The Best Strategies for FX Hedging

PEDRO CASTRO, CARL HAMILL, JOHN HARBER, CAMPBELL R. HARVEY, and OTTO VAN HEMERT [*]

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ABSTRACT

The question of whether, when, and how to hedge foreign exchange risk has been a vexing one for investors since the end of the Bretton Woods system in 1973. Our study provides a comprehensive empirical analysis of dynamic FX hedging strategies over several decades, examining various domestic and foreign currency pairs. While traditional approaches often focus on risk mitigation, we explore the broader implications for expected returns, highlighting the interplay between hedging and strategies such as the carry trade. Our findings reveal that incorporating additional factors - such as trend (12-month FX return), value (deviation from purchasing power parity), and carry (interest rate differential) - into hedging decisions delivers significant portfolio benefits. By adopting a dynamic, active approach to FX hedging, investors can enhance returns and manage risk more effectively than with static hedged or unhedged strategies.

Keywords: *FX, Hedging, Carry, Value, Momentum, Trend, Purchasing Power Parity, Active Investing, Dynamic Hedging*.

JEL codes: G11, G12, G15, G32, F31.

[*] All authors are affiliated with Man Group. Harvey is also affiliated with Duke University and the National Bureau of Economic Research. Please direct correspondence to otto.vanhemert@man.com. We have benefited from the comments of Alex Preston.

1. Introduction

One of the foundational decisions that asset owners need to make is whether to hedge the FX exposure of their international assets. Often an investment committee will come up with a broad policy such as fully hedging FX for foreign investments. This is often motivated by portfolio risk minimization because adding FX risk can make portfolio returns more volatile. It is also sometimes motivated by the fact that a global equity manager has no particular expertise in timing FX exposures so, it is argued, that risk should be expunged.

We contend that a binary and static framing of the question 'to hedge or not to hedge' is naïve for a number of reasons.[1] First, fully hedging FX risk may not minimize risk. The returns of an asset one seeks to hedge may be influenced by changes in exchange rates, even when those returns are expressed in the local currency. For example, the revenues of stocks in an equity index may be partially earned in a foreign currency. Similarly, input prices may be impacted by foreign exchange rate movements. For example, the FTSE100 index of the largest U.K. stocks will have FX exposures because global businesses inevitably derive their earnings in a range of different currencies.

Second, decisions are often made based on a risk minimization perspective. However, it is also important to take expected returns into account when making a hedging decision. This point is also emphasized in Boudoukh et al. (2019). A good example of this is carry. The interest rate differential between two countries creates a tension between the hedging and no hedging decision. That is, if the home country is a low relative interest rate country, the hedging decision should be different than if the home country is a high relative interest rate country – the reason for this will become clear in our analysis below. While carry is an important information component, there are others such as value and momentum that should be considered.

Third, the hedging decision is fundamentally a portfolio decision. Hedging the FX on an investment in country A's equity should impact the decision on hedging an investment in country's B's equity, assuming country A and B are not independent. Correlations must be considered.

Our paper is organized as follows. The first part of the paper looks at the simple case of hedging or not hedging in a large sample of equity markets from April 1973 onwards. We consider a matrix of equity market-home currency combinations. We then introduce some conditioning information in the form of carry and consider a carry-informed dynamic hedging strategy. [2] Our results suggest that hedging based on carry information shows considerable promise. We then test other information such as value and momentum. The next part of the paper examines the portfolio decision, where we detail optimal hedging. Our optimal hedging is constrained to be in a range of 0% to 100% of the country equity exposure which, from our experience, is the practical issue that most investors face.[3] The final part of the paper offers some concluding remarks. Here, we also link

[1] As expressed in numerous papers entitled "To Hedge or Not to Hedge". See for instance this paper: To Hedge or Not to Hedge | Diamond Hill (diamond-hill.com)

[2] Early work on currency hedging includes Black (1989, 1990), Perold and Schulman (1988), Eaker and Grant (1990), Glen and Jorion (1993), Levich and Thomas (1993), and Winston and Bailey (1996). More recent contributions examining dynamic hedging strategies include De Roon et al. (2003), Campbell et al. (2010), Schmittmann (2010), Topaloglou et al. (2011), Opie and Dark (2015), Kritzman et al. (2015), Christensen and Varneskov (2021), Arruda et al. (2021), Boudoukh et al. (2019), Opie and Riddiough (2024), and Cheema-Fox and Greenwood (2024).

[3] Boudoukh et al. (2019) explore an approach where they derive an optimal FX portfolio that is unconstrained, that is, the FX hedging is not directly linked to the country equity exposure.

this paper to two previous papers (Harvey et al. 2019 and Neville et al. 2021) and specifically show how, FX hedging approaches perform during large equity sell-offs and inflationary bursts.

2. Data

For our analysis, we focus on a range of developed market (DM) and emerging market (EM) currencies and a number of DM equity markets. We start our analysis of DM currencies in April 1973 after the end of the Bretton Woods system of fixed exchange rates. As a result of data availability, our EM history is shorter.

For Eurozone countries, we stitch the euro to the relevant local currency, with the euro returns starting on the 1st of January 1999, the day that the euro was introduced. When we are considering the historical experience of a "euro investor", we use the series where the euro is stitched to the deutschmark. As Germany is the largest economy in the Eurozone, the mark is the most representative predecessor currency. However, when considering the historical experience of, for example, an investor investing into Italian equities, we use the Italian lira before 1999 and the euro afterwards. Similarly, when considering the experience of an Italian investor allocating into foreign equities, we use the Italian lira spliced with the euro from 1999.

For our FX returns, we use forward returns when they are available. Before that, we backfill the returns by creating "synthetic" FX forwards, using a combination of spot FX returns and short-term interest rate differentials between currencies.[4] For equities, we use futures returns once available. Prior to that, we use cash equity returns and subtract the relevant short-term interest rate in the country to calculate an excess return (this can be thought of as a "synthetic" futures return). Further details on the calculation of our FX and equity returns are given in Appendix A1.

Exhibit 1 provides start dates for each of the markets used in the analysis and summarizes their returns. For the FX pairs, all currencies are shown against the US dollar (USD).

[4] We assume the cross-currency basis is zero when backfilling with the FX forward returns. The basis impacts the realized carry one pays or receives. Usually very small (<10% of overall carry) and but more relevant in a crisis. See Du and Huber (2024).

Exhibit 1: Summary Statistics

The returns and start dates for each of the currencies and equity markets that we use in this paper as well as some descriptive statistics. For the FX markets, we show both the mean annualized total return based on futures contracts (or synthetic futures) and the mean annualized spot return. For the equities markets, we just show the mean annualized return in local currency terms. The skewness and kurtosis are both calculated on the futures/forwards returns. DEM, ESP, FRF, ITL and NLG are shown up to the start of 1999 in this table. In later analysis, their returns are spliced with the euro at the end of 1999. All other data are through June 2024.

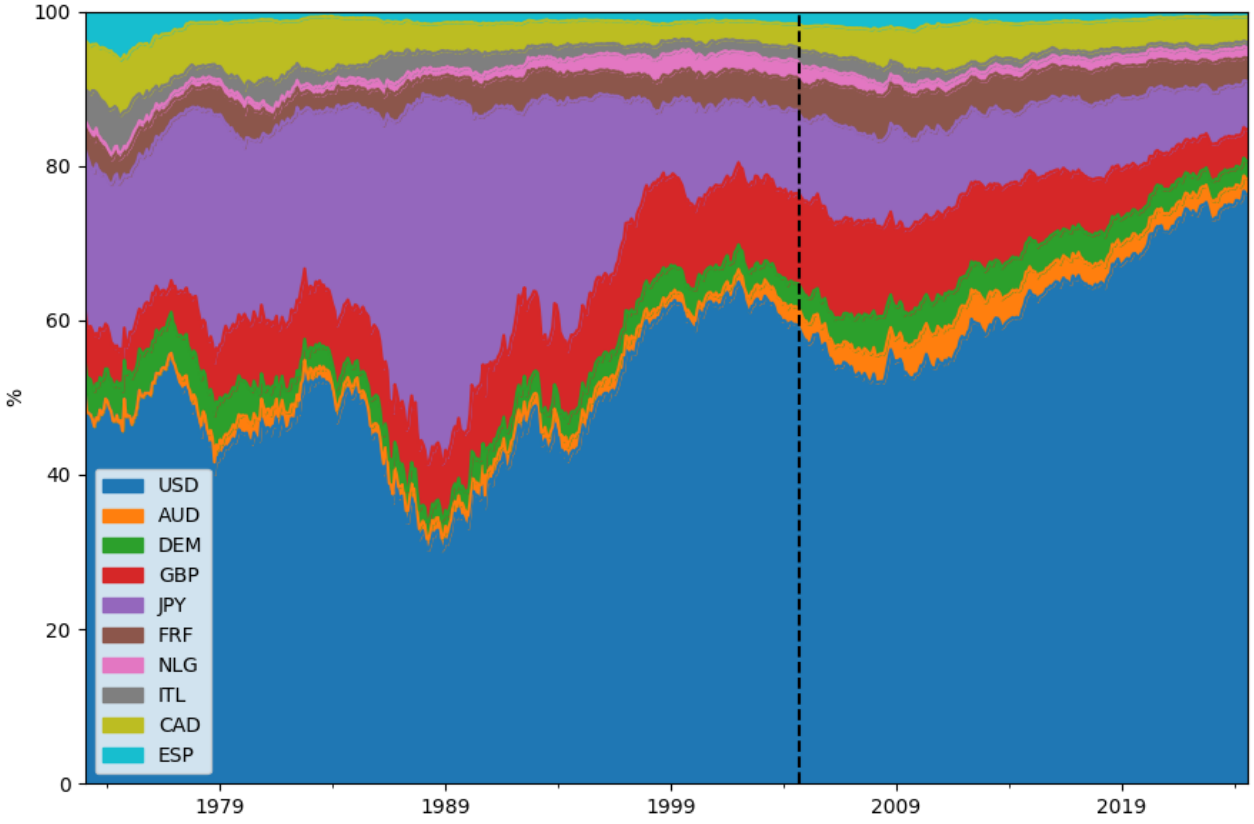
	Start Date	Mean Excess (annualized)	Mean Spot (annualized)	Standard Deviation (annualized)	Skewness	(Excess) Kurtosis
Developed Market FX						
Australian dollar (AUD)	Jan-1977	1.2%	-1.0%	10.7%	-0.44	1.96
Canadian dollar (CAD)	Apr-1973	-0.0%	-0.6%	6.7%	-0.77	6.41
Swiss franc (CHF)	Apr-1973	-0.2%	2.5%	11.4%	0.06	1.01
German mark (DEM)	Apr-1973	0.7%	2.1%	11.8%	-0.02	0.50
Spanish peseta (ESP)	Apr-1973	1.0%	-3.4%	10.7%	-0.95	4.20
French franc (FRF)	Apr-1973	1.4%	-0.8%	11.1%	-0.19	0.31
British pound (GBP)	Apr-1973	0.1%	-1.3%	9.9%	-0.06	1.85
Italian lira (ITL)	Apr-1973	1.4%	-4.0%	10.6%	-0.52	1.57
Japanese yen (JPY)	Apr-1973	-1.6%	1.0%	10.9%	0.52	1.93
Dutch guilder (NLG)	Apr-1973	1.1%	1.7%	11.6%	-0.02	0.43
Norwegian krone (NOK)	Apr-1973	-0.4%	-1.1%	10.9%	-0.13	0.88
New Zealand dollar (NZD)	Apr-1973	1.7%	-1.5%	11.9%	-0.35	5.94
Swedish krona (SEK)	Apr-1973	-0.8%	-1.7%	10.9%	-0.40	2.00
Euro (EUR)	Jan-1999	-1.1%	-0.3%	9.5%	0.02	1.36
Emerging Market FX						
Brazilian real (BRL)	Aug-2000	3.5%	-4.7%	16.7%	-0.37	2.25
Mexican peso (MXN)	Nov-1997	3.3%	-3.0%	10.7%	-0.78	2.83
Chilean peso (CLP)	Apr-1998	-0.4%	-2.7%	11.8%	-0.55	2.15
South African rand (ZAR)	Dec-1988	1.1%	-5.6%	14.5%	-0.22	1.26
Turkish lira (TRY)	Dec-1996	1.7%	-18.8%	16.7%	-1.53	8.73
Equities						
S&P 500 (USD)	Apr-1973	5.7%	--	15.3%	-0.39	1.31
Australian SPI 200 (AUD)	Apr-1973	4.2%	--	17.7%	-1.37	10.87
Dax (DEM)	Apr-1973	3.3%	--	19.7%	-0.33	1.83
FTSE (GBP)	Apr-1973	4.0%	--	19.0%	1.04	15.68
Topix (JPY)	Apr-1973	3.0%	--	17.4%	-0.17	1.09
CAC 40 (FRF)	Apr-1973	4.3%	--	20.1%	-0.14	1.17
Dutch All Index (NLG)	Apr-1973	6.4%	--	18.4%	-0.45	2.36
Italy All Index (ITL)	Apr-1973	1.0%	--	23.7%	0.21	1.09
S&P Canada 60 (CAD)	Apr-1973	3.8%	--	16.0%	-0.71	2.54
Ibex 35 (ESP)	Apr-1973	1.7%	--	21.1%	0.02	1.93

Note that the historical analysis is subject to a survivorship bias, particularly in the EM currencies. FX forward rate start dates usually begin when a currency has experienced a period of prolonged stability. For instance, the 96% drop in the Brazilian currency's spot price in 1993 is not captured in Exhibit 1. This does not preclude subsequent volatility, as the example of the Turkish lira illustrates.

For our analysis, we evaluate how different hedging strategies perform for an investor allocating to both individual equity markets as well as to a basket of world equities. To construct the basket, we first define an equity portfolio that a typical investor might hold. Exhibit 2 displays these weights through time for the DM markets we considered. Further details on how these weights were obtained, as well as a discussion of some of the limitations of this approach can be found in Appendix A.1.

Exhibit 2: World Equity Basket Weights

We define a world equity basket with the following weights to each of the equity indices. From September 2004 onwards, the weights are derived by taking the actual MSCI World weights at each point-in-time, restricting them to the markets in our universe and renormalizing to sum to 100%. Prior to September 2004, we calculate the relative weights by deflating the September 2004 weights by the USD performance between that date and September 2004. Weights are renormalized at each point to sum to 100%. The data run from April 1973 to June 2024.



3. Hedged vs. Unhedged Equity Returns

A key question for many investors allocated to assets denominated in foreign currency is whether to bear the full currency risk or to hedge some or all of the risk with FX forwards or futures.[5] While our paper advocates a dynamic approach which includes partial hedging, we start by considering the traditional binary decision of hedging vs. no hedging.[6]

3.1 Performance of Hedged and Unhedged Equity Returns

In Exhibit 3, we show both hedged and unhedged returns (in excess of the equity market's local short rate) from investing in a range of equity indices from the perspective of investors with various home currencies. At least historically, it has been profitable for investors with lower yielding currencies, such as the Japanese yen, to leave their FX exposure unhedged (for Japanese-based investors, unhedged returns are greater than hedged returns for every equity market). Similarly, for investors with higher yielding currencies, such as the New Zealand dollar, it has been profitable to hedge their currency exposure (notice in the New Zealand row, the hedged returns are greater for every foreign equity market). One explanation for this is that investors earn positive "carry" by taking a long position in higher yielding currencies and a short position in lower yielding currencies, provided changes in FX spot rates do not negate this accrued positive return. We explore this phenomenon in more detail in the next section.

[5] As explored in Dales and Meese (2001) who emphasize the trade-offs between risk reduction and return potential when deciding between fully hedged and unhedged strategies.
[6] In Appendix B: Calculations, we provide further details on the exact calculation of hedged and unhedged equity returns.

Exhibit 3: Annualized Excess Equity Returns by Home Currency

The table below shows annualized excess returns for an investor in a given home currency investing in individual foreign equity markets with their FX exposure hedged or unhedged. We highlight in blue those cases where an investor in a given home currency would have realized higher returns by hedging. We highlight in yellow, those cases where an investor in a given home currency would have realized higher returns by leaving their FX exposure unhedged. The data run from April 1973 to June 2024.

		Equity Market										
		USD	AUD	CAD	DEM	ESP	FRF	GBP	ITL	JPY	NLG	Mean
Home Currency	DM FX											
	USD Hedged	5.5%	5.9%	4.2%	3.2%	2.0%	4.4%	3.9%	1.4%	2.7%	6.2%	3.9%
	USD Unhedged	5.5%	6.5%	3.8%	3.4%	2.0%	4.8%	4.1%	1.5%	1.5%	6.6%	4.0%
	AUD Hedged	5.9%	4.1%	4.7%	3.6%	3.0%	5.5%	4.4%	2.7%	2.9%	6.5%	4.3%
	AUD Unhedged	5.2%	4.1%	3.6%	2.5%	2.4%	4.8%	4.3%	2.5%	0.8%	5.8%	3.6%
	CAD Hedged	5.1%	5.5%	3.8%	2.8%	1.5%	4.1%	3.6%	1.0%	2.4%	5.8%	3.6%
	CAD Unhedged	5.5%	6.5%	3.8%	3.3%	1.9%	4.7%	4.1%	1.4%	1.5%	6.6%	3.9%
	CHF Hedged	5.5%	5.8%	4.1%	3.5%	2.2%	4.6%	4.0%	1.7%	2.7%	6.6%	4.1%
	CHF Unhedged	5.5%	7.0%	3.8%	3.3%	1.9%	4.7%	4.1%	1.4%	1.5%	6.6%	4.0%
	DEM Hedged	5.3%	5.8%	4.0%	3.4%	2.0%	4.4%	3.9%	1.5%	2.6%	6.4%	3.9%
	DEM Unhedged	5.5%	7.0%	3.8%	3.4%	1.9%	4.7%	4.1%	1.4%	1.5%	6.6%	4.0%
	ESP Hedged	5.4%	5.7%	4.1%	3.3%	1.9%	4.4%	3.9%	1.4%	2.6%	6.4%	3.9%
	ESP Unhedged	5.4%	6.3%	3.7%	3.2%	1.9%	4.6%	4.0%	1.3%	1.4%	6.5%	3.8%
	FRF Hedged	5.3%	5.7%	4.0%	3.3%	1.9%	4.5%	3.8%	1.4%	2.6%	6.4%	3.9%
	FRF Unhedged	5.2%	6.4%	3.4%	3.0%	1.6%	4.5%	3.7%	1.1%	1.2%	6.2%	3.6%
	GBP Hedged	5.3%	5.6%	3.9%	3.1%	1.8%	4.3%	3.7%	1.2%	2.5%	6.2%	3.8%
	GBP Unhedged	5.3%	5.9%	3.6%	3.1%	1.8%	4.5%	3.7%	1.3%	1.3%	6.4%	3.7%
	ITL Hedged	5.4%	5.7%	4.0%	3.2%	1.8%	4.4%	3.9%	1.2%	2.5%	6.4%	3.9%
	ITL Unhedged	5.4%	5.9%	3.6%	3.2%	1.8%	4.6%	3.9%	1.2%	1.4%	6.4%	3.7%
	JPY Hedged	5.6%	5.9%	4.2%	3.5%	2.1%	4.6%	4.0%	1.6%	2.9%	6.5%	4.1%
	JPY Unhedged	7.0%	8.1%	5.2%	4.8%	3.4%	6.2%	5.5%	2.9%	2.9%	8.1%	5.4%
	NLG Hedged	5.3%	5.8%	4.0%	3.3%	1.9%	4.4%	3.9%	1.5%	2.6%	6.5%	3.9%
	NLG Unhedged	5.4%	6.7%	3.6%	3.2%	1.8%	4.6%	3.9%	1.3%	1.4%	6.5%	3.8%
	NOK Hedged	5.1%	5.5%	3.8%	3.1%	1.7%	4.2%	3.7%	1.1%	2.4%	6.1%	3.7%
	NOK Unhedged	5.7%	7.0%	4.0%	3.5%	2.1%	4.9%	4.3%	1.6%	1.7%	6.8%	4.2%
	NZD Hedged	4.9%	5.2%	3.6%	2.7%	1.4%	3.9%	3.4%	0.9%	2.2%	5.7%	3.4%
	NZD Unhedged	3.5%	3.8%	1.8%	1.4%	0.0%	2.8%	2.1%	-0.5%	-0.4%	4.6%	1.9%
	SEK Hedged	5.2%	5.5%	3.8%	3.0%	1.8%	4.2%	3.7%	1.1%	2.4%	6.1%	3.7%
	SEK Unhedged	6.3%	7.5%	4.5%	4.1%	2.7%	5.5%	4.9%	2.2%	2.3%	7.4%	4.7%
	EM FX											
	BRL Hedged	3.9%	3.9%	2.7%	0.9%	1.4%	1.1%	0.9%	-0.2%	2.8%	1.5%	1.9%
	BRL Unhedged	1.6%	2.9%	0.2%	-1.1%	-0.9%	-1.2%	-1.8%	-2.6%	-3.0%	-0.5%	-0.6%
	CLP Hedged	4.8%	4.5%	4.7%	2.5%	2.1%	3.7%	1.5%	1.7%	3.7%	2.9%	3.2%
	CLP Unhedged	6.1%	6.4%	5.4%	2.8%	2.1%	3.8%	1.7%	1.7%	2.2%	3.2%	3.5%
	MXN Hedged	5.1%	4.6%	5.2%	3.1%	2.9%	4.4%	1.9%	2.4%	3.2%	3.6%	3.6%
	MXN Unhedged	2.6%	2.6%	2.2%	-0.1%	-0.5%	0.9%	-1.4%	-0.9%	-2.0%	0.2%	0.4%
	TRY Hedged	6.0%	4.6%	5.2%	4.2%	4.0%	5.3%	2.3%	3.8%	2.7%	4.6%	4.3%
	TRY Unhedged	5.0%	3.5%	3.6%	1.9%	1.5%	2.7%	0.6%	1.5%	-1.5%	2.3%	2.1%
	ZAR Hedged	6.7%	3.8%	4.8%	4.2%	2.8%	4.0%	2.6%	1.2%	-0.4%	5.8%	3.6%
	ZAR Unhedged	6.3%	3.8%	3.9%	3.6%	2.3%	3.6%	2.3%	0.7%	-3.2%	5.2%	2.9%

4. The Role of Carry in Hedging Strategies

In this section, we explore an active approach to FX hedging aimed at maximizing our expected return by attempting to earn carry, drawing on work by Burnside, Eichenbaum, and Rebelo (2011).

4.1 Historical Performance of Carry

We define carry as the return that an investor would expect to earn by taking a long position in one currency versus another, if spot prices remain unchanged. In other words, carry is the interest rate differential between two currencies. Carry, in general, is a strategy in which an investor borrows in a currency with a low interest rate to invest in a currency offering a higher interest rate, aiming to profit from the yield differential.

Uncovered Interest Rate Parity (UIP) is a hypothesis that the difference in interest rates between two countries should equal the expected change in their exchange rates, leaving no arbitrage opportunities. If we believe that Uncovered Interest Rate Parity[7] holds and the expected FX return (including the carry component) is zero, then there should be no way to improve our returns on average through FX hedging. Exhibit 4 presents the returns to an investor in a particular country investing in the world equity portfolio that we created. We consider three choices: hedged, unhedged, and hedging informed by carry (which we call max carry). For developed market FX, each currency appears to have higher returns when carry is positive than when carry is negative, consistent with UIRP not holding.[8] More importantly, it suggests that performance can be improved by conditioning the hedging decision on interest rate differentials.

The results in Exhibit 4 suggest that the interest rate differential (local minus U.S.) is important. When the average interest rate differential was positive, each of the DM currencies delivered positive returns. When the differential was negative, 11 of 13 were negative. If UIP held, the average returns should be zero in both situations. This type of analysis is less useful for EMs given the interest rate differential is almost always positive.

In Exhibit 5, we create a simple FX strategy that trades each of the developed market FX currencies against the U.S. dollar on an equally weighted basis. In this initial analysis, we are not taking portfolio considerations into account. That is, we treat each currency pair independently. If a currency has a higher interest rate than the U.S. in the previous month, we take a long position in that currency against the US dollar for the subsequent month; if not, we take a short position. As such, the strategy is always positioned to earn carry.

We implement this strategy using FX forwards which should already incorporate the interest rate differential. This can be considered as an unfunded strategy, given that an investor only needs to pay an initial margin to enter this position. These margins are typically small, particularly for

[7] Covered Interest Rate Parity (CIP) is a condition where the forward exchange rate between two currencies eliminates any arbitrage opportunities by offsetting differences in interest rates between those currencies through the use of a forward contract. CIP assumes no exchange rate risk as it is hedged. Uncovered Interest Rate Parity (UIP) is a hypothesis that the difference in interest rates between two countries should equal the expected change in their exchange rates, leaving no arbitrage opportunities. Unlike CIP, UIP involves taking on exchange rate risk, as it does not use a forward contract. For more on CIP, see Jorion (1994).

[8] As evidenced in Fama (1984), Froot and Thaler (1990), Engle (1996), Flood and Rose (1996), Bansal and Dahlquist (2000), Chinn and Meridith (2004), Lustig and Verdelhan (2007), Lothian and Wu (2011), as well as the literature review in Engle (2016).

developed market pairs and often pay interest in the currency the margin is deposited in. The strategy could also be implemented by borrowing in the lower yielding currency and using the proceeds to buy short-term bills denominated in the higher yielding currency.

We compare the total carry that we would earn from such a strategy if spot prices remained unchanged to the actual total returns from this strategy in Exhibit 5.[9] If Uncovered Interest Rate Parity holds, then the returns from such a strategy should be close to zero as changes in the spot price are expected to offset the gains from carry. However, with over 50 years of data, the cumulative total return from such a strategy is only slightly below the return we would expect to earn from carry if spot prices remained unchanged.[10] Note that the performance over recent years is flat, which is likely a result of an extended period of near-zero interest rates. Consistent with Exhibit 4, there is little to be learned from studying EMs, where the carry is routinely positive.[11]

Exhibit 4: Conditioning FX and Equity Returns on Carry

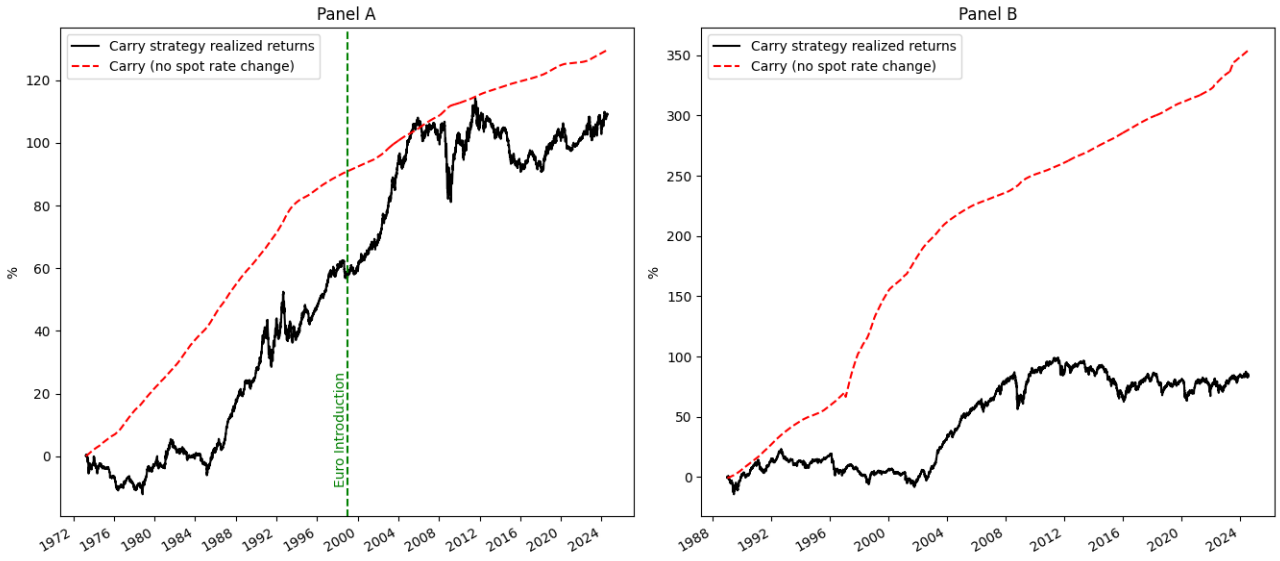
The interest rate differential (IRD) is defined as the local interest rate minus the U.S. interest rate. This table shows the percentage of months where the IRD is positive and the average annualized return of each of the currencies against the USD in periods when the IRD is positive/negative. In addition, the final three columns show world equity excess returns in that currency on either a hedged, unhedged or "max carry" basis. In the "max carry" version, we hedge the FX exposure if the local interest rate is higher than the foreign interest rate; otherwise, we leave the FX exposure unhedged. For each currency, we highlight in green the hedging approach that achieves the highest return and highlight in red the hedging approach that realizes the lowest return. The data run from April 1973 to June 2024.

	% of Months with Positive IRD vs USD	Average FX Return when IRD Positive	Average FX Return when IRD Negative	Average World Equity Return (Hedged)	Average World Equity Return (Unhedged)	Average World Equity Return (Max Carry)
DM						
USD	--	--	--	5.4%	5.6%	6.0%
AUD	77.4%	4.0%	-5.9%	5.8%	5.3%	6.8%
CAD	75.6%	0.4%	-0.6%	5.0%	5.4%	5.5%
CHF	13.9%	1.6%	0.6%	5.3%	5.9%	6.1%
DEM	30.3%	4.8%	-1.2%	5.2%	5.7%	6.5%
ESP	63.3%	2.7%	-2.8%	5.2%	5.6%	6.3%
FRF	59.1%	4.4%	-4.1%	5.2%	5.3%	6.6%
GBP	77.0%	1.9%	-3.2%	5.2%	5.4%	5.8%
ITL	66.7%	2.6%	-3.2%	5.2%	5.5%	6.2%
JPY	21.8%	1.8%	-1.4%	5.4%	7.2%	7.2%
NLG	33.3%	5.8%	-1.8%	5.2%	5.5%	6.7%
NOK	59.9%	2.6%	-3.0%	5.0%	5.9%	6.3%
NZD	89.3%	2.8%	0.7%	4.8%	3.8%	5.0%
SEK	59.4%	2.9%	-4.5%	5.1%	6.4%	7.0%
EM						
BRL	98.3%	4.2%	45.6%	4.3%	2.1%	3.7%
MXN	100.0%	3.8%	--	5.5%	2.5%	5.5%
CLP	81.9%	-0.3%	3.7%	5.2%	6.0%	5.1%
ZAR	100.0%	2.1%	--	5.1%	4.8%	5.0%
TRY	100.0%	3.3%	--	6.1%	5.4%	6.1%

[9] The dynamics of carry trades and their pricing are explored in Jurek (2014). Also see Menkhoff et al. (2012).
[10] For a similar exercise performed over a shorter period, see Koijen et al. (2018).
[11] Deviations from PPP and EM currency performance are discussed in greater depth in Taylor and Peel (2001).

Exhibit 5: FX carry strategy total return vs. cumulative theoretical carry (Panel A: developed markets (DM). Panel B: emerging markets (EM)

The black line shows the cumulative returns that we would have earned if we had invested equally in a set of U.S. dollar currency pairs, always taking a position in the direction to earn carry. Specifically, for each currency, we take a long position against the USD if that currency has a higher interest rate at the end of the previous month and take a short position against the USD if not. In Panel A, we use all of the developed market USD pairs and in Panel B we use all of the emerging market USD pairs. The red dotted line shows the total (theoretical) carry that we would earn if the spot prices remained unchanged throughout the period. The green dotted line on the left-hand plot indicates the point at which we switch from the individual euro area currencies to a single euro currency and the number of developed market currency pairs drops from 13 to 9. The data run from April 1973 to June 2024.



4.2 A Dynamic FX Hedging Strategy to Harvest Carry

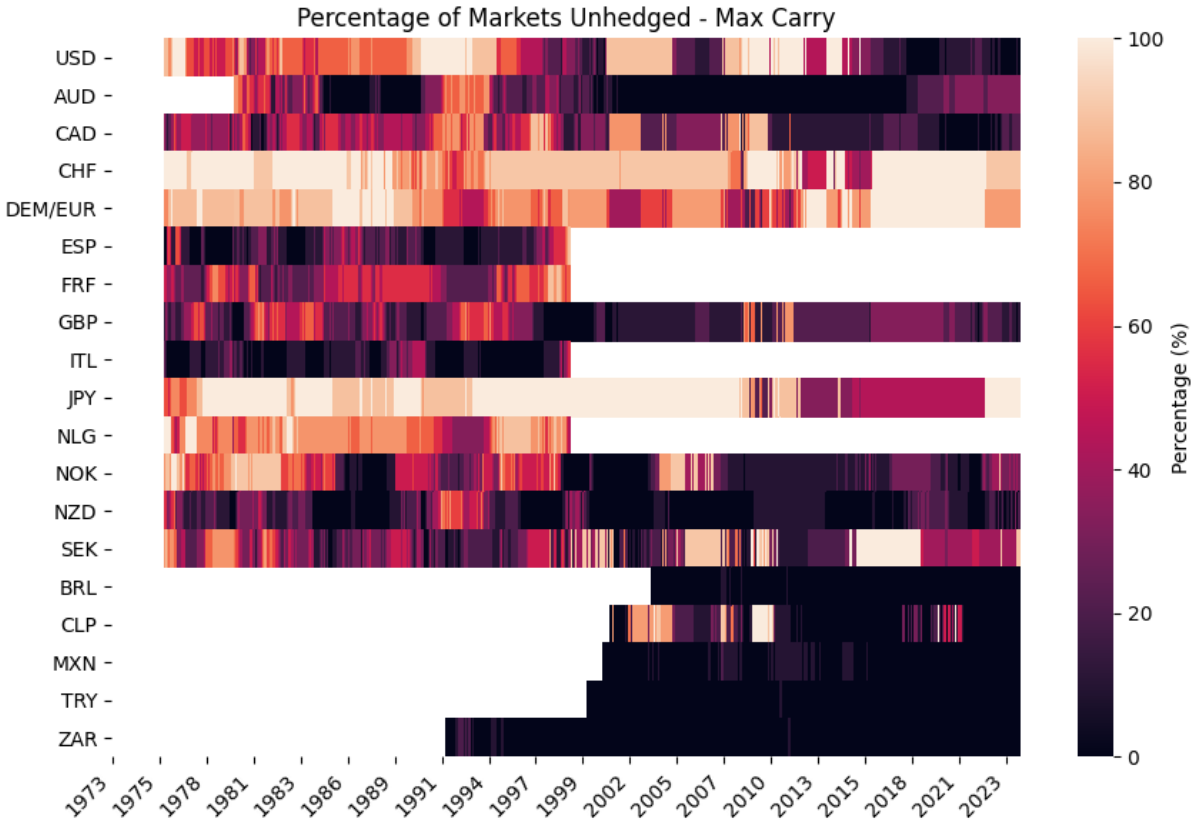
Exhibit 4 also considers investment in the world equity portfolio from the perspective of investors with different home currencies. Columns 4 and 5 show the equity returns under the hedging and no hedging scenarios. In all but two DMs (Australian and New Zealand), investors in those currencies would do better with no hedging, which is consistent with our analysis of carry. Indeed, the unhedged excess return for Japan is 7.2%, compared to 5.4% for the hedged approach.

The final column in Exhibit 4 implements a dynamic hedging approach which we label as "Max Carry".[12] With this strategy, if the interest rate differential (equity market currency minus home currency) is positive, then there is no hedging. When the differential is negative, the investor will hedge the FX. The results in column 6 show that the max carry approach dominates the static strategies across the 14 developed markets. In nine of the 14 markets, the improvement over full static hedging exceeds 100bps per year. The proportion of markets unhedged through time is presented in Exhibit 6.

[12] This approach is supported by observations by Froot and Thaler (1990).

Exhibit 6: Percentage of Markets Unhedged by Home Currency when Hedging to Maximize Carry

Percentage of equity markets unhedged at any point using the approach of maximizing carry. The data run from April 1976 to June 2024.



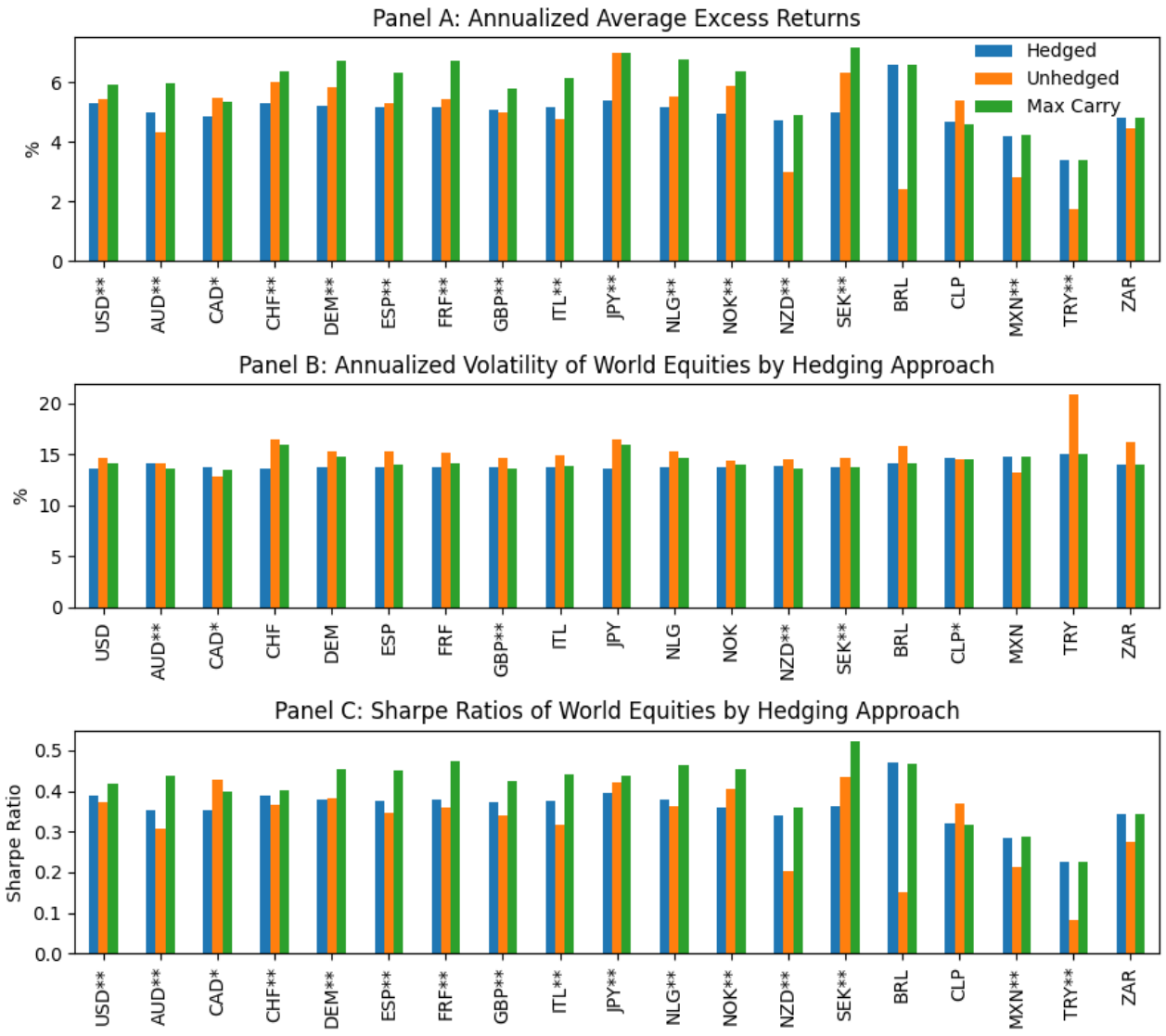
In Exhibit 4, we presented excess returns of the hedged, unhedged, and max carry portfolio over the full sample. We then add volatility and Sharpe ratios (as well as including the average excess returns) in Exhibit 7 over a slightly different sample. Instead of beginning our analysis in 1973, we begin in 1976 because we need to hold out three years for covariance estimation in the multivariate analysis in Section 4.

While the dynamic hedging based on carry typically results in higher volatility than from fully hedging, the volatility is generally still lower than the unhedged version. Despite the generally higher volatility, the Sharpe ratio from this dynamic approach is higher than the hedged and unhedged version in almost every DM market.[13] The only exception is the Canadian dollar; although a Canadian dollar investor would have achieved a higher return by employing this approach, their overall Sharpe ratio would have been lower than if they had left their FX exposure fully unhedged. As we will see in the next section, this is primarily due to the fact that the Canadian dollar has historically been very negatively correlated with equity returns. As such, for a Canadian investor, an unhedged FX position has historically provided a natural hedge for their long equity exposure.

[13] This is consistent with Pojarliev and Levich (2008) who find that "dynamic hedges that are conditional on the interest rate spread" result in "significant improvements in portfolio performance for a US-Dollar based stock portfolio from the G5 countries."

Exhibit 7: World Equity Performance by Hedging Approach

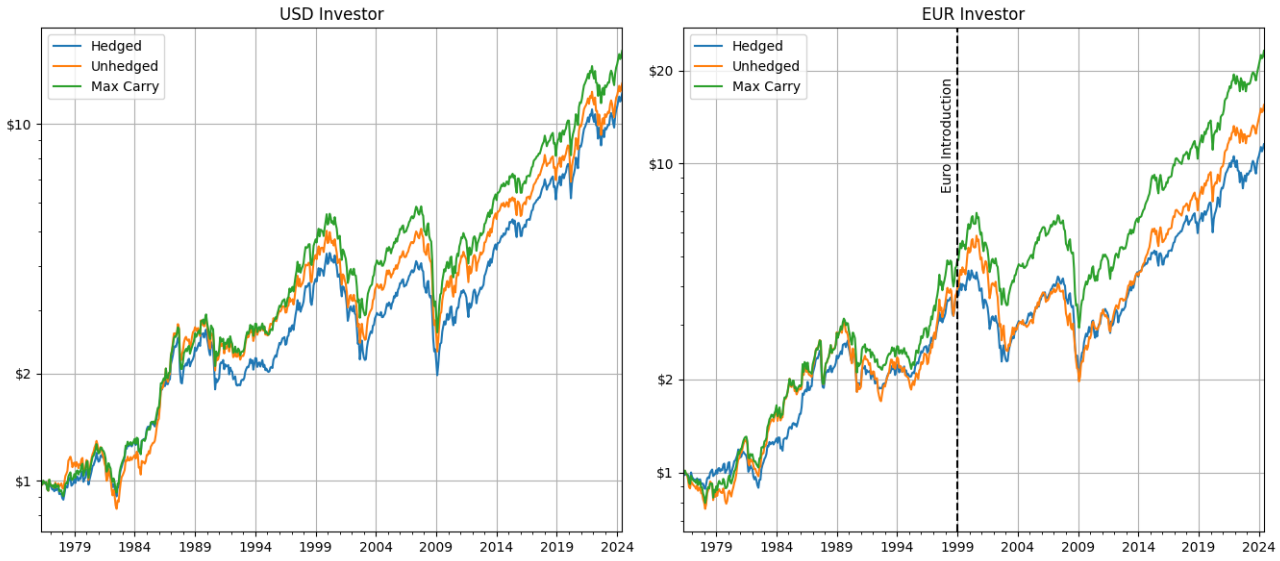
The following three panels show the excess returns, volatilities and Sharpe ratios that an investor would have achieved from investing in world equities from a given home currency on a hedged, unhedged and dynamically hedged basis. In the dynamically hedged approach (called "Max Carry"), we fully hedge our FX exposure if the interest rate in the home currency is higher than that of the equity market's currency and leave our FX exposure fully unhedged when the interest rate in the equity market's currency is higher than that of the home currency. A double asterisk denotes outperformance by Max Carry of either the hedged or unhedged approach (or lower volatility in Panel B). A single asterisk denotes outperformance of one of either the hedged or unhedged approach. The returns are calculated from April 1976 to June 2024. Each individual currency starts three years and one month after the start date for the FX returns in Exhibit 1. We start at this point to make the sample period comparable with that used in the later analysis where a three year "burn-in" is required to calculate covariances. All Eurozone currencies are stitched with the Euro from 1999. The data run from April 1976 to June 2024.



The cumulative returns from the perspective of a U.S. dollar investor as well as a euro-based investor are presented in Exhibit 8. The Max Carry strategy is consistently the highest in terms of excess returns. Furthermore, the strategy continues to do well after the introduction of the Euro in 1999.

Exhibit 8: Cumulative Returns for USD and EUR Investors Investing in World Equities

The plots in this exhibit show the cumulative returns that an investor whose home currency was the USD (LHS plot) or EUR (RHS plot) would have experienced from investing in World Equities on either a hedged, unhedged or a dynamically hedged basis. The dynamically hedged version is designed to maximize the carry earned. The returns are calculated from April 1976 to June 2024.



5. Minimum Volatility Hedging

In the previous section, we explored a dynamic rule that attempted to maximize our returns from FX hedging by leaving our FX exposure unhedged only if the home interest rate is higher than the interest rate of the market in which we are investing. While that simple rule improved average performance in all cases and generally improved the risk adjusted returns, it ignores any predictive information relevant to the FX exposure or the relationship between the FX returns and those of the underlying equities. In this section, we explore a different approach where we instead try to employ a dynamic FX hedge that minimizes the volatility of our portfolio. In this approach we do not consider the expected returns of the FX markets at all.[14]

5.1 Finding the Optimal Hedge Ratio to Minimize Volatility

To find the optimal hedge ratio for each of the FX exposures that we hold, thereby minimizing our portfolio volatility, we must establish the set of hedge ratios that minimize the overall portfolio variance. The partially hedged portfolio returns are given by:

$$\sum_{\forall i} w_i (R_{T,t}^{hedged_{i,j}} + (1 - h_i) R_{T,t}^{FX\ Fwd_{j,i}})$$

[14] For more on minimum volatility hedging in international portfolios, see, for example, Glen and Jorion (1993), Boudoukh et al. (2019) and Czasonis, Kritzman and Turkington (2024).

Where $\boldsymbol{w_i}$ is the weight given to the $\boldsymbol{i^{th}}$ equity market. For the purposes of our analysis, we assume that these weights are fixed at each point in time and take the values shown in Exhibit 4.

The variance of this portfolio can be written as $\boldsymbol{u^T \Omega u}$ where $\boldsymbol{\Omega}$ is the 2n x 2n covariance matrix of equities and corresponding FX forwards.

$$\Omega = \begin{bmatrix} \sigma_{eq_1,eq_1} & \cdots & \sigma_{eq_1,eq_n} & \sigma_{eq_1,fx_1} & \cdots & \sigma_{eq_1,fx_n} \\ \vdots & \ddots & \vdots & \vdots & \ddots & \vdots \\ \sigma_{eq_n,eq_1} & \cdots & \sigma_{eq_n,eq_n} & \sigma_{eq_n,fx_1} & \cdots & \sigma_{eq_n,fx_n} \\ \sigma_{fx_1,eq_1} & \cdots & \sigma_{fx_1,eq_n} & \sigma_{fx_1,fx_1} & \cdots & \sigma_{fx_1,fx_n} \\ \vdots & \ddots & \vdots & \vdots & \ddots & \vdots \\ \sigma_{fx_n,eq_1} & \cdots & \sigma_{fx_n,eq_n} & \sigma_{fx_1,fx_n} & \cdots & \sigma_{fx_n,fx_n} \end{bmatrix}$$

And $\boldsymbol{u} = [\boldsymbol{w^T}, (\boldsymbol{1} - \boldsymbol{h})^T]^T$, where $\boldsymbol{w}$ is the fixed matrix of equity weights and $\boldsymbol{h}$ is the vector of hedge ratios. In order to obtain our optimal hedge ratios, we minimize $\boldsymbol{u^T \Omega u}$ subject to the constraints that:

$$\boldsymbol{u_i = w_i} \qquad \textbf{if } \boldsymbol{i \leq n}$$

$$\boldsymbol{0 \leq u_i \leq 1} \quad \textbf{if } \boldsymbol{i > n}$$

In the event that an investor holds merely a single foreign equity, we get a simple, closed-form solution for the optimal hedge. $\boldsymbol{1 + \beta_{hedged,fx}}$, where $\boldsymbol{\beta_{hedged,fx}}$ is the beta of the (hedged) excess equity returns to the FX forward returns. [15]

Assuming that the hedge ratio is bounded between 0 and 1, this suggests that, if the home currency is positively correlated with the equity in the home country, then an investor should fully hedge their FX exposure to minimize their portfolio volatility. However, if the home currency is negatively correlated with the home country's equity returns, then the optimal hedge ratio to minimize the portfolio volatility will be less than 1.

As we shall see in the example in the next section, if an investor is not bound by the constraint that the hedge ratio must be between 0 and 1, then there are cases where an investor could further decrease their portfolio volatility by over- or under-hedging their FX exposure.

5.2 Betas and Hedge Ratios

Exhibit 9 shows the historical beta of FX returns to hedged excess equity returns in each of the equity markets. This analysis uses all the historical data and is meant to summarize what average exposures would be on an ex-post basis. Later, we will look at conditional hedge ratios that can be used by investors in real time. Under this approach, investors in traditionally defensive currencies, such as the yen and Swiss franc, would want to hedge almost all of their FX exposure when investing in foreign equities, while investors in more "risk-on" currencies, such as the Canadian dollar and Australian dollar, would be better served leaving some of their FX exposure unhedged. Similarly, investors allocating to equities denominated in defensive currencies are typically better served leaving some of their FX exposure unhedged to enjoy the "defensive hedge" of that FX

[15] Further details on the derivation of this can be found in Appendix A.5.

exposure. If we look at the CAD row and the USD column below, this shows that the Beta of the S&P 500[16] to CAD/USD returns is -0.90, suggesting an optimal hedge ration of 10%. This reflects the defensive nature of USD with respect to CAD: the USD tends to appreciate relative to CAD when equities sell-off (and vice versa).

Exhibit 9: Full Sample Betas of Currencies to FX Markets

This table shows the betas of the FX returns to the hedged equity return for each of the currencies and equity markets in our sample. The rows represent the home currency of the investor and the columns represent the currency of the equity exposure. The betas are calculated between January 1973 and June 2024. Where the start date for the home currency shown in Exhibit 1 is later than January 1973, we use this start date instead for the beta calculation. All Eurozone currencies are stitched with the Euro from 1999 onwards.

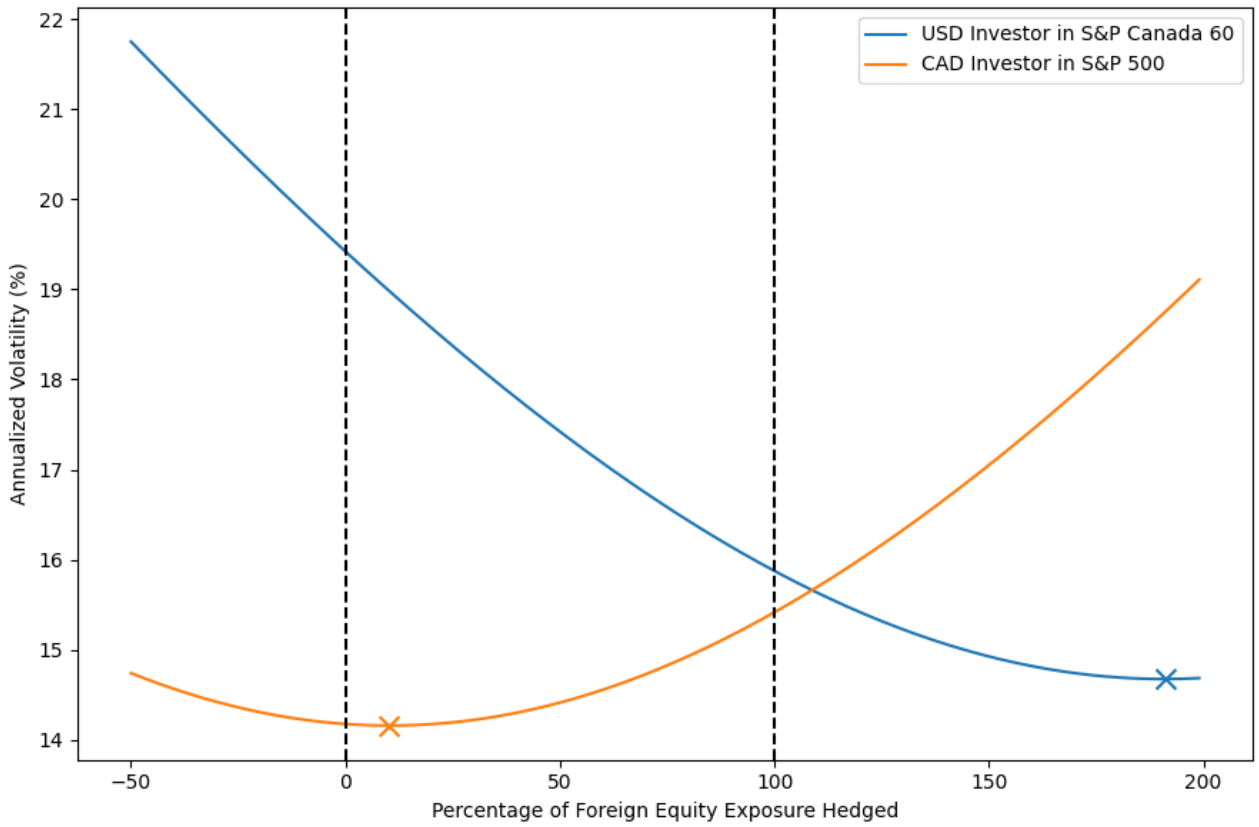
		Equity Market										
		USD	AUD	CAD	DEM	ESP	FRF	GBP	ITL	JPY	NLG	Mean
Home Currency	USD	-	0.51	0.91	-0.07	0.11	0.03	0.04	0.08	-0.15	-0.20	0.14
	AUD	-0.48	-	-0.26	-0.45	-0.40	-0.34	-0.42	-0.35	-0.36	-0.53	-0.40
	CAD	-0.90	0.35	-	-0.37	-0.26	-0.27	-0.29	-0.28	-0.32	-0.50	-0.32
	CHF	-0.06	0.33	0.22	0.45	0.43	0.48	0.11	0.58	-0.14	0.39	0.28
	DEM	-0.19	0.37	0.20	-	0.25	0.44	0.00	0.60	-0.22	0.01	0.16
	ESP	-0.17	0.29	0.25	-0.03	-	0.04	-0.04	0.18	-0.20	-0.14	0.02
	FRF	-0.20	0.36	0.20	0.09	0.27	-	-0.09	0.77	-0.22	-0.10	0.12
	GBP	-0.22	0.25	0.13	-0.20	0.00	-0.14	-	-0.15	-0.29	-0.27	-0.10
	ITL	-0.18	0.37	0.23	-0.24	0.00	0.01	0.03	-	-0.26	-0.15	-0.02
	JPY	0.02	0.28	0.24	0.12	0.14	0.11	0.03	0.18	-	0.02	0.13
	NLG	-0.20	0.36	0.20	0.09	0.23	0.47	-0.04	0.60	-0.22	-	0.17
	NOK	-0.33	0.19	0.04	-0.49	-0.24	-0.45	-0.31	-0.28	-0.29	-0.61	-0.28
	NZD	-0.38	0.05	-0.15	-0.38	-0.26	-0.34	-0.32	-0.25	-0.34	-0.43	-0.28
	SEK	-0.31	0.22	0.04	-0.57	-0.13	-0.32	-0.23	-0.30	-0.30	-0.64	-0.25
	BRL	-0.43	-0.12	-0.28	-0.51	-0.39	-0.41	-0.38	-0.37	-0.41	-0.50	-0.38
	CLP	-0.53	0.13	-0.04	-0.51	-0.36	-0.35	-0.37	-0.30	-0.55	-0.51	-0.34
	MXN	-0.71	0.01	-0.14	-0.66	-0.55	-0.55	-0.52	-0.63	-0.59	-0.55	-0.49
	TRY	-0.21	0.06	-0.09	-0.28	-0.22	-0.21	-0.21	-0.24	-0.28	-0.28	-0.20
	ZAR	-0.32	-0.03	-0.14	-0.41	-0.33	-0.33	-0.33	-0.27	-0.41	-0.37	-0.29

In Exhibit 10, we compare the volatility that a US dollar investor would have realized investing into Canadian equities with various static hedging percentages to the realized volatility that a Canadian dollar investor would have realized investing into US equities. We can see that a Canadian dollar investor would have minimized their volatility historically by leaving most of their US dollar exposure unhedged, whereas a USD investor would have minimized their volatility by fully hedging their Canadian Dollar exposure. In fact, in the absence of constraints, a USD investor would actually have minimized their realized volatility by overhedging their FX exposure and adding a short position in the Canadian dollar.

[16] This is the S&P 500 hedged returns hedged to Canadian dollars in excess of Canadian dollar cash.

Exhibit 10: Historical Realized Volatility for a USD Investor investing into Canadian Equities and a CAD Investor investing into US Equities

These plots show the volatility that a USD investor would realize from investing 100% of their capital into the S&P Canada 60 with varying hedge ratios and the volatility that a CAD investor would realize from investing 100% of their capital into the S&P 500 with varying hedge ratios. The points at which the volatility is minimized are marked with an X. The date range for the analysis is April 1973 to June 2024.

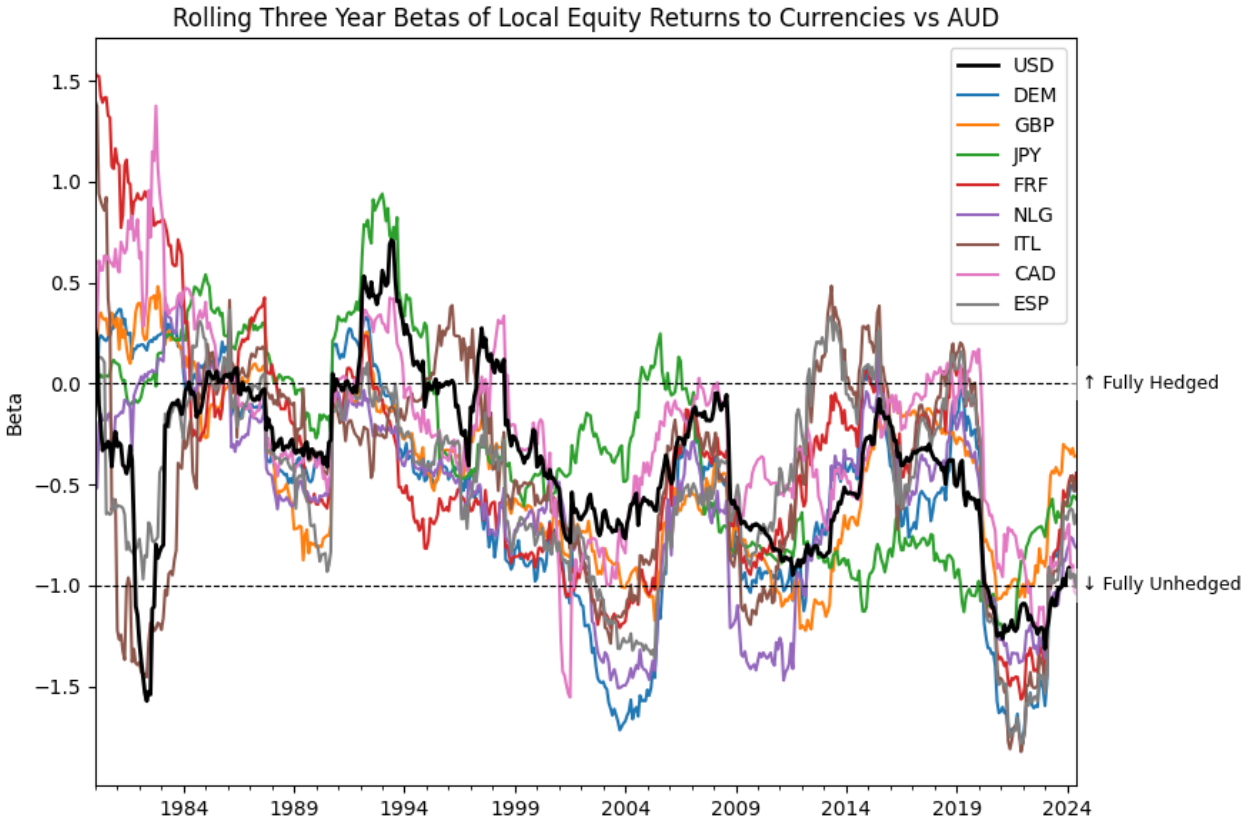


Of course, the betas between FX and equities are time-varying. While it is easy to calculate what the optimal hedge ratio would have been historically for any given pair, for this to have any practical relevance, we need to be able to reliably estimate the betas on an ex-ante basis.

In Exhibit 11, we show the rolling 3-year realized betas of some key AUD pairs to the AUD hedged equity returns in those countries. The betas vary extensively through time. In 2020, most of the betas were less than -1, suggesting that AUD investors investing in those countries would have been best served by leaving all of their exposures unhedged, whereas, as recently as 2019, the betas to GBP and CAD were positive, suggesting that an AUD investor would have been better served fully hedging their exposure to these currencies.

Exhibit 11: Rolling 3-Year Betas for an AUD Investor Hedging Various Equity Market Returns

In this plot, we show the beta of each of our AUD hedged equity markets to the FX returns from the relevant AUD FX pair. For example, the blue USD line shows the beta of the S&P 500 to the returns AUDUSD returns. The betas are shown between January 1980 and June 2024.



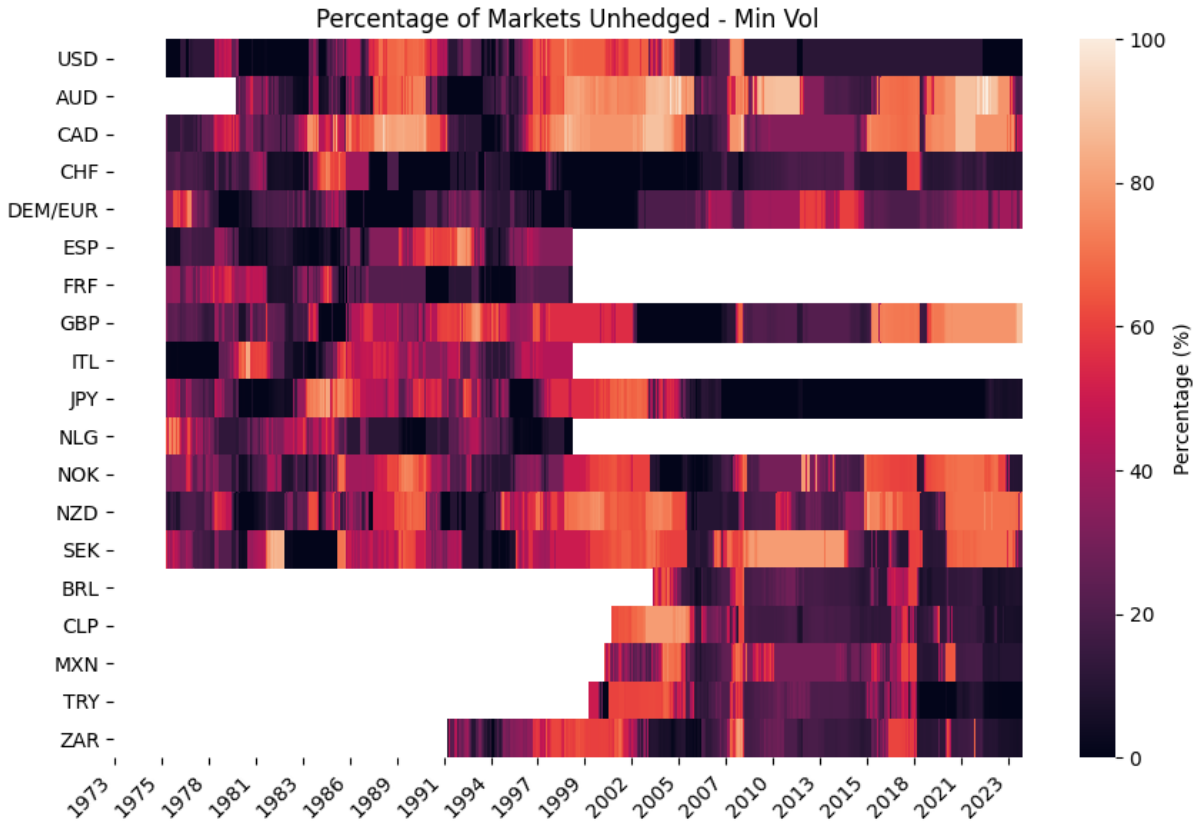
5.3 Performance of the Minimum Volatility FX Hedging Portfolios

In Exhibit 12, we show the percentage of markets unhedged under this minimum volatility approach, using a covariance matrix estimated from the past three years of returns at each point in time. We implement the rule on a rolling out-of-sample basis, only using data available up to the end of the previous month to determine the weights for the next month.

The hedging profile is very different to that which we saw when we were trying to maximize carry in the previous section. Low yielding but defensive currencies like JPY and CHF were typically fully unhedged in the previous approach, whereas in this approach, they are typically left much closer to fully hedged.

Exhibit 12: Percentage of Foreign FX Exposure Unhedged Through Time by Minimum Volatility Hedging

This figure shows the percentage of the FX markets that are unhedged through time under the minimum volatility hedging approach. Markets may be partially hedged under this approach. So, for example, if the FX exposure of two of ten markets was 50% hedged and the others were all left unhedged, the percentage unhedged shown here would be 90%. The data is shown between April 1976 and June 2024.



In Exhibit 13, we show the returns, volatilities and Sharpe ratios that investors with different home currencies would have achieved from employing this hedging approach to world equities historically, and how these would have compared to those they would have achieved by either hedging all of their FX exposures or leaving all of their FX exposures unhedged.

The "Min Vol" hedging rule does a good job of reducing portfolio volatility, resulting in a volatility the same as or lower than the fully hedged or fully unhedged version for each of our currencies. This method does not consider expected returns and, as a result, we do not see an improvement in the Sharpe ratio in all cases. However, the Sharpe ratio is higher than the hedged or unhedged version in all but three of the developed markets.

Exhibit 14 shows the rolling one- and three-year volatility that AUD and EUR investors would have realized from investing into a basket of global equities under the three hedging approaches. We can see that, not only is the full sample volatility better under the Min Vol approach, but the approach generally performs favorably on a rolling basis as well. It's striking that the hedging profile of the EUR changed dramatically during the years of the European Debt Crisis, showing that the profile exhibits regime-dependent behavior. This was consistent with the EUR moving from a traditionally defensive, or "risk-off" currency to one that exhibits more "risk-on" behavior. Once the crisis receded, the hedging profile switched back to its previous pattern.

Exhibit 13: World Equity Performance by Hedging Approach with Minimum Volatility Hedges

The following three panels show details of the performance that an investor would have achieved from investing in world equities from a given home currency on a hedged, unhedged and dynamically hedged basis. In the dynamically hedged approach, we choose our hedge ratio for each currency at each point in time based on the Min Vol approach detailed in Section 5.3. In Panel A, we show the average annualized excess returns. Currencies where the dynamic Min Vol approach outperforms the hedged version are marked with an asterisk. Currencies where the Min Vol version outperforms both the hedged and unhedged versions are marked with a double asterisk. In Panel B, we show the annualized volatility of the excess returns. Currencies where the dynamic Min Vol realizes lower volatility than the hedged version are marked with an asterisk. Currencies where the Min Vol version realizes lower volatility than either the hedged or unhedged versions are marked with a double asterisk. In Panel C, we show the Sharpe ratio. Currencies where the dynamic Min Vol realizes a higher Sharpe ratio than the hedged version are marked with an asterisk. Currencies where the Min Vol version realizes a higher Sharpe ratio than either the hedged or unhedged versions are marked with a double asterisk. The returns are calculated from April 1976 to June 2024. Each individual currency starts three years and one month after the start date for the FX returns in Exhibit 1. We start at this point because a three year "burn-in" is required to calculate covariances. All Eurozone currencies are stitched with the Euro from 1999.

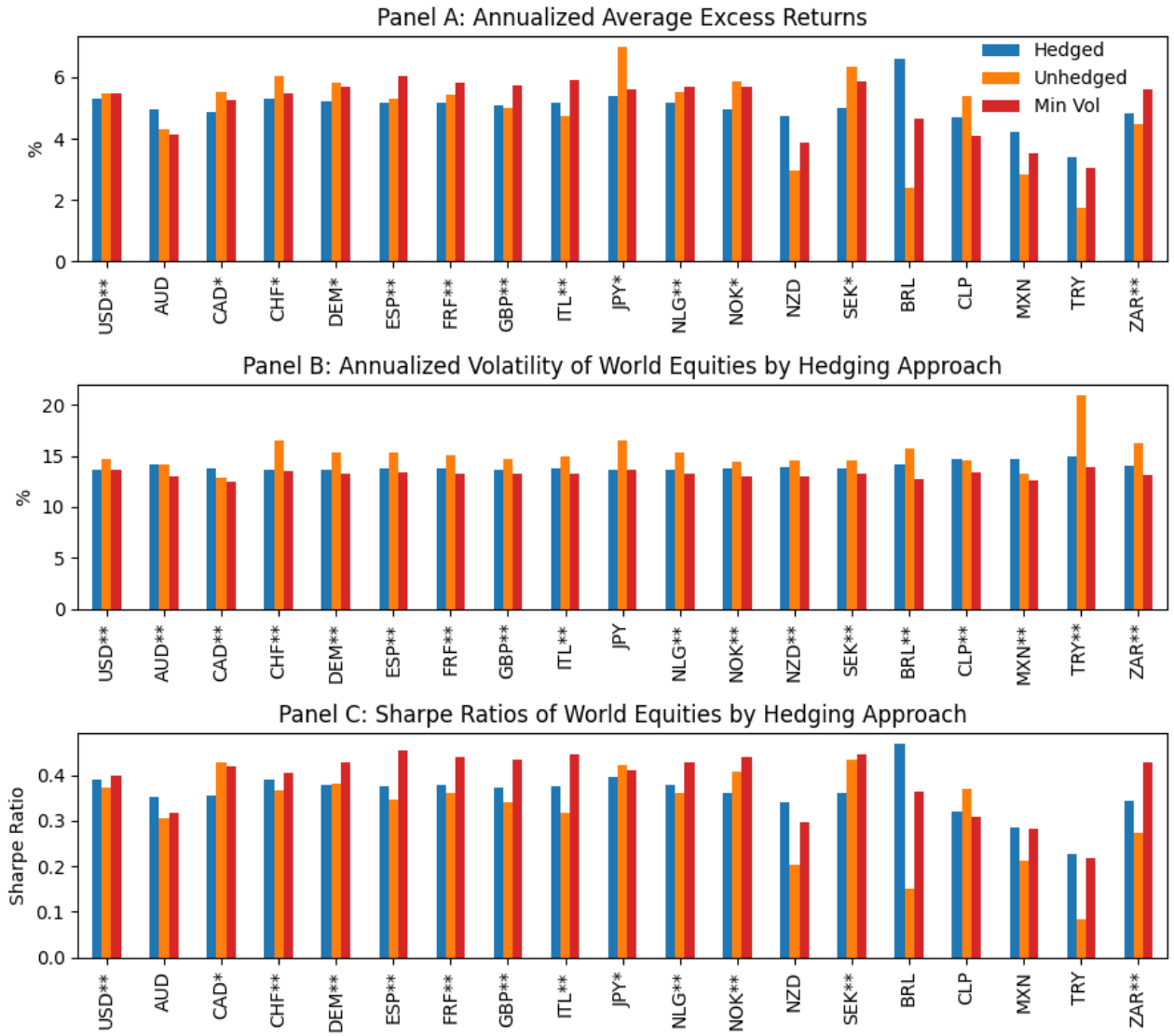
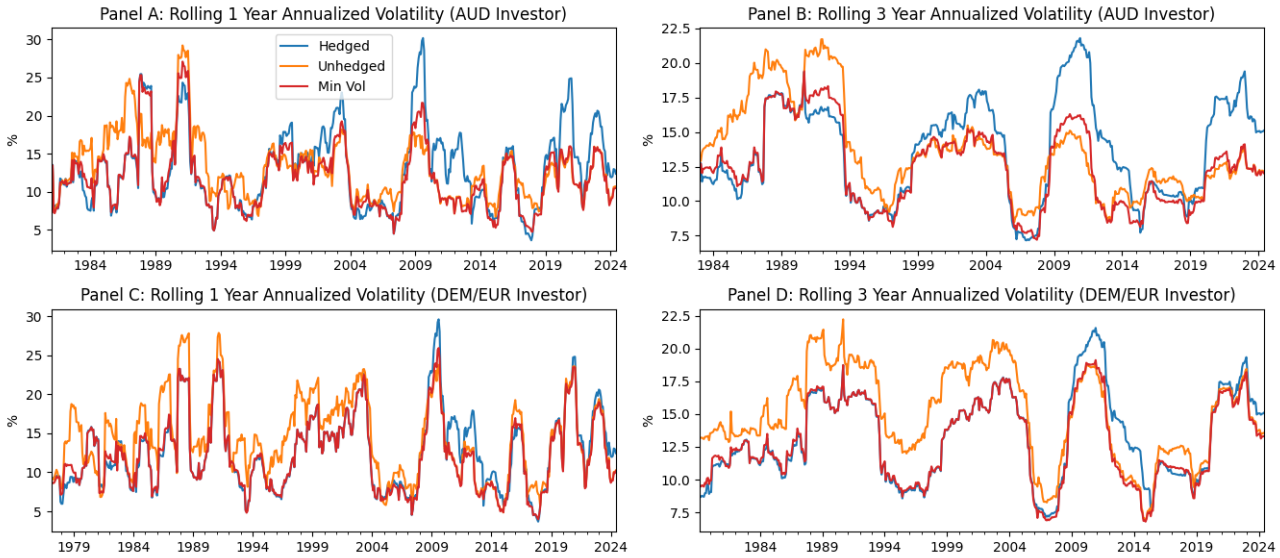


Exhibit 14: Rolling Realized Volatility for AUD and EUR Investors Under Various Hedging Approaches

Here we show the 1 year and 3 year rolling annualized volatility from investing in global equities from a given home currency on a hedged, unhedged and "min vol" basis. In the Min Vol approach, we hedge using the approach detailed in section 5.3. Panel A shows the 1-year rolling volatility for an investor whose home currency is AUD. Panel B shows the 3-year rolling volatility for an investor whose home currency is AUD. Panel C shows the 1-year rolling volatility for an investor whose home currency is DEM/EUR. Panel D shows the 3-year rolling volatility for an investor whose home currency is DEM/EUR.



6 Informed "Optimal" Hedging

In the previous two sections, we explored dynamic rules which either tried to maximize our returns from FX hedging or tried to use FX hedging to minimize our portfolio volatility. While both approaches showed promise, in some cases they led to contradictory conclusions about how much to hedge. Many of the more defensive currencies have also, historically, had lower yields. In this section, we combine the two approaches to FX hedging.[17]

Boudoukh et al. (2019) demonstrated the importance of considering both expected returns and risk minimization of the portfolio when adding an unconstrained FX portfolio to a portfolio of international equities. In this paper we follow a different approach by only allowing FX exposures resulting from the underlying equity portfolio to be hedged, a key constraint that many investors face.

6.1 Finding the Optimal Hedge Ratio for a Portfolio of Equities

In practice, an investor will be invested in a basket of equities, denominated in both their domestic and foreign currencies. To find the optimal hedge ratios for a basket of equities, we need to maximize:

$$w^T\mu - \lambda w^T \Omega w$$

[17] See Campbell and Viceira (2002) and Campbell, Serfaty-de Medeiros, and Viceira (2010) for an analysis of global currency hedging.

Where $\boldsymbol{\mu} = \left[\mu_{eq_1}, \ldots, \mu_{eq_n}, \mu_{fx_1}, \ldots, \mu_{fx_n}\right]^T$, $\boldsymbol{w} = \left[w_{eq_1}, \ldots, w_{eq_n}, w_{fx_1}, \ldots, w_{fx_n}\right]^T$, $\boldsymbol{\Omega}$ is the covariance matrix defined in Section 5.3 and $\boldsymbol{\lambda}$ is the investor's risk aversion. Subject to the constraints that $\boldsymbol{w_{eq_i}}$is fixed at the weight to country $\boldsymbol{i}$ in our world equity weights at each point in time and $\boldsymbol{0 \leq w_{fx_i} \leq 1}$ $\forall \boldsymbol{i}$. The optimal hedge ratios are then given by $\boldsymbol{h_i = 1 - w_{fx_i}}$. This optimization is independent of the choice of equity expected returns, as the equity weights are fixed. For our analysis, we use the ex-ante implied interest rate differential from FX forwards as our expected return for each of the FX markets. If an investor assumes that one expects to earn less than the full interest rate differential over time, then they could multiply this number by a factor.[18]

In the event that an investor holds merely a single foreign equity, we get a simple, closed-form solution for the optimal hedge ratio: $\boldsymbol{1 - \frac{\mu_{fx}}{2\lambda\sigma_{fx}^2} + \beta_{hedged,fx}}$, where $\boldsymbol{\beta_{hedged,fx}}$ is the beta of the (hedged) excess equity returns to the FX forward returns. [19]

If we believe that Uncovered Interest Rate Parity holds and the expected return of each FX pair is zero, then the optimal hedge ratio becomes $\boldsymbol{1 + \beta_{eq,fx}}$, , as in our minimum volatility approach. Similarly, as our risk aversion approaches infinity, this rule converges to the minimum volatility hedging approach. Conversely, if we believe that Uncovered Interest Rate Parity does not hold fully and we earn at least some of the interest rate differential, then this rule approaches our binary rule to maximize carry as our risk aversion nears zero.[20]**6.3 Choice of Risk Aversion**

The drawback of this rule is that it explicitly depends on the investor's risk aversion. For the purpose of our analysis, we need to choose a risk aversion parameter. We do this by "backing out" the risk aversion of an investor who is fully invested in equities. If an investor can only invest in equities, their optimal weight to equities will be:

$$\boldsymbol{w_{eq} = \frac{\mu_{eq}}{2\lambda\sigma_{eq}^2} = \frac{Sharpe_{eq}}{2\lambda\sigma_{eq}}}.$$

If we assume that equities have a typical Sharpe of 0.4 and a volatility of 15%, then setting $\boldsymbol{w_{eq} = 1}$ allows use to solve for a risk aversion coefficient ($\boldsymbol{\lambda}$) of 4/3. We will use this value going forward.[21]

6.4 Amount Hedged Through Time under "Optimal" Rule

Exhibit 15 shows the amount of hedging stipulated when we employ this rule with a risk aversion parameter of 4/3.

Looking at JPY, some appealing properties of this approach are immediately evident. When we purely tried to maximize carry, JPY was mainly left fully unhedged. Conversely, when we tried to minimize volatility, we mostly wanted to fully hedge JPY because of its defensive nature. In the

[18] For example, when investing in emerging markets, one might want to assume that only a fraction of the ex-ante interest rate differential is earned over time, given the results in Exhibit 5.
[19] Further details on the derivation of this can be found in Appendix A.6.
[20] See, for instance, Sushko, Vladyslav, Borio, and McCauley (2016).

[21] Another possibility would be to choose a dynamic risk aversion parameter, such that the ex-ante volatility is less than or equal to the volatility of the hedged equity portfolio.

optimal version, JPY is mostly unhedged up until the Global Financial Crisis. However, in the years after that it is mostly fully hedged. As developed market interest rates all converge towards zero and interest rate differentials get squeezed lower, this model no longer views the carry that can be earned by leaving the FX exposure unhedged as sufficient to justify the higher volatility from not hedging. It is not until interest rate differentials between Japan and the rest of the developed world start to widen again in the final few years of our sample that the expected return from hedging to JPY becomes sufficiently negative that the model switches back towards leaving the foreign FX exposure unhedged again.

In Exhibit 16, we show the Sharpe ratios from investing in a basket of world equities following each of the FX hedging rules we have considered so far. The approach of maximizing carry tends to generate the highest returns and the approach of minimizing volatility tends to generate the lowest volatility, but the optimal hedge rule generally results in better Sharpe ratios.

Exhibit 15: Number of Markets Unhedged using "Optimal" Hedge Rule with risk aversion of 1.333

This figure shows the percentage of the foreign FX markets that are unhedged through time under the Optimal hedging approach. Markets may be partially hedged under this approach. The data is shown between April 1976 and June 2024.

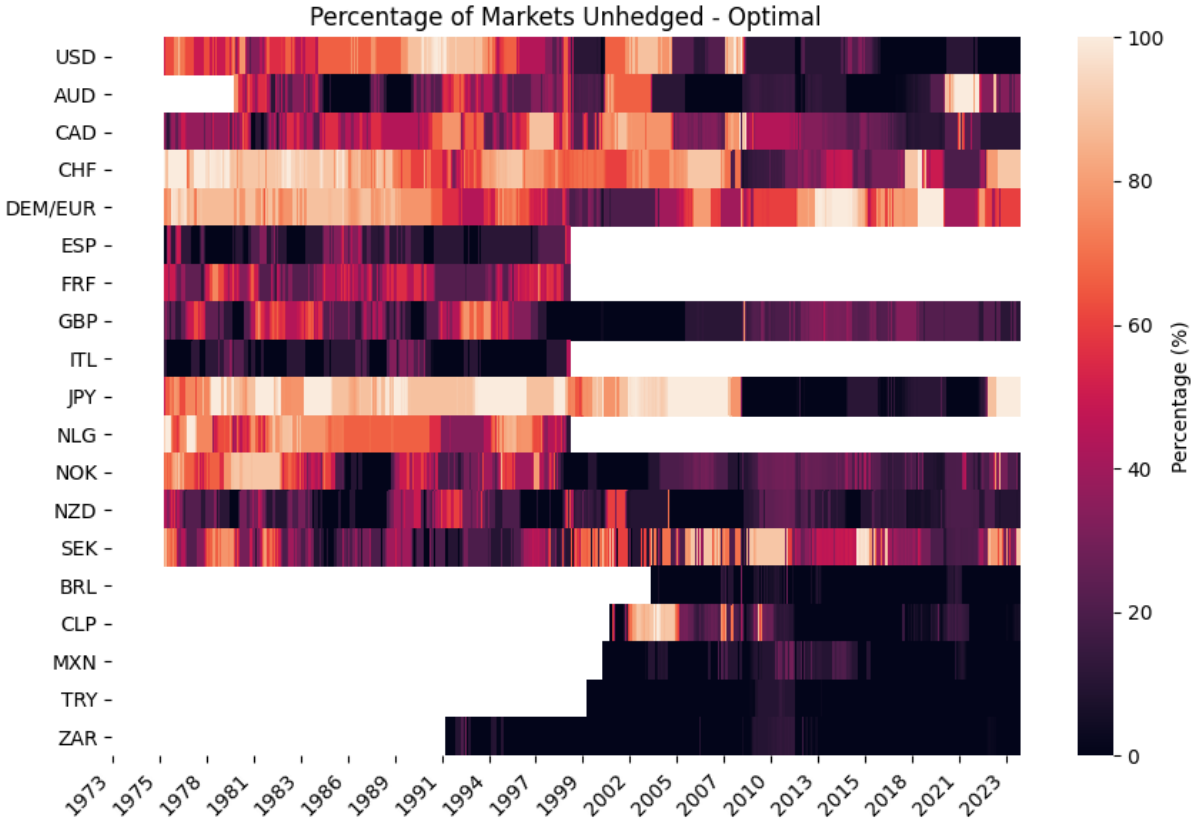


Exhibit 16: Sharpe of Global Equity Returns by FX Hedging Approach (Lambda = 1.333)

This plot shows the Sharpe ratio that an investor would have achieved from investing in world equities from a given home currency on a hedged, unhedged, Min Vol, Max Carry or Optimal basis. The Min Vol approach calculates hedge ratios based on the approach detailed in Section 5.3. The Max Carry approach calculates hedge ratios based on the approach detailed in Section 4.2. The Optimal approach chooses hedge ratios based on the approach detailed in Section 6.2. The returns are calculated from April 1976 to June 2024. Each individual currency starts three years and one month after the start date for the FX returns in Exhibit 1. We start at this point to make the sample period comparable with that used in the later analysis where a three year "burn-in" is required to calculate covariances. All Eurozone currencies are stitched with the Euro from 1999.

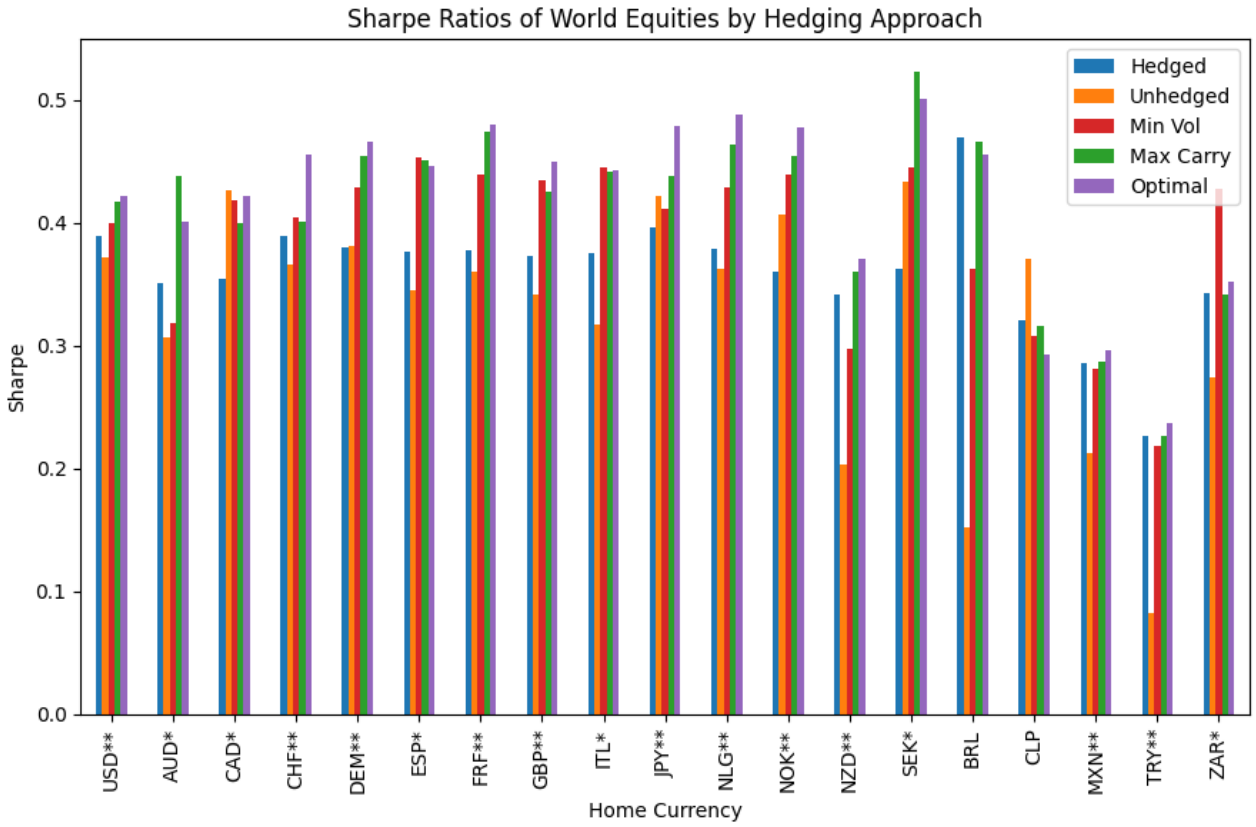


Exhibit 17: Sharpe Ratio of Global Equity Returns by Hedging Approach

This table shows the difference Sharpe of the Optimal hedging approach and the other hedging approaches we have explored so far. We assume the risk aversion parameter is 1.33. The returns are calculated from April 1976 to June 2024. Each individual currency starts three years after the start date for the FX returns in Exhibit 1. We start at this point to make the sample period comparable with that used in the later analysis where a three year "burn-in" is required to calculate covariances. For each currency, we highlight the best performing approach in green and the worst approach in red. Among the DMs, the optimal approach leads to the highest SR in 9 countries. In four other DMs, it falls slightly short of max carry or min vol. Canada is the only developed market where a static hedging approach delivers the highest Sharpe ratio.

	Hedged	Unhedged	Min Vol	Max Carry	Optimal
Developed Markets					
USD	0.39	0.37	0.40	0.42	0.42
AUD	0.35	0.31	0.32	0.44	0.40
CAD	0.35	0.43	0.42	0.40	0.42
CHF	0.39	0.37	0.40	0.40	0.46
DEM	0.38	0.38	0.43	0.45	0.47
ESP	0.38	0.35	0.45	0.45	0.45
FRF	0.38	0.36	0.44	0.47	0.48
GBP	0.37	0.34	0.44	0.43	0.45
ITL	0.38	0.32	0.45	0.44	0.44
JPY	0.40	0.42	0.41	0.44	0.48
NLG	0.38	0.36	0.43	0.46	0.49
NOK	0.36	0.41	0.44	0.46	0.48
NZD	0.34	0.20	0.30	0.36	0.37
SEK	0.36	0.43	0.44	0.52	0.50
Emerging Markets					
BRL	0.47	0.15	0.36	0.47	0.46
CLP	0.32	0.37	0.31	0.32	0.29
MXN	0.29	0.21	0.28	0.29	0.30
TRY	0.23	0.08	0.22	0.23	0.24
ZAR	0.34	0.27	0.43	0.34	0.35

7 Value- and Trend-Based Hedging Rules

So far, we have focused on interest rate differentials as the main driver of expected returns in FX markets. Two other metrics that are commonly used to forecast FX returns are trend and value signals. In this section, we will evaluate two simple trend- and value-based signals.[22]

For the trend signal, we use a simple binary twelve-month trend signal. If the equity market's currency has been outperforming the home currency, we leave our FX exposure fully unhedged over the following month. Conversely, if the equity market's currency has underperformed the home currency, we fully hedge our exposure.[23]

For the value signal, we compare the spot exchange rate to the Purchasing Power Parity (PPP) exchange rates calculated by the Organization for Economic Co-operation and Development

[22] Boudoukh et al. (2019) demonstrate the benefits of combining carry, value and momentum signals to build an unconstrained FX alpha portfolio to sit alongside international equities.
[23] When determining whether one currency has outperformed another over a period, we consider the total return, including the interest rate differential, rather than just the change in the spot rate.

(OECD).[24] The OECD defines PPPs as "the rates of currency conversion that try to equalize the purchasing power of different currencies, by eliminating the differences in price levels between countries."[25] They measure PPP by taking the ratio of the price of a basket of goods and services in one currency and comparing that to the price of the same basket in US dollars.

The law of one price and absolute PPP suggests that a basket of identical goods and services sold in different locations should have the same price when expressed in a common currency. This would imply that spot exchange rates should converge towards PPP exchange rates. As such, we can compare the spot exchange rate to the PPP exchange rate to determine whether a particular currency is "cheap" or "expensive".

We define a simple binary rule: our currency exposure is fully unhedged if the equity market's currency is undervalued according to PPP (i.e., the equity market's currency currently buys fewer units of the home currency than would be implied by the PPP exchange rate and the currency is expected to appreciate) and is fully hedged if the equity market's currency is overvalued according to PPP (i.e., the equity market's currency currently buys more units of the home currency than would be implied by the PPP exchange rate suggesting depreciation).

We note that these binary rules are deliberately simple. In practice, it is more likely that one would employ a more sophisticated rule that varied the hedge ratio as the trend and value signals became stronger. However, for the purposes of our analysis, we restrict ourselves to these simple formulations to illustrate our result in a parsimonious way.

In Exhibit 18, we show the percentage of markets that would be unhedged at any point in time under these two approaches. As might be expected, the 12-month trend approach (Panel A) induces a significant amount of turnover. The PPP approach (Panel B) is much more stable. Note that for emerging markets, the PPP deviation rule would always have us fully hedge our currency exposure. This reflects the fact that emerging market currencies typically look cheap according to PPP, one of the limitations of the approach. Labor costs are typically lower in emerging markets, which can cause goods and, particularly, services to be persistently cheaper. Restrictions on labor movement and differences in local minimum wages mean that cheap labor cannot easily be exported to equalize the cost of services across developed and emerging markets. In addition, tariffs and trade barriers may limit the ability of emerging markets to export goods and services, suppressing demand for their currencies.

In Exhibit 19, we show the Sharpe ratios that would have been realized by investors in different home currencies from investing in a basket of global equities.[26] Notice that in every developed market the lowest performers are the static unhedged or fully hedged. The dynamic approaches show distinct advantages. Even with these relatively simple formulations, both the PPP approach and the momentum approach show reasonable promise. The PPP hedging rule outperforms both the hedged and unhedged version in all but one of the developed market currencies and the momentum rule outperforms in 12 of the 14 developed markets. Furthermore, in a number of markets, either the PPP rule or the momentum rule generate the highest Sharpe ratio, suggesting that both value and momentum may be additive to our existing rules.

[24] See Meese and Rogoff (1983).
[25] Purchasing power parities (PPP) | Conversion rates | OECD iLibrary (oecd-ilibrary.org)
[26] The returns and volatilities are shown in Exhibits A6 and A7 of the appendix.

To explore this idea further, we create a simple blended hedging rule, which equal weights the Optimal, momentum and PPP hedging weights. In the final column of Exhibit 19, we show the Sharpe ratios that this rule realizes. While it only provides the best Sharpe ratio in three of the markets, it appears to be the most consistent hedging rule, outperforming both the hedged and unhedged versions in each of the developed markets.

There are many ways to refine our analysis. For example, we could translate the momentum and value signals into explicit expected returns and combine them with the carry to create a blended expected return that could be used in the optimization described in Section 6.1. Further, we could use the carry signal to create a state-contingent volatility and covariance estimation. Indeed, it is best to think of our results as a lower bound on the possibilities for benefits of dynamic FX hedging.

Exhibit 18: Percentage of Foreign FX Exposure Unhedged using 12-Month Trend

Percentage of FX markets that are unhedged through time under the 12-month trend approach (Panel A) and the PPP approach (Panel B). The data are from April 1976 and June 2024.

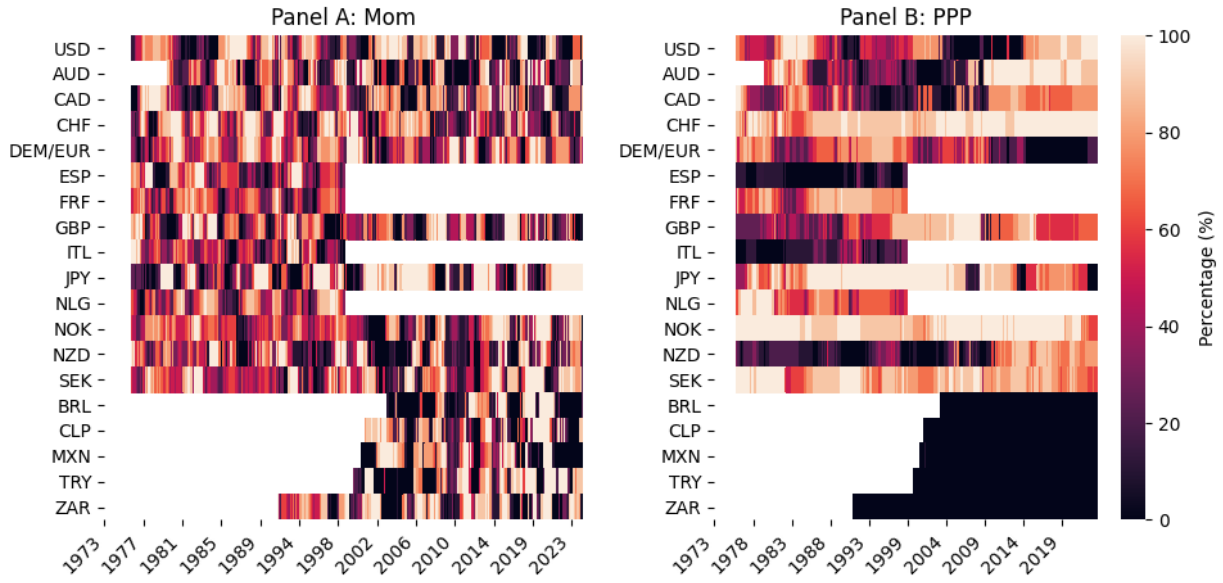


Exhibit 19: Sharpe Ratio of Global Equity Returns by FX Hedging Approach

Sharpe ratios from investing in a world equity portfolio from the perspective of a given home currency (rows) for each of the hedging rules. We highlight the hedging approach with the highest Sharpe ratio returns in green and the lowest in red. The returns are calculated from April 1976 to June 2024. Each individual currency starts three years and one month after the start date for the FX returns in Exhibit 1. We start at this point because a three year "burn-in" is required to calculate covariances. All Eurozone currencies are stitched with the Euro from 1999.

	Unhedged	Hedged	Min Vol	Max Carry	Optimal	Mom	PPP	Blend
Developed Markets								
USD	0.37	0.39	0.40	0.42	0.42	0.43	0.40	0.42
AUD	0.31	0.35	0.32	0.44	0.40	0.32	0.44	0.41
CAD	0.43	0.35	0.42	0.40	0.42	0.45	0.45	0.45
CHF	0.37	0.39	0.40	0.40	0.46	0.41	0.41	0.44
DEM	0.38	0.38	0.43	0.45	0.47	0.42	0.43	0.45
ESP	0.35	0.38	0.45	0.45	0.45	0.41	0.42	0.44
FRF	0.36	0.38	0.44	0.47	0.48	0.41	0.41	0.44
GBP	0.34	0.37	0.44	0.43	0.45	0.42	0.44	0.45
ITL	0.32	0.38	0.45	0.44	0.44	0.36	0.41	0.41
JPY	0.42	0.40	0.41	0.44	0.48	0.52	0.42	0.48
NLG	0.36	0.38	0.43	0.46	0.49	0.40	0.43	0.45
NOK	0.41	0.36	0.44	0.46	0.48	0.43	0.46	0.47
NZD	0.20	0.34	0.30	0.36	0.37	0.36	0.39	0.39
SEK	0.43	0.36	0.44	0.52	0.50	0.45	0.46	0.49
Emerging Markets								
BRL	0.15	0.47	0.36	0.47	0.46	0.43	0.47	0.48
CLP	0.37	0.32	0.31	0.32	0.29	0.28	0.32	0.31
MXN	0.21	0.29	0.28	0.29	0.30	0.25	0.29	0.29
TRY	0.08	0.23	0.22	0.23	0.24	0.01	0.23	0.16
ZAR	0.27	0.34	0.43	0.34	0.35	0.31	0.34	0.36

8 FX Hedging in the Best of Times and the Worst of Times

So far, our results point to the significant benefits of active FX hedging over the long term. While understanding long-term performance is crucial, it is equally important to assess how these strategies perform during periods of stress.

Investors often think of hedging as a technique to reduce risk. However, in Exhibit 20, we can see that it is frequently the FX hedged portfolio that performs worst in the crisis periods defined in Harvey et al. (2019). This is particularly true for “risk-on” currencies such as the Australian dollar, where the gap between the annualized return of the hedged and unhedged portfolios in crisis periods is 9.2%. What is more surprising is that we see a similar pattern emerge for a number of more traditionally defensive currencies such as the euro and British pound.

In Section 4, we explored carry as a key driver of FX market returns, emphasizing its role in hedging decisions. One common criticism of carry is that it generates small, steady profits in times of relative calm, but incurs large losses in periods of stress. As such, we might expect the carry-based strategies to outperform in the non-crisis periods, but exacerbate our losses in crisis periods. While the carry-based strategies do tend to generate most of their outperformance outside of crisis periods, we do not see any evidence of consistent underperformance in crises. The Max Carry approach does not have the worst performance in crises for any of the currencies in our sample. In fact, it outperforms the hedged approach in all but one of the developed markets.

In Section 5, we showed how the dynamic Min Vol approach to FX hedging did an effective job of minimizing the volatility of our portfolio, resulting in lower volatility than either the hedged or unhedged portfolio for all but one of the currencies in our sample. This technique also appears to be effective at reducing losses in crisis periods. The Min Vol approach results in better crisis period returns than the hedged portfolio for every currency and frequently has the best crisis period returns of any of the hedging strategies we have considered.

When it comes to "risk-on" currencies like the Australian and Canadian dollars, as well as Emerging Market currencies, the unhedged version typically performs best during crises. However, this crisis protection often comes at a cost. For example, while Australian dollar investors have historically benefited from leaving currency exposure unhedged during crises, from April 1976 to June 2024, this approach underperformed a max carry strategy by 1.5% per annum—a significant insurance premium.

Exhibit 20: Annualized Returns of World Equities in Crisis and Non-Crisis Periods (January 1985 – June 2024)

The performance of world equities using the different FX hedging techniques. In Panel A, we show the annualized performance in crisis periods. Panel B shows the performance in non-crisis periods and in the final panel, we show the performance across the full sample period. We use the crisis periods defined in Harvey et al. (2019), i.e. S&P 500 peak-to-trough selloffs that exceed 15%. That paper started in 1985 and used daily data. We keep the same starting date for the analysis (as the crises before that date are not defined), but expand the start and end date of the crisis periods to the start and end of the months to reflect the fact that we are using monthly data and to ensure that we capture the full crises. The full start and end dates of the crisis periods are detailed in Appendix A.1. The returns are calculated from January 1985 to June 2024. Where the start date for a currency is later than January 1985, it starts three years and one month after the start date for the FX returns in Exhibit 1. We start at this point because a three year “burn-in” is required to calculate covariances. All Eurozone currencies are stitched with the Euro from 1999.

Panel A: Crisis Periods

	Unhedged	Hedged	Min Vol	Max Carry	Optimal	Mom	PPP
Developed Markets							
USD	-30.1%	-30.4%	-29.7%	-30.1%	-29.9%	-29.9%	-30.6%
AUD	-24.7%	-32.2%	-28.7%	-29.2%	-29.0%	-28.7%	-28.5%
CAD	-24.1%	-31.5%	-26.2%	-29.8%	-27.4%	-27.6%	-28.6%
CHF	-32.9%	-30.4%	-29.9%	-32.1%	-31.3%	-32.1%	-31.7%
DEM	-30.4%	-30.8%	-29.1%	-30.3%	-29.5%	-30.9%	-30.2%
ESP	-30.7%	-30.9%	-29.1%	-30.2%	-29.2%	-31.1%	-29.5%
FRF	-30.5%	-30.9%	-29.1%	-30.2%	-29.2%	-31.0%	-30.3%
GBP	-27.8%	-30.8%	-27.7%	-29.2%	-28.3%	-27.3%	-28.7%
ITL	-30.4%	-30.9%	-29.2%	-30.2%	-29.2%	-31.0%	-29.8%
JPY	-30.2%	-30.0%	-28.5%	-28.8%	-27.6%	-27.7%	-31.0%
NLG	-30.5%	-30.8%	-29.1%	-30.5%	-29.3%	-31.0%	-30.1%
NOK	-29.0%	-31.5%	-28.2%	-30.3%	-28.5%	-28.5%	-28.3%
NZD	-29.2%	-32.1%	-30.5%	-31.4%	-30.6%	-27.9%	-30.9%
SEK	-26.8%	-31.4%	-28.2%	-28.1%	-27.5%	-28.5%	-29.1%
Emerging Markets							
BRL	-30.9%	-31.6%	-31.3%	-31.7%	-31.7%	-31.1%	-31.6%
CLP	-23.6%	-29.4%	-27.6%	-27.4%	-27.4%	-26.6%	-29.4%
MXN	-24.0%	-28.4%	-25.4%	-28.4%	-27.4%	-27.4%	-28.4%
TRY	-30.2%	-29.6%	-28.6%	-29.6%	-29.3%	-37.0%	-29.6%
ZAR	-19.8%	-30.0%	-23.4%	-30.0%	-29.3%	-25.4%	-30.0%

Panel B: Non Crisis Periods

	Unhedged	Hedged	Min Vol	Max Carry	Optimal	Mom	PPP
Developed Markets							
USD	15.8%	15.2%	15.2%	16.0%	15.8%	16.3%	15.9%
AUD	11.5%	14.8%	12.2%	15.3%	14.2%	13.0%	14.9%
CAD	13.3%	14.8%	13.3%	14.9%	14.1%	14.7%	15.2%
CHF	15.5%	15.2%	15.1%	15.6%	16.5%	15.5%	16.2%
DEM	14.9%	15.1%	15.4%	16.3%	15.8%	15.3%	15.8%
ESP	14.4%	15.1%	15.3%	16.6%	15.8%	15.3%	15.5%
FRF	14.1%	15.1%	15.4%	16.8%	16.1%	14.9%	15.2%
GBP	13.0%	15.0%	14.4%	14.7%	14.7%	13.8%	15.2%
ITL	13.9%	15.1%	15.2%	16.4%	15.7%	14.6%	15.4%
JPY	17.6%	15.2%	15.3%	17.0%	16.8%	18.3%	16.9%
NLG	14.6%	15.1%	15.4%	16.5%	16.0%	15.0%	15.7%
NOK	13.8%	14.9%	14.5%	15.5%	15.0%	14.1%	14.7%
NZD	10.3%	14.8%	12.6%	14.7%	14.4%	13.6%	15.3%
SEK	14.0%	15.0%	14.5%	16.9%	15.8%	15.0%	15.4%
Emerging Markets							
BRL	11.6%	17.5%	14.8%	17.5%	17.3%	17.2%	17.5%
CLP	15.8%	17.5%	15.8%	16.4%	15.7%	15.2%	17.5%
MXN	13.1%	17.4%	14.9%	17.4%	16.9%	16.0%	17.4%
TRY	14.7%	16.9%	15.8%	16.9%	16.9%	16.1%	16.9%
ZAR	11.0%	15.0%	13.7%	15.0%	14.9%	13.0%	15.0%

Panel C: All Periods

	Unhedged	Hedged	Min Vol	Max Carry	Optimal	Mom	PPP
Developed Markets							
USD	6.4%	5.8%	6.0%	6.5%	6.4%	6.7%	6.3%
AUD	4.3%	5.0%	3.9%	6.2%	5.4%	4.6%	6.0%
CAD	5.9%	5.3%	5.4%	5.7%	5.7%	6.1%	6.3%
CHF	5.4%	5.8%	5.8%	5.6%	6.6%	5.6%	6.2%
DEM	5.6%	5.7%	6.3%	6.6%	6.5%	5.8%	6.3%
ESP	5.1%	5.6%	6.2%	6.9%	6.5%	5.7%	6.2%
FRF	5.0%	5.6%	6.3%	7.1%	6.8%	5.4%	5.8%
GBP	4.8%	5.5%	5.9%	5.7%	6.0%	5.5%	6.3%
ITL	4.8%	5.6%	6.1%	6.8%	6.5%	5.2%	6.1%
JPY	7.7%	5.9%	6.4%	7.6%	7.8%	8.8%	7.0%
NLG	5.3%	5.6%	6.3%	6.7%	6.7%	5.5%	6.3%
NOK	5.1%	5.3%	5.8%	6.1%	6.2%	5.4%	6.0%
NZD	2.3%	5.1%	3.8%	5.1%	5.1%	5.2%	5.7%
SEK	5.8%	5.4%	5.8%	7.7%	7.0%	6.2%	6.3%
Emerging Markets							
BRL	2.4%	6.6%	4.6%	6.6%	6.4%	6.5%	6.6%
CLP	5.4%	4.7%	4.1%	4.6%	4.1%	4.0%	4.7%
MXN	2.8%	4.2%	3.5%	4.2%	4.3%	3.6%	4.2%
TRY	1.7%	3.4%	3.0%	3.4%	3.5%	0.2%	3.4%
ZAR	4.5%	4.8%	5.6%	4.8%	4.9%	4.5%	4.8%

In Exhibit 21, we look at the performance of the FX hedging strategies applied to world equities in U.S. inflationary and non-inflationary periods, as defined in Neville et al. (2021). There appears to be a pattern of the unhedged portfolios typically underperforming in inflationary periods and the hedged portfolios underperforming in non-inflationary periods. This may be partly driven by the fact that the inflationary periods are defined based on US CPI. For any non-USD investors, their largest foreign FX exposure will be the US dollar. If the US is experiencing higher inflation than other countries, relative PPP would suggest that its currency should depreciate. As a robustness check, we performed the analysis using UK inflation and found similar results.

Interestingly, while many of the more "risk-on" currencies benefitted from being unhedged in crisis periods, in inflationary periods they appear to suffer. For example, an Australian dollar investor's losses in inflationary periods are more than double when the FX exposure is unhedged rather than hedged. This may be driven by the fact that Australia is a commodity exporter whose currency benefits from rising commodity prices. This highlights the fact that a static hedging approach, which may seem prudent when looked at through one lens, can appear incautious when looked at through another.

Carry appears still to perform reasonably well in inflationary periods, outperforming either the hedged or unhedged versions for every developed market. Most importantly, in both inflationary and non-inflationary periods, it is almost always one of the dynamic rules that fares best, while it is most often the static rules that fare worst.

Exhibit 21: Annualized Returns of World Equities in Inflationary and Non-Inflationary Periods (April – June 2024)

In these tables, we show the performance of World Equities using the different hedging techniques that we have explored in this paper. In the Panel A, we show the annualized performance in inflationary periods. In Panel B, we show the performance in non-inflationary periods. We use the inflationary periods defined in Neville et al. (2021) which are calculated based on US CPI[27]. The full start and end dates of the inflationary periods are detailed in Appendix A.1. The returns are calculated from April 1976 to June 2024. Each individual currency starts three years and one month after the start date for the FX returns in Exhibit 1. We start at this point because a three year "burn-in" is required to calculate covariances. All Eurozone currencies are stitched with the Euro from 1999.

[27] We also ran the same analysis using the inflationary periods identified in the paper based on UK and Japanese CPI. The results using the UK inflationary periods were similar to those for the US inflationary periods. Japan has only had one inflationary period during our sample, so the results were not very informative.

Panel A: Inflation Periods

	Unhedged	Hedged	Min Vol	Max Carry	Optimal	Mom	PPP
Developed Markets							
USD	-1.8%	-2.8%	-2.4%	-1.1%	-1.3%	-0.5%	-2.2%
AUD	-11.5%	-6.2%	-6.4%	-4.4%	-4.6%	-8.4%	-6.2%
CAD	-3.0%	-3.1%	-3.3%	-2.3%	-2.1%	-1.4%	-2.0%
CHF	-4.1%	-2.5%	-3.3%	-1.8%	-2.2%	-1.5%	-3.0%
DEM	-4.0%	-2.7%	-2.6%	-1.2%	-1.2%	-1.6%	-4.1%
ESP	-8.5%	-2.8%	-2.1%	-1.9%	-1.6%	-3.3%	-3.9%
FRF	-5.6%	-2.7%	-3.2%	-1.1%	-0.9%	-2.7%	-5.2%
GBP	-7.6%	-2.8%	-2.8%	-2.6%	-2.1%	-3.0%	-2.4%
ITL	-6.3%	-2.8%	-2.0%	-1.8%	-1.5%	-2.5%	-3.9%
JPY	0.2%	-2.6%	-3.6%	0.8%	-0.4%	1.4%	-1.5%
NLG	-4.5%	-2.7%	-2.5%	-1.8%	-1.8%	-2.1%	-4.3%
NOK	-5.5%	-2.9%	-3.4%	-2.0%	-1.3%	-2.7%	-4.5%
NZD	-7.1%	-3.2%	-3.4%	-2.9%	-1.7%	-3.5%	-3.3%
SEK	-3.5%	-2.8%	-1.5%	-0.7%	-0.7%	-1.9%	-3.5%
Emerging Markets							
BRL	-23.5%	-7.7%	-13.0%	-7.7%	-8.1%	-14.5%	-7.7%
CLP	0.7%	-7.3%	-6.5%	-7.9%	-6.8%	-4.5%	-7.3%
MXN	-16.7%	-7.3%	-12.3%	-7.3%	-7.7%	-9.8%	-7.3%
TRY	2.5%	-7.1%	-5.2%	-7.1%	-7.1%	-3.1%	-7.1%
ZAR	-7.4%	-8.2%	-6.8%	-8.2%	-8.2%	-12.5%	-8.2%

Panel B: Non Inflation Periods

	Unhedged	Hedged	Min Vol	Max Carry	Optimal	Mom	PPP
Developed Markets							
USD	7.3%	7.4%	7.4%	7.7%	7.6%	7.7%	7.5%
AUD	7.2%	6.9%	5.9%	7.8%	7.0%	6.7%	8.1%
CAD	7.6%	6.9%	7.4%	7.3%	7.2%	7.6%	7.9%
CHF	8.6%	7.3%	7.6%	8.4%	9.1%	8.1%	8.8%
DEM	8.3%	7.2%	7.8%	8.7%	8.5%	8.0%	8.7%
ESP	8.9%	7.2%	8.1%	8.4%	7.9%	8.3%	8.1%
FRF	8.3%	7.2%	8.1%	8.7%	8.4%	8.0%	8.6%
GBP	8.2%	7.1%	7.9%	7.9%	8.0%	8.1%	8.2%
ITL	7.5%	7.1%	7.9%	8.1%	7.8%	7.1%	8.0%
JPY	8.6%	7.4%	7.9%	8.5%	9.1%	9.6%	8.5%
NLG	8.1%	7.1%	7.7%	8.9%	8.9%	7.8%	8.8%
NOK	8.8%	6.9%	8.0%	8.5%	8.3%	8.1%	9.4%
NZD	5.5%	6.7%	5.7%	6.9%	6.5%	7.0%	7.4%
SEK	8.8%	6.9%	7.7%	9.1%	8.4%	8.4%	9.2%
Emerging Markets							
BRL	6.1%	8.5%	7.0%	8.5%	8.3%	9.4%	8.5%
CLP	5.9%	6.1%	5.3%	6.1%	5.4%	5.0%	6.1%
MXN	5.1%	5.5%	5.4%	5.5%	5.6%	5.2%	5.5%
TRY	1.6%	4.5%	3.9%	4.5%	4.7%	0.5%	4.5%
ZAR	5.4%	5.9%	6.6%	5.8%	5.9%	5.9%	5.9%

Panel C: All Periods

	Unhedged	Hedged	Min Vol	Max Carry	Optimal	Mom	PPP
Developed Markets							
USD	5.5%	5.3%	5.5%	5.9%	5.8%	6.1%	5.6%
AUD	4.3%	5.0%	4.1%	6.0%	5.3%	4.4%	6.0%
CAD	5.5%	4.9%	5.2%	5.4%	5.4%	5.9%	5.9%
CHF	6.0%	5.3%	5.5%	6.4%	6.9%	6.2%	6.4%
DEM	5.8%	5.2%	5.7%	6.7%	6.6%	6.1%	6.1%
ESP	5.3%	5.2%	6.0%	6.3%	6.0%	5.9%	5.7%
FRF	5.5%	5.2%	5.8%	6.7%	6.5%	5.9%	5.8%
GBP	5.0%	5.1%	5.7%	5.8%	6.0%	5.9%	6.1%
ITL	4.8%	5.2%	5.9%	6.1%	6.0%	5.2%	5.6%
JPY	7.0%	5.4%	5.6%	7.0%	7.2%	8.0%	6.5%
NLG	5.5%	5.2%	5.7%	6.8%	6.8%	5.8%	6.1%
NOK	5.9%	5.0%	5.7%	6.4%	6.4%	5.9%	6.6%
NZD	3.0%	4.7%	3.9%	4.9%	4.9%	4.9%	5.3%
SEK	6.3%	5.0%	5.9%	7.2%	6.6%	6.3%	6.6%
Emerging Markets							
BRL	2.4%	6.6%	4.6%	6.6%	6.4%	6.5%	6.6%
CLP	5.4%	4.7%	4.1%	4.6%	4.1%	4.0%	4.7%
MXN	2.8%	4.2%	3.5%	4.2%	4.3%	3.6%	4.2%
TRY	1.7%	3.4%	3.0%	3.4%	3.5%	0.2%	3.4%
ZAR	4.5%	4.8%	5.6%	4.8%	4.9%	4.5%	4.8%

Conclusions

Investors with globally diversified equity portfolios inevitably face the decision as to whether their investments should hedge out foreign exchange risk. This is often framed as a static, binary choice: hedge or no hedge. Our paper shows that relatively simple dynamic strategies lead to higher performance.

We look at a variety of information that can be used to time FX hedging. The most obvious is the interest rate differential. We show that FX returns are always negative when the interest rate differential is negative. Further, FX returns when the interest rate differential is positive are always greater than when the differential is negative. The differential is just the carry. For investors in low interest rate countries like Japan, it is best not to hedge a diversified world portfolio. We find that the unhedged return is 180bps higher than the hedged return for the yen. For high interest rate countries like New Zealand, it is better to hedge, with NZ investors earning an extra 100bps per annum on average. However, what happens when a high interest rate country becomes a lower interest rate country?

We show that an active strategy based on carry outperforms in almost every country's perspective. For an investor in a global portfolio, the hedging decision for each country investment is based on the carry. Further, the hedging decision for that country is allowed to be dynamic through time.

We also examine two other active signals: momentum and value. For momentum, we look at the trend in the FX rate to inform the hedging decision. For value, we measure deviation from purchasing power parity. Our results suggest that both of these signals are useful.

However, none of the analysis takes the correlation structure between global equities and FX rates into account. We also explore two multivariate strategies. The first is the minimum variance portfolio which has the advantage of not needing estimates for expected returns. However, there are disadvantages of the minimum variance portfolio too: it is only optimal in very special circumstances.

Ideally, we want an efficient portfolio that reflects the investor's risk aversion. We construct this portfolio where we optimize across world equity returns and FX returns. Our optimization fixes the equity weights as the world portfolio weights and chooses the optimal FX hedge ratios for each country. Our expected FX returns are the interest rate differential. We show that this optimal approach has a number of attractive features in that it both incorporates important timing information based on the carry signal and allows for a rich covariance structure.

In the end, our results suggest that investors should consider adopting dynamic approaches to FX hedging. By choosing a static strategy, we suggest that money is left on the table.

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Appendices

Appendix A1: Data

FX Data

For our DM and EM FX pairs, we use FX forward data as far back as it is available. Prior to that, we backfill the DM FX returns using a combination of spot exchange rates and interest rate differentials to calculate the return of a synthetic forward contract. Our interest rate differentials are calculated using the yield on 3-month bills in the relevant currency. The spot FX returns are taken from Bloomberg and the return on 3-month bills are taken from Global Financial Data (GFD).

The exact calculation for the return on the synthetic forward between time **t** and time **T** is given in the equation below.

$$\frac{S_T - S_t}{S_t} + \left(i_{t,T}^{mkt} - i_{t,T}^{home}\right)$$

Where S_T and S_t are the spot exchange rates between the home currency and the currency of the equity market at times **T** and **t** and $i_{t,T}^{mkt}$ and $i_{t,T}^{home}$ are the yield earned on 3-month bills in the equity market's currency and the home currency between time **t** and time **T**.

In Exhibit A1, we show how the implied interest differentials from the AUDUSD FX forward compares to the interest rate differential we obtain from 3-month bills. We also compare the total returns from our synthetic FX forward to the actual total returns from the FX forward. While the two match closely over time, there are some periods of slight differences.

The differences are most likely driven by the cross-currency basis. While Covered Interest Rate Parity tells us that the price of the FX forward should be given by $S_t * (1 + \left(i_{t,T}^{mkt} - i_{t,T}^{home}\right))$, in practice they can diverge, leading to a basis between the implied interest rate differential and the actual interest rate differential. First, there could be misalignment of timing (rates and FX). Second, illiquidity. Third, there is no centralized market and, as such, there are multiple sources of quotes. These issues can be especially important when looking beyond the most prominent currency pairs. We cannot replicate this in our synthetic forwards. Nonetheless, we believe that the replication is accurate enough for the purposes of our analysis.

Exhibit A1: AUDUSD Implied Interest Rate Differential versus Difference in 3-month bills

Comparison of the difference in 3-month bill yields and the interest rate differential implied by comparing the 1-month forward FX price to the spot exchange rate. The data runs from January 1975 to June 2024.

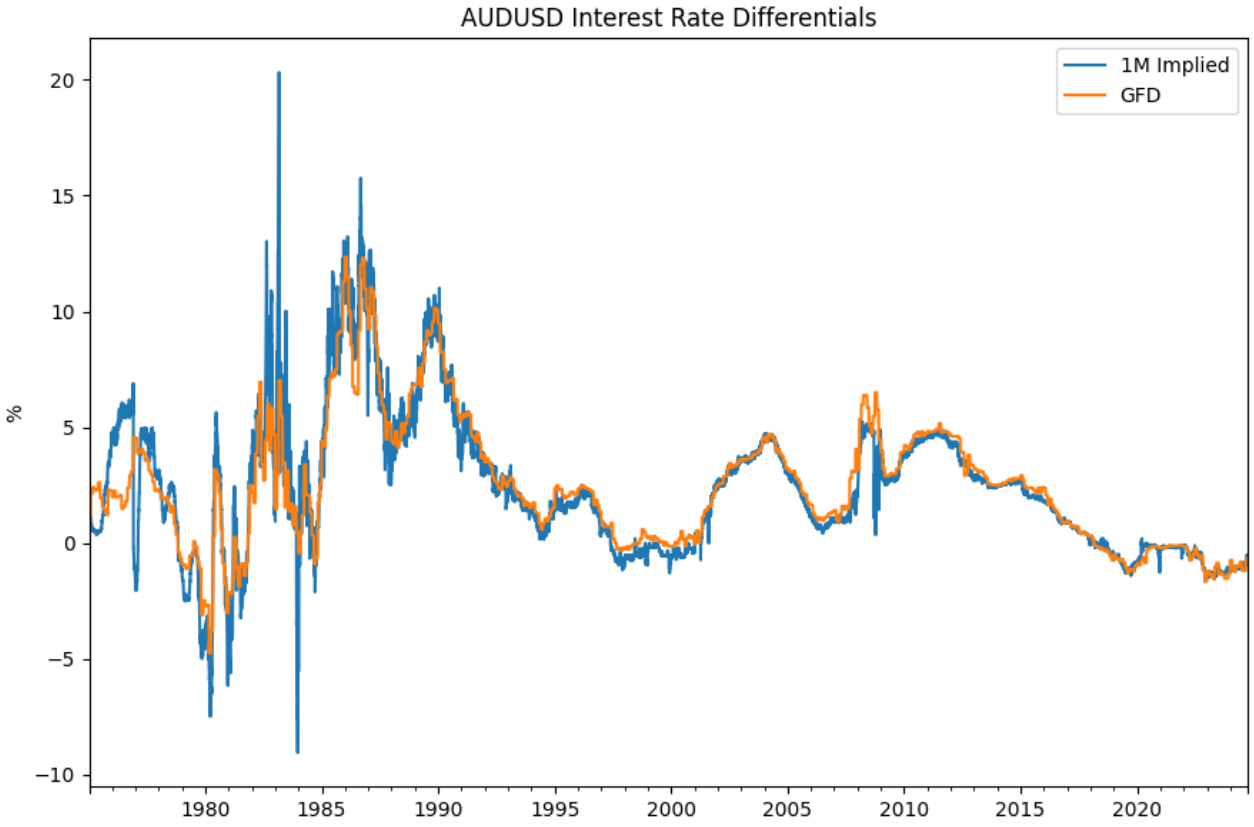
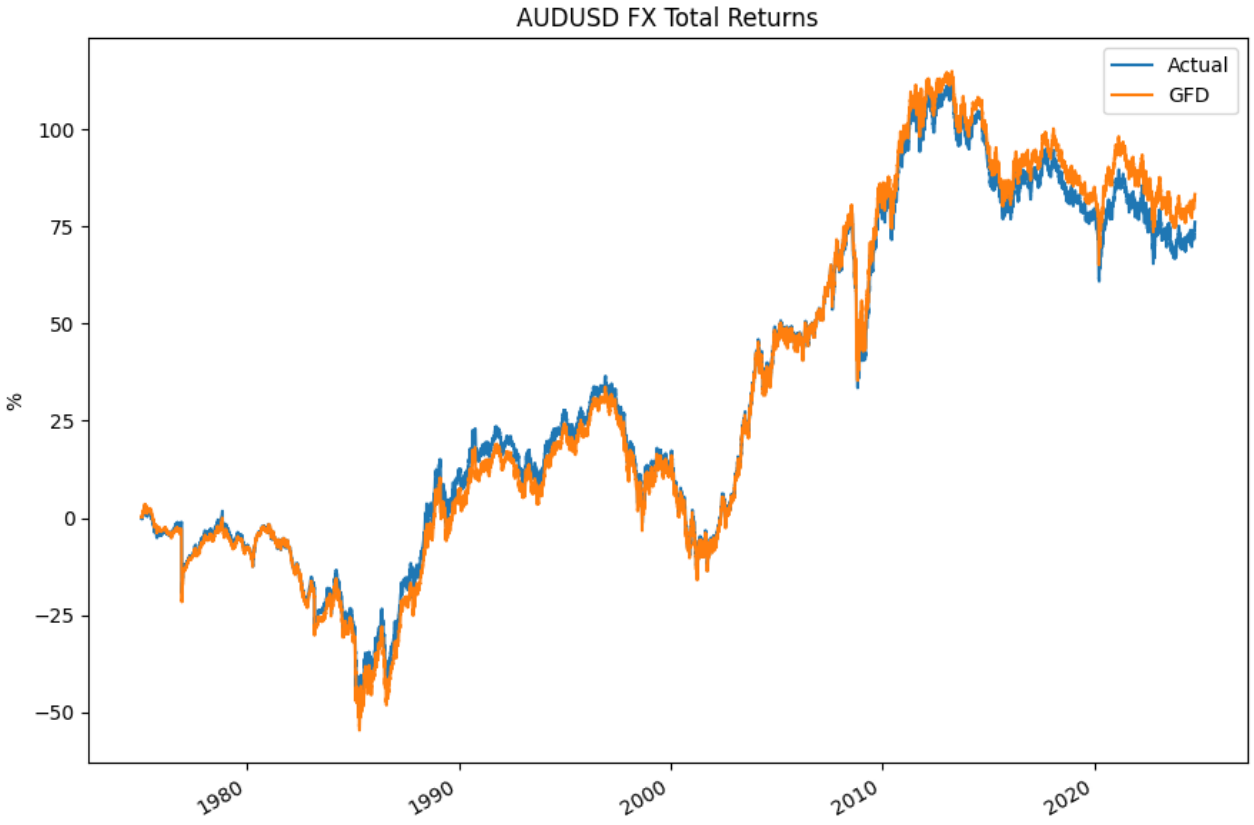


Exhibit A2: AUDUSD Total Return Comparison

Comparison of the total return of the synthetic FX forward for AUDUSD against the actual total returns from holding the FX forward contracts. The data runs from January 1975 to June 2024.



Equity Data

For our analysis of equity returns, we use monthly return data. We use a combination of cash equity returns from Global Financial Data (GFD)and futures returns. For the cash equity returns, we convert these to excess returns by subtracting the return on 3-month bills in the local currency. The returns on 3-month bills are also obtained from GFD. Futures returns are taken from AHL's own database. We use futures returns once they are available and backfill them with the data from GFD before that. Exhibit 1 shows the cash and futures start dates for each of the markets used and gives a summary of the excess returns of each of the markets.

World Equity Weights

There are two key limitations of our approach to constructing a representative world equity basket. First, we are deflating the relative equity weights using the total USD equity returns. The total returns include cash dividends, which do not contribute to the growth of the equity market. To the extent that cash dividend payout rates differ across regions, this will cause the actual weights to diverge from the deflated weights. Secondly, equity market returns only capture the change in size of a country's equity market due to the growth of its existing companies. A country's equity market can also grow or shrink in size due to listings and delistings. To test the robustness of our approach, we compared the weights we would obtain by deflating the MSCI World weights from

the end of December 2023 to the actual weights that we had from September 2004 onwards. For most regions, the weights tracked extremely closely. However, we did see differences in some regions.[28]

Crisis Period Start and End Dates

Crisis	Start Date	End Date
Black Monday	01/08/1987	31/10/1987
Gulf War	01/07/1990	31/10/1990
Asian Crisis	01/07/1998	31/08/1998
Tech Burst	01/09/2000	31/10/2002
Financial Crisis	01/10/2007	31/03/2009
Euro Crisis I	01/04/2010	31/07/2010
Euro Crisis II	01/04/2011	31/10/2011
Q4 2018	01/09/2018	31/12/2018
COVID-19	01/02/2020	31/03/2020
2022 Inflation	01/01/2022	30/09/2022

Inflation Period Start and End Dates

Inflationary Period	Start Date	End Date
OPEC oil embargo	01/07/1972	31/12/1974
Iranian Revolution	01/02/1977	31/03/1980
Reagan's Boom	01/02/1987	30/11/1990
China demand boom	01/09/2007	31/07/2008
Post-Covid	01/03/2021	30/06/2022

[28] For example, in the UK, our deflated weights were lower than the actual weights. This is driven by the fact that the UK has seen number of large companies, such as BHP Group, switching their listing away from the UK.

Appendix A2: Pre- and Post-Euro Excess Equity Returns by Home Currency

Exhibit A3: Annualized Excess Equity Returns by Eurozone Currency

Annualized excess returns for an investor in a given home currency investing in individual foreign equity markets with their FX exposure unhedged. We highlight in blue those cases where an investor in a given home currency would have realized higher returns by hedging. We highlight in yellow, those cases where an investor in a given home currency would have realized higher returns by leaving their FX exposure unhedged. We show the returns a Eurozone investor would have realized, broken down into the pre- and post-Euro period.

		Equity Market										
		USD	AUD	CAD	DEM	ESP	FRF	GBP	ITL	JPY	NLG	Mean
Home Currency	January 1999 - June 2024											
	EUR Hedged	6.1%	5.6%	6.8%	5.6%	4.6%	5.8%	2.9%	4.2%	6.1%	5.3%	5.3%
	EUR Unhedged	7.6%	9.1%	8.9%	5.6%	4.6%	5.8%	3.6%	4.2%	4.2%	5.3%	5.9%
	January 1973 - December 1998											
	DEM Hedged	6.7%	8.8%	3.7%	5.0%	3.7%	6.9%	8.2%	4.3%	2.2%	10.6%	6.0%
	DEM Unhedged	6.3%	9.9%	2.8%	5.0%	4.3%	7.7%	8.6%	4.9%	2.6%	10.8%	6.3%
	ESP Hedged	6.8%	8.6%	3.8%	4.9%	3.7%	6.9%	8.2%	4.1%	2.2%	10.5%	6.0%
	ESP Unhedged	6.1%	8.4%	2.6%	5.1%	3.7%	7.7%	8.4%	4.6%	2.5%	11.0%	6.0%
	FRF Hedged	6.7%	8.7%	3.7%	4.9%	3.7%	7.0%	8.1%	4.3%	2.2%	10.6%	6.0%
	FRF Unhedged	5.6%	8.6%	2.1%	4.4%	3.7%	7.0%	7.9%	4.2%	1.9%	10.3%	5.6%
	ITL Hedged	6.8%	8.7%	3.7%	4.8%	3.5%	6.9%	8.3%	3.8%	2.1%	10.6%	5.9%
	ITL Unhedged	6.0%	7.5%	2.4%	4.9%	3.9%	7.5%	8.4%	3.8%	2.3%	10.8%	5.8%
	NLG Hedged	6.7%	8.8%	3.7%	4.9%	3.7%	7.0%	8.1%	4.3%	2.2%	10.7%	6.0%
	NLG Unhedged	6.0%	9.3%	2.5%	4.7%	4.0%	7.4%	8.3%	4.6%	2.3%	10.7%	6.0%

Appendix A3: Calculating Arithmetic Hedged and Unhedged Excess Returns

The total return of the local equity in its local currency:

$$(R_{t,T}^{local} + i_{t,T}^{mkt})$$

Therefore, the unhedged total return of the local equity in the home currency is:

$$(R_{t,T}^{local} + i_{t,T}^{local}) * (1 + R_{t,T}^{spot}) + R_{t,T}^{spot}$$

Where the first term represents the total return in local currency converted to the home currency and the second term represents the FX return of the initial investment.

As such, the unhedged excess return between time t and time T for an investor in a given home currency investing in an equity in a different local currency can be written as:

$$R_{t,T}^{unhedged} = (R_{t,T}^{local} + i_{t,T}^{local}) * (1 + R_{t,T}^{spot}) + R_{t,T}^{spot} - i_{t,T}^{home}$$

Where:

- $R_{t,T}^{local}$ is the equity market's excess return in its local currency between time t and time T

- $R_{t,T}^{spot}$ is the spot FX return between time t and time T. A positive value for $R_{t,T}^{spot}$ indicates that the equity market's local currency has appreciated against the home currency, while a negative value indicates that it has depreciated.

- $i_{t,T}^{local}$ and $i_{t,T}^{home}$ are the annualized funding rates in the equity market's local currency the and home currency respectively

The first term represents the equity return, adjusted for the change in the spot exchange rate. The second term represents the change in value of the initial investment due to changes in the spot rate of FX. The final term is required to convert the return from an excess return in the local currency to an excess return in the home currency (i.e., adding the local funding rate back into the equity return and subtracting the funding rate in the home currency).

Now, if we would like to instead hedge our returns, we can enter into a forward contract to hedge our initial FX investment. The hedged excess return on this investment is given as:

$$R_{t,T}^{hedged} = (R_{t,T}^{local} + i_{t,T}^{local}) * (1 + R_{t,T}^{spot}) + R_{t,T}^{spot} - R_{t,T}^{FX\ Fwd} - i_{t,T}^{home}$$

Again, as $R_{t,T}^{spot} * i_{t,T}^{local}$ is small, this can be written approximately as:

$$R_{t,T}^{hedged} \cong R_{t,T}^{local}(1 + R_{t,T}^{spot}) + R_{t,T}^{spot} - R_{t,T}^{FX\ Fwd} + (i_{t,T}^{local} - i_{t,T}^{home})$$

Where the first term is the excess return on the local equity adjusted for the change in spot rate (this return cannot be hedged as it is not known in advance). The second term represents the spot return on the initial investment. The third term is the return on the FX hedge. The final term adds back the local funding rate and removes the funding rate in the home currency as an adjustment to convert the return from an excess return in the local currency to one in the home currency.

Recalling that, under Covered Interest Rate Parity, the return on an FX forward should be given by

$$R_{t,T}^{FX\ Fwd} = R_{t,T}^{spot} + (i_{t,T}^{local} - i_{t,T}^{home})$$

We can rewrite the hedged excess equity return as:

$$\boldsymbol{R_{t,T}^{hedged} = R_{t,T}^{local}\left(1 + R_{t,T}^{spot}\right)}$$

This equation highlights the limits of FX hedging: While we can hedge our known initial investment, we cannot hedge our unknown investment returns.

Furthermore, from the equations above, we get the intuitive result that:

$$\boldsymbol{R_{t,T}^{hedged} = R_{t,T}^{unhedged} - R_{t,T}^{FX\ Fwd}}$$

Appendix A4: Real Interest Rate Differentials in Emerging Markets

In Exhibit A4, we repeat the exercise from section 4.1, where we looked at the performance of an FX strategy that is always positioned to earn carry in each market. However, in this exercise, we use a measure of real carry, rather than nominal carry.

To calculate the real carry, we create a measure of the real interest rate in each country by subtracting the realized inflation, as measured by the annualized change in CPI, from the nominal interest rate. This is clearly an imperfect measure, as it is comparing the current interest rate to a trailing inflation measure. A number of forward-looking inflation measures exist, such as consensus estimates and breakeven inflation rates. However, these measures do not have the breadth of coverage or sufficient history to be appropriate for our analysis. We instead see if this crude measure can improve performance.

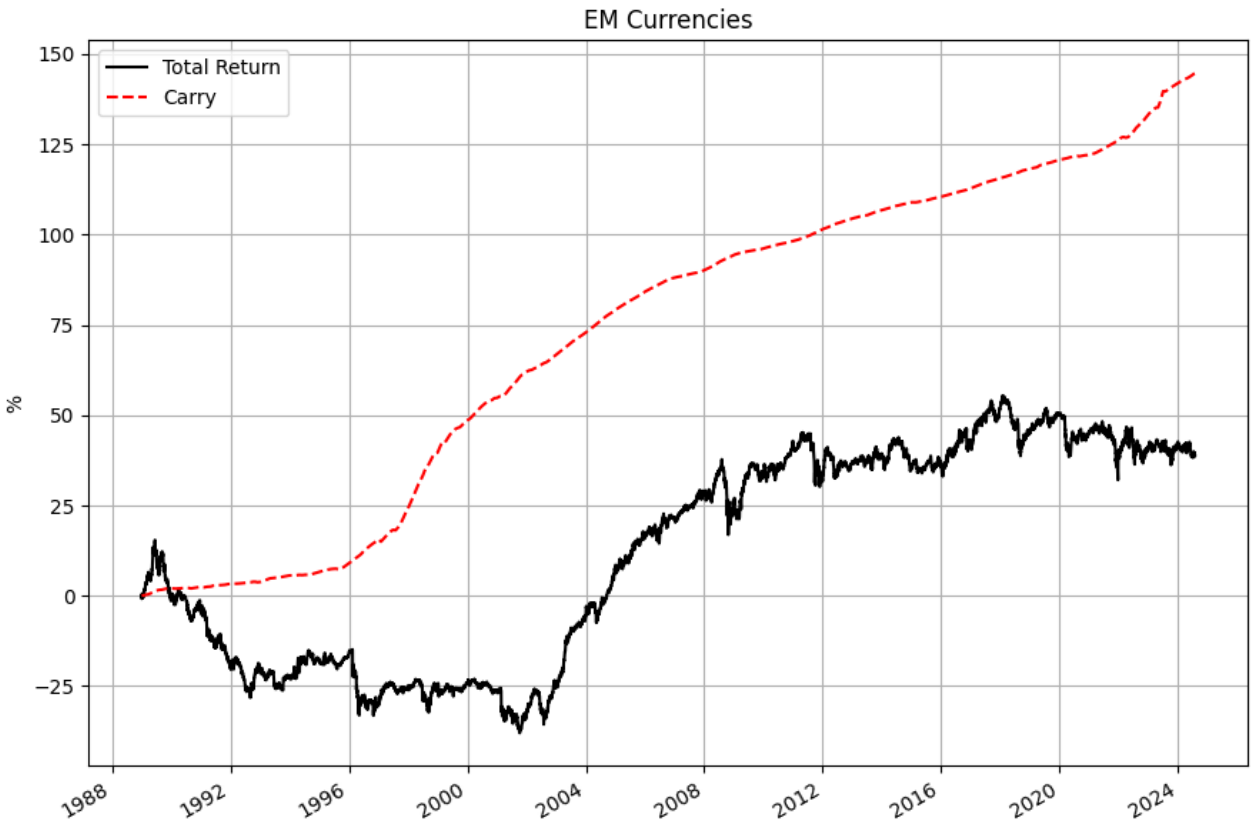
Relative PPP suggests that the ratio between the cost of a basket of goods in two different currencies should be constant; as such, if the rate of inflation is higher in one country than another, its currency should depreciate in order to keep the ratio constant. If this holds true, it suggests that an investor can only earn the real interest rate differential, not the nominal interest rate differential. The effect of differences in inflation rates is easier to discount in developed markets, where differences in inflation rates are typically small.[29] However, when comparing emerging markets to developed markets, the effects are often too large to ignore.[30]

In Exhibit A4, we can see that the absolute difference between the expected carry and realized carry is much lower than we saw in Exhibit 5. The fraction of carry earned only increases slightly from 23.6% to 28%.

[29] Small differences may also be as much to do with different inflation rate methodologies between countries as actual differences in inflation.
[30] For example, in Turkey, the measured inflation rate reached 85.5% in October 2022.

Exhibit A4: Emerging Markets Total Return vs. Carry

The black line shows the total returns that we would earn if we invested equally in each of the emerging market currencies against the USD, always taking a position in the direction to earn real carry. Real carry measures the difference in real interest rates between two countries. We calculate real interest rates by subtracting the realized annual inflation rate in each country from the nominal interest rate. Specifically, for each currency, we take a long position against the USD if that currency has a higher real interest rate at the end of the previous month and take a short position against the USD if not. The red dotted line shows the total carry that we would earn if the change in spot prices over each period moved in line with the measured relative inflation rates. The data runs from January 1989 to June 2024.



Appendix A5: Finding the Optimal Hedge Ratio to Minimize Volatility for a Single Foreign Equity Exposure

The partially hedged equity returns for a single foreign equity market can be written as:

$$h_i R_{T,t}^{hedged_{i,j}} + (1 - h_i) R_{T,t}^{unhedged_{i,j}}$$

Where:

- $R_{T,t}^{hedged_{i,j}}$ is hedged equity return between time t and T of an equity denominated in currency i for an investor whose home currency is j
- $R_{T,t}^{unhedged_{i,j}}$ is unhedged equity return between time t and T of an equity denominated in currency i for an investor whose home currency is j
- h is the percentage of the equity exposure that is hedged.

In Appendix A.3, we show that $R_{T,t}^{hedged_{i,j}}$ is equivalent to $R_{T,t}^{unhedged_{i,j}} - R_{t,T}^{FX\ Fwd_{j,i}}$

Where $R_{t,T}^{FX\ Fwd_{j,i}}$ is the return of an FX forward that is long currency j and short currency i

As a result, we can rewrite the partially hedged equity return as:

$$R_{T,t}^{hedged_{i,j}} + (1 - h) R_{T,t}^{FX\ Fwd_{i,j}}$$

The volatility of the partially hedged returns can then be written as:

$$\sigma_{hedged}^2 + (1 - h)^2 \sigma_{FX}^2 + 2(1 - h) \rho_{FX,hedged} \sigma_{hedged} \sigma_{FX}$$

If we take the derivative of this with respect to h and set it to zero, we the find that the optimal hedge ratio to minimize the volatility of the hedged equity returns is

$$1 + \frac{\rho_{FX,hedged} \sigma_{hedged} \sigma_{FX}}{\sigma_{FX}^2}$$

Which is simply $1 + \beta_{hedged,fx}$, where $\beta_{hedged,fx}$ is the beta of the (hedged) excess equity returns to the FX forward returns.

Assuming that the hedge ratio is bounded between 0 and 1, this suggests that, if a given country's local currency is positively correlated with its local equities, then an investor with a different home currency should fully hedge their FX exposure to minimize their portfolio volatility. However, if the local currency is negatively correlated with the local equity returns, then the optimal hedge ratio to minimize the portfolio volatility will be less than 1.

Appendix A6: Finding the Optimal Hedge Ratio for a Single Foreign Equity Exposure

If we consider an investor who is invested in a single foreign equity, with risk aversion $\boldsymbol{\lambda}$, we can calculate their optimal FX exposure by maximizing:

$$\boldsymbol{w_{eq}\mu_{eq} + w_{fx}\mu_{fx} - \lambda(w_{eq}^2\sigma_{eq}^2 + w_{fx}^2\sigma_{fx}^2 + 2w_{eq}w_{fx}\rho_{eq,fx}\sigma_{eq}\sigma_{fx})}$$

Where:

- $\boldsymbol{w_{eq}}$ is the weight invested in the equity market
- $\boldsymbol{w_{fx}}$ is the weight invested in the equity market's local currency (this is the same as $\boldsymbol{1 - h}$ where $\boldsymbol{h}$ is the percentage of the equity market's local FX exposure that is hedged)
- $\boldsymbol{\mu_{eq}}$ is the expected excess return of the hedged equity market
- $\boldsymbol{\mu_{fx}}$ is the expected return of the FX pair (ie. the return of the equity market's local currency against the home currency)
- $\boldsymbol{\sigma_{eq}}$ and $\boldsymbol{\sigma_{fx}}$ are the volatilities of the equity and the FX pair
- $\boldsymbol{\rho_{eq,fx}}$ is the correlation between the excess equity returns and the FX returns

If we assume that the investor is fully invested in the equity ($\boldsymbol{w_{eq} = 1}$), then this expression is maximized when $\boldsymbol{w_{fx}}$ is:

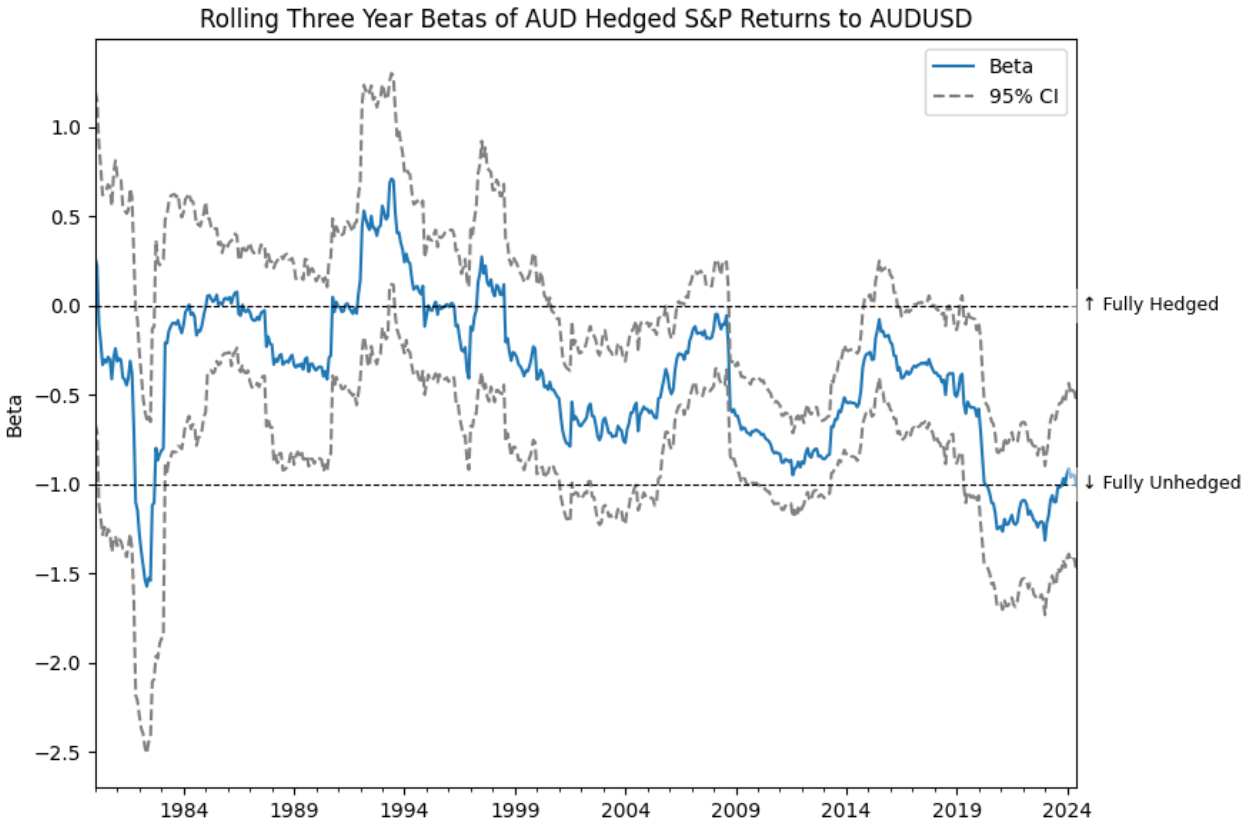
$$\boldsymbol{\frac{\mu_{fx}}{2\lambda\sigma_{fx}^2} - \beta_{eq,fx}}$$

Which implies that the optimal hedge ratio is given as: $\boldsymbol{h^* = 1 - \frac{\mu_{fx}}{2\lambda\sigma_{fx}^2} + \beta_{eq,fx}}$.

Appendix A7: Rolling Betas of AUD Hedged S&P Returns to AUDUSD

Exhibit A5: Rolling Three Year Betas of AUD Hedged S&P Returns to AUDUSD

In this plot, we show the rolling three-year betas of the S&P excess returns hedged to USD to the AUDUSD FX Forward Return. We also show the 95% Confidence Intervals for the Betas



Appendix A8: Global Equity Returns and Volatility by Hedging Approach

Exhibit A6: Annualized Returns of Global Equity Returns by FX Hedging Approach

In this table, we show the annualized excess returns from investing in global equities from a given base currency on each of the hedging rules that we have examined in this paper. For each currency, we highlight the hedging approach with the highest historical returns in green and the hedging approach with the lowest returns in red. The returns are calculated from April 1976 to June 2024. Each individual currency starts three years and one month after the start date for the FX returns in Exhibit 1. We start at this point because a three year "burn-in" is required to calculate covariances. All Eurozone currencies are stitched with the Euro from 1999.

	Unhedged	Hedged	Min Vol	Max Carry	Optimal	Mom	PPP	Blend
Developed Markets								
USD	5.5%	5.3%	5.5%	5.9%	5.8%	6.1%	5.6%	5.9%
AUD	4.3%	5.0%	4.1%	6.0%	5.3%	4.4%	6.0%	5.3%
CAD	5.5%	4.9%	5.2%	5.4%	5.4%	5.9%	5.9%	5.8%
CHF	6.0%	5.3%	5.5%	6.4%	6.9%	6.2%	6.4%	6.5%
DEM	5.8%	5.2%	5.7%	6.7%	6.6%	6.1%	6.1%	6.3%
ESP	5.3%	5.2%	6.0%	6.3%	6.0%	5.9%	5.7%	5.9%
FRF	5.5%	5.2%	5.8%	6.7%	6.5%	5.9%	5.8%	6.1%
GBP	5.0%	5.1%	5.7%	5.8%	6.0%	5.9%	6.1%	6.0%
ITL	4.8%	5.2%	5.9%	6.1%	6.0%	5.2%	5.6%	5.6%
JPY	7.0%	5.4%	5.6%	7.0%	7.2%	8.0%	6.5%	7.3%
NLG	5.5%	5.2%	5.7%	6.8%	6.8%	5.8%	6.1%	6.3%
NOK	5.9%	5.0%	5.7%	6.4%	6.4%	5.9%	6.6%	6.3%
NZD	3.0%	4.7%	3.9%	4.9%	4.9%	4.9%	5.3%	5.1%
SEK	6.3%	5.0%	5.9%	7.2%	6.6%	6.3%	6.6%	6.6%
Emerging Markets								
BRL	2.4%	6.6%	4.6%	6.6%	6.4%	6.5%	6.6%	6.6%
CLP	5.4%	4.7%	4.1%	4.6%	4.1%	4.0%	4.7%	4.4%
MXN	2.8%	4.2%	3.5%	4.2%	4.3%	3.6%	4.2%	4.1%
TRY	1.7%	3.4%	3.0%	3.4%	3.5%	0.2%	3.4%	2.5%
ZAR	4.5%	4.8%	5.6%	4.8%	4.9%	4.5%	4.8%	4.9%

Exhibit A7: Annualized Volatility of Global Equity Returns by FX Hedging Approach

In this table, we show the annualized volatility from investing in global equities from a given home currency on each of the hedging rules that we have examined in this paper. For each currency, we highlight the hedging approach with the lowest historical volatility in green and the hedging approach with the highest historical volatility in red.

The returns are calculated from April 1976 to June 2024. Each individual currency starts three years and one month after the start date for the FX returns in Exhibit 1. We start at this point because a three year "burn-in" is required to calculate covariances. All Eurozone currencies are stitched with the Euro from 1999.

	Unhedged	Hedged	Min Vol	Max Carry	Optimal	Mom	PPP	Blend
Developed Markets								
USD	14.7%	13.7%	13.7%	14.2%	13.8%	14.1%	14.0%	13.9%
AUD	14.1%	14.2%	12.9%	13.6%	13.2%	13.9%	13.6%	13.1%
CAD	12.9%	13.8%	12.5%	13.4%	12.7%	13.1%	13.2%	12.8%
CHF	16.5%	13.6%	13.5%	15.9%	15.1%	15.1%	15.6%	15.0%
DEM	15.3%	13.7%	13.3%	14.8%	14.1%	14.5%	14.3%	14.0%
ESP	15.4%	13.7%	13.3%	14.0%	13.5%	14.5%	13.5%	13.6%
FRF	15.1%	13.7%	13.3%	14.2%	13.6%	14.4%	14.1%	13.8%
GBP	14.7%	13.7%	13.2%	13.6%	13.3%	13.8%	14.0%	13.5%
ITL	15.0%	13.7%	13.3%	13.9%	13.5%	14.3%	13.5%	13.5%
JPY	16.5%	13.6%	13.6%	16.0%	15.1%	15.2%	15.6%	15.0%
NLG	15.3%	13.7%	13.3%	14.6%	13.9%	14.5%	14.1%	13.9%
NOK	14.4%	13.8%	12.9%	14.0%	13.3%	13.9%	14.3%	13.5%
NZD	14.6%	13.8%	13.0%	13.6%	13.2%	13.6%	13.6%	13.0%
SEK	14.6%	13.8%	13.2%	13.7%	13.1%	13.9%	14.5%	13.5%
Emerging Markets								
BRL	15.8%	14.1%	12.8%	14.1%	14.1%	15.2%	14.1%	13.8%
CLP	14.5%	14.6%	13.3%	14.6%	14.1%	14.3%	14.6%	13.8%
MXN	13.2%	14.7%	12.6%	14.8%	14.4%	14.3%	14.7%	14.2%
TRY	20.9%	15.0%	13.9%	15.0%	14.9%	17.8%	15.0%	15.1%
ZAR	16.3%	14.1%	13.1%	14.1%	13.9%	14.9%	14.1%	13.5%