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International interest rate arbitrage: Study on a novel strategy

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ABSTRACT

This study examines the time-varying excess returns in an international interest rate arbitrage (IIRA) strategy, with a particular emphasis on these excess returns. Unlike traditional carry strategies that typically match funding and investment bonds' maturities or currencies, our novel IIRA strategy is a dynamically adjusted approach involves funding with a 1-year low-yield treasury bond while investing in 2- to 10-year high-yield bonds in foreign currencies. An analysis of Sharpe ratios, foreign exchange (FX), and yield excess return shows variations in the joint expectations hypothesis of the term structure (EHTS) and the uncovered interest rate parity (UIRP) lead to profits. However, the international strategies perform worse than the domestic carry strategies. Predictive factors, such as the Cochrane–Piazzesi, show limited effectiveness due to FX volatility. Therefore, future studies should examine more predictability factors.

1. Introduction

The interest rate arbitrage -carry trade is a well-established financial strategy that has attracted considerable attention for leveraging interest rate differentials across countries. Investments in higher-rate currencies and borrowing in lower-rate currencies have historically produced excess returns for investors. However, scholarly debates on the underlying mechanisms that drive these strategies' profitability, particularly related to international (cross-currency) interest rate arbitrage trades, are ongoing (Bilson, 1980; Fama, 1984; Lustig, Roussanov, & Verdelhan, 2011). Although several studies have examined single currency carry strategies, little is known about its international dimension, especially long-term bonds. The current literature lacks a comprehensive analysis of the impact of the violations of expectations hypothesis of the term structure (EHTS) and the uncovered interest rate parity (UIRP) on the excess return associated with these strategies. We analyze the time-varying excess return in a new designed dynamically adjusted international interest rate arbitrage (IIRA) strategies and focus on how variations from combined FX and interest rate expectations impact excess returns.

This strategy employs a 1-year treasury bond as the funding instrument while investing in treasury bonds with maturities ranging from 2 to 10 years. These bonds may be denominated in various currencies, such as the dollar, euro, sterling, and yen. To maximize returns, we select the 1-year treasury bond with the lowest yield as the funding bond and allocate investments to 2- to 10-year treasury bonds offering the highest yields. We apply the investment each month. And the currency pair may be different at each time of investment - the strategy is 'dynamic'. The excess returns generated by this strategy arise from violations of the joint expectations hypothesis of the term structure (EHTS) and the uncovered interest rate parity (UIRP) . As discussed in Section 3, if the joint expectations hypothesis holds, this international “cross-carry” strategy would theoretically yield no profits.

This study highlights the economic significance of the proposed strategies. We believe that the excess return of the IIRA strategy result from variations in the joint expectation hypotheses. Therefore, we empirically show the distinct and combined effects of these deviations on UIRP and EHTS as follows: First, we assess the profitability of the IIRA strategy using Sharpe ratios. Second, we examine the impact of UIRP violations by simulating a time series of FX where future FX precisely equals forward FX. We implement the strategy under these conditions, assuming no profits from the FX component and calculating the FX excess return. We also assess the impact of the EHTS by simulating a time series of yields where the rate expectation hypothesis is valid, where future and forward yields match. We calculate the yield excess return using this method and find that both UIRP and EHTS violations impact the excess return of the IIRA strategy. However, these deviations also introduce considerable volatility, particularly for the violation of

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UIRP.

We also analyze potential international factors that could forecast excess returns of the IIRA strategy. These international predictors are like factors such as the Cochrane–Piazzesi (CP) or slope factor, although they relate mainly to single-currency predictions. We examine four predictive factors: the "international version" CP and slope factors using treasury bonds yields in the funding or investment currency separately. Our findings highlight the CP factor constructed from the forward rates of treasury bonds in the investment currency, specifically, the five forward rates spanning 1, 3, 5, 7, and 9 years, as having the highest predictive power. However, the associated R^2 value ranges from 5% to 9%, significantly lower than the 10% to 25% observed for domestic carry strategies with the CP factor. This outcome is expected as the strategy's excess return originate from both FX and yield risk premia, while the slope and CP factors are designed solely to capture the yield excess return. The unexplained FX excess return reduces the predictive efficacy of both the slope and CP factors, highlighting a key limitation of our study.

A key factor in understanding the IIRA strategy's profitability is interpreting the concurrent fluctuations of the bond yields and FX values of both the investing and funding currencies, which contribute to the excess return. As outlined in the theoretical framework in Section 3, we show that the IIRA strategy generates profits under specific conditions. These conditions include a scenario where investment bonds decrease, the funding currency depreciates against the investor's domestic currency, the investing currency appreciates, and there is a negative covariance between the investing bond yield and its currency value relative to the domestic currency.

Our findings have practical investment implications, especially in highly developed and liquid markets. However, as discussed in Section 4, unconditional IIRA strategies seldom outperform their domestic counterparts, which benefit from violations of the rate expectation hypothesis. The domestic carry strategy involves funding with 1-year bonds and investing in long-term domestic treasury bonds. This underperformance is due to unfavorable FX rate movements. In 59.10% of cases, the Japan Yen consistently appreciated, thereby increasing our funding costs. Our investment currency, identified as the UK GBP in 77% of cases, consistently depreciated, thus reducing the potential gains from higher yields. Typically, even the dynamic investment strategies that are adjusted based on factors predicting returns, such as in EU, UK, and Japan, these strategies fail to outperform domestic carry strategies. This underperformance is mainly because of the FX market volatility and the limited predictive power of the identified factors to predict returns. Furthermore, during the study period, UK bond yields decreased and the UK GBP weakened. The positive covariance between these two factors reduced the profit margin by 0.1% to 0.7%. Using the Munch Gospodinov technique, we confirmed the reliability, consistency, and robustness of our results.

This study significantly contributes to the literature on bond carry trade and international currency returns in two key areas. First, we examined the return-predicting factors (RPFs) for the excess return of IIRA strategies. Previous research has focused on the excess return of domestic carry strategies involving bonds from a single country and currency (Cochrane & Piazzesi, 2005; Fama & Bliss, 1987). There have been no analyses of RPFs for long-dated international carry trades involving two currencies, where even determining the slope is unclear. We address this issue in this empirical research. Second, we analyze IIRA strategies that invest in long-term bonds but hold positions for only one year. This approach contrasts with the existing literature, which focus on international carry strategies that hold investments until bond maturity (Berg & Mark, 2019; Bilson, 1980; Kesse & Blenman, 2024; Kim, 2015). Moreover, we study the strategy from the perspective of not only US-based investors (Laborda, Laborda, & Olmo, 2014) but also all the currencies under study. We offer both empirical results and an economic interpretation of the findings.

The study is presented as follows: Section 3 outlines the construction of the IIRA strategy, defining the parameters, introducing the strategy formula, explaining the strategy's profit and loss, establishing the theoretical connection between profitability and the FX and rate expectation hypotheses, and presenting our yield and foreign exchange rate data collection sources and methods. Section 4 presents our empirical results and discussions. Finally, Section 5 covers the conclusions, practical implications, and suggestions for future research.

2. Literature review

2.1. Excess returns from carry

Many scholars attribute the excess return of carry trades to the failure of uncovered interest rate parity (UIRP) (Georgoutsos & Kouretas, 2016; Hutchinson, Kyziropoulos, O'Brien, O'Reilly, & Sharma, 2022; Kesse & Blenman, 2024; Li, Zhou, & Tong, 2019; Tse & Wald, 2013). They have also attempted to model the time-varying profitability of currency carry trades. For example, Sakemoto (2019) used a conditional factor model, showing that the alphas and betas change over time. They found that the alpha of a high-interest-rate currency portfolio increases during business cycle troughs and periods high market uncertainty. However, the beta on the dollar factor decreases under these market conditions, indicating reduced foreign currency risk exposure. Zhang, Chen, and Li (2022) used a two-country model and panel data from 22 countries to examine the relationship between carry trade activity and returns and found that previous carry trade positions positively affect current returns and scale, leading to asset bubbles. However, increased foreign exchange risk reduces returns and positions, resulting in traders reducing their carry trade positions. Craighead, Davis, and Miller (2010) found that the profitability is higher with smaller interest differentials in a two-country model, and vice versa.

2.2. Explaining excess returns of carry

Studies so far have proposed four key empirical regularities in cross-currency carry returns: the downward forward premium bias, carry trade excess return, long-term risk reversal, and trading activity of nondealer financial firms. The downward forward premium bias refers to regression evidence of UIRP violations in the data. If the UIRP holds, the portion of the excess return earned by funding in a low interest–rate currency and investing in a high interest–rate currency would be precisely offset by a loss in the value of the investing currency. In such a scenario, there is no FX excess return, and the yield excess return is the only source of profit for IIRA strategies. However, empirical evidence shows that UIRP does not hold. Bilson (1980) and Fama (1984) conducted regressions of future currency depreciation against today's interest rate differential and found that the slope was often less than one and frequently negative, indicating that larger interest rate differentials correspond to lower subsequent currency depreciation rates. Berg and Mark (2019) attributes the downward forward premium bias to excess return across currencies with different risk levels. In particular, the international carry trade is a consistent profitable strategy, especially when currencies are grouped into portfolios. Lustig et al. (2011) reported an annual excess return of 6.2% by shorting low-interest currency portfolios and longing high-interest currency portfolios. These findings on the forward premium bias and the carry trade suggest that high-interest countries pay a positive excess return, indicating higher risk levels. However, Engel (2016) contends that there is risk reversal when the excess return turns negative over time, although this might hold true in the short term through carry trades. Engel noted that a country's currency strengthens when it has high relative real interest rates, implying safety and leading to a negative long-term excess return. Besides, Boschen and Smith (2016) examined the long-term relationship between the forward premium (or discount) and interest rate differentials in Japan's FX markets, finding that some meet the CIP condition while others do not. When the interest rate differential approaches zero, liquidity risk increases; however, it decreases with negative interest

Table 1
The definitions of parameters.

Term	Explanation
D	The domestic currency
I	The investment currency in which bonds are bought/currency has the highest yield
F	The funding currency in which bonds are issued/currency has the lowest yield
PF_t^T	The value of a zero-coupon bond issued in currency F at time t with maturity T
PI_t^T	The value of a zero-coupon bond issued in currency I at time t with maturity T
$FX_t(A,B)$	The exchange rate of one unit of B in currency A at time t, A and B can be any pair of currencies
$FFX_0(A,B;T)$	The time-0 forward foreign exchange rate of one unit of B in currency A for delivery at T
$FyA_\tau(T-\tau)$	The time-0 forward yield in currency A for delivery at τ with remaining maturity $T-\tau$; A can represent the currency of I, F, or D
yA_0^t	The time-0 yield rate of bond in currency A with maturity t; A can represent the currency. of I, F, or D
$\mathbb{E}[-]$	The statistic expectation signal
$\mathbb{COV}[-]$	The statistic covariance signal

rates, potentially increasing banks' capital utilization and market liquidity. The final explanation is the trading activities of nondealer financial firms. Boschen and Smith (2016) examined whether the rise in trading by nondealer financial firms affected the UIRP anomaly, which appears to offer opportunities for excess returns. They found that the increase in trading volume by nondealer financial firms helps in reducing the UIRP anomaly. In contrast, the anomaly remains unaffected by the growth in dealer-to-dealer and dealer-to-nonfinancial firm trading volume. A key distinction between these scholars' works and ours is the investment horizon. In their carry trades, the investment bond matures when the strategy ends, while our IIRA strategy involves investing in bonds with 2- to 10-year maturity for only one year.

2.3. Predicting excess returns of carry

Several predicting factors were developed by researchers in the early studies of the single-currency carry strategy. Fama and Bliss (1987) and Campbell and Shiller (1991) identified a "slope-like" factor as a crucial indicator of excess returns. Unlike the traditional "slope," Cochrane and Piazzesi (2005) introduced a "tent-like" RPF using five forward rates. The slope, defined as the difference between the 10-year and 1-year treasury yields, is a key factor in predicting excess returns. Factors such as the Cochrane–Piazzesi (CP) and the Cieslak–Povala can be interpreted as "refinements" of the slope factor. The CP factor, popularized by Cochrane and Piazzesi (2005), is a single tent-shaped linear combination of forward rates that predicts excess returns on bonds with maturities ranging from one to five years, achieving an R^2 up to 0.44. However, the simple slope factor performs more robustly out of the sample than the CP factor, showing a minimal decline in predictive power. The CP factor, similar to the simple slope factor, overlooks information that cannot be extracted from the yield curve. To address this issue, Cieslak and Povala (2015) and Cieslak and Povala (2009) developed a factor that combines yield curve information with macro-information not fully captured by the yield curve. The Cieslak–Povala factor includes a highly persistent component that is economically and statistically related to the shifting long-term mean of inflation and saving rate, along with "cycles" of short-lived fluctuations showing rapid reversion and specific characteristics for each maturity term. Their findings indicate that this factor explains a greater proportion of variance (greater R^2) in predicting excess returns than the CP factor. However, these studies have focused on the domestic carry trade strategy within a single country and currency, while this study determines whether slope or CP-like factors can effectively predict the excess returns of IIRA strategies.

3. Methodology

3.1. Terminology

In this study, the IIRA strategy involves funding one currency by shorting 1-year maturity treasury bonds in that currency and investing in another currency by buying long-term (2- to 10-year maturity) treasury bonds of another country. The parameters used to model this strategy are defined in Table 1.

3.2. Excess return, profitability, and expectation hypotheses

The IIRA strategy for an investor using domestic currency D involves investing a fixed (unit) amount of currency D in a long-dated bond in currency I, while funding the position in currency F for 12 months. The same strategy is implemented monthly across 12 months, with the investor using the same (unit) amount of currency D each month. Therefore, at any point, there are 12 active strategies, each started one month apart, which results in overlapping returns.

The construction of this strategy involves three steps. First, at time 0, we borrow $\frac{1}{FX_0(D,F)}$ units of currency F.One unit of currency F can be obtained by issuing an amount $\frac{1}{PF_0^1}$ of the 1-period bond in currency F. Therefore, the position of bonds in currency F that we need for funding $\frac{1}{FX_0(D,F)}$ units of currency F is $-\left[\frac{1}{FX_0(D,F)}\,\frac{1}{PF_0]}\right]$. This amount of borrowing is equal to $\left[\frac{1}{FX_0(D,F)}\,\frac{1}{PF_0^1}\right]\cdot PF_0^1\cdot FX_0(D,F)=1$ unit of domestic currency D and can be converted to $\frac{1}{FX_0(D,I)}$ units of currency I. Second, at time 0, we invest this amount of currency I in long-term bond. The investment position is $+\left[\frac{1}{FX_0(D,I)}\,\frac{1}{PI_0^n}\right]$. Therefore, at time 0, the value of the portfolio, Π_0, in currency D is given by Eq. 1

$$\mathrm{P\&L}_0=-\underset{\text{F notional funding}}{\left[\frac{1}{FX_0(DF)}\,\frac{1}{PF_0^1}\right]}\cdot PF_0^1\cdot FX_0(DF)+\underbrace{\left[\frac{1}{FX_0(DI)}\,\frac{1}{PI_0^1}\right]}_{\text{I notional investing}}\cdot PI_0^1\cdot FX_0(DI)$$
$$=0 \tag{1}$$

Third, at time 1, we close our position in steps 1 and 2. $PF_1^1=1$. Therefore, the profit and loss of this strategy, i.e., the value of the portfolio, Π_1, in domestic currency D at time 1 is given by Eq. 2:

$$\mathrm{P\&L}_1=-\underbrace{\left[\frac{1}{FX_0(DF)}\,\frac{1}{PF_0^1}\right]}_{\text{F notional funding}}\cdot 1\cdot FX_1(DF)+\underbrace{\left[\frac{1}{FX_0(DI)}\,\frac{1}{PI_0^n}\right]}_{\text{I notional investing}}\cdot PI_1^{n-1}\cdot FX_1(DI) \tag{2}$$

We find the relationship between bond price and yield as

$$P_0^n=e^{-y_0^n\cdot n}\approx\frac{1}{1+y_0^n\cdot n} \tag{3}$$

In terms of yields (after linearizing), the profit and loss in Eq. 2 is nearly equal to

$$\mathrm{P\&L}_1=-\frac{FX_1(D,F)}{FX_0(D,F)}\left(1+yF_0^1\right)+\frac{FX_1(D,I)}{FX_0(D,I)}\left(1+yI_0^n\cdot n-yI_1^{n-1}\cdot(n-1)\right) \tag{4}$$

Taking expectation for both sides of Eq.4, the time-0 expectation of the time-1 profits in currency X is given by Eq.5:

$$
\begin{aligned}
\mathbb{E}[\text{P\&L}_1] = & -\frac{1+yF_0^1}{FX_0(D,F)}\mathbb{E}[FX_1(D,F)] + \frac{1}{FX_0(D,I)}\mathbb{E}[FX_1(D,I)] \\
& \left(1+yI_0^n \cdot n - \mathbb{E}\left[yI_1^{n-1}\right](n-1)\right) - \frac{1}{FX_0(D,I)}\mathbb{COV}\left(FX_1(D,I), yI_1^{n-1}\right)
\end{aligned}
\tag{5}
$$

Eq. 5 shows that the strategy earns profits when:

1. I yield reduces (I bond price increases)
2. F currency weakens against D currency
3. I currency strengthens against D currency
4. Negative covariance between I yields and $FX(D,I)$, domestic D currency should weaken (strengthen) when I yields fall (rise)

These four situations are favorable for investors pursuing the IIRA strategy. We discuss the reality and implications of these situations in Section 4. A time-0 forward FX rate for delivery at time-1, $FFX_0(D,A;T)$, is defined as:

$$
FFX_0(D,A;1) = FX_0(D,A)\cdot\frac{1+yD_0^1}{1+yA_0^1}
\tag{6}
$$

At time-0, the forward yield in currency A for delivery at time-1 with remaining maturity $n-1, FyA_1^{n-1}$, is defined as

$$
1+FyA_1^{n-1}\cdot(n-1) = \frac{1+yA_0^n\cdot n}{1+yA_0^1\cdot 1}
\tag{7}
$$

Approximately

$$
FyA_\tau^{n-1}\cdot(n-1) = yA_0^n\cdot n - yA_0^1
\tag{8}
$$

A can be F or I in Eqs.6–8. Appling Eqs. 6 and 8 to Eq.4, after linearization, the strategy's profit and loss can also be written as

$$
\text{P\&L}_1 \approx \left(1+yD_0^1\right)\left\{-\frac{FX_1(D,F)}{FFX_0(D,F;1)} + \frac{FX_1(D,I)}{FFX_0(D,I;1)}\cdot\left(1+FyI_1^{n-1}\cdot(n-1) - yI_1^{n-1}\cdot(n-1)\right\}\right.
\tag{9}
$$

The exchange rate expectation hypothesis states that the forward exchange rates are unbiased expectations of future exchange rates, as shown in Eqs. 10 and 11:

$$
\mathbb{E}[FX_1(D,I)] = FFX_0(D,I;1), \quad \text{i.e., } \mathbb{E}\left[\frac{FX_1(D,I)}{FFX_0(D,I;1)}\right] = 1
\tag{10}
$$

$$
\mathbb{E}[FX_1(D,F)] = FFX_0(D,F;1), \quad \text{i.e., } \mathbb{E}\left[\frac{FX_1(D,F)}{FFX_0(D,F;1)}\right] = 1
\tag{11}
$$

The rate expectation hypothesis states that the forward bond prices are unbiased expectations of future bond prices. The following applies to the bond in high-yield currency:

$$
\mathbb{E}\left[yI_1^{n-1}\right] = FyI_1^{n-1}
\tag{12}
$$

Eq. 12 can also be presented as

$$
yI_0^n n - \mathbb{E}\left[yI_1^{n-1}\right](n-1) = yI_0^1
\tag{13}
$$

If the joint strong expectation hypotheses hold, Eqs.10–12 would all be satisfied simultaneously, implying no excess return and zero

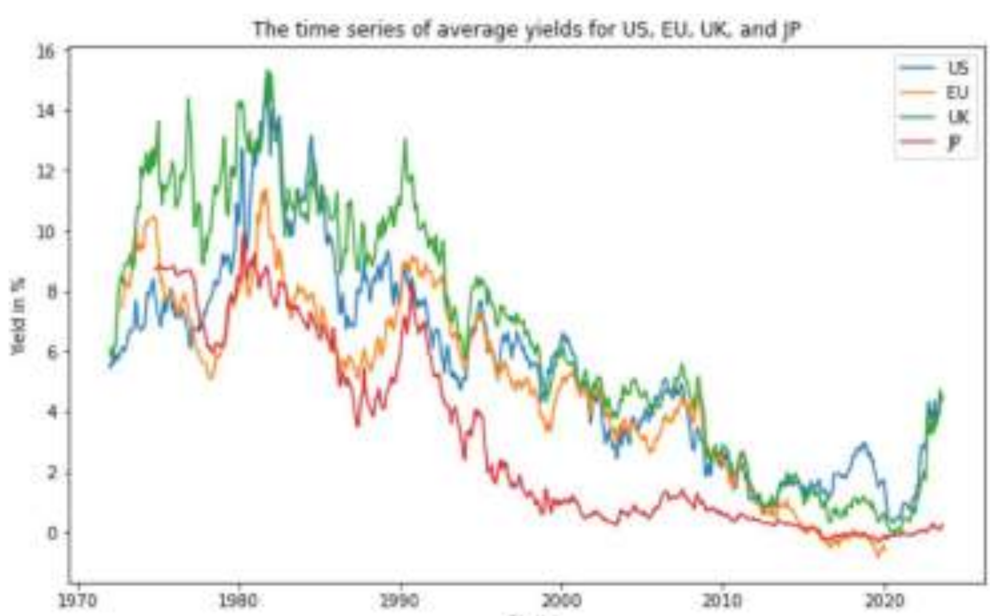

Fig. 1. The time series of average yield for US, EU, UK, and JP.

Table 2
Summary of fund/investment currency frequency.

Currency	frequency as fund currency	frequency as invest currency
USD	6.6%	22.4%
EUR	34.3%	1.1%
GBP	0	**76.5%**
JPY	**59.1%**	0

covariance terms. However, these hypotheses are often violated. We can measure the excess return from the two FX sources and the yield separately by assuming that only one expectation holds and then calculating the corresponding covariance term. The results are summarized in Table 4, and we examine these effects in Section 4.

3.3. Data

The empirical analysis examines treasury bonds from four countries denominated in four major international currencies (USD, GBP, EUR, JPY). Government bond yields ranging from 1-year to 10-year maturities (nine in the case of Japan) are examined monthly. All yields are derived using an adapted version of the original model from Nelson and Siegel (1987). The data range from the 1970s to 2023 and includes approximately 600 monthly observations. The US treasury yield data are sourced from the Federal Reserve website and computed using the methodology outlined in Gürkaynak, Sack, and Wright (2007). German yield time-series data, denominated in EUR, are obtained from the Bundesbank database starting from December 1975. For periods before

Fig. 2. The time series of the foreign exchange rate of EUR, GBP, and JPY against USD dollar.

Table 3
The violation of UIRP and EHTS.

	2Y	3Y	4Y	5Y	6Y	7Y	8Y	9Y	10Y
Panel A: US investors									
S_US_int	0.18	0.23	0.26	0.29	0.30	0.32	0.33	0.34	0.36
S_US_int_UIRP	0.37	0.39	0.39	0.40	0.42	0.43	0.43	0.44	0.46
S_US_int_EHTS	0.13	0.13	0.14	0.13	0.11	0.10	0.09	0.08	0.07
Panel B: EU investors									
	2Y	*3Y*	*4Y*	*5Y*	*6Y*	*7Y*	*8Y*	*9Y*	*10Y*
S_EU_int	0.19	0.23	0.27	0.29	0.30	0.32	0.33	0.34	0.37
S_EU_int_UIRP	0.37	0.39	0.39	0.41	0.42	0.44	0.44	0.45	0.46
S_EU_int_EHTS	0.14	0.14	0.14	0.13	0.12	0.11	0.10	0.09	0.09
Panel C: UK investors									
	2Y	*3Y*	*4Y*	*5Y*	*6Y*	*7Y*	*8Y*	*9Y*	*10Y*
S_UK_int	0.14	0.18	0.22	0.24	0.26	0.28	0.29	0.30	0.33
S_UK_int_UIRP	0.37	0.39	0.39	0.40	0.42	0.43	0.43	0.44	0.45
S_UK_int_EHTS	0.09	0.09	0.09	0.09	0.07	0.06	0.05	0.04	0.04
Panel D: JP investors									
	2Y	*3Y*	*4Y*	*5Y*	*6Y*	*7Y*	*8Y*	*9Y*	*10Y*
S_JP_int	0.24	0.28	0.32	0.34	0.35	0.36	0.37	0.38	0.40
S_JP_int_UIRP	0.37	0.39	0.39	0.40	0.42	0.43	0.44	0.44	0.46
S_JP_int_EHTS	0.20	0.20	0.20	0.19	0.18	0.17	0.16	0.14	0.14

Table 4
Comparison of mean and volatility of excess returns for IIRA strategies.

Panel A: Excess return of IIRA strategies	2Y	3Y	4Y	5Y	6Y	7Y	8Y	9Y	10Y
S_US_int	0.024	0.029	0.035	0.039	0.042	0.045	0.048	0.051	0.057
	(0.13)	*(0.13)*	*(0.13)*	*(0.14)*	*(0.14)*	*(0.14)*	*(0.15)*	*(0.15)*	*(0.16)*
S_EU_int	0.024	0.030	0.036	0.040	0.044	0.048	0.051	0.054	0.060
	(0.13)	*(0.13)*	*(0.13)*	*(0.14)*	*(0.14)*	*(0.15)*	*(0.15)*	*(0.16)*	*(0.16)*
S_UK_int	0.019	0.025	0.030	0.035	0.038	0.042	0.045	0.048	0.053
	(0.14)	*(0.14)*	*(0.14)*	*(0.14)*	*(0.15)*	*(0.15)*	*(0.16)*	*(0.16)*	*(0.16)*
S_JP_int	0.031	0.036	0.041	0.045	0.048	0.052	0.054	0.057	0.062
	(0.13)	*(0.13)*	*(0.13)*	*(0.13)*	*(0.14)*	*(0.14)*	*(0.15)*	*(0.15)*	*(0.16)*
Panel B: Excess return of “fake” IIRA strategies when EHTS holds									
	2Y	3Y	4Y	5Y	6Y	7Y	8Y	9Y	10Y
S_US_int_EHTS	0.017	0.017	0.018	0.017	0.015	0.013	0.011	0.010	0.010
	(0.13)	*(0.13)*	*(0.13)*	*(0.13)*	*(0.13)*	*(0.13)*	*(0.13)*	*(0.13)*	*(0.13)*
S_EU_int_EHTS	0.018	0.018	0.019	0.018	0.016	0.015	0.013	0.012	0.012
	(0.13)	*(0.13)*	*(0.13)*	*(0.13)*	*(0.13)*	*(0.13)*	*(0.13)*	*(0.13)*	*(0.13)*
S_UK_int_EHTS	0.012	0.012	0.013	0.012	0.010	0.009	0.007	0.005	0.005
	(0.14)	*(0.14)*	*(0.14)*	*(0.14)*	*(0.14)*	*(0.14)*	*(0.14)*	*(0.14)*	*(0.14)*
S_JP_int_EHTS	0.025	0.025	0.025	0.024	0.023	0.021	0.020	0.018	0.018
	(0.13)	*(0.13)*	*(0.13)*	*(0.13)*	*(0.13)*	*(0.13)*	*(0.13)*	*(0.13)*	*(0.13)*
Panel C:Excess return of “fake” IIRA strategies when UIRP holds									
	2Y	3Y	4Y	5Y	6Y	7Y	8Y	9Y	10Y
S_int_UIRP	0.007	0.013	0.018	0.024	0.030	0.035	0.040	0.045	0.051
	(0.02)	*(0.03)*	*(0.05)*	*(0.06)*	*(0.07)*	*(0.08)*	*(0.09)*	*(0.10)*	*(0.11)*
Panel D: Covariance term between H yields and FX of H currency									
	2Y	3Y	4Y	5Y	6Y	7Y	8Y	9Y	10Y
ϵ_US_int	−0.001	−0.001	−0.002	−0.002	−0.003	−0.003	−0.003	−0.003	−0.004
ϵ_EU_int	−0.001	−0.001	−0.001	−0.002	−0.002	−0.002	−0.003	−0.003	−0.004
ϵ_UK_int	0.000	−0.001	−0.001	−0.001	−0.001	−0.002	−0.002	−0.002	−0.003
ϵ_JP_int	−0.001	−0.002	−0.003	−0.003	−0.004	−0.005	−0.005	−0.006	−0.007

the introduction of the EUR currency, German Bund prices are used. The GBP yield time series are sourced from the Bank of England database, while Japanese bond data are from the Japanese Ministry of Finance statistics website. Fig. 1 shows the time series of yield data for the four currencies throughout the study period. In particular, the Japanese yield rate is often the lowest among the four, suggesting a funding preference for JPY bonds in “cross-currency” carry strategies. Conversely, the UK yield rate often consistently ranks highest, indicating an investing preference for UK bonds in such strategies.

Table 2 summarizes the frequencies of four currencies (USD, EUR, GBP, and JPY) used as funding and investment currencies throughout our study period. Notably, JPY is the most used funding currency at 59.1% of the time, followed by EUR as the second most used funding currency at 34.3% of the time. On the investment side, GBP leads, being used 76.5% of the time. Notably, GBP is exclusively used for investment and never for funding, while JPY is never used as an investment currency. These observations are crucial for analyzing IIRA strategy performance in Section 4.

Table 2 summarizes the frequency of the four currencies (USD, EUR, GBP, and JPY) used as fund/investment currency. JPY is most often used as the funding currency (59.1%). UK GBP is most used as the investment currency (76.5%).

Data on spot FX rates are sourced from the FRED website. Fig. 2 plots the time series of GBP, EUR, and JPY exchange rates against the USD. Remarkably, JPY and EUR have shown nearly continuous appreciation, while GBP has experienced almost continuous depreciation over the study period. This trend implies that the appreciation of JPY poses a challenge for IIRA strategies, given its prevalent use for funding. This impact of FX movements on IIRA strategy performance is discussed in Section 4.

4. Empirical results and analysis

4.1. The joint failure of FX and rate expectation hypotheses

Recall that Eq. 5 in Section 3 presents the formula for the excess return of the IIRA strategy. If both the UIRP and the EHTS hold, we would expect no average profit, i.e., an expected return of zero. The FX expectation hypothesis, also known as UIRP, posits that forward exchange rates are unbiased expectations of future exchange rates. If the FX hypothesis for high-yield (low-yield) bonds holds, as shown in Eq. 10 (Eq.11), the covariance term in Eq. 5 is zero. The EHTS states that forward bond prices are unbiased expectations of future bond prices, as shown by Eq.12. Additionally, it implies no profit for pure interest rate carry, as expressed in Eq.13. If the joint expectation hypotheses hold, within Eq. 5, the expectation of the first term inside the square brackets is -1, while the second term is $+1$.

Our results (Tables 3 and 4) indicate that the UIRP and EHTS do not hold jointly, as shown by the nonzero Sharpe ratios (excess returns) of the original IIRA strategies. We further examine the effect of violating each expectation hypothesis by assuming its validity and comparing the resulting Sharpe ratios with the original ones. To examine the effect of the EHTS, we assume that Eq. 10 holds and create a synthetic time series of forward rates where future rates precisely match the forward rates. We then implement a “fake” strategy using this data, expecting no profit from interest rate carry. Regarding the effect of the UIRP, we assume both Eqs. 10 and 11 hold and repeat a similar procedure to observe whether any profit can be earned from the FX component. Table 3 and Fig. 3 present the summarized results. Notably, the “fake” strategies, if the rate expectation hypothesis holds, show smaller Sharpe ratios, approximately 0.05 to 0.29 lower than their original counterparts. This suggests that, in reality, IIRA strategies are profitable due to the violation of the EHTS, consistent with the conclusions of Hutchinson et al.

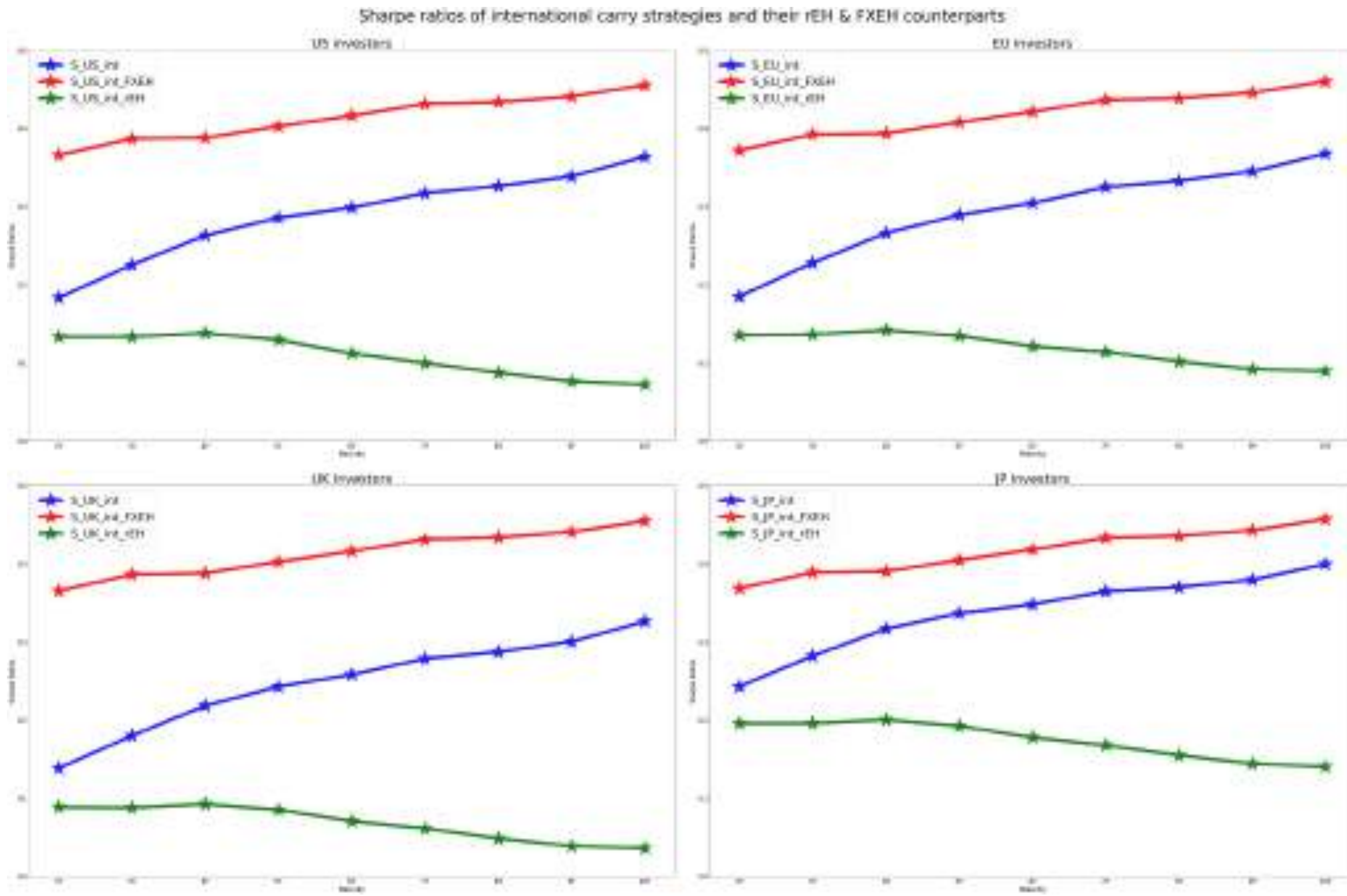

Fig. 3. Plots of Sharpe ratios of IIRA strategies vs. their EHTS and UIRP counterparts for US, EU, UK, and JP investors.

Table 5
R^2 of predicting IIRA strategies.

Panel A: using the slope factor of investment bond's 10y-ly yield									
	2Y	*3Y*	*4Y*	*5Y*	*6Y*	*7Y*	*8Y*	*9Y*	*10Y*
S_US_int	0.02	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00
S_EU_int	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00
S_UK_int	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00
S_JP_int	0.02	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00
Panel B: using the slope factor of investment bond's 10y-funding bond's ly yield									
	2Y	*3Y*	*4Y*	*5Y*	*6Y*	*7Y*	*8Y*	*9Y*	*10Y*
S_US_int	0.03	0.03	0.04	0.04	0.05	0.05	0.06	0.06	0.07
S_EU_int	0.04	0.04	0.04	0.05	0.05	0.05	0.06	0.06	0.07
S_UK_int	0.03	0.03	0.03	0.03	0.04	0.04	0.05	0.05	0.06
S_JP_int	0.04	0.04	0.05	0.05	0.06	0.06	0.07	0.07	0.08
Panel C: using the CP factor of 5 investment bond's forward rates									
	2Y	*3Y*	*4Y*	*5Y*	*6Y*	*7Y*	*8Y*	*9Y*	*10Y*
S_US_int	0.08	0.07	0.07	0.07	0.06	0.05	0.04	0.04	0.04
S_EU_int	0.08	0.08	0.08	0.08	0.06	0.05	0.05	0.05	0.05
S_UK_int	0.08	0.08	0.08	0.08	0.07	0.06	0.05	0.05	0.05
S_JP_int	0.09	0.08	0.09	0.08	0.07	0.06	0.05	0.05	0.05
Panel D: using the CP factor of 5 funding bond's forward rates									
	2Y	*3Y*	*4Y*	*5Y*	*6Y*	*7Y*	*8Y*	*9Y*	*10Y*
S_US_int	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
S_EU_int	0.03	0.02	0.02	0.02	0.02	0.03	0.02	0.02	0.02
S_UK_int	0.04	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02
S_JP_int	0.03	0.02	0.02	0.02	0.03	0.03	0.03	0.03	0.03

Table 6
R^2 of predicting domestic strategies.

Panel A: using the slope factor-bond's 10y–ly yield									
	2Y	*3Y*	*4Y*	*5Y*	*6Y*	*7Y*	*8Y*	*9Y*	*10Y*
S_US_US	0.02	0.04	0.06	0.08	0.10	0.11	0.12	0.13	0.13
S_EU_EU	0.01	0.02	0.03	0.04	0.06	0.07	0.08	0.09	0.10
S_UK_UK	0.01	0.01	0.01	0.02	0.02	0.03	0.04	0.06	0.07
S_JP_JP	0.00	0.01	0.04	0.06	0.07	0.08	0.09	0.07	NaN
Panel B: using the Cochrane–Piazzessi (CP)factor									
	2Y	*3Y*	*4Y*	*5Y*	*6Y*	*7Y*	*8Y*	*9Y*	*10Y*
S_US_US	0.19	0.20	0.21	0.22	0.23	0.24	0.24	0.25	0.25
S_EU_EU	0.09	0.10	0.11	0.11	0.11	0.11	011	0.11	0.11
S_UK_UK	0.09	0.09	0.09	0.09	0.08	0.08	0.08	0.08	0.09
S_JP_JP	0.15	0.20	0.19	0.23	0.25	0.23	0.18	0.13	NaN

(2022), Koijen, Moskowitz, Pedersen, and Vrugt (2018), and MacDonald and Nagayasu (2015), which indicates profitability through interest rate carry. Furthermore, a comparison of the excess returns of the original IIRA strategies in Panel A of Table 4 with those of "fake" strategies where the EHTS is upheld in Panel B shows that the violation of EHTS can generate excess returns of 0.06 to 0.46.

However, the "fake" strategies that assume the validity of the UIRP have 0.10–0.23 higher Sharpe ratios than their original counterparts, which contradicts the empirical evidence of Fama (1984) and Aziz (2024). This suggests that profits can be earned through the violation of UIRP. To further clarify, instead of examining the Shape ratios, we examined the expected excess returns and their standard errors for both the "fake" and original strategies. Table 4 shows that while higher expected excess returns can be earned from violating UIRP, resulting in greater volatility. The excess returns of the original strategies violating UIRP are 0.006–0.024 higher than those of "fake" strategies with UIRP holding, but the standard errors of the former strategies are 0.05 to 0.12 higher than those of the latter strategies. The increase in volatility is almost one order of magnitude greater than the increase in excess return. Therefore, the smaller Sharpe ratios of the original strategies are due to the substantial volatility caused by the UIRP violation in both funding and investment currencies. Panel C of Table 4 summarizes the excess returns and volatilities of "fake" strategies with UIRP holding. Notably, it has only one row because, in scenarios where the UIRP holds, investors from the US, EU, UK, and JP face identical excess returns. These returns represent the spread between the yields of investment and funding bonds, highlighting the uniformity of returns across different investor bases when the UIRP is upheld.

Table 4 also shows that violating the UIRP has a stronger impact in the long term, while violating the EHTS is more significant in the short term. Panel C shows a substantial increase in excess return/excess return from violating the UIRP, increasing from 0.007 to 0.051 as the maturity of investing bonds extends from 2 years to 10 years. Conversely, in Panel B, the excess return from violating the EHTS shows a slight decrease (which can be disregarded and remains near constant at 0.015) from 0.02 to 0.01 as the maturity of the investing bonds extends from 2 years to 10 years. For strategies investing in short-term bonds, such 2- to 3-year bonds, the excess returns from violating the EHTS are higher, accounting for approximately 70%–80% of the total excess return, while the excess returns from violating the UIRP are only about 20%–30%. Conversely, for strategies investing in long-term bonds with maturities of 9 or 10 years, the excess returns from violating the UIRP dominate,

Fig. 4. Time series spread between the investment and funding yields.

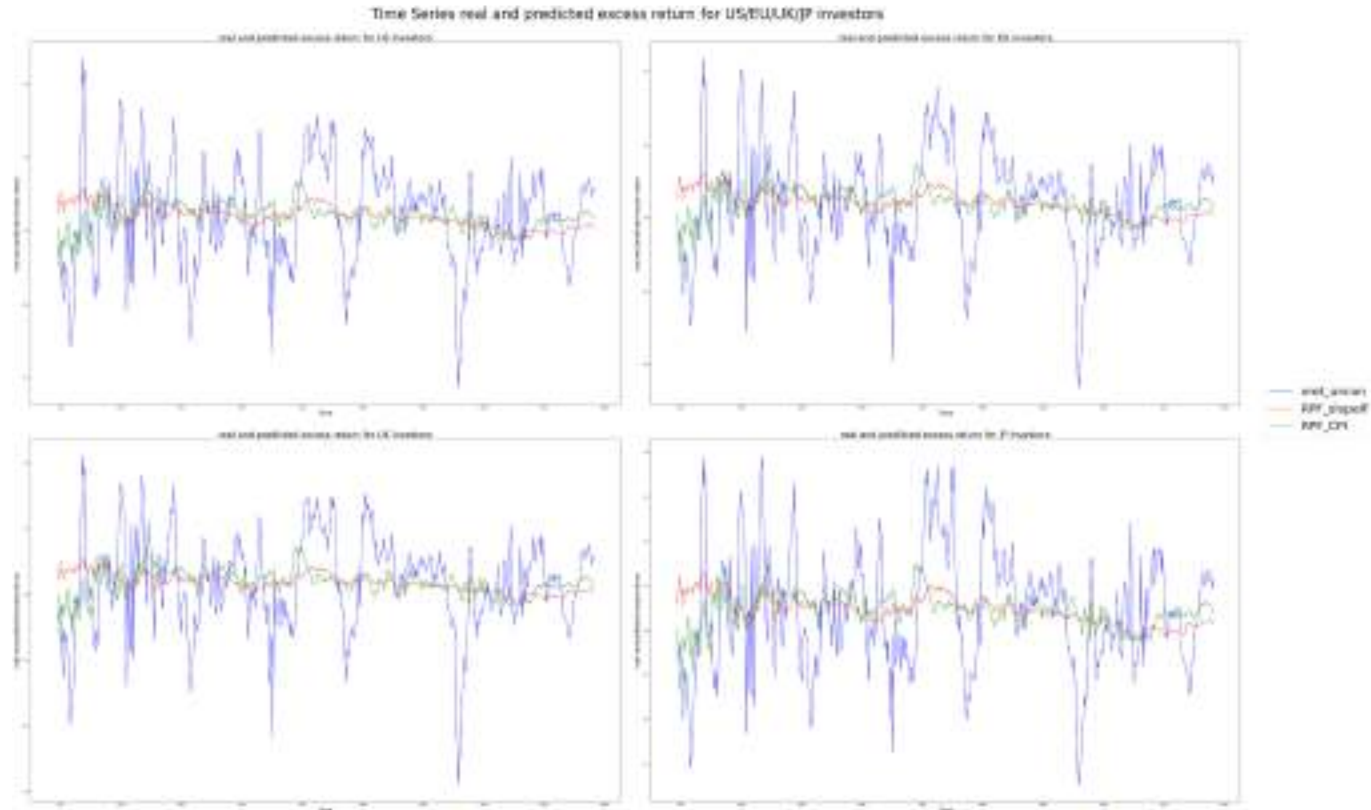

Fig. 5. Time series real and predicted excess returns for US/EU/UK/JP investors.

accounting for more than 80% of the total excess return, with the excess returns from violating the EHTS accounting for less than 20%. This observation implies that the excess return derived from violating the EHTS remains relatively constant, about 0.015, over time. In contrast, the excess return from violating the UIRP increases with longer-maturity investments.

Table 3 summarizes the Sharpe ratios for international strategies from US, EU, UK, and JP investors. In Panel A, strategies named "S_US_int" is the unconditional international strategy for US investors. Strategies named "S_US_int_UIRP" are the US unconditional international strategy when the exchange rate expectation hypothesis holds, i.e., forward FX rate matches the expected FX rate implied by UIRP. "S_US_int_EHTS" is the US unconditional international strategy when the yield rate expectation hypothesis holds, i.e., real forward yield matches the expected forward yield. Panels B, C, and D use the same name method of strategies for EU, UK, and JP investors.

4.2. The predictability of risk premia

$$\text{excess return} = a + b \cdot \text{RPFs} + \epsilon \tag{14}$$

Fig. 3 forecasts the excess return of IIRA strategies using four distinct RPFs. For each RPF, we conduct a regression analysis, as described in Eq. 14, to assess its predictive power by examining the R-square value of the regression. The first RPF is the investment currency's slope factor, measured as the difference between the 10-year and 1-year yields of government bonds in the investment currency. The second RPF is the cross-currency slope factor, calculated as the difference between the 10-year and 1-year yields of government bonds in the investment currency. The third RPF is the investment currency's Cochrane–Piazessi (CP) factor, including the 1-year, 3-year, 5-year, 7-year, and 9-year forward yields of government bonds in the investment currency. The fourth RPF is the funding bond's Cochrane–Piazessi factor, including the five forward yields of government bonds in the funding currency.

Table 5 shows that, in most instances, the fourth RPF has exhibits the highest explanatory power for excess returns. For IIRA strategies involving US, EU, UK, and JP investors, their predicted R-squared (R^2) values are approximately 0.07. However, for strategies investing in long-term maturity (over 8 years) high-yield bonds, the explanatory power of the cross-currency slope factor slightly outperforms that of the investment bond's CP factor. Specifically, the R-squared value using the cross-currency slope RPF is approximately 0.07, while that using the investment currency's CP RPF is about 0.05.

The ability to predict the excess return of IIRA strategies is limited, as shown by Table 5, where the R^2 values for all RPFs are less than 10 %. The low R^2 values for predicting excess returns of IIRA strategies are substantially lower than for domestic strategies. Table 6 shows that, for domestic strategies, the predictive power (R^2) of the CP factor ranges from 0.10 to 0.25 and consistently surpasses that of the slope factor. Additionally, for strategies investing in long-term maturity (over 8 years) bonds, the explanatory power of the slope factor for domestic strategies (R^2 over 0.10) also exceeds that of the cross-currency slope factor for IIRA strategies (R^2 around 0.07). The lower predictive power for IIRA strategies is expected because the RPFs used for predicting excess return only include information about yields, while those of IIRA strategies also include the excess return resulting from FX movements. The uncertainty introduced by the FX movement reduces the predictive power of pure yield-based RPFs, such as the cross-slope factor and the investment bond's CP factor.

Table 4 summarizes the average excess return and volatility for international strategies and their EHTS & UIRP parts of US, EU, UK, and JP investors. In Panel A, Strategies named "S_US(EU/UK/JP) _int" is the unconditional international strategy for $US(EU/UK/JP)$ investors. In Panel B, strategies named "S_US(EU/UK/JP)_int_EHTS" are the $US(EU/UK/JP)$ unconditional international strategy when the interest rate expectation hypothesis holds, i.e., forward interest rate matches

Table 7
Sharpe ratios of unconditional strategies—domestic vs. IIRA strategies.

Strategies	2*Y*	3*Y*	4*Y*	5*Y*	6*Y*	7*Y*	8*Y*	9*Y*	10*Y*
S_US_US	0.35	0.35	0.35	0.35	0.34	0.33	0.32	0.31	0.30
S_US_int	0.18	0.23	0.26	0.29	0.30	0.32	0.33	0.34	0.36
S_EU_EU	0.43	0.47	0.49	0.49	0.50	0.49	0.49	0.49	0.48
S_EU_int	0.19	0.23	0.27	0.29	0.30	0.32	0.33	0.34	0.37
S_UK_UK	0.30	0.34	0.35	0.36	0.37	0.38	0.39	0.39	0.39
S_UK_int	0.14	0.18	0.22	0.24	0.26	0.28	0.29	0.30	0.33
S_JP_JP	0.34	0.39	0.39	0.43	0.47	0.46	0.47	0.46	*NaN*
S_JP_int	0.24	0.28	0.32	0.34	0.35	0.36	0.37	0.38	0.40

Fig. 6. Plot of time-series foreign rate of UK GBP against USD, EUR, and JPY.

Fig. 7. Plot of time-series foreign rate of Japan JPPY against USD, EUR, and GBP.

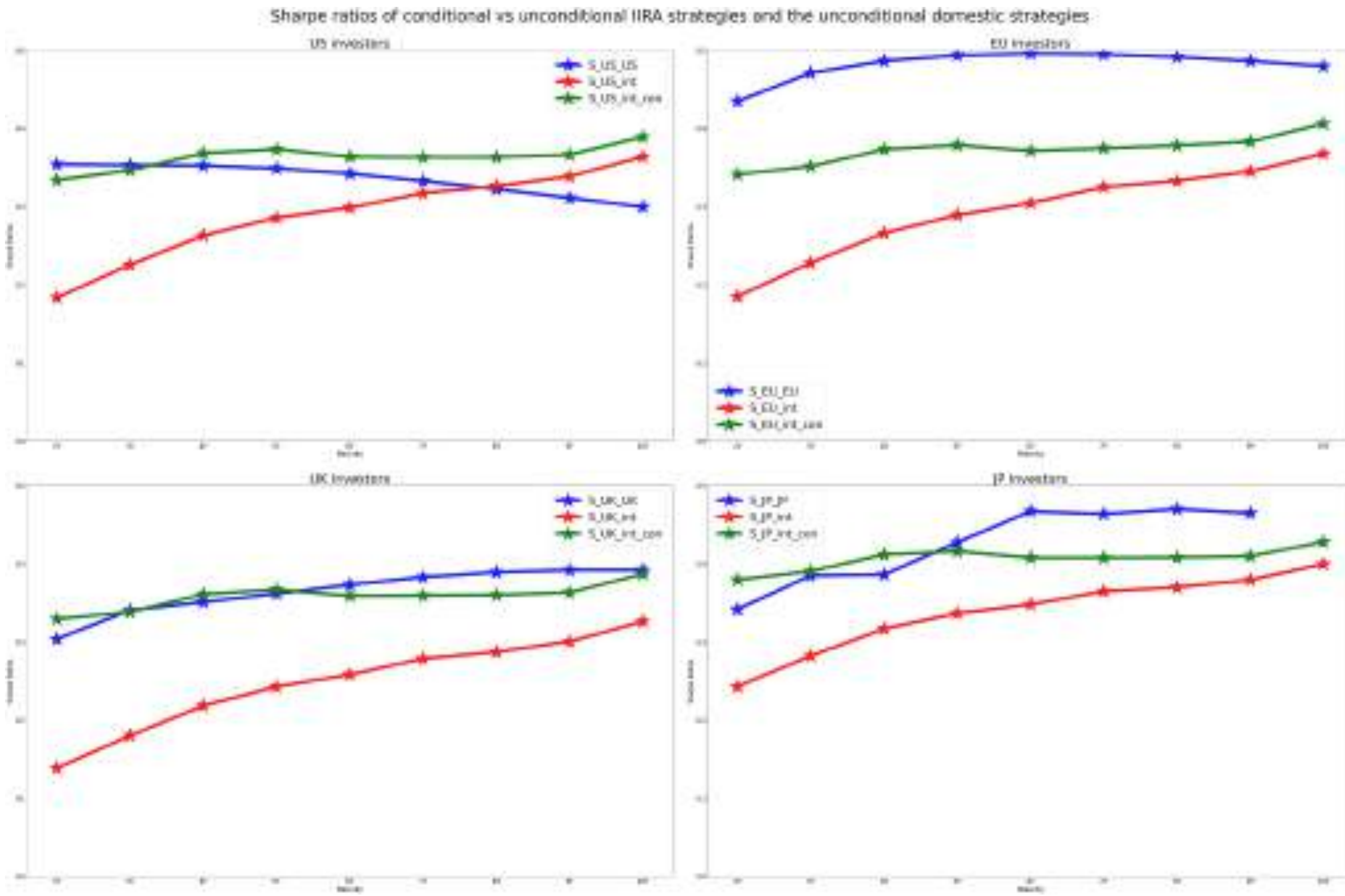

Fig. 8. Sharpe ratios of conditional vs. unconditional IIRA strategies and unconditional domestic strategies.

expected rate. In Panel C, strategies named "S_int_UIRP" are the unconditional international strategy for $US/EU/UK/JP$ investors when the exchange rate expectation hypothesis holds, i.e., forward FX rate matches the expected FX rate implied by UIRP. In Panel D, "$\epsilon\_US(EU/UK/JP)\_int$" is the remaining error term, which is too small to be omitted. It is calculated by subtracting the excess return of *rEH*and UIRP from the original unconditional excess return.

Fig. 4 shows the yield spread between the average investment and

Fig. 9. Time-series exchange rate of foreign currencies against EUR.

Table 8
Sharpe ratios of conditional IIRA strategies.

Panel A: using the slope factor of the investment bond's 10-year to l-year yield									
	2Y	*3Y*	*4Y*	*5Y*	*6Y*	*7Y*	*8Y*	*9Y*	*10Y*
S_US_int	0.20	0.23	0.26	0.28	0.30	0.31	0.32	0.34	0.37
S_EU_int	0.19	0.23	0.26	0.28	0.30	0.32	0.33	0.35	0.38
S_UK_int	0.15	0.18	0.22	0.24	0.26	0.28	0.29	0.30	0.34
S_JP_int	0.25	0.29	0.32	0.34	0.35	0.36	0.37	0.38	0.40
Panel B: using the slope factor of the investment bond's 10 year–funding bond's l-year yield									
	2Y	*3Y*	*4Y*	*5Y*	*6Y*	*7Y*	*8Y*	*9Y*	*10Y*
S_US_int	0.22	0.24	0.27	0.28	0.29	0.30	0.31	0.32	0.34
S_EU_int	0.23	0.25	0.28	0.29	0.30	0.31	0.32	0.33	0.35
S_UK_int	0.19	0.21	0.24	0.25	0.26	0.28	0.28	0.30	0.32
S_JP_int	0.27	0.28	0.31	0.32	0.33	0.34	0.34	0.35	0.37
Panel C: using the CP factor of five investment bonds' forward rates									
	2Y	*3Y*	*4Y*	*5Y*	*6Y*	*7Y*	*8Y*	*9Y*	*10Y*
S_US_int	0.33	0.35	0.37	0.37	0.36	0.36	0.36	0.37	0.39
S_EU_int	0.34	0.35	0.37	0.38	0.37	0.37	0.38	0.38	0.41
S_UK_int	0.33	0.34	0.36	0.37	0.36	0.36	0.36	0.36	0.39
S_JP_int	0.38	0.39	0.41	0.42	0.41	0.41	0.41	0.41	0.43
Panel D: using the CP factor of five funding bond's forward rates									
	2Y	*3Y*	*4Y*	*5Y*	*6Y*	*7Y*	*8Y*	*9Y*	*10Y*
S_US_int	0.12	0.11	0.11	0.11	0.11	0.13	0.15	0.17	0.21
S_EU_int	0.12	0.12	0.12	0.12	0.12	0.14	0.16	0.19	0.22
S_UK_int	0.12	0.11	0.11	0.11	0.11	0.12	0.12	0.14	0.17
S_JP_int	0.13	0.12	0.13	0.13	0.13	0.15	0.16	0.19	0.22

funding yields, similar to the second slope of the RPF. It represents the excess return that can be examined from the violation of the EHTS. We can benefit from this excess return as it consistently exceeds zero, averaging around 4%. The low explanatory power for IIRA strategies indicates that the excess return from the violation of EHTS can only explain a portion of the total excess return. The omitted portion is the excess return that can be examined from the violation of the UIRP, information not included in the four aforementioned RFPs. Fig. 5 shows the time series of real excess return for IIRA strategies and the predicted excess return using the cross-currency slope and the investment bonds' CP factors for US, EU, UK, and JP investors separately. While the investment bonds' CP factor captures more volatility than the cross-currency slope factor, a significant portion of volatility remains unexplained.

Table 5 summarizes conditional R^2 of all international strategies for US, EU, UK, and JP investors. In Panel A, the predicting factor is the slope factor of the high-yield bond's $10y - 1y$ yield. In Panel B, the predicting factor is the slope factor of the High-yield bond's 10-year low-yield bond's 1-year yield. In Panel C, the predicting factor is the CP factor of five high-yield bond's forward rates. In Panel D, the predicting factor is the CP factor of five low-yield bond's forward rates.

Table 6 summarizes conditional R^2 of all domestic strategies for US, EU, UK, and JP investors. In Panel A, the predicting factor is the slope factor of the bond's $10y - 1y$ yield. In Panel B, the predicting factor is the Cochrane–Piazzessi (CP) factor of 5 forward rates (1y, $3y$,$5y$,$7y$, and $9y$).

4.3. Can unconditional IIRA strategy outperform domestic carry strategy?

We analyzed the profitability of unconditional IIRA strategies by comparing the Sharpe ratios of these strategies with their domestic counterparts. The latter refers to unconditional carry strategies that exclusively fund and invest in a single currency. Table 7 summarizes the Sharpe ratios for unconditional IIRA and domestic strategies with investment bonds' maturities ranging from 2 to 10 years, categorized for US, EU, UK, and JP investors. The results show that unconditional IIRA strategies most often fail to outperform their domestic counterparts. Specifically, for EU, UK, and JP investors, these strategies consistently and significantly underperform. The Sharpe ratios of these IIRA strategies are 0.06 to 0.24 lower than those of domestic carry strategies, except for US investors. Only unconditional IIRA strategies investing in the highest-yield bonds with long-term maturities (8 to 10 years) show a slight outperformance over their domestic counterparts, achieving a Sharpe ratio gain from 0.01 to 0.06.

This Table 7 summarizes the unconditional Shape ratios for both domestic and IIRA strategies of US,EU,UK, and JP investors. "S_US_US" is the unconditional domestic strategy for US investors; "S_US_int" is the unconditional IIRA strategy for US investors; and "$S\_EU/UK/JP\_EU/UK/JP$(int)" is the unconditional domestic (IIRA) strategy for EU/UK/JP investors.

The observed underperformance in IIRA strategies are because of the unfavorable movements in funding and investment currencies. In our study, investors from US, EU, UK, or JP have access to treasury bond markets in the US, EU, UK, and JP, thus sharing identical potential profitability opportunities. This implies that all investors face the same funding and investment currency pairs. As explained in Section 3, the appreciation of the funding currency or the depreciation of the investment currency can significantly reduce the profitability of IIRA strategies. Fig. 7 shows that the Japanese Yen (JPY), the most frequently used funding currency, consistently appreciated. Conversely, Fig. 6 shows the British Pound (GBP), the primary investment currency, depreciating substantially over the 50-year study period. The simultaneous unfavorable currency movements worsen the performance of most IIRA strategies.

These findings highlight the contributions of currency movements to the profitability dynamics of international carry strategies, underscoring the need for currency risk management strategies to reduce potential losses and increase overall profit.

4.4. Can conditional IIRA strategy outperform domestic carry strategy?

The excess return for each conditional strategy, $cxrt^n_{t+1}$, is calculated by multiplying the unconditional excess return by the appropriate RPF, $cxret^n_{t+1} = xret^{t+1}_n \cdot RPFs$. This represents the excess return from a strategy whose notional value relative to the unconditional strategy is scaled in both magnitude and sign by the magnitude of the RPF. The RPFs are shown in Eq.14. In our study of conditional strategies, we use each RPF for US, EU, UK, and Japanese investors. The Sharpe ratios of these strategies are summarized in Table 8. Remarkably, the Sharpe ratios of strategies depending on the investment currency's CP factor (ranging from 0.33 to 0.43) consistently outperform those of strategies using other factors. This result is consistent with the findings in Table 5, showing that the investment currency's CP factor has the strongest predictive power.

Fig. 8 shows the Sharpe ratios of unconditional domestic strategies, unconditional IIRA strategies, and conditional strategies based on the investment currency's CP factor for US, EU, UK, and Japanese investors. The conditional IIRA strategies always outperform their unconditional counterparts for all four investors, which results solely from examining the excess return resulting from the violation of EHTS. As discussed earlier, the investment currency's CP factor captures the excess return resulting from the violation of EHTS.

However, the conditional IIRA strategies do not always outperform the unconditional domestic strategies. For US investors, the conditional strategies investing in long-term maturity bonds outperform their unconditional domestic counterparts. However, for UK and Japanese investors, the conditional strategies investing in long-term maturity (over 4 years) bonds perform worse than their unconditional domestic counterparts. For EU investors, the conditional strategies are always inferior to their unconditional domestic counterparts. The underperformance of conditional IIRA strategies is because of the appreciation of the funding currency and the depreciation of the investing currency. Considering EU investors, for example, Fig. 9 shows the time-series foreign exchange movement of EUR currency against other. It is evident that JPY, typically used as the funding currency, appreciated significantly. In contrast, GBP and USD are used as the investing currency 98.9% of the time, consistently depreciated during our study. These unfavorable movements in FX rates reduce the profit potential of IIRA strategies.

In Table 8, we summarize conditional Sharpe ratios of all international strategies for US, EU, UK, and Japanese investors. In Panel A, the predicting factor is the slope factor of the high-yield bond's 10y–1y yield. In Panel B, the predicting factor is the slope factor of the high-yield bond's 10*y*–Low-yield bond's 1*y* yield. In Panel C, the predicting factor is the Cochrane–Piazzessi (CP) factor of five high-yield bond's forward rates. In Panel D, the predicting factor is the CP factor of 5 low-yield bond's forward rates.

5. Conclusion

This study examined the profitability dynamics and implications of the dynamically adjusted international interest rate arbitrage strategy. By examining the joint movement of investment bond yields and FX values, we explain the source of excess return and its association with UIRP and EHTS. Our empirical analysis provides insights into the performance of the IIRA strategy, highlighting its challenges and opportunities in highly developed and liquid markets. However, this study has limitations. First, we focus on factors associated with yield excess return, overlooking those necessary to capture FX excess return. Future studies should examine such factors for a deeper understanding of the strategy's profitability. We also focused on treasury bonds from highly developed markets, neglecting emerging countries' government bonds with lower liquidity. Further research about emerging markets can build on the studies by Skinner and Mason (2011) and Karahan and Soykök (2022). Examining the potential benefits from these countries and their associated liquidity excess return presents a promising avenue for further research. Furthermore, while our study used Sharpe ratios as a measure of profitability, future research could include other metrics to provide a more nuanced assessment of strategy performance. Diversifying the range of metrics would offer a more comprehensive evaluation of the strategy's risk-adjusted returns.

In summary, our study contributes to the existing literature on bond carry trade and international currency returns, offering insights into the IIRA strategy. Despite its limitations, our findings offer valuable implications for practitioners and lay the groundwork for future research in international finance and investment strategies.

Declaration of competing interest

The authors declare no conflict of interest.

Data availability

Data will be made available on request.

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