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The performance of NDF carry trades

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A B S T R A C T

This paper investigates the performance of carry trade strategies for currencies with non-deliverable forward (NDF) contracts. We find that carry trades for currencies with NDF contracts are associated with higher Sharpe ratios compared to carry trades for currencies with deliverable forward (DF) contracts. We also find that, during the recent financial crisis, DF carry trades incur heavy losses while NDF carry trades realize insignificant losses. DF carry trade payoffs are shaped by credit risk, global foreign exchange (FX) volatility and crash risk. In contrast, NDF carry trade payoffs are driven by global FX volatility and crash risk, liquidity risk, and currency convertibility risk measured by deviations from covered interest parity in offshore markets while global convertibility risk has a limited effect on carry trades.

1. Introduction

The past decade has seen rapid growth of foreign exchange trading in emerging market currencies. According to the 2010 Triennial Central Bank Survey published by the Bank for International Settlements (BIS), the global foreign exchange market turnover in emerging countries has reached a daily volume of US$879 billion, a 210% increase for the 10-year period from 2001 to 2010 (BIS, 2010). The percentage of global foreign exchange market turnover in emerging countries increased from 16.6% to 17.4% during the same period. The turnover of high- and low-yielding currencies (carry trades) forms an important part of emerging market foreign exchange transactions. Offshore trading, that is, foreign exchange trading outside of a currency's home country, has become increasingly important and many

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offshore foreign exchange transactions occur in non-deliverable forward (NDF) markets due to currency convertibility restrictions and capital controls (Mihajek and Packer, 2010; McCauley and Scatigna, 2011).

This paper investigates the performance of carry trade strategies for currencies with NDF contracts and the payoff differences between deliverable forward (DF) and NDF carry trades on a sample of 66 developed and emerging countries from October 1997 to February 2011. Our undertaking is motivated by the following observations. First, despite the rapid growth of NDF trading, the empirical evidence regarding the NDF markets is scarce (De Zwart et al., 2009). There is a void about the payoff properties of carry trade strategies for currencies with convertibility restrictions and capital controls.[2] While recent empirical studies have examined the payoff properties of carry trades (Burnside et al., 2007; Menkhoff et al., 2012), they focus on DF currencies. However, for many of the non-convertible currencies, offshore DF markets do not exist, their forward contracts traded in international markets are NDFs, where trading takes place in offshore centers. Given the rising importance of NDF trading in recent years and the lack of empirical research, to the best of our knowledge, this is the first study to address the payoff properties of NDF carry trades and shed light on the differences between NDF and DF carry trades.

Second, previous carry trade studies assume that covered interest parity (CIP) holds for DF and NDF currencies. However, multinational firms and international investors hedge exchange rate risk arising from currency convertibility restrictions and capital controls using NDF contracts. Similar to DFs, the pricing of NDF contracts reflects the interest rate differential between two countries. However, when onshore and offshore capital markets are segmented by currency convertibility restrictions and capital controls, onshore interest rates are unavailable to international investors, and offshore interest rates must be inferred from the NDF prices. Contingent on the effectiveness of capital controls in place, the gap between onshore and offshore interest rates is affected by a number of factors, such as expectations of future exchange rates, perceived changes in foreign exchange policy, market liquidity, accessibility to onshore money markets, speculative positioning, and the relation between offshore and onshore currency forward markets (Park and Rhee, 2001; Ma et al., 2004; Lipscomb, 2005). Therefore, the onshore interest rates for non-convertible currencies may differ from offshore interest rates implied in NDF prices, presenting unique trading opportunities for NDF carry trade strategies due to deviations from covered interest parity in offshore markets.

Aliber (1973), long ago, argued that the risk of exchange controls influences forwards rates. More recent studies show that carry trade returns are related to alternative risk factors such as dollar risk (Lustig et al., 2011), global foreign exchange (FX) market volatility (Menkhoff et al., 2012), global FX bid–ask spread, and carry trade funding market liquidity and FX skewness (Brunnermeier and Pedersen, 2009). This strand of research argues that the exchange rate risk due to currency convertibility restrictions and capital controls may be another source of risk for NDF carry trades. Hence, NDFs provide us with a unique opportunity to study the relation between NDF returns and deviations from CIP and shed light on the risk of exchange controls on carry trade returns while controlling for other sources of risk mentioned above. To the best of our knowledge, deviations from CIP have not been examined as a risk factor in the carry trade literature, mainly because the research focus has been on developed currencies where the covered interest differential (CID) is near zero. However, there is little reason to expect that covered interest parity hold in emerging markets where currency convertibility restrictions and capital controls are in effect. There is an additional, more subtle, but interesting prediction that surfaces from our analysis. Deviations from covered interest parity, as a risk factor, will remain as long as emerging economies impose currency convertibility restrictions and capital controls. Furthermore, our findings suggest that such a risk factor is likely to become relevant if policy makers consider the adoption of measures (i.e., excise taxes such as the Tobin tax on cross-border currency transactions) with the intention to curb speculative currency trades.

[2] The NDF currencies in this paper refer to currencies that are subject to foreign exchange convertibility restrictions and trade in NDF markets. A number of emerging economies with convertible currencies also trade in NDF markets, such as Kazakhstan, Poland, Russia, and Ukraine. This study includes them in the sample of convertible currencies by retrieving DF data for these countries.

Finally, the NDF markets, being offshore, have stayed outside the regulatory purview of the local monetary authorities. The differences between offshore NDF and onshore forward prices contain important information, e.g., market expectations and supply/demand conditions, which cannot be fully reflected in onshore forward prices for countries with capital controls. Therefore, studying the behavior of NDF market players is of interest to central bank policy makers.

The main findings of this research are as follows: NDF carry trades tend to be associated with higher Sharpe ratios compared to DF carry trades. For the period 1997–2003, DF carry trades realize positive returns, but for the period 2004–2011, they earn near-zero mean returns. Further investigation reveals that the near-zero mean returns during 2004–2011 are the result of the heavy losses of DF carry trades realized during the 2008 financial crisis, while NDF carry trades incur insignificant losses during the crisis period. Multivariate regression results indicate that DF carry trade returns are driven by carry trade funding market conditions, and global FX market volatility and crash risk. The heavy losses of developed and emerging DF carry trades during the 2008 financial crisis are attributable to the drying up of the carry trade funding markets and increased global FX market volatility and crash risk. In contrast, NDF carry trades are driven by deviations from covered interest parity, measured by the covered interest differential (CID), and global FX market volatility, skewness and liquidity risks. While covered interest parity holds for DF currencies, the onshore–offshore interest rate differential for NDF currencies is economically large at −3.5% on an annual basis, indicating deviations from covered interest parity in offshore markets. Our investigation shows that, on average, CID contributes positively to NDF carry trade returns, suggesting that the superior performance of NDF carry trades reflects compensation for risk due to currency convertibility restrictions and capital controls. We also find that global FX market volatility and crash risk has a negative impact on both DF and NDF carry trades, while global convertibility risk has a limited effect on carry trades.

This paper is organized as follows. Section 2 discusses the technical details of NDF contracts and the implications on calculating carry trade returns for NDF currencies. Sections 3 reviews the literature of covered interest parity and carry trades in emerging markets. Section 4 discusses the methodology. Section 5 describes the data. Section 6 presents the empirical results. Section 7 concludes the paper.

2. Non-deliverable forwards

The NDF contract, created in the early 1990s, is a derivative product offered by large providers of foreign exchange derivatives in the over-the-counter market. The NDFs are primarily used by multinational corporations, portfolio managers and currency traders for hedging and speculation in emerging currency markets, which are not-freely convertible (or non-convertible, for brevity). Hence, the liquidity of the NDF market largely comes from (i) multinational firms and international portfolio managers hedging the exchange rate risk in non-convertible currencies, (ii) non-residents wishing to speculate on the NDF underlying currency without any exposure to the country, and (iii) arbitrageurs who attempt to exploit the differentials in the prices in the two markets without any outlay of capital on their part by two offsetting transactions.[3] The NDF markets are active for emerging economies with substantial cross-border investment flows and trade flows where currency convertibility restrictions and capital controls remain in effect. According to J.P. Morgan estimates, the average daily turnover in Q4 2008 was US$2.3 billion for the Chinese yuan, US$1.05 billion for the Indian rupee, US$1.45 billion for the Korean won, US$1 billion for the Malaysian ringgit, and US$1.7 billion for the Taiwan dollar (Piron, 2009). The most actively traded NDF currencies include the Brazilian real, the Chilean peso, the Chinese yuan, the Indian rupee, the Korean won, and the Taiwan dollar. New York tends to dominate trading in Latin American NDFs, Singapore and Hong Kong tends to dominate trading in Asian NDFs, and London deals with transactions in both markets.[4]

Under an NDF contract, a non-convertible currency, such as the Korean won or Taiwan dollar, is specified against a freely convertible currency. This is typically the U.S. dollar, but other currencies such

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[3] Some of the money center banks which trade NDFs include Deutsche Bank, UBS AG, Citibank, JP Morgan Chase, ABN Amro, Barclays, ANZ Investment bank and BNP.

[4] For an in-depth analysis of the NDF markets, see Lipscomb (2005).

as the euro or Swiss franc are also possible. The NDF contract is for a notional amount of the convertible currency, on a specific future date (settlement date), and at an agreed forward rate set on the date of the contract (trade date). On the fixing date (valuation date), the prevailing spot exchange rate (fixing rate) is compared with the contracted forward rate. If the fixing rate is greater than the contracted forward rate, quoted in non-convertible currency units per convertible currency unit, the seller of the convertible currency must pay the buyer on the settlement date, and vice versa. The amount of the payment, settled in the convertible currency, equals the difference between the fixing rate and the contracted forward rate, multiplied by the notional amount of the convertible currency and divided by the fixing rate. Depending on the currencies involved in an NDF transaction, the valuation date is typically one or two business days before the settlement date.[5] The key difference between the NDFs and traditional forward contracts is that NDFs are cash settled. The non-convertible currency being bought forward or sold forward in an NDF transaction is not delivered. This cash settlement feature reflects the fact that NDFs are contracted offshore and are beyond the regulatory frameworks of the local authorities with non-convertible currencies.[6]

When an NDF transaction is agreed upon, the parties must also agree on a way to determine the fixing rate on the valuation date. This can be the official exchange rate set by the country's central bank or other authorities, or an average of interbank prices displayed on a Reuters or Telerate screen at a specified time. In general, the fixing rate for an NDF contract is based on the spot rate traded onshore (Lipscomb, 2005). An important feature of NDF contracts is that there is no bid–ask spread in the fixing rate. This is in contrast to DFs, where paying the bid or ask price in the spot market is necessary to close out a position in the forward market. The valuation day for an NDF contract is typically one or two business days before the settlement day, depending on the currencies involved. Therefore, the carry trade returns for NDF contracts should be calculated using the fixing rate on the valuation day.

3. Covered interest parity and carry trades in emerging markets

Academic studies of political risk as a determinant of deviations from covered interest parity date back to Aliber (1973), who defines the concept of political risk as the probability that controls will be imposed on capital flows. Dooley and Isard (1980) examine the onshore–offshore interest rate differentials caused by a series of capital controls introduced in Germany between 1970 and 1974. The authors find that deviations from covered interest parity due to existing capital controls explain the main portion of the observed interest rate differentials (about 75%), while the prospect of further controls explains a minor fraction (about 25%). Frankel and MacArthur (1988) and Frankel (1991) find that covered interest parity does not hold in emerging markets, based on the forward exchange rates of 24 countries (eight emerging) from 1982 to 1988. Obstfeld (1995) calculates onshore–offshore interest rate differentials and finds that deviations from covered interest parity exist for several developed countries in the mid-1980s when capital controls are in place. Kumhof (2001) reports that covered interest parity does not hold in three emerging economies during the 1997 Asian currency crisis, based on forward exchanges rates. Recent studies find that covered interest parity holds in developed foreign exchange markets at daily or lower frequencies (e.g., Akram et al., 2008).

Empirical tests of uncovered interest parity (UIP) and carry trades in emerging economies show mixed results. Chinn (2006) describes the uncovered interest differentials for emerging markets as the sum of the political risk premium and exchange risk premium. However, the author does not test whether the political risk premium is significant for emerging currencies. Bansal and Dahlquist (2000)

[5] Two-business day settlement applies to the currencies of Brazil, China, Egypt, India, Indonesia, Korea, Malaysia, and Taiwan, the one-business day settlement applies to Chile and the Philippines, and the same-day settlement applies to Argentina, Colombia, and Peru. To minimize settlement risk, the interbank foreign exchange dealers adopt the standardized NDF agreement specified by the U.S. and European regulators since 2007. In recent regulatory reforms of OTC foreign exchange trading, NDF contracts can be executed on an exchange or equivalent electronic platforms, and settled through central clearing agencies, such as CLS Bank, Intercontinental Exchange (ICE) and the CME group by executing one-way payment instructions with agreements on collateral and transactions netting.

[6] The cash settlement feature of NDF contracts is similar to currency futures contracts which can be settled in cash without delivery of the underlying currency.

find that UIP tends to hold better in emerging economies, especially for the periods of high inflation and for countries with lower per capita income, based on the data of 28 countries (14 emerging) from 1976 to 1998. Frankel and Poonawala (2010) report that the forward rates in emerging market currencies are less biased than those in developed country currencies in terms of UIP, based on a sample of 35 countries (14 emerging) from 1996 to 2004. Consistent with the UIP, Lustig et al. (2010) report that, based on a sample of 37 currencies (18 emerging) from 1983 to 2010, the excess returns for emerging market currencies are less predictable than for developed currencies. Their findings suggest that UIP tends to hold better for emerging market currencies, and therefore carry trades based on the latter currencies should be less profitable. Based on a sample of 63 countries (48 emerging) from 1997 to 2006, Burnside et al. (2007) find that carry trade returns for emerging economies are comparable to those in developed economies. Based on a sample of 48 countries (33 emerging) from 1983 to 2009, Menkhoff et al. (2012) report that carry trade portfolios in developed countries are more profitable in the 1980s and 1990s, while carry trade portfolios of emerging market currencies begin outperforming developed countries starting around 2003 (see Menkhoff et al., 2012, Fig. 1).

A growing literature aims at explaining the carry trade returns and deviations from UIP. Hansen and Hodrick (1980) attribute the forward bias to risk premiums and expectation errors. Fama (1984) decomposes the forward premium and suggests that the forward bias is attributable to time-varying risk premiums. Recent studies of carry trades have identified a number of risk factors including global FX market volatility (Christiansen et al., 2010; Christiansen, 2011; Menkhoff et al., 2012), carry trade funding market liquidity (Brunnermeier and Pedersen, 2009), currency skewness and crash risk (Jurek, 2008; Farhi et al., 2009; Christiansen, 2011), rare disasters or peso problems (Barro and Ursua, 2011; Burnside, 2011; Burnside et al., 2011; Christiansen, 2011; Farhi and Gabaix, 2011; Lothian and Wu, 2011), and dollar risk (Lustig et al., 2011).

Because of limited opportunities of covered interest arbitrage between onshore and offshore interest rates for NDF currencies, we conjecture that deviations from covered interest parity in offshore markets may explain the returns of NDF carry trades. Extending the previous studies, this research investigates the performance of carry trades using DF and NDF contracts based on exchange rate risk arising from currency convertibility restrictions and capital controls, as well as other risk factors identified in the literature.

4. Methodology

4.1. The returns of DF and NDF carry trades

We investigate the carry trade performance of DF and NDF currencies based on the transaction-cost-based carry trade strategies developed in Burnside et al. (2007), by selling forward currencies that are at a forward premium and buying forward currencies that are at a forward discount. The spot and forward exchange rates are quoted in foreign currency units per U.S. dollar unit. Specifically, our decision rule is as follows:

$$x_t = \begin{cases} +1 & \text{if } F_t^b/S_t^a > 1 \\ -1 & \text{if } F_t^a/S_t^b < 1 \\ 0 & \text{otherwise} \end{cases} \tag{1}$$

where F_t^b and F_t^a denote the bid and ask forward exchange rates at time t and x_t equals $+1$, -1, or 0 for selling x_t dollars forward, buying x_t dollars forward, or taking no position at time t, respectively.

The realized payoffs, z_{t+n}^{DF}, are calculated for DF carry trades as follows:

$$z_{t+n}^{DF} = \begin{cases} x_t\left(F_t^b/S_{t+n}^a - 1\right) & \text{if } x_t > 0 \\ x_t\left(F_t^a/S_{t+n}^b - 1\right) & \text{if } x_t < 0 \\ 0 & \text{if } x_t = 0 \end{cases} \tag{2}$$

where S_{t+n}^b and S_{t+n}^a denote the bid and ask spot exchange rates at the maturity of the forward contract and n refers to the number of days to the maturity of the forward contract.

For NDF currencies, we modify Eq. (2) by including the fixing rate on the valuation day. The realized payoffs, z_{t+n}^{NDF}, are calculated for NDF carry trades as follows:

$$z_{t+n}^{NDF} = \begin{cases} x_t\left(F_t^b/S_V^{FIX} - 1\right) & \text{if } x_t > 0 \\ x_t\left(F_t^a/S_V^{FIX} - 1\right) & \text{if } x_t < 0 \\ 0 & \text{if } x_t = 0 \end{cases} \tag{3}$$

where S_V^{FIX} denotes the fixing rate for an NDF contract on the valuation day; n refers to the number of days to the settlement day; v equals $t+n-2D$, $t+n-1D$, or $t+n$, depending on the currencies involved; D stands for business days; and the other variables are defined previously.

4.2. Determinants of carry trade returns

To test whether carry trades are related to deviations from covered interest parity, we rewrite the carry trade returns as follows:

$$z_{t+n}^{k} \approx i_{k,t} - i_{k,t}^{*} - \Delta s_{k,t+n} \tag{4}$$

where z_{t+n}^{k} is the return on carry trade transaction k defined in Eqs. (2) and (3), $i_{k,t}$ is the bid (or ask) foreign interest rate, $i_{k,t}^{*}$ is the ask (or bid) U.S. interest rate, $\Delta s_{k,t+n} = s_{k,t+n} - s_{k,t}$, $s_{k,t+n} = \ln(S_{k,t+n}^{b})$ or $\ln(S_{k,t+n}^{a})$ and $s_{k,t} = \ln(S_{k,t}^{a})$ or $\ln(S_{k,t}^{b})$ for a long (short) position in foreign currency and short (long) position in the U.S. dollar. The left-hand side of Eq. (4) is carry trade returns based on transactions using forward and spot contracts as defined in this research. The right-hand side of Eq. (4) is the return of carry trades by holding a long (short) position in high-yielding (low-yielding) foreign currency and a short (long) position in U.S. dollars. Although the two strategies are operationally different, the excess returns should be approximately equal under the condition of covered interest parity, for example, Eq. (3) of Menkhoff et al. (2012).[7]

We then decompose the interest rate differential, $i_{k,t} - i_{k,t}^{*}$, based on Frankel (1992) and Chinn (2006), as follows:

$$i_{k,t} - i_{k,t}^{*} \equiv \left[i_{k,t} - i_{k,t}^{*} - \left(f_{k,t} - s_{k,t}\right)\right] + \left(f_{k,t} - s_{k,t+n}^{e}\right) + \Delta s_{k,t+n}^{e} \tag{5}$$

where $f_{k,t} = \ln(F_{k,t}^{b})$ or $\ln(F_{k,t}^{a})$, $s_{k,t} = \ln(S_{k,t}^{a})$ or $\ln(S_{k,t}^{b})$, $s_{k,t+n}^{e}$ is the expected bid or ask spot rate for time $t+n$ and $\Delta s_{k,t+n}^{e} = s_{k,t+n}^{e} - s_{k,t}$ is the expected change in the bid or ask spot rate from time t to $t+n$. Substituting Eq. (5) into Eq. (4), we decompose the carry trade returns into three components:

$$z_{t+n}^{k} \approx \left[i_{k,t} - i_{k,t}^{*} - \left(f_{k,t} - s_{k,t}\right)\right] + \left(f_{k,t} - s_{k,t+n}^{e}\right) + \left(\Delta s_{k,t+n}^{e} - \Delta s_{k,t+n}\right) \tag{6}$$

The first component, in squared brackets in Eq. (6), is the “covered interest differential” or “political risk premium” for carry trade transaction k measured at time t when the trade is entered:

$$CID_{k,t} = \left[i_{k,t} - i_{k,t}^{*} - \left(f_{k,t} - s_{k,t}\right)\right] \tag{7}$$

CID captures the effect of barriers to capital flows across national boundaries, such as currency convertibility restrictions, capital controls, default risk, and the prospect of future controls. The CID calculated from the forward rates also reflects the expectation of future exchange rates. As shown in Obstfeld (1995), the components of CID may be separated if offshore interest rates are available. For NDF currencies, however, offshore interest rates are unavailable and must be inferred from the NDF prices. For NDF currencies, CID is a risk factor reflecting exchange rate risk arising from currency convertibility restrictions and capital controls. CID can be negative or positive, depending on the relation between onshore and offshore interest rates. A positive CID suggests controls on capital inflows while a negative CID indicates controls on capital outflows (Frankel, 1992). A significant magnitude of CID indicates

[7] See Burnside et al. (2007) for discussions on the differences between the two carry trade strategies.

deviations from covered interest parity. A zero CID implies that covered interest parity holds. The concept of CID has been tested empirically in the economics literature under the context of international capital mobility (e.g., Frankel and MacArthur, 1988; Frankel, 1991; Obstfeld, 1995; Kumhof, 2001).

To the best of our knowledge, CID has not been examined as a risk factor in the carry trade literature. As noted before, Chinn (2006) shows that uncovered interest differentials for emerging markets are manifestations of political risk and exchange rate risk. However, the author does not test whether CID is significant in his data. We expect that CID should be close to zero for developed countries. There is little reason to expect that covered interest parity holds for emerging markets where currency convertibility restrictions and capital controls are in effect. Therefore, we expect that CID should relate to the returns of NDF carry trades. For emerging economies with convertible currencies and DFs, we expect positive (negative) CID changes during periods of financial crisis due to the increased probability of future controls on capital inflows (outflows). A growing CID of substantial size depicts the increasing convertibility risk, which will spike when the conditions are met (e.g., economic crisis), and could be relevant for both DF and NDF carry trades (see Appendix A for the case of Icelandic Krona).

The second and third components in Eq. (6) stand for the foreign exchange risk premium and the forecast error of expected change in exchange rates, respectively. Eq. (6) is not directly testable because we do not have the information on expectations at time t. The usual approach in the UIP literature is to assume rational expectations, with $s_{k,t+n} = s^e_{k,t+n} + \zeta_{k,t+n}$, where $\zeta_{k,t+n}$ is a white-noise error term that is uncorrelated with all information known at time t. This research chooses not to conduct a joint test of covered interest parity and rational expectations because our main interest is to investigate whether CID is related to the returns of NDF carry trades. Our empirical work follows the carry trade literature by using alternative risk factors, including global FX volatility, global FX bid–ask spread, and the interest differential between 3-month Eurodollar interbank deposits and 3-month U.S. Treasury bills (TED).

We test whether carry trade returns are related to deviations from covered interest parity by estimating the following cross-sectional regression:

$$z^k_{t+n} = \alpha + \beta * CID_{k,t} + \varepsilon_k \tag{8}$$

where z^k_{t+n} is the carry trade return on transaction k defined in Eqs. (2) and (3), $CID_{k,t}$ is the covered interest differential defined in Eq. (7), α is the intercept, β is the estimated coefficient, and ε_k is the error term. The null hypotheses of $\alpha = 0$ and $\beta = 0$ indicate that the mean carry trade returns are equal to zero after controlling for $CID_{k,t}$ and covered interest parity holds. The alternative hypothesis of $\alpha \neq 0$ indicates that the excess returns exist after controlling for $CID_{k,t}$, and $\beta \neq 0$ indicates that covered interest parity does not hold and $CID_{k,t}$ is related to carry trade returns. We estimate Eq. (8) for developed DF, emerging DF and NDF currencies, respectively.

As discussed above, CID is a risk factor reflecting exchange rate risk arising from currency convertibility restrictions and capital controls concerning a specific currency. In order to investigate whether the worldwide situation on convertibility risk affects carry trades, we construct a time-series proxy for global convertibility risk (GCID) by calculating the daily averages of CIDs across all available currencies in our sample. We focus on the innovations of global convertibility risk (DGCID) by calculating the changes of GCID on daily basis. We match each carry trade transaction k with $DGCID_{k,t}$ and estimate Eq. (8) using $DGCID_{k,t}$ as the independent variable.

We test whether carry trade returns are related to alternative risk factors documented in the literature by estimating the following multifactor model:

$$z^k_{t+n} = \alpha + \beta * CID_{k,t} + \eta * DGCID_{k,t} + \sum_{j=1}^{N} \gamma_j * RKF^j_{k,t} + \sum_{j=1}^{N} \tau_j * RKF^j_{k,t+n} + \varphi_k \tag{9}$$

where $RKF^j_{k,t}$ is the risk factor j for carry trade transaction k measured at time t when the trade is entered, $RKF^j_{k,t+n}$ is the risk factor j for carry trade transaction k measured at time $t+n$ when the return is calculated, N is the number of risk factors, φ_k is the error term, and other variables are as defined previously. Significant β, η, γ_j and τ_j estimates would indicate that carry trade returns are related to deviations from covered interest parity and other risk factors. Our measures of alternative risk factors are defined as follows.

4.2.1. Volatility proxy

Following Menkhoff et al. (2012), we estimate global FX volatility ($FXVOL_t$) by calculating the daily absolute log returns of spot exchange rates, $|r_{m,t}| = |\Delta s_{m,t}|$, for each currency m in our sample on day t and then averaging all currencies available on any day t. We obtain our weekly and monthly global FX volatility when $T = 5$ and 25 trading days, respectively:

$$FXVOL_t = \frac{1}{T}\sum_{t=1}^{T}\left[\sum_{m=1}^{M}\frac{|r_{m,t}|}{M}\right] \tag{10}$$

where M is number of currencies on day t and T is number of trading days. Our regression analysis focuses on weekly and monthly volatility innovations ($DVOLW_t$ and $DVOLM_t$) by taking the first difference of the global FX volatility series, following Ang et al. (2006).

4.2.2. Liquidity proxies

Following Menkhoff et al. (2012), we employ the global FX bid–ask spread as our measure of global FX market liquidity. We calculate the global FX bid–ask spread ($SPREAD_t$) using the same aggregating scheme as global FX volatility in Eq. (10):

$$SPREAD_t = \frac{1}{T}\sum_{t=1}^{T}\left[\sum_{m=1}^{M}\frac{SPREAD_{m,t}}{M}\right] \tag{11}$$

where $SPREAD_{m,t}$ is the percentage bid–ask spread in the spot rate for currency m on day t. Higher $SPREAD_t$ indicates illiquidity in the global FX markets. We use current global FX bid–ask spread ($T = 1$) in our regression analysis.

We use the TED spread as our measure of carry trade funding market liquidity (Brunnermeier and Pedersen, 2009). We calculate the TED_t spread as

$$TED_t = i_t^{EUD} - i_t^{TBILL} \tag{12}$$

where i_t^{EUD} is 3-month Eurodollar interbank deposit rate and i_t^{TBILL} is 3-month U.S. Treasury bill rate. Differences between the two rates indicate the lending conditions in the interbank market at time t. A higher TED_t spread indicates unwillingness of bank lending and low liquidity in the funding market for carry trades.

4.2.3. Skewness proxies

Following Brunnermeier and Pedersen (2009) and Christiansen (2011), we compute the absolute realized skewness as our measure for currency crash risk as follows:

$$SKEW_{m,t} = \left|\frac{\frac{1}{T}\sum_{t=1}^{T}\left(r_{m,t}-\overline{r}_{m,t}\right)^3}{\left[\frac{1}{T}\sum_{t=1}^{T}\left(r_{m,t}-\overline{r}_{m,t}\right)^2\right]^{3/2}}\right| \tag{13}$$

where $\overline{r}_{m,t}$ is the mean return of log spot rates for currency m on day t and $T = 5$ trading days. We compute a global skewness factor, $GSKEW_t$, by averaging the skewness measure for 66 currencies in our sample for each trading day.

We match $DVOLW_{k,t}$, $DVOLM_{k,t}$, $SPREAD_{k,t}$, $TED_{k,t}$, $SKEW_{k,t}$, and $GSKEW_{k,t}$ with carry trade transaction k when the trade is entered at time t. We estimate Eqs. (8) and (9) using OLS regressions with heteroskedasticity-consistent standard errors (White, 1980).

5. Data

Our total sample consists of exchange rates for 66 countries, quoted against the U.S. dollar, including Argentina, Australia, Austria, Belgium, Brazil, Bulgaria, Canada, Chile, China, Columbia, Croatia, Cyprus, the Czech Republic, Denmark, Egypt, Estonia, Euro, Finland, France, Germany, Greece, Hong Kong, Hungary, Iceland, India, Indonesia, Ireland, Israel, Italy, Japan, Kazakhstan, Kenya, Korea, Kuwait, Latvia, Lithuania, Malaysia, Malta, Mexico, Morocco, the Netherlands, New Zealand, Norway, Pakistan, Peru, the Philippines, Poland, Portugal, Qatar, Romania, Russia, Saudi Arabia, Singapore, Slovakia, Slovenia, South Africa, Spain, Sweden, Switzerland, Taiwan, Thailand, Tunisia, Turkey, United Arab Emirates, the United Kingdom, and Ukraine.

We divide the total sample into developed and emerging countries based on the country classifications of Dow Jones Total Stock Market Index and MSCI All Country World & Frontier Markets Index. The subsample of developed (DF) currencies consists of 21 countries, but 10 major world currencies after the introduction of the euro, including Australia, Austria, Belgium, Canada, Denmark, Euro, Finland, France, Germany, Greece, Ireland, Italy, Japan, the Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, and the United Kingdom. The subsample of NDF currencies comprises 13 emerging countries, including Argentina, Brazil, Chile, China, Columbia, Egypt, India, Indonesia, Korea, Malaysia, Peru, the Philippines, and Taiwan. The subsample of emerging currencies (DF) contains 30 countries that are not included in the other two subsamples. The final sample consists of 64 countries used in the empirical analysis.[8]

We obtain the daily spot exchange rates and daily 1-week forward rates from Datastream for the total sample from October 27, 1997, to February 28, 2011.[9] For DF currencies, we obtain the closing bid–ask spot and forward exchange rates from WM/Reuters via Datastream. For Argentina, Brazil, Chile, Columbia, Egypt, and Peru, the NDF rates are already included in the WM/Reuters forward rates (see Section 3.3 of WM Company, 2010) and are available for the period March 29, 2004, to February 28, 2011. Therefore, we obtain the closing bid–ask spot and NDF rates from WM/Reuters for those currencies. For China, India, Indonesia, Korea, Malaysia, the Philippines, and Taiwan, we obtain the closing bid–ask spot rates from WM/Reuters, and the closing bid–ask NDF rates from Tullett Prebon via Datastream.[10] The NDF rates are available for China, India, Indonesia, Korea, Malaysia, and the Philippines from January 7, 2006, to February 28, 2011, and for Taiwan dollar from August 25, 2005, to February 28, 2011.

We note that the Thai baht is non-convertible but trades in offshore DF markets. Tullett Prebon does not provide NDF data for the Thai baht. Therefore, we obtain WM/Reuters offshore forward rates and include the Thai baht in the DF subsample. The Russian ruble (RUB) is non-convertible until June 30, 2006. Our communication with WM/Reuters indicates that WM/Reuters does not distinguish the deliverable/non-deliverable status of the RUB in its forward rate service until NDF rates become available in March 2010. Therefore, we include RUB forward rates in our DF subsample.

Before we proceed with our analysis, we scan the data for errors by searching for large daily price reversals. Tullett Prebon NDF data are of high quality, except for errors for the Taiwan dollar from March 26, 2007 to December 15, 2009, and for the Korean won on January 7, 2011. We exclude from the analysis the Taiwan dollar from March 26, 2007, to December 15, 2009 and the Korean won on January 7, 2011. We cannot find errors in the WM/Reuters data, except for incorrect descriptions of several exchange rate series.[11] Further investigations show that the bid–ask spreads from Tullett Prebon are higher than their counterparts from WM/Reuters with a mean difference of 0.05%, based on NDF prices available from both sources after October 2009.

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[8] We exclude Iceland and Israel from developed currencies in order to obtain the subsample of 10 major world currencies, and include these two countries in constructing the global FX variables. See Appendix A for convertibility risk in Iceland. Following previous studies, we include Hong Kong and Singapore in the sample of emerging currencies (DF). Our results remain unchanged without these two countries. Classifying the sample into developed or emerging countries may result in survivorship bias but is not a concern for this study given our large sample size.

[9] Outright forwards and foreign exchange swaps of up to 7 days are highly liquid, accounting for 68% of global foreign exchange turnover by maturity (2010 Triennial Central Bank Survey).

[10] Tullett Prebon is an established and recognized inter-dealer broker in emerging markets and forward FX. Quotes are obtained from the over-the-counter financial market, a snapshot of the best bid-offer rates as of 4:00 PM London time and available on Datastream between 4:30 PM and 5:00 PM.

[11] The Taiwan dollar (TWD) forward rate is described as both NDF currency and "local close currency" under Sections 3.3 and 3.4.1 of WM Company (2010) online. Our communication with WM/Reuters indicates that, consistent with the spot rate methodology, the TWD forward rate is local close currency according to an updated version of WM Company (2010), available upon request.

Following Burnside et al. (2007), we construct our sample by entering trades on every Wednesday based on Eq. (1) and calculate carry trade returns based on Eqs. (2) and (3) for DF and NDF currencies, respectively. All exchange rates are converted to foreign currency units per U.S. dollar unit. Currencies are included in the sample when exchange rates data become available. Three countries do not have any trades entered based on Eq. (1) during the sampling period. Following the Indicative Survey Rate Methodology published by the EMTA for determining NDF fixing rates, we use the midpoint of the WM/Reuters closing bid–ask spot exchange rates on the valuation day for an NDF contract to calculate NDF carry trade returns.

The interest rate data are from Datastream. We obtain 1-week interbank rates for foreign interest rates (i) and 1-week London Interbank Offered Rate (LIBOR) for the United States ($i*$). When 1-week interbank rates are unavailable, we use 1-week deposit rates or overnight interbank rates. The available data for interest rates, at daily frequency, consists of 53 countries, including the United States. We compute the $CID_{k,t}$ by matching each carry trade transaction with its forward premium and interest rate differential. Because the LIBOR is fixed after the Asian markets are closed, we use the LIBOR for the previous business day to compute the interest rate differentials for all Asian currencies (Kumhof, 2001). To compute the TED, we obtain 3-month Eurodollar interbank deposit rate and 3-month U.S. Treasury bill rate from Datastream.

6. Empirical results

6.1. DF and NDF carry trade returns

Panel A of Table 1 reports the summary statistics of carry trade returns with the mean, median, standard deviation, kurtosis, skewness and Sharpe ratios for the entire sample period 1997–2011, and sub-periods 1997–2003 and 2004–2011. Because the data show departures from normality based on Jarque–Bera tests, we perform the univariate t-tests and non-parametric sign tests on the null hypothesis that the mean and median of carry trade returns are equal to zero. We perform the univariate z-tests on the null hypothesis that the Sharpe ratios are equal to zero based on Opdyke (2007) which is derived without the assumption of normal distribution. Consistent with previous studies, the mean return for the total sample is 0.07% on a weekly basis and statistically significant at the 0.01 level. Across the three subsamples, carry trade returns increase monotonically with mean returns of 0.05%, 0.08%, and 0.11% for developed DF, emerging DF, and NDF currencies, respectively. The standard deviation of returns is the highest for emerging DF currencies, at 1.75%, followed by NDF currencies at 1.67% and the lowest for developed DF currencies at 1.48%. The NDF currencies have the highest Sharpe ratio at 0.0638, followed by emerging DF currencies at 0.0485 and the lowest for developed currencies at 0.0311. The median of the carry trade returns across the three subsamples shows that the highest median carry trade return is 0.13% for developed DF currencies, and the lowest median carry trade return is 0.03%, for emerging DF currencies, suggesting that carry trades in developed DF currencies are highly profitable in a market environment without significant negative shocks. Test 1 in Panel C of Table 1 reports the equality tests on the null hypotheses of equal means, equal medians, and equal variances across the three subsamples. The results show that an ANOVA F-test cannot reject the null hypothesis of equal means, while a chi-square test and Bartlett test reject the null hypotheses of equal medians and equal variances at the 0.01 level, confirming the differential performance of carry trades across developed DF, emerging DF, and NDF currencies during the entire sample period 1997–2011.[12]

We then divide the entire sample into two sub-periods 1997–2003 and 2004–2011. The main reason for dividing our sample in two sub-periods stems from data availability. A total of 33 of the 66 countries in our sample have forward rate data from Datastream starting in 2004 or later,

[12] Carry trade returns for individual currencies show substantial volatility with the highest standard deviations for Australia and Greece for developed DF currencies, Ukraine and Croatia for emerging DF currencies, and Chile and Korea for NDF currencies. To investigate whether our findings are robust to changes in currency convertibility, we calculate carry trade returns by excluding the Thai baht and Russian ruble from the total and emerging DF samples. The results are similar to the findings reported in Table 1 and available upon request. We also test a sample of 15 developed countries excluding Finland, Greece, Ireland, Portugal and Spain. The results are similar to the findings reported in Table 1 and available upon request.

Table 1
DF and NDF carry trade returns.

Panel A: summary statistics for the entire sample period and subsample periods

	Total sample			Developed			Emerging			NDF
	1997–2011	1997–2003	2004–2011	1997–2011	1997–2003	2004–2011	1997–2011	1997–2003	2004–2011	2004–2011
Mean	0.0768***	0.1592***	0.0342	0.0462	0.1619***	−0.0826*	0.0850**	0.1564***	0.0433	0.1063***
Median	0.0050***	0.1000***	0.0400***	0.1300***	0.2500***	0.0200	0.0300***	0.0200***	0.0400***	0.0600***
SD	1.6488	1.5272	1.7069	1.4864	1.3972	1.5704	1.7500	1.6529	1.8033	1.6671
# OBS	7016	2391	4625	2319	1222	1097	3172	1169	2003	1525
Kurtosis	23.1043	16.0523	25.1140	7.9272	8.0940	7.9705	26.8363	19.6466	29.4641	26.3750
Skewness	−0.1580	0.5660	−0.4107	−0.4762	−1.0080	10.0118	0.2298	1.5518	−0.3533	−0.7638
Jarque–Bera	118,185***	17,099***	94,369***	2433***	1528***	1129***	75,121***	13,966***	58,491***	34,867***
Sharpe ratio	0.0466***	0.1042***	0.0200	0.0311	0.1159***	−0.0526	0.0485***	0.0946***	0.0240	0.0638***

Panel B: summary statistics for crisis and non-crisis periods

	Crisis period 8/2007–3/2009			Non-crisis period 1997–2011			Non-crisis period 2004–2011		
	Developed	Emerging	NDF	Developed	Emerging	NDF	Developed	Emerging	NDF
Mean	−0.3297***	−0.1204	−0.0166	0.1030***	0.1403***	0.1819***	0.0121	0.1262***	0.1819***
Median	−0.2650 **	0.0200**	0.0100	0.1700***	0.0400***	0.0800***	0.1100*	0.0500***	0.0800***
SD	2.0846	2.6680	2.2089	1.3654	1.3993	1.2140	1.3107	1.1309	1.2140
# OBS	304	673	581	2015	2499	944	793	1330	944
Kurtosis	7.7601	17.8960	21.1319	6.6670	19.2305	7.8942	4.0655	5.7385	7.8942
Skewness	0.3812	−0.1963	−0.7827	−0.7427	1.2494	0.1334	−0.2815	0.1492	0.1334
Jarque–Bera	294***	6226***	8018***	1312***	28,079***	944***	948***	420***	944***
Sharpe ratio	−0.1581***	−0.0451	−0.0075	0.0754***	0.1003***	0.1498***	0.0092	0.1116***	0.1498***

Panel C: Equality tests across developed, emerging and NDF currencies for the entire sample period and subsample periods

	Test 1	Test 2	Test 3	Test 4	Test 5
ANOVA *F*-test of equal means	0.6810 (0.5061)	3.9627** (0.0191)	1.7036 (0.1824)	1.1431 (0.3189)	4.4004** (0.0124)
Chi-square test of equal medians	11.9874*** (0.0025)	2.3282 (0.3122)	5.2341* (0.0730)	21.5553*** (0.0000)	3.2626 (0.1957)
Bartlett test of equal variances	70.3632*** (0.0000)	28.6171*** (0.0000)	34.6759*** (0.0000)	26.4933*** (0.0000)	22.2162*** (0.0000)

Note: this table reports the summary statistics for carry trade returns, reported in percentage. Univariate *t*-tests and sign tests are performed on the null hypotheses that the means and medians are equal to zero. Univariate *z*-tests are performed on the null hypothesis that the Sharpe ratios are equal to zero. Equality tests are performed on the null hypotheses of equal means, equal medians and equal variances across developed DF, emerging DF and NDF carry trade returns. Test 1 refers to equality tests for the period 1997–2011. Test 2 refers to equality tests for the period 2004–2011. Test 3 refers to equality tests for the crisis period 8/2007–3/2009. Test 4 refers to equality tests for the non-crisis period 1997–2011, excluding the crisis period. Test 5 refers to equality tests for the non-crisis period 2004–2011, excluding the crisis period. Bartlett tests are adjusted for non-normality. We denote *, **, and *** for significance at 0.10, 0.05 and 0.01 levels, respectively. *P*-values are in parentheses.

including 13 NDF currencies. In addition, these two sub-periods provide approximately equal window intervals for comparing carry trade performance. As shown in Panel A of Table 1, the mean carry trade return for the total sample is higher for 1997–2003 than for 2004–2011 (0.16% versus 0.03%), the median carry trade return is also higher for 1997–2003 than for 2004–2011 (0.1% versus 0.04%), with a Sharpe ratio of 0.1042 for 1997–2003 versus 0.0200 for 2004–2011. Developed DF and emerging DF currencies show a similar return–risk profile with higher Sharpe ratios for 1997–2003 than for 2004–2011 (0.1159 versus −0.0526 and 0.0946 versus 0.0240). Across the three subsamples, an interesting finding that emerges is that NDF carry trades for 2004–2011 outperform DF carry trades for the same period. Specifically, NDF carry trades have the highest Sharpe ratio of 0.0638, which is significant at 0.01 level, compared to developed DF currencies of −0.0526 and emerging DF currencies of 0.0240, both are statistically insignificant. The equality tests (Test 2) in Panel C of Table 1 indicates that the means and variances are significantly different across developed DF, emerging DF, and NDF currencies during 2004–2011, confirming the superior performances indicated by the Sharpe ratios.

As noted above, previous studies find that carry trades suffer substantial losses due to currency crashes and rare disaster events. To test the sensitivity of our findings, we divide the data around the 2008 U.S. financial crisis. The crisis period is defined as August 1, 2007, to March 31, 2009, when the Fed released the first warning of "downside risk" amid financial market turmoil on August 17, 2007, and by the end of March 2009 the world financial markets are stabilized. The non-crisis period for the total sample is from 1997 to 2011 excluding the crisis period. The non-crisis period for the subsample is from 2004 to 2011 excluding the crisis period.

Panel B of Table 1 reports the results during the crisis period for the three subsamples. Carry trades of developed DF currencies suffer the heaviest losses, with a mean return of −0.33% and median return of −0.26%, both statistically significant at the 0.01 and 0.05 levels, respectively. Emerging DF currencies also have a negative mean return of −0.12% and the median return is 0.02%, which is significant at 0.05 level. For NDF currencies, the mean and median returns are insignificant at −0.02% and 0.01%. Across the three subsamples, the Sharpe ratios are the lowest for developed DF at −0.1581, which is significant at 0.01 level, and the highest for NDF currencies at −0.0075 which is statistically insignificant. The equality tests (Test 3) in Panel C of Table 1 confirm the differential performance across developed DF, emerging DF, and NDF currencies during the 2008 financial crisis. The null hypotheses of equal medians and equal variances are rejected at the 0.10 and 0.01 levels. Overall, these results indicate that, during the 2008 financial crisis, the performance of NDF carry trades is more stable, as indicated by higher Sharpe ratios, compared to DF carry trades.[13]

Panel B of Table 1 reports the carry trade performance across the three subsamples during the non-crisis period of 1997–2011, which is purged of data observations that span the crisis period. The results show that developed DF, emerging DF, and NDF carry trades offer comparable mean returns (0.10%, 0.14%, and 0.18%, respectively), while the Sharpe ratios are the highest for NDF and the lowest for developed DF carry trades (0.1498 versus 0.0754, respectively). The Sharpe ratios are significant at 0.01 level across the three subsamples. The equality tests (Test 4) indicate that, for the non-crisis period of 1997–2011, the mean returns across the three subsamples are not significantly different, while the medians and variances are significantly different at the 0.01 level.

During the non-crisis period of 2004–2011, the mean returns for developed DF carry trades are near zero, at 0.01%. Emerging DF and NDF carry trade returns are comparable, at 0.13% and 0.18%, respectively. The Sharpe ratios are the highest for NDF currencies at 0.1498, which is significant at 0.01 level, and the lowest for developed DF currencies at 0.0092 which is statistically insignificant. Equality tests (Test 5) confirm that the mean and standard deviations across the three subsamples are significantly different at the 0.05 and 0.01 levels, respectively.

To summarize this section's findings, we conclude that NDF carry trades tend to generate superior performance (indicated by the Sharpe ratios) compared to carry trades of DF currencies. During both the crisis and non-crisis periods, NDF carry trades realize higher Sharpe ratios. Although developed DF

[13] Heavy losses could occur if the target currency faces an economic crisis. See, e.g., Park and Rhee (2001) for the Korean Won in 1997 and Appendix A for the Icelandic Krona in 2008.

carry trades have the highest mean returns during 1997–2003, the mean return for 2004–2011 is negative due to heavy losses during the 2008 financial crisis. Similar patterns are found for emerging DF carry trades, with positive returns during the non-crisis period and losses during the crisis period. Why do NDF carry trades exhibit superior performances compared to DF carry trades? We address this question and offer an explanation in the next section.

6.2. Determinants of carry trade returns

Section 4 conjectures that NDF carry trade returns are related to deviations from covered interest parity (measured by the $CID_{k,t}$ and $DGCID_{k,t}$) and alternative risk factors, including global FX volatility, global FX bid–ask spread, the liquidity of carry trade funding markets, and skewness of carry trade returns. This section tests this conjecture by estimating Eqs. (8) and (9) with cross-sectional regressions.

6.2.1. CID and carry trade returns

Panel A of Table 2 reports the estimated means of $CID_{k,t}$. We also report the interest rate differentials, $i - i*$, and the forward premium for the U.S. dollar, $f_t - s_t$, for reference. The data are matched with each carry trade transaction k when the trade is entered at time t. The results show that, for the total sample, the mean $CID_{k,t}$ is −0.02% on a weekly basis (−1% annual). Across the three subsamples, $CID_{k,t}$ is small for developed DF currencies, at 0.0002% weekly (0.01% annual), and at −0.009% weekly (−0.5% annual) for emerging DF currencies. These results indicate that covered interest parity holds for developed and emerging DF currencies, confirming the results of previous research, such as Akram et al. (2008). For NDF currencies, $CID_{k,t}$ is −0.0677% on a weekly basis (−3.5% annual), which is economically large and statistically significant at the 0.01 level. This result indicates that, on average, covered interest parity does not hold for NDF currencies in our sample. For DF currencies, the onshore interest differential approximately equals the U.S. dollar appreciation, for example, −0.0028% versus −0.0030% for developed DF, and 0.1342% versus 0.1433% for emerging DF. For NDF currencies, however, the onshore interest differential of 0.09% is significantly lower than the U.S. dollar appreciation of 0.16%, indicating deviations from covered interest parity for NDF currencies. Panel A of Table 2 also indicates that $CID_{k,t}$ has changed substantially during the crisis period for the total sample and three subsamples. For developed DF currencies, $CID_{k,t}$ increases from −0.0002% to 0.0027% in the crisis period, consistent with the previous studies on major world currencies during 2008 financial crisis (Levich, 2011). For emerging DF currencies, $CID_{k,t}$ increases from −0.0031% during the non-crisis period to −0.0337% (−1.7% on annual basis) in the crisis period. For NDF currencies, $CID_{k,t}$ increases from −0.0195% in the non-crisis period to −0.1492% (−7.7% on annual basis) in the crisis period.

Panel B of Table 2 reports the results for ordinary least squares (OLS) estimates of Eq. (8), with carry trade returns as the dependent variable and $CID_{k,t}$ as the independent variable. The standard errors are in parentheses. For the total sample, the estimated coefficient β for $CID_{k,t}$ is −0.44, which is significant at the 0.01 level. The F-test for the regression is significant at the 0.01 level. For developed DF emerging DF currencies, the estimated coefficient β for $CID_{k,t}$ is −2.60 and 0.07, respectively, both are not statistically significant. For NDF currencies, the estimated coefficient β for $CID_{k,t}$ is −0.47, which is significant at the 0.01 level. The negative sign of β indicates a *positive* relation between carry trade returns and $CID_{k,t}$. For example, the mean $CID_{k,t}$ for NDF currencies is −0.0677%, and the mean NDF return, z^k_{t+n}, increases by 0.03% (=−0.4776*−0.0677%) due to the effect of $CID_{k,t}$. Therefore, carry trade returns are higher when the onshore–offshore interest rate differential is larger, confirming that $CID_{k,t}$ contributes positively to NDF carry trade returns. We note that the R^2 of the regression is low at 2.9%. Overall, these regression results corroborate that $CID_{k,t}$ is a significant determinant of NDF carry trade returns, and the superior NDF performance, reported in Table 1, relates to compensation for the exchange rate risk arising from currency convertibility restrictions and capital controls.[14]

We estimate the following regression model to investigate the relation between carry trade returns and $CID_{k,t}$ during crisis and non-crisis periods:

[14] If an offshore market exists to circumvent taxes, the gains to NDF carry trades could reflect the division of the tax advantage between dealers and investors.

Table 2
Carry trade returns, CID and DGCID.

Panel A: summary statistics

	Total sample			Developed			Emerging			NDF		
	All	Crisis	Non -crisis	All	Crisis	Non -crisis	All	Crisis	Non -crisis	All	Crisis	Non -crisis
$i - i^*$	0.0770	0.0861	0.0744	−0.0028	0.0318	−0.0084	0.1342	0.1138	0.1392	0.0929	0.0898	0.0948
$f - s$	0.0971	0.1597	0.0742	−0.0030	0.0291	−0.0082	0.1433	0.1475	0.1423	0.1606	0.2390	0.1143
CID	−0.0201	−0.0736	0.0002	0.0002	0.0027	−0.0002	−0.0091	−0.0337	−0.0031	−0.0677	−0.1492	−0.0195
DGCID	−0.0010	−0.0079	0.0010	−0.0013	−0.0078	−0.0002	−0.0007	−0.0076	0.0010	−0.0012	−0.0084	0.0032
#OBS	6306	1406	4900	2171	304	1867	2610	521	2089	1525	581	944

Panel B: OLS estimates of carry trade returns and $CID_{k,t}$

	Total sample		Developed		Emerging		NDF	
	Eq. (8)	Eq. (14)	Eq. (8)	Eq. (14)	Eq. (8)	Eq. (14)	Eq. (8)	Eq. (14)
α	0.0404**	0.0992***	0.0275	0.0855**	0.0355	0.0798***	0.0739*	0.1710***
	(0.0199)	(0.0183)	(0.0321)	(0.0318)	(0.0323)	(0.0273)	(0.0413)	(0.0381)
β	−0.4465***	−0.6241***	−2.6063	1.5331	0.0757	−0.5351	−0.4776***	−0.6226***
	(0.1422)	(0.0874)	(3.3079)	(3.7506)	(0.9316)	(0.7522)	(0.1355)	(0.0858)
λ		−0.2610***		−0.3933***		−0.0023*		−0.2461**
		(0.0659)		(0.1206)		(0.1216)		(0.0989)
γ		0.2556		−9.6777		0.5825		0.2304
		(0.2481)		(7.8610)		(1.2634)		(0.2469)
Adj R^2	0.0072	0.0124	−0.0091	0.0090	−0.0003	0.0022	0.0290	0.0353
F-stat	46.7329***	27.3141***	0.8016	7.6053***	0.0860	2.9521**	46.5271***	19.5953***
DW	2.0712	2.0824	1.8917	1.9084	1.9054	1.9099	2.7241	2.7448

Panel C: OLS estimates of carry trade returns and $DGCID_{k,t}$

	Total sample		Developed		Emerging		NDF	
	Eq. (8)	Eq. (14)	Eq. (8)	Eq. (14)	Eq. (8)	Eq. (14)	Eq. (8)	Eq. (14)
α	0.0525***	0.1025***	0.0324	0.0849***	0.0394	0.0798***	0.1061**	0.1881***
	(0.0198)	(0.0185)	(0.0317)	(0.0318)	(0.0315)	(0.0273)	(0.0421)	(0.0400)
β	3.0623***	−0.2579	4.2624**	−1.0028	6.5599***	1.6185	−0.1411	−1.9210
	(1.3020)	(0.8941)	(2.8827)	(3.7127)	(2.4273)	(1.4217)	(1.6685)	(1.1964)
λ		−0.2009***		−0.3788***		−0.1580		−0.2004**
		(0.0623)		(0.1173)		(0.1126)		(0.0959)
γ		4.8061**		5.6078		8.0930*		2.4355
		(2.1899)		(5.0338)		(4.1867)		(2.9214)
Adj R^2	0.0029	0.0074	0.0026	0.0156	0.0119	0.0175	−0.0006	0.0023
F-stat	19.5088***	16.6893***	6.5596**	8.7201***	32.4826***	16.5592***	0.0178	2.1933*
DW	2.0726	2.0809	1.9020	1.9114	1.9459	1.9538	2.6395	2.6539

Note: Panel A reports the estimated means of interest differential ($i - i^*$), forward premium ($f - s$), covered interest differential ($CID_{k,t}$) and innovations of global convertibility risk (*DGCID*), reported in percentage. The data are matched with each carry trade transaction k when the trade is entered at time t. Panels B and C report the estimated coefficients of Eq. (8) $z^k_{t+n} = \alpha + \beta^* X_{k,t} + \varepsilon_k$ and Eq. (14) $z^k_{t+n} = \alpha + \beta^* X_{k,t} + \lambda^* CRISIS + \gamma^* CRISIS^* X_{k,t} + \varepsilon_k$, where X refers to *CID* or *DGCID*. *CRISIS* is a dummy variable with a value of 1 for the crisis period of 8/2007–3/2009 and 0 otherwise. We denote *, **, and *** for significance at 0.10, 0.05 and 0.01 levels, respectively. The standard errors, reported in parenthesis, are heteroskedasticity-consistent estimators (White, 1980).

$$z^k_{t+n} = \alpha + \beta * CID_{k,t} + \lambda * CRISIS + \gamma * CID_{k,t} * CRISIS + \varepsilon_k \quad (14)$$

where, *CRISIS* is a dummy variable with a value of 1 for the crisis period of 8/2007–3/2009 and 0 otherwise. The estimated coefficients of α and β indicate the relation between carry trade returns and $CID_{k,t}$ during the non-crisis period, and λ and γ indicate the differences for the estimated coefficients between crisis and non-crisis periods. Panel B of Table 2 reports the results for OLS estimates of Eq. (14). The estimated α and λ are statistically significant across the three subsamples. For developed and emerging DF currencies, $CID_{k,t}$ is not significant in explaining carry trade returns during both periods. The estimated β coefficients are insignificant with low R-squared values. In contrast, for NDF currencies, the estimated β coefficient is significant at the 0.01 level for non-crisis period and remains the same for the crisis period. These results are consistent with the previous findings for the total sample period, confirming that $CID_{k,t}$ is significantly related to NDF carry trade returns in both the crisis and non-crisis periods. Again, this new evidence seems to explain the NDF payoffs during the crisis and non-crisis periods, reported in Table 1, suggesting that NDF returns contain a premium for the exchange rate risk due to convertibility restrictions and capital controls.

6.2.2. DGCID and carry trade returns

Panel A of Table 2 indicates that the innovations of global convertibility risk are small at 0.001% on daily basis for the total sample. However, $DGCID_{k,t}$ is 7 times higher during the crisis period than the non-crisis period. This pattern is similar to $CID_{k,t}$. We estimate Eq. (8) using $DGCID_{k,t}$ as the independent variable. The results in Panel C of Table 2 indicate that $DGCID_{k,t}$ is significant at 0.01 level for the total sample and emerging DF currencies, and at 0.05 level for developed DF currencies for the entire sampling period. However, when we estimate Eq. (14) to separate the effect of crisis and non-crisis periods, $DGCID_{k,t}$ becomes significant only for the total sample and emerging DF currencies during financial crisis. $DGCID_{k,t}$ is insignificant for the NDF currencies during both crisis and non-crisis periods. Overall, these findings suggest that global convertibility risk has a limited effect on carry trades.

6.2.3. Multiple regression analysis

We now investigate the determinants of carry trade returns using alternative risk factors by estimating the cross-sectional regressions of Eq. (9). In addition to $CID_{k,t}$ and $DGCID_{k,t}$, other risk factors include the innovations of weekly global FX volatility ($DVOLW_{k,t}$), innovations of monthly global FX volatility ($DVOLM_{k,t}$), global FX bid–ask spread ($SPREAD_{k,t}$), $TED_{k,t}$, currency skewness ($SKEW_{k,t}$) and global FX skewness ($GSKEW_{k,t}$). The data are matched with each carry trade transaction k when the trade is entered at time t. Preliminary analysis indicates that the correlation between the two liquidity proxies of $SPREAD_{k,t}$ and $TED_{k,t}$ is 0.36. Therefore, we estimate a regression with $SPREAD_{k,t}$ as the dependent variable and $TED_{k,t}$ as the independent variable. We use the residuals of the regression ($DSPRED_{k,t}$) as our orthogonal variable in the regression analysis. We also add $DVOLW_{k,t+n}$, $DSPRED_{k,t+n}$, $TED_{k,t+n}$, $SKEW_{k,t+n}$ and $GSKEW_{k,t+n}$ to the regression analysis, where $t+n$ is the holding time period (including the trading day) when the returns are computed according to Eqs. (2) and (3).

Table 3 reports the OLS estimates of Eq. (9). The base model excludes $CID_{k,t}$ and $DGCID_{k,t}$. The results show that $DVOLW_{k,t+n}$ is significantly related to the total sample and developed DF currencies. $TED_{k,t}$ is significant for the total sample and across the three subsamples. $SKEW_{k,t+n}$ is significant for NDF currencies, and $GSKEW_{k,t+n}$ is significant for the total sample and emerging DF currencies. We note that the R-squares are low for the base model ranging from 0.01 for the total sample to 0.02 for emerging DF sample, respectively. We then estimate the full model by adding $CID_{k,t}$ and $DGCID_{k,t}$ to Eq. (9). The results show that, for the total sample, $CID_{k,t}$ and $DGCID_{k,t}$ are significant at the 0.01 level in the presence of alternative risk factors. The estimated coefficients for $DVOLW_{k,t+n}$ and $TED_{k,t}$ are significant at the 0.05 and 0.01 level, confirming that global FX volatility and funding market liquidity affect carry trade returns negatively. $GSKEW_{k,t}$ and $GSKEW_{k,t+n}$ are negative and significant at 0.01 level while $SKEW_{k,t}$ and $SKEW_{k,t+n}$ are insignificant. This result indicates that skewness for individual currencies has little impact on changes in exchange rates (Christiansen, 2011) and that global crash risk significantly affect carry trade returns. Across three subsamples, $CID_{k,t}$ remains significant at 0.01 level for NDF currencies, confirming that the risk of exchange control (Aliber, 1973) affect NDF carry trade returns. $CID_{k,t}$ is not related to carry trade returns of developed and emerging DF currencies while $DGCID_{k,t}$ remains insignificant for developed DF and NDF currencies. $DVOLW_{k,t+n}$ is significant for developed DF currencies and $TED_{k,t}$ is significant across three subsamples. $GSKEW_{k,t}$ and $GSKEW_{k,t+n}$ are significant for emerging DF at 0.01 levels but insignificant for developed DF currencies and NDF currencies. We note that, in contrast to the base model, R-squares for the full model increase from 0.01 to 0.02 for the total sample and from 0.01 to 0.04 for the NDF sample, indicating the added explanatory power from $CID_{k,t}$.

Table 3 also reports the OLS estimates of Eq. (9) for crisis and non-crisis periods. The results show that $CID_{k,t}$ is significant at the 0.01 level for NDF currencies during both periods and insignificant for developed and emerging DF currencies, while $DGCID_{k,t}$ becomes insignificant for the total sample and across the three subsamples. For crisis period, global FX volatility ($DVOLM_{k,t}$) and funding market

Table 3
Carry trade returns and alternative risk factors.

Coefficient	Total sample				Developed			
	Base model	Full model	Crisis	Non-crisis	Base model	Full model	Crisis	Non-crisis
α	0.1706*** (0.0416)	0.1644*** (0.0888)	0.1715 (0.2155)	0.1108*** (0.0384)	0.1605*** (0.0539)	0.1495*** (0.0538)	−0.8265** (0.4022)	0.2330*** (0.0639)
$CID_{k,t}$		−0.5615*** (0.1348)	−0.4519** (0.2276)	−0.642*** (0.0855)		0.2944 (3.4517)	−10.9186 (9.1627)	1.7283 (3.9416)
$DGCID_{k,t}$		2.6989** (1.2677)	3.2782 (2.2629)	0.7922 (0.9005)		2.5721 (2.7532)	5.4853 (3.8359)	−1.2355 (3.7801)
$DVOLM_{k,t}$	−2.4483 (2.4135)	−2.2269 (2.3354)	−3.3095 (4.0217)	1.2752 (1.7078)	−1.6274 (3.3433)	−1.5609 (3.3753)	−17.574** (7.1357)	2.2785 (3.1367)
$DVOLW_{k,t+n}$	−1.0144* (0.5257)	−1.0612** (0.5234)	−1.1054 (1.0711)	0.9460** (0.4127)	−3.049*** (0.6772)	−3.040*** (0.6765)	−1.9488 (1.5974)	2.8685*** (0.7490)
$DSPRED_{k,t}$	1.0055 (1.0235)	0.6661 (1.2021)	2.9185 (2.7653)	−0.8139 (1.0306)	−0.7378 (1.3939)	−0.7912 (1.4088)	−1.0873 (6.0365)	−0.6566 (1.5054)
$TED_{k,t}$	−0.0017*** (0.0007)	−0.0018*** (0.0007)	−0.0016 (0.0015)	−0.0002 (0.0008)	−0.0022** (0.0010)	−0.0019** (0.0009)	−0.0039* (0.0023)	−0.0033** (0.0015)
$SKEW_{k,t}$	0.0001 (0.0003)	0.0001 (0.0003)	−0.0015 (0.0009)	0.0005 (0.0003)	0.0011 (0.0007)	0.0011 (0.0009)	0.0019 (0.0023)	0.0010 (0.0007)
$SKEW_{k,t+n}$	0.0003 (0.0003)	0.0003 (0.0003)	0.0005 (0.0009)	0.0002 (0.0002)	0.0004 (0.0006)	0.0004 (0.0006)	−0.0001 (0.0018)	0.0006 (0.0006)
$GSKEW_{k,t}$	−0.0033*** (0.0009)	−0.0030*** (0.0009)	−0.009*** (0.0029)	−0.0007 (0.0008)	0.0017 (0.0016)	0.0018 (0.0016)	−0.0144** (0.0058)	0.0042*** (0.0016)
$GSKEW_{k,t+n}$	−0.0028*** (0.0010)	−0.0029*** (0.0010)	−0.012*** (0.0030)	−0.0001 (0.0009)	−0.0023 (0.0017)	−0.0024 (0.0016)	−0.0052 (0.0056)	0.0013 (0.0017)
Adj. R^2	0.0109	0.0225	0.0428	0.0132	0.0198	0.0199	0.0411	0.0218
F-stat	9.7251***	15.5271***	7.2894***	7.5683***	6.4916***	5.4098***	2.2974**	5.1653***
DW	2.0758	2.1091	2.3314	1.9790	1.9081	1.9130	2.0510	1.8570
#OBS	6306	6306	1406	4900	2171	2171	304	1867

Coefficient	Emerging				NDF			
	Base model	Full model	Crisis	Non-crisis	Base model	Full model	Crisis	Non-crisis
α	0.1909*** (0.0707)	0.1584** (0.0693)	0.5249 (0.3503)	0.0098 (0.0589)	0.2584*** (0.0909)	0.2742*** (0.0950)	0.2283 (0.3317)	0.1286* (0.0779)
$CID_{k,t}$		−0.0275 (0.9494)	0.0778 (1.0194)	−0.3754 (0.7579)		−0.522*** (0.1312)	−0.4229* (0.2408)	−0.621*** (0.0884)
$DGCID_{k,t}$		5.0430** (2.2390)	6.3013 (4.1550)	1.4023 (1.3914)		0.4133 (1.7972)	−0.0267 (3.4664)	0.7003 (1.2163)
$DVOLM_{k,t}$	−1.9420 (4.2274)	−1.9326 (4.1829)	−2.9172 (8.3247)	4.6428** (2.3617)	−4.5577 (4.2013)	−4.0561 (3.9046)	−3.2678 (5.6049)	−9.635*** (3.5395)
$DVOLW_{k,t+n}$	−0.5684 (0.6389)	−0.4671 (0.6439)	−1.7385 (1.5731)	−0.0104 (0.6039)	−0.1098 (1.0494)	−0.3127 (1.0554)	−0.7194 (1.7080)	0.6665 (0.7646)
$DSPRED_{k,t}$	1.0567 (1.5090)	0.9590 (1.5036)	−1.8494 (4.6925)	0.0855 (1.4936)	8.2240** (3.4381)	6.7227* (3.4786)	8.3696** (3.9539)	−1.3923 (4.8733)
$TED_{k,t}$	−0.0024** (0.0011)	−0.0019 (0.0011)	−0.0034 (0.0022)	0.0015 (0.0012)	−0.0023* (0.0012)	−0.0019* (0.0011)	−0.0016 (0.0022)	0.0006 (0.0016)
$SKEW_{k,t}$	−0.0007 (0.0005)	−0.0007 (0.0005)	−0.0025 (0.0019)	−0.0001 (0.0004)	−0.0002 (0.0006)	−0.0003 (0.0006)	−0.0010 (0.0012)	0.0001 (0.0005)
$SKEW_{k,t+n}$	−0.0003 (0.0005)	−0.0003 (0.0005)	0.0024 (0.0021)	−0.0006 (0.0004)	0.0010** (0.0005)	0.0008* (0.0004)	0.0006 (0.0013)	0.0010** (0.0004)
$GSKEW_{k,t}$	−0.0084*** (0.0014)	−0.0083*** (0.0015)	−0.018*** (0.0057)	−0.005*** (0.0012)	−0.0018 (0.0021)	−0.0014 (0.0021)	−0.0001 (0.0042)	−0.0012 (0.0019)
$GSKEW_{k,t+n}$	−0.0030** (0.0015)	−0.0029** (0.0015)	−0.022*** (0.0055)	−0.0019 (0.0013)	−0.0029 (0.0022)	−0.0036 (0.0022)	−0.0066 (0.0044)	−0.0014 (0.0021)
Adj. R^2	0.0263	0.0323	0.0833	0.0108	0.0152	0.0468	0.0266	0.0748
F-stat	9.8156***	9.7172***	5.723***	3.2886***	3.931***	8.483***	2.5887***	8.6239***
DW	1.9527	1.9775	2.0126	2.0398	2.6440	2.7502	2.9741	2.2123
#OBS	2610	2610	521	2089	1525	1525	581	944

Note: this table reports the OLS estimates of Eq. (9) $z^k_{t+n} = \alpha + \beta * CID_{k,t} + \eta * DGCID_{k,t} + \sum_{j=1}^{N} \gamma_j * RKF^j_{k,t} + \sum_{j=1}^{N} \tau_j * RKF^j_{k,t+n} + \varphi_k$ for carry trade returns and alternative risk factors. The data, reported in percentage, are matched with each carry trade transaction k when the trade is entered at time t. We denote *, **, and *** for significance at 0.10, 0.05 and 0.01 levels, respectively. The standard errors, reported in parenthesis, are heteroskedasticity-consistent estimators (White, 1980).

liquidity ($TED_{k,t}$) significantly affect carry returns for developed DF currencies. Global FX crash risk ($GSKEW_{k,t}$ and $GSKEW_{k,t+n}$) are significant at 0.05 level for developed and emerging DF currencies. For non-crisis period, $DVOLW_{k,t+n}$ and $DVOLM_{k,t}$ are significant across all three subsamples, while $TED_{k,t}$ is significant for developed DF currencies and insignificant for emerging DF and NDF currencies. $GSKEW_{k,t}$ is significant for developed and emerging DF currencies while insignificant for NDF currencies. We note that the estimated α's are significantly different from zero for developed currencies during both crisis and non-crisis periods and for NDF currencies during the non-crisis period, indicating positive excess returns after controlling for identified risk factors in our analysis. Overall, the results confirm that $CID_{k,t}$ significantly affects NDF carry trade returns while controlling for alternative risk factors including global FX volatility, funding market liquidity, global FX crash risk and global convertibility risk.

7. Conclusion

This paper examines the performance of carry trade strategies for currencies with NDF contracts and sheds light on the risk of exchange controls on carry trade returns, using a sample of 66 countries across developed and emerging currencies for the period October 1997 to February 2011. We find that NDF carry trades tend to be associated with higher Sharpe ratios compared to DF carry trades. The DF carry trades realize higher returns during the period 1997–2003, and near-zero mean returns for the period 2004–2011. Further investigation reveals that the near-zero mean returns during 2004–2011 are the result of heavy losses DF carry trades realized during the 2008 financial crisis, while NDF carry trades realize insignificant losses during the crisis periods.

Multivariate regression results indicate that DF carry trade returns are driven by credit risk arising from carry trade funding constraints ($TED_{k,t}$) and global FX market volatility risk ($DVOLM_{k,t}$ and $DVOLW_{k,t+n}$), and global FX crash risk ($GSKEW_{k,t}$). The heavy losses of developed and emerging DF carry trades during the 2008 financial crisis are attributable to the drying up of the carry trade funding markets, increased global FX market volatility and crash risk. In addition to these common risk factors, we find that NDF carry trade payoffs are shaped by deviations from covered interest parity ($CID_{k,t}$) due to currency convertibility restrictions and capital controls during both the crisis and non-crisis periods.

We also find that the onshore–offshore interest rate differential is economically large for NDF currencies, indicating deviations from covered interest parity in offshore markets. Our results show that, on average, $CID_{k,t}$ contributes positively to NDF carry trade returns, suggesting that the superior performance of NDF carry trades reflects compensation for risk due to currency convertibility restrictions and capital controls. Finally, our results confirm that funding market liquidity, global FX volatility and crash risk negatively affect both DF and NDF carry trades, while global convertibility risk ($DGCID_{k,t}$) has a limited effect on carry trades.

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Appendix A. Convertibility risk in Iceland

Iceland's economy went into a boom during 2004–2007, fueled by foreign capital inflow. External debt reached 550% of GDP in 2007 and inflation in Iceland was among the highest in developed countries. During 2002–2007, the Icelandic Krona (ISK) appreciated 64% against the U.S. dollar. Iceland was hit hard in 2008 by global liquidity crisis. Three of its largest banks collapsed and ISK depreciated sharply. On October 15, onshore and offshore ISK markets ceased to operate, and the reference rate for ISK was set by the Central Bank of Iceland (CBI) through daily auctions. On November 24, Standard & Poor's downgraded Iceland's sovereign debt rating to BBB- from BBB. The S&P Transfer and Convertibility Assessment on Iceland was also downgraded to BBB- from A-. On November 28, CBI introduced Rules on Foreign Exchange making the ISK non-convertible. As a result, capital investments in Iceland must be reinvested within the country and conversion to foreign currency was not permitted. Capital controls had been relaxed in 2009 and 2010, but ISK remained not-freely convertible (IMF, 2008, 2009).

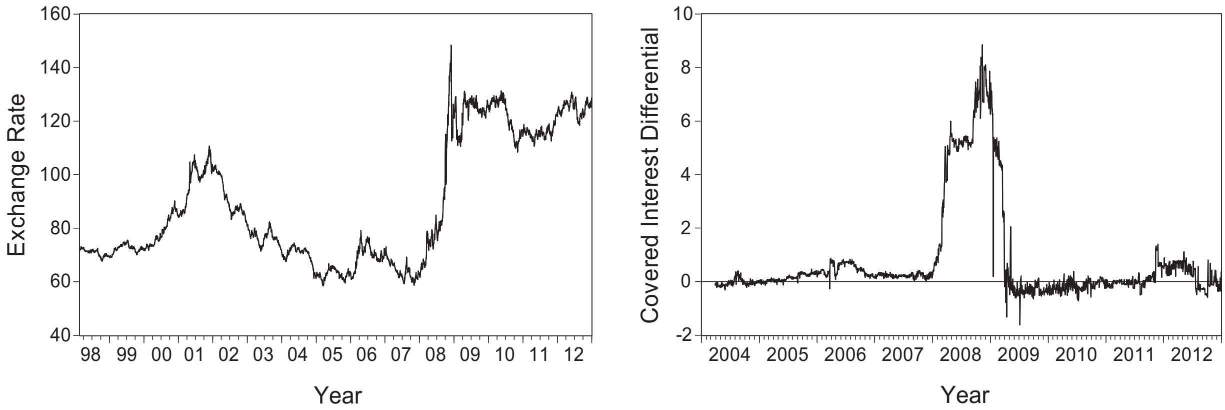

Fig. 1. The left panel plots the ISK spot rates in Icelandic Krona per U.S. dollar. The right panel plots the 12-month ISK-USD covered interest differential (CID) in percentage.

As Fig. 1 below shows, CID increased sharply from 0.25% in early January 2008 to 6% in April and 8% in November, indicating high risk in ISK. Based on the available data, we find that carry trades on ISK are profitable at 6.5% per annum during the non-crisis periods, but incur heavy losses of 23.7% (annual) during the crisis period. Therefore, as a risk factor, a growing CID of substantial size depicts the increasing convertibility risk, which will spike when the conditions are met (e.g., economic crisis) and could be relevant for both DF and NDF carry trades.

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