.24	0.44	-5.12
	[-8.28]	[30.78]	[-9.41]	[-9.33]	[32.82]	[16.45]	[-9.23]
			2007/07 – 2011/08				
rx	-21.80	-2.84	-19.12	-15.95	-1.88	-2.67	-14.89
	[-1.21]	[-0.75]	[-0.99]	[-0.89]	[-1.42]	[-1.22]	[-0.93]
Δs	-12.39	-2.86	-9.61	-5.79	-2.09	-2.70	-4.78
	[-0.69]	[-0.75]	[-0.50]	[-0.32]	[-1.59]	[-1.23]	[-0.30]
$i^* - i$	-9.41	0.02	-9.51	-10.16	0.22	0.03	-10.11
	[-28.21]	[0.56]	[-30.37]	[-35.56]	[11.71]	[0.96]	[-35.70]

Table IA.2: Intervention profits/losses by country group

This table reports average daily profits/losses (in million USD) for different country groups and sample periods. DEV (EM) denotes developed (emerging) countries, "carry" denotes the forward discount (i.e., the interest rate differential between a foreign country and the U.S.), and NFA denotes net foreign assets. P/L denotes the overall profit/loss, $P/L(\Delta s)$ denotes the profit/loss arising from changes in exchange rates, and $P/L(i^* - i)$ denotes the profit/loss arising from interest rate differentials. Numbers in squared brackets are t-statistics based on Newey and West (1987) standard errors. The frequency is daily and the sample is from 1995/01 – 2011/08.

	All	DEV	EM	High carry	Low carry	High NFA	Low NFA
			Full sample (1995/01 – 2011/08)				
P/L	-7.66	1.70	-10.94	-8.17	0.22	0.19	-5.51
	[-1.51]	[1.33]	[-1.78]	[-1.47]	[0.57]	[0.21]	[-1.33]
$P/L(\Delta s)$	0.74	1.26	-0.52	-0.60	-0.02	-0.14	0.78
	[0.14]	[0.99]	[-0.10]	[-0.11]	[-0.04]	[-0.15]	[0.19]
$P/L(i^* - i)$	-6.06	0.44	-7.59	-7.58	0.24	0.34	-6.30
	[-12.32]	[20.64]	[-14.34]	[-14.64]	[29.51]	[13.75]	[-13.59]
			Pre-crisis (1995/01 – 2007/06)				
P/L	-3.02	3.19	-7.66	-5.10	0.91	1.13	-2.62
	[-0.87]	[2.69]	[-1.89]	[-1.53]	[3.07]	[1.12]	[-1.00]
$P/L(\Delta s)$	5.05	2.62	2.44	1.45	0.67	0.69	2.49
	[1.38]	[2.21]	[0.70]	[0.46]	[2.25]	[0.69]	[0.98]
$P/L(i^* - i)$	-4.95	0.57	-6.82	-6.56	0.24	0.44	-5.12
	[-8.28]	[30.78]	[-9.41]	[-9.33]	[32.82]	[16.45]	[-9.23]
			(Post-)Crisis (2007/07 – 2011/08)				
P/L	-21.80	-2.84	-19.12	-15.95	-1.88	-2.67	-14.89
	[-1.21]	[-0.75]	[-0.99]	[-0.89]	[-1.42]	[-1.22]	[-0.93]
$P/L(\Delta s)$	-12.39	-2.86	-9.61	-5.79	-2.09	-2.70	-4.78
	[-0.69]	[-0.75]	[-0.50]	[-0.32]	[-1.59]	[-1.23]	[-0.30]
$P/L(i^* - i)$	-9.41	0.02	-9.51	-10.16	0.22	0.03	-10.11
	[-28.21]	[0.56]	[-30.37]	[-35.56]	[11.71]	[0.96]	[-35.70]

Table IA.3: Intervention-mimicking portfolios and currency factors: Spot exchange rate changes

This table reports results for regressions of intervention-mimicking portfolio spot exchange rate changes on currency factors (carry, momentum, value, and dollar). IR denotes the information ratio (annualized assuming 252 trading days per year). For specification (1), the information ratio equals the Sharpe Ratio. The regression intercept (α) is annualized and in percent. Numbers in squared brackets are t-statistics based on Newey/West standard errors. The frequency is daily and the sample is from 1995/01 – 2011/08.

	(1)	(2)	(3)	(4)	(5)	(6)
Panel A. All countries						
α	-0.07	1.57	-0.08	-0.25	1.48	1.13
	[-0.04]	[1.08]	[-0.05]	[-0.17]	[2.68]	[2.00]
β_{Carry}		-0.51				0.15
		[-11.90]				[7.39]
β_{Momentum}			0.00			-0.02
			[0.08]			[-1.47]
β_{Value}				0.37		0.05
				[7.11]		[2.98]
β_{Dollar}					-0.78	-0.83
					[-50.49]	[-53.42]
adj. R^2 (%)		17.61	-0.02	9.11	84.11	85.33
IR	-0.01	0.28	-0.01	-0.04	0.60	0.48
Panel B. Developed countries						
α	-0.78	0.56	-0.62	-0.98	0.94	0.20
	[-0.42]	[0.32]	[-0.34]	[-0.56]	[1.17]	[0.25]
β_{Carry}		-0.42				0.39
		[-7.87]				[13.57]
β_{Momentum}			-0.06			-0.10
			[-0.98]			[-3.41]
β_{Value}				0.41		0.07
				[6.53]		[2.31]
β_{Dollar}					-0.87	-1.01
					[-30.75]	[-44.92]
adj. R^2 (%)		8.24	0.19	7.78	72.95	78.46
IR	-0.11	0.08	-0.08	-0.14	0.25	0.06
Panel C. Emerging countries						
α	0.77	2.93	0.56	0.64	2.20	2.49
	[0.49]	[2.12]	[0.37]	[0.42]	[2.47]	[2.80]
β_{Carry}		-0.65				-0.17
		[-16.35]				[-6.79]
β_{Momentum}			0.07			0.05
			[1.09]			[2.41]
β_{Value}				0.30		0.00
				[6.44]		[0.07]
β_{Dollar}					-0.69	-0.62
					[-42.41]	[-35.20]
adj. R^2 (%)		27.14	0.43	5.72	61.37	62.77
IR	0.12	0.54	0.09	0.10	0.56	0.64

Table IA.4: Price impact of intervention flows

This table reports results for regressions of daily exchange rate appreciation rates in basis points on intervention flows (I, in million USD) and the currency factors carry, momentum, value, and dollar. The scaling of intervention flows and (log) exchange rate changes is such that a positive slope coefficient means that a purchase of foreign currency (against USD) is associated with an appreciation of the foreign currency (against USD). Specifications (i) and (ii) are based on all observations (currency-day combinations). Specifications (iii) and (iv) are based on a matching procedure where we match currency-day combinations based on the following items: We require an exact match of currency and exchange rate regime (coarse classification from Reinhart and Rogoff (2004)) and we match on propensity scores of a global factor (the VIX) and currency-specific factors, i.e., the foreign country's financial risk rating, the exchange rate change over the previous day, the previous week, and the previous quarter, as well as the interest rate differential (against USD). The resulting matched sample has 1,094 observations. Note that the coefficients on I measure the price impact of a one million USD purchase of foreign currency. In the main text we employ a standard trade size of three million USD, so the price impact of 0.2 basis points in the main paper is obtained from multiplying the slope coefficients by three.

	All obs (i)	All obs (ii)	Matched (iii)	Matched (iv)
I	0.014	0.001	0.079	0.066
	[1.33]	[0.27]	[3.75]	[3.29]
Carry		-0.016		0.235
		[-1.00]		[2.33]
Momentum		0.003		-0.235
		[0.25]		[-3.07]
Value		0.030		-0.213
		[2.22]		[-2.28]
Dollar		0.950		1.042
		[82.04]		[14.76]
obs	21,107	21,107	1,094	1,094