Are Intermediary Constraints Priced?*

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Abstract

Violations of no-arbitrage conditions measure the shadow cost of intermediary constraints. Intermediary asset pricing and intertemporal hedging together imply that the risk of these constraints tightening is priced. We describe a "forward CIP trading strategy" that bets on CIP violations shrinking and show that its returns help identify the price of this risk. This strategy yields the highest returns for currency pairs associated with the carry trade. The strategy's risk contributes substantially to the volatility of the stochastic discount factor, is correlated with both other near-arbitrages and intermediary wealth measures, and appears to be priced consistently across various asset classes.

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1 Introduction

Covered interest parity (CIP) violations post the Global Financial Crisis (GFC) have been interpreted by many authors as a sign that intermediaries are constrained (e.g. Du et al. (2018b), Avdjiev et al. (2019), Fleckenstein and Longstaff (2018), Hébert (2018)). Meanwhile, the intermediary asset pricing literature argues that constraints on intermediaries have important implications for asset prices (see, e.g., Kondor and Vayanos (2019), and He and Krishnamurthy (2017) for a survey). In this paper, we combine these two ideas, and provide direct evidence that the risk of intermediary constraints becoming larger is priced. Our results offer novel evidence in support of intermediary-based asset pricing.

We begin by demonstrating, in a standard intermediary asset pricing model, that the intermediaries' stochastic discount factor (SDF) is a function of the return on intermediary wealth and the magnitude of a cross-currency basis (i.e. a CIP violation). The existence of liquid foreign exchange (FX) and interest rate derivatives across very granular maturities allows us to directly measure innovations to intermediaries' SDF due to shocks to the cross-currency basis. We argue that the most straightforward test of this model is a test of whether "forward CIP trading strategies" that bet on arbitrages becoming smaller earn excess returns.

We then proceed to the data, and estimate the excess returns of these forward CIP trading strategies. We define the forward CIP trading strategy as using FX forwards and forward-starting interest rate swaps to conduct a forward-starting CIP trade, and then unwinding the trade at its forward starting date. Consider a trader who, at time t, first enters into a forward-starting CIP trade to go long Japanese yen and short Australian dollars for three months between $t + 1$ and $t + 4$, with the currency risk fully hedged. We refer to this trade as a one-month forward three-month CIP trade. Then in a month, at $t + 1$, the trader unwinds the forward CIP trade by going long Australian dollars and short Japanese yen for three months, cancelling all the promised cash flows of the forward CIP trade. The profits of this two-step forward CIP trading strategy are proportional to the difference between the market-implied one-month forward three-month CIP deviation observed at t and the actual three-month CIP deviation realized one month later at $t + 1$. The forward CIP trading strategy has a positive (negative) return if the future CIP deviation is smaller (bigger) than the market-implied forward CIP deviation today.

The expected return on the forward CIP trading strategy offers a direct test of intermediary asset pricing theories in which large positive CIP deviations indicate that intermediaries are very constrained, because the forward CIP trading strategy pays off poorly in these constrained states. If the constraints of financial intermediaries are indeed a priced factor, we should expect the forward CIP trading strategy to earn positive excess returns on average, as a risk premium to compensate investors for bearing the systematic risk exposure to variations in the shadow cost of intermediary constraints.

We find that there is a significant risk premium in the forward CIP trading strategy during the post-GFC period. Specifically, we study our forward CIP trading strategy for seven of the most liquid currencies: Australian dollar (AUD), Canadian dollar (CAD), Swiss franc (CHF), euro (EUR), British pound (GBP), Japanese yen (JPY), and U.S. dollar (USD). We consider both the cross-currency basis vis-à-vis the USD and the basis between two non-USD cross pairs.

We find that there is a strong relationship between the spot cross-currency basis, interest rate differentials, and forward CIP trading profits. For the USD-based pairs post-GFC, the forward CIP trading strategy going long the USD and shorting the foreign currency in the initial forward CIP trade generates positive average returns for high interest rate currencies, such as AUD and CAD, and negative average returns for low-interest-rate currencies, such as JPY.[1] In contrast, the returns of the forward CIP trading strategy pre-GFC were negligible.

Our model emphasizes the importance of the currency pairs with the largest spot cross-currency bases. We show that the average returns of the forward CIP trading strategies for these pairs are generally sizable and statistically significant post-GFC. In particular, the forward CIP trading strategy for the "classic carry" AUD-JPY pair has annualized average profit equal to 14 basis points and an annualized Sharpe ratio of roughly 1.4.

We also examine the performance of the forward CIP trading strategies for portfolios of currency pairs. The returns of the forward CIP trading strategy (henceforth "forward CIP returns") are significant and positive post-GFC for portfolios of currency pairs with large interest rate differentials and large spot cross-currency bases. In contrast, we do not find evidence of risk premia when using a dollar strategy that equally weights all currencies vis-à-vis the USD. The strong performance of the carry and the basis portfolios and the lack of significance of the dollar portfolio are consistent with our model's prediction that the largest

[1]Positive returns for the low-interest-rate currencies can be achieved by switching the direction of the forward CIP arbitrage to go long the foreign currency and short the USD in the initial forward CIP trade.

CIP violations are most informative about intermediary constraints.

Intermediary constraints, if present, should affect many asset markets beyond the FX market. We show that CIP deviations are correlated with the first principal component of various other near-arbitrages. We also show that the returns of the forward CIP trading strategy are correlated with the proxies for intermediary wealth returns of He et al. (2017).

However, the correlation between the forward CIP return and the intermediary equity return measure of He et al. (2017) cannot explain the risk premium we uncover. We demonstrate this in regressions and more formally using the Bayesian factor model comparison method of Barillas and Shanken (2018) and Chib et al. (2020). These results justify the inclusion of the forward CIP return as an additional factor (along with the intermediary wealth return) in the SDF, consistent with our model. In particular, the results suggest that intermediaries are risk-tolerant and perceive strategies that perform poorly when investment opportunities are best to be especially risky.

We then test whether the excess returns of the tradable factors in this SDF (intermediary equity and the forward CIP return) are consistent with the prices of risk implied by the cross-section of assets, in an exercise building on He et al. (2017) and related to Hu et al. (2013) and Pasquariello (2014).[2] We cannot reject the hypothesis that this risk is priced consistently across the various asset classes we consider, even when pooling across asset classes.

Our paper sits at the intersection of literature on arbitrage and on intermediary asset pricing. Recent empirical work on covered interest parity violations has documented the existence and time series properties of spot CIP arbitrages, as well as the quarter-end dynamics of these arbitrages arising from post-GFC bank regulations (for example, Du et al. (2018b)).[3]

[2]We focus on arbitrage opportunities post-GFC, which we attribute to constraints on financial intermediaries resulting from post-GFC regulations, whereas Hu et al. (2013) and Pasquariello (2014) study mostly pre-GFC price dislocations attributable to transaction costs, stale prices, and related issues. Their results can be seen as demonstrating that marginal utility is high when transaction costs are high.

[3]Besides Du et al. (2018b), there has been a large recent literature on CIP deviations post-GFC. For example, Borio et al. (2016) argue that hedging demand of different national banking systems can help explain cross-sectional variations in CIP deviations. Rime et al. (2019) discuss the role of market segmentation in explaining CIP violations. Anderson et al. (2019) measure the amount of potential arbitrage capital available to global banks for CIP arbitrage. Liao (2019) finds that CIP deviations post-GFC affects the corporate sector's funding currency decision. Avdjiev et al. (2019) examine the relationship between CIP deviations, the dollar exchange rate, and the cross-border bank flows in dollars. Du et al. (2018a) and Jiang et al. (2018), and Krishnamurthy and Lustig (2019) use the CIP deviations for government bond yields to measure convenience yield differentials between safe-haven government bonds and study implications for exchange rate dynamics.

Spot CIP arbitrage opportunities exist at very short horizons (e.g. overnight), making it difficult for any risk-based story to explain the existence of these arbitrages. This differentiates our work from the large literature on "limits to arbitrage" that focuses the convergence risk.[4] Instead, short-dated CIP deviations can exist because of *constraints* on intermediaries, and in particular, non-risk-weighted total leverage constraints in the post-GFC regulatory environment. Other authors, including Boyarchenko et al. (2018), also attribute the existence a broad class of arbitrages post-GFC to the leverage ratio constraints. Fleckenstein and Longstaff (2018) link the cash-derivative basis in the interest rate future market to the cost of renting financial intermediary balance sheet space. Hébert (2018) interprets these arbitrages through an optimal policy framework.

We broaden this burgeoning literature on constraints-induced arbitrage by studying the term structure of arbitrage violations, as opposed to spot arbitrage violations, and emphasizing the general asset pricing implications of these deviations. In particular, we show that a significant fraction of the time-series variation in spot CIP violations is anticipated by the forward curve of CIP violations. This is true both generally and with respect to the quarter-end spikes documented in Du et al. (2018b).

Within the intermediary asset pricing framework (surveyed by He and Krishnamurthy (2017)), models such as Gabaix and Maggiori (2015) and Fang (2018) feature intermediary constraints as explanations of exchange rates dynamics. Unlike much of this literature, which considers constraints that limit intermediaries' ability to access investments with favorable risk/return trade-offs, we emphasize constraints that inhibit true arbitrages. In this respect, our model builds on Garleanu and Pedersen (2011). We also contribute to this literature by emphasizing the importance of intertemporal hedging considerations, following Campbell (1993) and Kondor and Vayanos (2019), whereas much of the literature (e.g. He and Krishnamurthy (2011), Garleanu and Pedersen (2011), and He et al. (2017)) relies on log utility for intermediaries and neglects these considerations.

In taking the model to the data, we are building on He et al. (2017), Adrian et al. (2014), Hu et al. (2013), and Haddad and Muir (2020). Specifically, our model can be thought of as nesting the SDFs discussed by Adrian et al. (2014) and He et al. (2017). When risk aversion is equal to one, the intertemporal terms in our SDF vanish, and the intermediary wealth return is the SDF (as in He et al. (2017)). When risk aversion is equal to zero

[4] See e.g. Shleifer and Vishny (1997), Liu and Longstaff (2003), Duarte et al. (2007) and Duffie (2010).

(the risk-neutral case), the SDF consists only of intertemporal hedging terms, which are proxied for by the shadow cost of intermediary constraints (as in Adrian et al. (2014)). We measure these shadow costs using CIP violations, which we argue in the context of our model is a clean and valid measure. In contrast, Adrian et al. (2014) measure these shadow costs using leverage. It is not clear, however, whether the price of leverage risk comes from its correlation with intermediary wealth returns, its correlation with intermediary shadow costs, or some combination thereof. Closer in spirit to our exercise is Hu et al. (2013), who measure intermediary constraints using treasury yield curve dislocations. A comparison to this approach reveals the second key advantage of using CIP violations to measure shadow costs: we can directly estimate the price of risk from our forward arbitrage trading strategy, instead of relying on the usual cross-sectional asset pricing analysis. We focus our analysis on this direct estimate of the price of risk, and verify in our cross-sectional analysis that the price of risk we infer from the cross-section is consistent with the price of risk we estimate directly.

We begin by outlining the key elements of our model in section 2. We then describe our forward CIP trading strategy and the relevant data in section 3. Section 4 presents our main results on excess returns and high Sharpe ratios for these strategies. Section 5 discusses additional implications of our model and our results, and argues for the inclusion of the forward CIP return in models of the SDF. We conclude in section 6.

2 Hypothesis and Model

In the empirical analysis that follows, we will test the hypothesis that changes in the magnitude of cross-currency bases (i.e. CIP violations) are a priced risk factor. This hypothesis is motivated by an intermediary asset pricing model, which we outline below and describe in detail in the Internet Appendix Section B. The purpose of the model is both to motivate the hypothesis and to provide a framework to interpret our results. The model is a discrete time version of He and Krishnamurthy (2011) that incorporates a regulatory constraint (building on He and Krishnamurthy (2017)) and intertemporal hedging considerations (following Campbell (1993)).

In particular, we are motivated by log SDFs m_{t+1} of the form

$$m_{t+1} = \mu_t - \gamma r^w_{t+1} + \xi |x_{t+1,1}|, \tag{1}$$

where r^w_{t+1} is the return on the manager of an intermediary's wealth portfolio and $|x_{t+1,1}|$ is the absolute value of a one-period cross-currency basis. Our hypothesis is that ξ is economically and statistically distinguishable from zero.

The key idea behind this hypothesis is that the cross-currency basis $|x_{t,1}|$ is both a literal arbitrage and a measure of the investment opportunities available to intermediaries at time t. An arbitrage can exist only if intermediaries are constrained and cannot take advantage of the otherwise attractive investment opportunity. In the presence of such constraints, an intermediary concerned with hedging against changes in future investment opportunities should perceive assets whose returns are correlated with $|x_{t+1,1}|$ as particularly risky or safe, depending on the sign of the intermediary's intertemporal hedging concerns.

We begin by discussing intertemporal hedging. Campbell (1993) shows that SDFs with the functional form of (1) can be derived using CRRA or Epstein-Zin preferences (and assuming log-normality and homoskedasticity). In this case, $|x_{t+1,1}|$ must proxy for the revision in expectations about future investment opportunities. That is,

$$|x_{t+1,1}| - E_t[|x_{t+1,1}|] \propto \sum_{j=1}^{\infty} \rho^j (E_{t+1} - E_t)[r^w_{t+1+j}].$$

The sign of the coefficient ξ depends on whether the relative risk aversion[5] coefficient γ is greater or smaller than one ($\gamma < 1 \Leftrightarrow \xi > 0$).

The SDF in (1) nests the SDFs discussed in Adrian et al. (2014) and He et al. (2017). When $\gamma = 1$, $\xi = 0$, and the SDF is exactly the intermediary wealth return as in He et al. (2017). When $\gamma = 0$, $\xi > 0$, meaning that the marginal value of wealth is high when future investment opportunities are best (as in Adrian et al. (2014)).[6]

[5]As discussed in Campbell (1993), this result holds for both CRRA and Epstein-Zin preferences. That is, it is γ and not the elasticity of intertemporal substitution coefficient that determines the sign of ξ.

[6]Adrian et al. (2014) build on Brunnermeier and Pedersen (2009) (effectively a three-period model), and therefore summarize investment opportunities with single future return. Adrian et al. (2014) also assume investment opportunities are negatively correlated with intermediary leverage; it is not a priori clear this should be the case, but it holds in the Brunnermeier and Pedersen (2009) model.

Let us suppose the manager of an intermediary has CRRA or Epstein-Zin preferences and holds an equity claim on the intermediary.[7] The intermediary is subject to a regulatory constraint,

$$\sum_{i \in I} k^i |\alpha_t^i| \leq 1. \tag{2}$$

Here, $i \in I$ denotes an asset that the intermediary can hold, α_t^i is the intermediary's holding of asset i at time t as a share of the intermediary's equity, and k^i is an asset-specific weight in the leverage calculation. This constraint captures some of the key features of leverage ratios and risk-weighted capital requirements. First, to the extent that the k^i differ across assets, the constraint can capture risk-weights. Second, the constraint is relaxed by increasing the level of equity financing the intermediary relative to debt, holding fixed the dollar holdings of each asset. Third, the constraint can omit entirely certain assets such as derivatives, consistent with how some leverage constraints and risk-weighted capital constraints operate. To simplify our exposition, we will assume in what follows that derivatives are not included in the regulatory constraint.[8]

The manager's first-order condition for the portfolio share α_t^i is

$$E_t[\exp(m_{t+1})(R_{t+1}^i - R_t^b)] = \lambda_t^{RC} k^i sgn(\alpha_t^i), \tag{3}$$

where m_{t+1} is the manager's SDF, R_{t+1}^i is the gross return on asset $i \in I$, $R_t^b = \exp(r_t^b)$ is the gross rate on the intermediary's debt between dates t and $t+1$, $sgn(\cdot)$ is the sign function, and λ_t^{RC} is the (scaled) multiplier on the regulatory constraint.[9] Let us apply this equation to two portfolios of assets: the cross-currency basis arbitrage and the wealth portfolio.

Let S_t denote the exchange rate at time t (in units of foreign currency per U.S. dollar), and let $F_{t,1}$ denote the one-period ahead forward exchange rate. We define the spot one-period

[7]We follow He and Krishnamurthy (2011) in assuming that the manager must hold an equity claim of a certain size to avoid moral hazard. For the remainder of this section, we will assume that this constraint does not bind. We make this assumption both for simplicity and to emphasize that the regulatory constraint can bind even if the equity constraint does not. For formulas that extend to the case with a binding constraint, and a more detailed discussion of this issue, see Internet Appendix Section B.

[8]This particular functional form follows He et al. (2017). Its details are not essential for our result; in particular, we could easily accommodate a constraint that treats long ($\alpha_t^i > 0$) and short ($\alpha_t^i < 0$) positions asymmetrically. Considering regulatory constraints that include derivatives complicates the analysis but does not alter the main predictions of the model that we will take to the data.

[9]In the particular case in which $\alpha_t^i = 0$, we have the usual inaction inequalities, $-\lambda_t^{RC} k^i \leq E_t[\exp(m_{t+1})(R_{t+1}^i - R_t^b)] \leq \lambda_t^{RC} k^i$ (see Internet Appendix section B).

cross-currency basis as

$$X_{t,1} = \frac{R_t^b}{R_t^c}\frac{F_{t,1}}{S_t} - 1$$

where R_t^c is the foreign currency risk-free rate, and let $x_{t,1} = \ln(1 + X_{t,1})$ be the log version. The first order condition is, taking absolute values,

$$E_t[\exp(m_{t+1} + r_t^b)]|1 - \exp(-x_{t,1})| = \lambda_t^{RC} k^c, \tag{4}$$

where k^c is the risk-weights of the foreign currency risk-free bond.

The key takeaway from this equation is that the absolute value of the cross-currency basis can be used to measure the shadow cost of the regulatory constraint. Intuitively, if an arbitrage opportunity is available to the intermediary, the intermediary would take advantage of it if it could; therefore, the intermediary must be constrained. The size of the arbitrage opportunity can be used to measure the degree to which the constraint binds (a point emphasized by Hébert (2018)).

Let us now consider the first-order condition applied to the entire wealth portfolio (i.e. taking the α_t^i-weighted sum of Equation (3) across the various assets). In this case, by the definition of the constraint,

$$E_t[\exp(m_{t+1})(\exp(r_{t+1}^w) - \exp(r_t^b))] = \lambda_t^{RC}. \tag{5}$$

This equation captures the usual intuition that the shadow cost of the constraint is equal to the marginal value of the forgone investment opportunities. The constraint can bind only if the intermediary has valuable investment opportunities that it cannot exploit due to the constraint.

Combining these two equations to eliminate the shadow cost,

$$\frac{E_t[\exp(m_{t+1})(\exp(r_{t+1}^w - r_t^b) - 1)]}{E_t[\exp(m_{t+1})]} = \frac{|1 - \exp(-x_{t,1})|}{k_c}.$$

That is, the arbitrage available at time t can measure the investment opportunities available at time t. Log-linearizing and assuming homoskedasticity,

$$(E_{t+1} - E_t)[r_{t+1+j}^w] = (E_{t+1} - E_t)[r_{t+j}^b + k_c^{-1}|x_{t+j,1}|].$$

Thus, revisions in expected future cross-currency bases measure revisions in future investment opportunities more generally. Moreover, these effects are amplified by leverage k_c^{-1}. Because innovations to the cross-currency basis are persistent, we can proxy for revisions in expectations about $|x_{t+j,1}|$ with the innovation to $|x_{t+1,1}|$. This result, combined with intertemporal hedging, justifies the SDF of Equation (1).

This argument (described in more detail in the Internet Appendix) motivates our empirical exercise, which attempts to measure price of cross-currency basis risk (ξ). The most direct way to estimate this price of risk is to study a derivative contract whose payoff is linear in $|x_{t+1,1}|$. If such a contract has an excess return that cannot be explained by the covariance between $|x_{t+1,1}|$ and the other parts of the hypothesized SDF (i.e. r^w_{t+1}), we should conclude that innovations in the cross-currency basis are indeed a priced risk factor (or at least correlated with an omitted factor). The forward CIP trading strategy that we construct in our empirical analysis is exactly this derivative contract. The following remarks discuss some basic insights from the model that guide our empirical analysis.

Omitted Factors. Equation (1) likely omits important elements of the SDF. Any factor that predicts revisions in expectations (about the future cross-currency basis, future risk-free rates, or, in a heteroskedastic model like Campbell et al. (2018), future volatility) should also enter the SDF.

Correlation between Factors. The two factors in our SDF (the intermediary wealth return and the basis) likely move together. Because our model treats asset prices as exogenous, it makes no predictions about this co-movement. Most general equilibrium intermediary asset pricing models (e.g. He and Krishnamurthy (2011)) predict that investment opportunities are best for intermediaries precisely when intermediaries have lost wealth, and hence we should expect a negative correlation between the two factors.

Sources of Variation. Our model shows that the shadow cost of regulatory constraints can be measured with CIP violations, but is silent on why CIP violations vary over time. We expect that supply shocks (low intermediary net worth), demand shocks (e.g. changing household preferences), and changes in the structure of the regulatory constraint will all affect the shadow cost of the constraints on intermediaries. Our results demonstrate that, regardless of what is driving changes in these shadow costs, the SDF in Equation (1) should price the assets available to the intermediary.

CIP vs. Other Arbitrages. Our model places no special emphasis on CIP violations. Any arbitrage that intermediaries engage in could be used to measure λ_t^{RC}. In subsection 5.1, we argue that among various arbitrages and near-arbitrages documented in the literature, CIP violations are unique in terms of our ability to accurately measure the spot arbitrage x_t and to construct a trading strategy that directly bets on x_t becoming larger or smaller in the future. We also document that spot CIP violations are highly correlated with other arbitrages, consistent with our model.

Magnitudes. Shocks to the cross-currency basis are small (basis points). However, intermediaries are quite levered, meaning that k^c might be small, consumption-wealth ratios for managers are likely small (meaning ρ is close to one), and innovations to the basis are persistent. These forces increase the price of cross-currency basis risk, and might cause a significant fraction of the volatility of the SDF to be attributable to innovations in the basis.

Leverage Constraints post-GFC In our model, CIP violations can arise only if the regulatory constraint binds for this riskless arbitrage. In the absence of a binding constraint, CIP violations cannot exist in equilibrium, even if the inside equity constraint binds. The lack of CIP violations pre-GFC in the data is therefore consistent with the absence of non-risk-weighted leverage constraints for many banks prior to the GFC. The persistence of CIP violations and other short-term arbitrages (such as the interest rate on reserve arbitrage) post-GFC is consistent with binding leverage constraints under Basel III.[10]

Heterogeneity Across Currencies. Our description of the model has emphasized a single cross-currency basis, whereas our empirical analysis will consider a variety of currency pairs. In the context of the model, all of the cross-currency bases that the manager invests in will have the maximal arbitrage per unit risk weight available. Any basis that offers an

[10] Non-U.S. banks did not face a non-risk-weighted leverage ratio requirement prior to the 3% leverage ratio requirement under Basel III. U.S. banks had a 3% leverage ratio requirement prior to Basel III, and a 5-6% leverage ratio requirement under Basel III.

inferior level of arbitrage per unit risk weight will receive a zero portfolio weight. In particular, if the risk-weights are identical across currencies, the manager would invest only in the basis with the largest arbitrage violation. In reality, there are several reasons why a smaller measured basis might nevertheless be actively traded by intermediaries.

- Intermediaries may have some degree of market power, and face different demand curves across currencies (Wallen (2020)). Intermediaries are also heterogeneous, and in particular have different deposit bases and access to wholesale funding markets across currencies.[11]

- Some regulatory metrics, such as the liquidity coverage ratio (LCR), are monitored on the currency-by-currency basis.[12] In addition, the allocation of CIP arbitrage activities across currency pairs also affects the distribution of liquidity across different entities and jurisdictions, which could make liquidity stress tests and resolution planning rules more binding (Correa et al. (2020)). These considerations would lead to the intermediary having different shadow costs for different currencies.

- The meaning of the benchmark OIS rate varies across currencies, and it may be a better proxy for the banks' borrowing/lending costs in some currencies than in others. Heterogeneity in the basis might be caused in part by a lack of perfect comparability of interest rates across currencies.

In our empirical analysis, we strike a balance between the literal interpretation of our model and these real-world considerations by focusing on the currency pairs with the largest and most robust bases.

3 Forward CIP Arbitrage

We describe the forward CIP trading strategy that bets on the size of the future cross-currency basis in three steps. First, we revisit "spot" cross-currency bases (as in Du et al. (2018b)), and describe the cross-currency bases based on overnight index swap (OIS) rates

[11] See, for example, Rime et al. (2019) on the impact of money market segmentation on CIP deviations.

[12] Even though the Basel III LCR requirement is calculated at the aggregate level across all currencies, currency-specific LCRs are nevertheless actively monitored by bank examiners and bank internal managers.

that we use in our empirical analysis.[13] Second, we discuss "forward" cross-currency bases, constructed from forward-starting OIS swaps and FX forwards. Third, we introduce our forward CIP trading strategy, which initiates a forward-starting cross-currency basis trade but then unwinds the trade once it becomes a spot trade. This trading strategy is not itself an arbitrage, but rather a risky bet on whether available arbitrages will become bigger or smaller.

We study cross-currency bases in seven major currencies, AUD, CAD, CHF, EUR, GBP, JPY and USD.[14] We examine the bases of both individual currency pairs and portfolios of currency pairs. All data on spot and forward FX rates, interest rate swaps, and FRAs are daily data obtained from Bloomberg using London closing rates. Our dataset begins in January 2003 and ends in August 2018.[15] We divide our data into three periods based on potentially different regulatory environments facing the intermediaries: Pre-GFC, January 1, 2003 to June 30, 2007, GFC, July 1, 2007 to June 30, 2010, and Post-GFC, July 1, 2010 to August 31, 2018.

Our main analysis focuses on the post-GFC period, which features a non-risk-weighted leverage ratio constraint under the Basel III regulatory environment. This stands in sharp contrast to the pre-GFC and GFC samples, during which bank capital constraints were largely based on risk and riskless short-term CIP arbitrages faced no capital charge. An important lesson from the GFC turmoil was that the ex-ante risk weights could inaccurately reflect risk, and in 2010 the non-risk-weighted leverage ratio requirement was drafted as an important pillar of Basel III. Since then, the Basel III regulations have been finalized and gradually implemented. Even before the final rules took effect, early compliance of Basel III was common among large banking organizations, as it takes time to re-organize complex business activities. Regulators and bank shareholders may also have taken Basel

[13]For robustness, in Internet Appendix Tables A4 and A5, we also consider a forward CIP trading strategy based on interbank offer rates (IBOR) and forward rate agreements (FRAs) indexed to these IBOR rates. The OIS and FRA data for the pre-GFC period appear less reliable (more missing or erroneous values) than the data for the GFC and post-GFC periods.

[14]We began with the G10 currencies, and excluded the Norwegian Krona (NOK) and Swedish Krona (SEK) due to limited data availability on OIS rates and IBOR FRAs. We also exclude the New Zealand dollar (NZD) because the OIS floating leg for the NZD is not a market rate but rather an administered central bank policy rate, the Official Cash Rate (OFR). The OFR is not equal to the actual overnight rate in the financial market, which generally fluctuates 0.25% around the OFR.

[15]As a robustness check, in Internet Appendix Table A8 we extend our baseline sample period through March 2020 to cover the financial market turmoil during the COVID-19 pandemic and obtain similar results.

III regulatory metrics into account even before the regulations were formally implemented. See Section 4.5 for more discussion on the additional sample splits post-GFC.

3.1 OIS-Based Spot Cross-Currency Bases

We first define the τ-month tenor OIS-based spot cross-currency basis vis-à-vis the USD. Let $R^{c}_{t,0,\tau}$ denote the annualized spot gross τ-month interest rate in foreign currency c available at time t, and let $R^{\$}_{t,0,\tau}$ denote the corresponding spot rate in U.S. dollars. The middle subscript "0" denotes a spot rate (as opposed to a forward rate). We express exchange rates in units of foreign currency per USD. That is, an increase in the spot exchange rate at time t, S_t, is a depreciation of the foreign currency and an appreciation of the USD. The τ-month forward exchange rate at time t is $F_{t,\tau}$.

Following convention (e.g. Du et al. (2018b)), we define the τ-month tenor spot cross-currency basis of foreign currency c vis-à-vis the USD as

$$X^{c,\$}_{t,0,\tau} = \frac{R^{\$}_{t,0,\tau}}{R^{c}_{t,0,\tau}} \left(\frac{F_{t,\tau}}{S_t} \right)^{\frac{12}{\tau}} - 1, \tag{6}$$

and the log version as $x^{c,\$}_{t,0,\tau} = \ln\left(1 + X^{c,\$}_{t,0,\tau}\right)$. This definition is identical to the one employed in our model, except that we now consider an arbitrary tenor τ and use annualized interest rates.

The classic CIP condition is that $x^{c,\$}_{t,0,\tau} = X^{c,\$}_{t,0,\tau} = 0$. If the cross-currency basis $x^{c,\$}_{t,0,\tau}$ is positive (negative), then the direct U.S. dollar interest rate, $R^{\$}_{t,0,\tau}$, is higher (lower) than the synthetic dollar interest rate constructed from the foreign currency bond and exchange rate transactions.

The CIP condition is a textbook no-arbitrage condition if the U.S. and foreign interest rates used in the analysis are risk-free interest rates. For our main analysis, we choose OIS rates as our proxy for risk-free interest rate. The OIS rate is the fixed rate of a fixed-for-floating interest rate swap in which the floating rate is an overnight unsecured rate.[16]

The OIS is a good proxy for the risk-free rate across maturities for several reasons. First,

[16]The list of overnight reference rates for the OIS and their day count conventions for the seven major currencies currencies we study can be found in Internet Appendix Table A1. For two currencies, the OIS rate is non-standard. For CAD, the overnight rate is a repo (secured) rate; for CHF the unsecured overnight rate had volumes so low that the OIS rate was changed to reference a secured rate in 2017.

the OIS allows investors to lock in fixed borrowing and lending rates for a fixed maturity, by borrowing and lending at the nearly risk-free floating overnight rate each day over the duration of the contract. Second, the interest rate swaps themselves have very little counterparty risk, because there are no exchanges of principal, only exchanges of interest. These derivative contracts are also highly collateralized and in recently years have been centrally cleared in most major jurisdictions. Third, OIS swaps are generally very liquid and traded at a large range of granular maturities (unlike e.g. repo contracts).

Internet Appendix Figure A1 shows the three-month OIS-based cross-currency basis for the six sample currencies vis-à-vis the USD between January 2003 and August 2018. The three-month OIS basis was close to zero pre-GFC and deeply negative during the peak of the GFC. After the GFC, OIS-based CIP deviations persisted. Among our sample currencies, AUD has the most positive OIS basis, and JPY, CHF, and EUR have the most negative OIS bases. Internet Appendix Figure A2 shows three-month IBOR cross-currency bases, which follow similar patterns.

We define the spot cross-currency basis between two non-USD currencies c_1 and c_2 as the difference in their respective log cross-currency basis vis-à-vis the USD,

$$x_{t,0,\tau}^{c_1,c_2} = x_{t,0,\tau}^{c_1,\$} - x_{t,0,\tau}^{c_2,\$}. \tag{7}$$

We use this definition, as opposed to directly constructing the cross-currency basis between c_1 and c_2, both because most trades in currency forwards involve a USD leg and to restrict our sample to US FX trading days.[17]

3.2 Forward Bases

We next define a forward-starting cross-currency basis. Trading a forward starting cross-currency basis allows an agent to lock-in the price of a cross-currency basis trade that will start in the future.

We define a forward-starting cross-currency basis using forward interest rates and FX

[17]According to recent BIS FX derivatives statistics, 90% of global FX swaps have the USD on one leg. Some cross pairs, such as EURJPY and EURCHF, are actively traded. There are only negligible differences between the cross-currency basis calculated directly using the FX swap rates for the cross pairs and the basis calculated using Equation (7). The triangular arbitrage for the cross-currency basis holds quite well post-GFC because the arbitrage only involves trading FX derivatives with limited balance sheet implications.

forwards. Let $R^{c}_{t,h,\tau}$ be the h-month forward-starting annualized τ-month gross interest rate in currency c at time t, and let $R^{\$}_{t,h,\tau}$ be the equivalent rate in the USD. The forward-starting cross-currency basis of foreign currency c vis-à-vis the USD is

$$X^{c,\$}_{t,h,\tau} = \frac{R^{\$}_{t,h,\tau}}{R^{c}_{t,h,\tau}} \left(\frac{F_{t,h+\tau}}{F_{t,h}} \right)^{\frac{12}{\tau}} - 1, \tag{8}$$

and the log version is $x^{c,\$}_{t,h,\tau} = \ln\left(1 + X^{c,\$}_{t,h,\tau}\right)$. Figure 1 illustrates the definitions of the spot and forward cross-currency basis.

Equivalently, we can define the log h-month forward τ-month cross currency basis at time t in terms of two spot cross-currency bases under the assumption of no-arbitrage between forward interest rate swaps and the term structure of spot interest rate swaps:

$$x^{c,\$}_{t,h,\tau} = \frac{h+\tau}{\tau} x^{c,\$}_{t,0,h+\tau} - \frac{h}{\tau} x^{c,\$}_{t,0,h}. \tag{9}$$

The equivalence between Equations (8) and (9) is shown in Internet Appendix C. Equation (9) also shows that there is a close analogy between forward cross-currency bases and forward interest rates. As in Equation (7), we define the forward cross-currency basis between non-USD currencies c_1 and c_2 as

$$x^{c_1,c_2}_{t,h,\tau} = x^{c_1,\$}_{t,h,\tau} - x^{c_2,\$}_{t,h,\tau}. \tag{10}$$

We next consider the typical shape of the term structure of CIP violations – that is, the shape of the cross-currency basis forward curve. It is possible to construct forward CIP trades of many different horizons h and tenors τ. However, the most liquid and reliable OIS tenors are 1M, 2M, 3M, 4M, 6M, 9M, and 12M. In Figure 2, we present the forward curves of AUD and JPY vis-à-vis the USD for all reliable horizons: spot, 1M, 2M, 3M, 4M, 6M, and 9M. The tenor τ of these forward CIP trades differs, beginning at one month and increasing to three months. Internet Appendix Figure A3 presents an alternative version of the forward curve that uses only three month tenors.

We present these forward basis curves as time series averages for two currencies, AUD and JPY. These two currencies stand out in the data as having very positive/negative spot cross-currency bases vis-à-vis the USD during our post-GFC sample period, respectively. For each currency, we divide our sample into three sub-samples based on the tercile of the level of the spot 3M tenor basis. We then compute the time-series average of the spot and forward-starting cross-currency basis within each sub-sample.

From these forward curves, it is immediately apparent that the forward cross-currency bases tend to be larger (more positive) than the spot cross-currency basis for AUD, and smaller (more negative) for JPY. This fact is somewhat analogous to the tendency of the term-structure of interest rates to be upward sloping. If we think of forward cross-currency bases as being equal to expectations under a risk-neutral measure (an approach that is valid in our model despite the presence of arbitrage), then this suggests that the absolute value of spot cross-currency basis is generally expected to increase under the risk-neutral measure.

This raises the question of whether the spot cross-currency basis is also expected to increase in absolute value under the physical measure. That is, do the slopes of these forward curves reflect expectations, risk premia, or some combination thereof?

3.3 Forward CIP Trading Strategy

The forward CIP trading strategy consists of a forward cross-currency basis trade and a spot cross-currency basis trade at a later date. At time t, an agent enters into the h-month forward τ-month cross-currency basis trade. After h months, at time $t+h$, the agent unwinds the trade by shorting the then-spot τ-month cross-currency basis.

Although the forward CIP trading strategy involves two potential arbitrage opportunities, it is itself risky in that the spot τ-month cross currency basis at time $t+h$ is not guaranteed to be equal to the h-month forward τ-month cross-currency basis at time t. Figure 3 illustrates the mechanics this trading strategy.

The profits from this trading strategy are primarily a function of the realized cross-currency basis at time $t+h$ compared to τ-month forward cross-currency basis at time t. To first-order, the annualized profit per dollar notional (which can be thought of as an excess return) is

$$\pi^{c_1,c_2}_{t+h,h,\tau} \approx \frac{\tau}{h}(x^{c_1,c_2}_{t,h,\tau} - x^{c_1,c_2}_{t+h,0,\tau}). \tag{11}$$

The term $\frac{\tau}{h}$ plays the role of a duration, converting the difference between the forward and realized basis, $x^{c_1,c_2}_{t,h,\tau} - x^{c_1,c_2}_{t+h,0,\tau}$, into an annualized dollar profit per unit notional.[18]

[18] We derive this expression, which is a first-order approximation, from a more exact calculation in Internet Appendix section D.

The key property of the forward CIP trading strategy for our purposes is that it allows an intermediary to bet on whether the cross-currency basis will be higher or lower than implied by the forward cross-currency basis. Our model equates the magnitude of the basis with the degree to which regulatory constraints binds. Consequently, this strategy allows intermediaries to bet on whether constraints will be tighter or looser in the future.

The forward CIP trading strategy is a valid trading strategy even if the underlying cross-currency basis is not actually tradable or not a pure arbitrage. For example, individual arbitrageurs may not have direct access to the OIS floating leg.[19] Nevertheless, the forward CIP trading strategy is a valid trading strategy that bets on whether the basis as measured by OIS swaps referencing this rate becomes larger or smaller.

Moreover, the forward CIP trading strategy per se does not materially contribute to the balance sheet constraints of financial intermediaries, especially in comparison with the spot CIP arbitrage. This is because interest rate forwards and FX derivatives have zero value at inception. The required initial and variation margins for the derivative positions are generally a few percent of the total notional of the trade. In contrast, the spot CIP arbitrage requires actual cash market borrowing and lending, and is therefore balance sheet intensive.

4 Forward CIP Trading Strategy's Excess Returns

In this section, we present evidence that the forward CIP trading strategy is profitable on average. The excess returns are observed in certain individual currencies against the USD, in trades between cross-currency pairs, and in portfolios. We find that the currency pairs with the highest excess returns are the currency pairs associated with the "FX carry trade." These currency pairs have high interest rate differentials, large CIP violations, and unhedged currency returns that are positively correlated with returns on the S&P 500 index. We also study a one-day forward CIP arbitrage to examine balance sheet constraints on quarter-end regulatory reporting dates.

[19] In the United States, the floating leg of the OIS is the federal funds rate. Only banks with reserve accounts at the Federal Reserve can trade in the federal funds market.

4.1 USD-based Currency Pairs

We begin by discussing results for individual currencies. Panel A of Table 1 reports the profits per dollar notional on the one-month-forward three-month tenor forward CIP trading strategy in each of the six sample currencies vis-a-vis the USD. For each forward CIP trading strategy, we present the annualized mean profit per dollar notional and the Sharpe ratio, by period. Standard errors of the statistics are reported in parentheses.[20]

Beginning with the pre-GFC period, we observe that for all sample currencies vis-à-vis the USD, the pre-GFC profits are virtually zero. Post-GFC, the profits in most currencies are larger in absolute value. Some currencies such as JPY have marginally statistically significant Sharpe ratios in the pre-GFC period, but this reflects small mean profits and even smaller standard deviations. In contrast, post-GFC, four currencies vis-à-vis USD have non-trivial mean profits and both statistically and economically significant Sharpe ratios.

Panel B of Table 1 illustrates that the sign of a currency's forward CIP trading profits (vis-à-vis the USD) is related to a number of other economically important properties of the currency. AUD, CAD, and GBP have positive forward CIP arbitrage profits, while EUR, CHF, and JPY have negative forward CIP arbitrage profits. The former group are high-interest-rate "investing currencies" and the latter group are low-interest-rate "funding currencies" for the unhedged FX carry trade. In bad times (proxied by low S&P 500 returns), the "funding currencies" tend to appreciate against the USD, while the "investing currencies" depreciate. CIP deviations make "funding currencies" more appealing in terms of their synthetic dollar interest rates. These currencies have substantial negative cross-currency bases (higher synthetic dollar interest rates), whereas "investing currencies" have less negative or even positive cross-currency bases vis-à-vis USD.

Moreover, the AUD, CAD, and GBP all have an upward-sloping CIP term structure on average.[21] In contrast, EUR, CHF, and JPY have a downward-sloping CIP term structure on average. Put another way, the increases in the absolute value of the basis implied by the

[20]Means and Sharpe ratios are calculated using overlapping monthly profits per dollar notional from daily data and then scaled up by 12 and $\sqrt{12}$, respectively. We use Newey-West standard errors and the Newey and West (1994) bandwidth selection procedure, and use the "delta" method to compute standard errors for the Sharpe ratios (Lo, 2002). Internet Appendix Table A6 presents for robustness virtually identical results for portfolios (Table 3 below) using non-overlapping monthly data.

[21]We define slope as the difference between the 1-month forward 3-month basis and the spot 3-month basis.

forward curves do not actually occur, on average. This result is analogous to the existence of the term premium in the term structure literature. Taking this analogy one step further, in Internet Appendix E we show that the slope of the forward curve predicts forward CIP trading profits, just as the slope of the term structure predicts bond returns (Campbell and Shiller, 1991).

4.2 Choice of Currency Pairs and the Classic Carry Strategy

Our model suggests that intermediaries will actively trade the bases with the maximal arbitrage per unit risk weight. If risk weights are roughly equal across currencies, this suggests focusing on the currency pairs with the largest bases. As discussed earlier ("Heterogeneity Across Currencies" in Section 2), for a variety of reasons we do not take a stand on which currency pair truly has the largest basis but instead present results for the ten currency pairs with the largest bases. In the context of our model, if intermediaries actively trade all of these bases, the differences in the magnitude of the basis across pairs must be due either to measurement issues or differences in risk weights. In both of these cases, we would expect positive expected returns and Sharpe ratios from our forward arbitrage strategy for all ten bases.[22]

In Table 2, we present the forward CIP returns associated with the ten currency pairs with the largest average spot 3-month bases post-GFC.[23] The mean returns of these currency pairs are linear combinations of the mean returns for each currency leg vis-à-vis USD presented earlier; the Sharpe ratios are not. The mean average profits are positive for all ten pairs post-GFC, and the annualized Sharpe ratio is above 0.5 for 8 out of 10 currency pairs. The average interest rate differential for each of these ten pairs is positive, once again suggesting a relationship between carry and the profits of the forward CIP trading strategy.

Because of this relationship between the carry trade and the profits of the forward CIP trading strategy, in what follows we will use as a leading example the "classic carry" currency pair of long AUD, short JPY. This pair has one of the largest spot bases, and is particularly

[22]If each of the ten forward arbitrage strategies were an exact (noiseless) bet on the size of the shadow cost λ_{t+1}^{RC}, scaled by the risk weight k^i, they would all have positive expected returns and the same Sharpe ratios. In the presence of currency-specific noise, the Sharpe ratio will be attenuated for each currency pair based on the magnitude of the noise.

[23]These ten pairs also all have a positive spot 3M basis on virtually every day in our sample.

associated with the carry trade.[24] We find that the AUD-JPY forward CIP trading strategy earns an a post-GFC average profit equal to 14 basis points and its annualized Sharpe ratio is 1.38. Both results are highly statistically significant, and the magnitude of the Sharpe ratio is high compared to many documented trading strategy returns in the literature. For comparison, the traditional un-hedged FX carry trade has an annualized Sharpe ratio of 0.48 for developed market currencies from 1987 to 2009, and the annualized Sharpe ratio of a value-weighted portfolio of all U.S. stocks from 1976 to 2010 is 0.42 (Burnside et al. (2010), Burnside et al. (2011)). Note, however, that our analysis is limited to the post-GFC period, which is a short sample. During this period, the developed market carry trade and U.S. stock portfolio had annualized Sharpe ratios (0.13 and 1.31, respectively) that are not representative of the longer sample.[25]

The connection between interest rate differentials and the spot cross-currency basis was documented in Du et al. (2018b). Those authors suggest that the basis is induced by the interaction of customer demand for the un-hedged carry trade and intermediary constraints. One implication of this theory, through the lens of our model, is that the risk that the classic carry basis becomes larger is priced because it correlates with intermediary constraints more broadly. Consistent with this theory, our results show that there is a relationship between the spot basis, interest rate differentials, and forward CIP trading profits.

4.3 Portfolio Forward CIP Trading Strategies

In addition to the "classic carry" AUD-JPY currency pair, we examine four portfolios of forward CIP trading profits: "three-currency carry", "dynamic top-five basis", "top-ten basis", and "dollar". The first three of these are based on interest rate differentials and the size of the spot cross-currency basis; they generate positive mean returns and high Sharpe ratios post-GFC. In contrast, the return for the dollar portfolio is insignificant.

The portfolios are defined as follows. The "three-currency carry" portfolio is a dollar-neutral carry strategy. The portfolio goes long in the forward CIP trading strategy for the

[24] AUD-CHF is also associated with the carry trade and has a slightly larger average basis. This pair is not desirable as a benchmark because of the pegging and de-pegging of CHF during the sample and the low quality of the CHF OIS data, which led to changes in the OIS definition in December 2017.

[25] That said, the correlation of the forward CIP return to the U.S. market is low (0.1 monthly), so there is no particular reason to think that whatever forces caused the market to have high returns post-GFC also influenced the forward CIP return.

AUD, CAD, and GBP vis-à-vis the USD, and short in the forward CIP trading strategy for the EUR, CHF, and JPY vis-à-vis the USD. The "dynamic top-five basis" portfolio equally weights the forward CIP trading strategies for the largest five spot cross-currency basis pairs and is rebalanced monthly. The "top-ten basis" equally weights the forward CIP trading strategies for the ten pairs shown in Table 2, which were selected based on the average spot 3-month cross-currency basis in the post-GFC sample. The "dollar" portfolio places equal weights on each of the individual sample currencies vis-à-vis the USD.

We report the annualized mean profit and the Sharpe ratio for these four portfolios, together with the performance for the "classic carry" strategy in Table 3. The pre-GFC mean profits of these portfolios are all close to zero. The post-GFC mean profits are significantly positive at about 10 basis points for the first three portfolios sorted on the carry and the spot basis. These carry and spot basis sorted portfolios also all have a significant Sharpe ratio above 1. In contrast, the post-GFC profits and the Sharpe ratio for the dollar portfolio remain close to zero.

In robustness checks, we show similar patterns hold for three-month horizons and for strategies based on IBOR bases (Internet Appendix Tables A3, A4, and A5).

4.4 Quarter-Ends

Quarter-ends offer an interesting window to examine forward CIP deviations and the profits of our forward trading strategy. As documented in Du et al. (2018b), there are large spikes in short-term CIP deviations for contracts that cross the quarter-ends. This and other evidence suggests that quarter-ends are associated with significantly tighter balance sheet constraints, likely because the Basel III leverage ratio is calculated using quarter-end snapshots of bank balance sheets in many non-U.S. jurisdictions. We have side-stepped this issue in our analysis thus far by studying forward CIP trading strategies with a three-month tenor, ensuring that the contracts in question always cross quarter-end. In this subsection, we instead study a forward CIP trading strategy that uses tenors of a single business day and focus on quarter-end effects.

We find that these quarter-end effects are anticipated and priced into forward CIP deviations. To calculate quarter-end effects precisely, we follow Correa et al. (2020) and construct overnight (ON) and tomorrow/next (TN) CIP deviations. The ON CIP deviation is a one day spot CIP violation; the TN CIP deviation is a one-day-forward-starting one-day CIP violation. From these, we can construct a one-day forward CIP trading strategy by betting on whether the TN CIP deviation traded at time t is larger than the subsequent realized spot ON CIP deviation traded at $t+1$. We provide details on ON and TN basis calculations in Internet Appendix F.

In Table 4, we regress the annualized ON CIP deviation, one-day lagged TN CIP deviation, and the profit on the one-day forward CIP trade on a constant and quarter-end dummy, pooled across the funding currencies (CHF, EUR and JPY) vis-à-vis the USD.[26] Column 1 shows that the ON basis jumps by 145.6 basis points on average when crossing quarter-ends. Column 2 shows that the TN basis jumps by 215.2 basis points on average one (business) day before the quarter-ends. Since the jump in the TN premium is on average larger than ON premium, there is an additional positive risk premium on our one-day forward CIP trading strategy crossing the quarter-ends. In Column 3, we can see that the average profit on the ON-TN forward CIP trading strategy outside quarter-ends is about 3.7 basis points, and about 69.5 basis points higher on quarter-ends.

In Internet Appendix Figure A4, we show the shape of the forward curve of the 1M-tenor AUD-JPY basis with three sub-samples based on whether the next quarter-end is within the next month, between one and two months in the future, or more than two months in the future. We observe that all three lines exhibit a spike, precisely when the interest tenor in the basis crosses the quarter end. This further illustrates that intermediary's quarter-end constraints are anticipated and priced. However, we cannot detect additional risk premium for the 1M-tenor forward associated with quarter-end crossings in Internet Appendix Table A10, likely due to limited power when using the longer-tenor contracts in detecting the risk premium associated with quarter-ends.

4.5 Additional Sub-sample Analysis and Transaction Costs

Our post-GFC sample begins in 2010, which marks the beginning of the lengthy process for the introduction and implementation of Basel III banking regulations. These regulations substantially affected banks ability to engage in balance-sheet intensive activities.[27] Notably,

[26]Because of our limited sample of quarter-ends, pooling across currencies is necessary to precisely estimate quarter-end effects. We focus on the funding currencies vis-à-vis the USD because of the relationship between forward CIP returns and the carry trade documented thus far.

[27]Besides CIP deviations, higher balance sheet costs are also manifested in the repo market. In Internet Appendix Figure A5, we show that the average gross repo position of primary dealers declined by more

the public disclosure of the Basel III leverage ratio starts on January 1, 2015. Given that the leverage ratio requirement under Basel III is the most relevant regulatory constraint for CIP arbitrage, we split the post-GFC period into pre- and post-2015. Internet Appendix Table A7 shows that our main results are robust in both sub-samples post-GFC, but somewhat stronger in the post-2015 sub-sample.

Our results also remain strong even after we extend our sample period to through March 2020, covering the financial market turmoil amid the COVID-19 pandemic (Internet Appendix Table A8). As expected, the strategies experienced sharply negative returns between February and March 2020, consistent with our interpretation that they perform poorly when intermediaries are distressed but have good investment opportunities.[28]

We have limited data on the transactions costs associated with implementing the forward CIP trading strategy. Large intermediaries are likely to implement the strategy at low costs (either collecting the bid-offer when trading with clients or trading at close to the mid-price in inter-dealer transactions). Anecdotal evidence suggests that some large hedge funds use interest rate and FX derivatives to arbitrage the term structure of CIP violations, suggesting that the transaction costs are not prohibitively large.

However, we study these forward CIP trading strategies because they reveal interesting information about currencies and intermediaries, and not because we advocate them as an investment strategy. It may well be the case that a typical trader in a small hedge fund paying the bid-offer on the various instruments used to implement the trading strategy would not find it profitable. We provide a conservative estimate of transaction costs by assuming the full quoted bid-offer spreads from Bloomberg are paid on every single instrument involved in the trading strategy. Note this approach likely substantially overstates total transaction costs as our trade can be easily structured as an asset package. Taking the USD-JPY OIS trade as an example, the annualized transaction costs based on full Bloomberg bid-offer spreads are about twice the size of the annualized profit for the one-month horizon forward trade and slightly below the profit for the three-month horizon forward trade (Internet Appendix

than 40% in the post-GFC sample compared to their pre-GFC peak, which is consistent with more binding non-risk-weighted leverage constraints. The spread between large banks' lending rate and borrowing rate in repo markets also widened significantly post-GFC.

[28]It is difficult to say whether the post-GFC period through August 2018 (our original sample) or the period including the recent pandemic is more representative of the average returns of the forward CIP trading strategy. We find it reassuring that our results are not too sensitive to this choice.

Table A11).

5 Implications for the Price of Risk

In the preceding section, we found that there is a substantial risk premium associated with the risk that AUD-JPY and other bases become larger. We interpret this, through the lens of our model, as implying that this basis is a measure of intermediary constraints and that the risk that intermediary constraints tighten is a priced risk factor.

This interpretation has several implications that we explore in this section. First, it suggests that the AUD-JPY cross-currency basis should be correlated both with other arbitrages affected by constraints on intermediaries. Second, it suggests that the basis should be correlated with measures of intermediary wealth. Third, it implies (assuming an intertemporal hedging motive) that the forward CIP risk premium should exist even after controlling for intermediary wealth, and that the forward CIP return should be included along with intermediary wealth in the SDF. Fourth, the forward CIP risk premium should be consistent with the prices of risk extracted from other assets that intermediaries trade. We explore each of these implications in turn.

5.1 CIP vs. Other Arbitrages

We interpret the AUD-JPY basis and other CIP deviations as measures of intermediary constraints. However, our model implies that intermediary constraints, if present, should affect many no-arbitrage relationships and not just CIP. To verify that the bases we study are indeed measures of intermediary constraints, we begin by confirming that they co-move with other documented near-arbitrages. Specifically, we show that the AUD-JPY cross-currency basis co-moves with the first principal component of other near-arbitrages from outside the FX market.

We consider seven types of near-arbitrages: the bond-CDS basis, the CDS-CDX basis, the USD Libor tenor basis, 30-year swap spreads, the Refco-Treasury spread, the KfW-Bund spread, and the asset-swapped TIPS/Treasury spread. These near-arbitrages have been examined in recent literature, such as Bai and Collin-Dufresne (2019); Boyarchenko et al. (2018); Fleckenstein et al. (2014); Jermann (2019); Longstaff (2002); Schwarz (2018). We describe these near-arbitrages in more detail in Internet Appendix G.

Each of these near-arbitrages is subject to measurement errors and idiosyncratic supply and demand shocks. We use a principal component analysis to extract the common component. Our model implies that variation in the balance sheet capacity of financial intermediaries should affect all these near-arbitrages, and we therefore view this common component as an alternative measure of intermediary constraints.

We show in Figure 4 that our benchmark AUD-JPY cross-currency basis and the first principal component (PC) of the other near-arbitrages follow broadly similar trends. We find that the first PC both explains 53% of total variation in the level of the seven near-arbitrages between January 2005 and August 2018, and has a 50% correlation with the level of the AUD-JPY cross-currency basis post-GFC. The correlation between the two variables provides additional support to our interpretation that CIP deviations reflect intermediary constraints.[29]

However, CIP deviations have several advantages over these other near-arbitrages. First, they are close to true arbitrages, unlike some of these other measures. For example, the Libor tenor basis and Treasury swap spread may reflect credit risk rather than intermediary constraints, while the bond-CDS basis has a cheapest-to-deliver option and other complications. Second, they are precisely measured, exhibiting less high frequency volatility than most of these other measures. Third, and most importantly for our empirical strategy, they have a rich term structure that allows us to construct our forward CIP trading strategy. For these reasons, we use CIP violations, and specifically the AUD-JPY cross-currency basis, as our as our preferred measure of intermediary constraints.

5.2 CIP vs. Intermediary Wealth

If the cross-currency basis measures intermediary constraints, then the general equilibrium models of He and Krishnamurthy (2011) and Kondor and Vayanos (2019) imply that it should co-move with intermediary net worth. However, demand and regulatory shocks should also affect the tightness of intermediary constraints, so we do not expect a perfect correlation.

We explore the relationship between intermediary wealth measures and the AUD-JPY cross-currency basis in Figure 5 and in the next sub-section. We use as our primary measure of intermediary wealth the intermediary equity value of He et al. (2017) (henceforth HKM),

[29] All seven near-arbitrages are long-term (five years or above), while the cross-currency basis we use has a three-month tenor, so the correlation between the two series should not be perfect.

which is the cumulative return of value-weighted equity of primary dealers. We also consider, following those authors, the equity capitalization ratio of the dealers (HKM Capital Ratio), and the value of the entire stock market.

In Figure 5, we present a time series of the spot 3M AUD-JPY basis and these three intermediary wealth measures.[30] The cross-currency basis and the proxies for intermediary wealth appear to be (negatively) correlated. This suggests that variations in the spot basis are in part driven by shocks to intermediary wealth. However, in recent years, we observe an upward trend in the basis, likely attributable to changes in regulation (e.g. the implementation of Basel III). During this period, intermediary wealth also increases. As discussed earlier, we expect the basis to capture regulatory and demand shocks in addition to changes to intermediary wealth.

5.3 The Basis and the SDF

Can the correlation between the AUD-JPY basis and intermediary equity returns explain the risk premia we documented in the previous section? If the intermediary's SDF consisted only of the intermediary wealth return, then regressions of excess asset returns on proxies for this factor should generate intercepts of zero (Cochrane (2009)). Panel A of Table 5 reports these regressions for four configurations of intermediary wealth return proxies: Market only, Intermediary Equity only, Market and Intermediary Equity, and Market and HKM Factor.[31] Here, Market and Intermediary Equity refer to the return on the stock market and the value-weighted equity of primary dealers, respectively, and HKM Factor refers to innovations to the AR(1) process of primary dealers' equity capital ratio, as defined in He et al. (2017). The outcome variable is the profits of the 1M-forward 3M-tenor AUD-JPY forward CIP trading strategy, scaled by 1/3 to convert the units from annualized profits per dollar notional to bps per month (see Equation (11)).

All four configurations generate statistically significant intercepts ("α"), rejecting the null that the HKM wealth-portfolio factors are sufficient to explain the risk premia on the forward CIP trading strategy. Moreover, the point estimates for the intercepts range from 3.8 to 4.2 bps per month when using overlapping daily data, which is close to the average excess return

[30] Internet Appendix Figure A6 shows that other cross-currency bases constructed using the portfolios defined in section 4.3 closely track the AUD-JPY basis.

[31] We use daily observations of monthly returns where possible. The HKM Factor is constructed by those authors and is available only in monthly frequencies.

of 4.8 bps/month (see column (1)). That is, proxies for intermediary wealth returns explain only a small part of the excess returns associated with the AUD-JPY forward CIP trading strategy.

This result suggests that SDFs which include both intermediary wealth returns and forward CIP returns (as in Equation (1)) should fit the data better than SDFs that use only intermediary wealth. The Bayesian approach of Barillas and Shanken (2018) and Chib et al. (2020) provides a method of comparing SDFs to formalize this intuition. We consider the same proxy factors for the intermediary wealth return: Market only, Intermediary Equity only, Market and Intermediary Equity, and Market and HKM Factor. In Panel B of Table 5, for each of these four specifications, we calculate the posterior probabilities for factor models that do and do not include the forward CIP return (see Internet Appendix I for more details).

Across all specifications, the model that includes the forward CIP return has a posterior probability close to one. For example, when the intermediary wealth proxies are Intermediary Equity and Market, the factor models considered are Intermediary Equity only, Intermediary Equity and Market, Intermediary Equity and forward CIP return, and all three factors; the posterior probability of the model with all three factors is 98.7%.

If the forward CIP return is part of the SDF, its mean return can help identify the coefficients of the SDF. By construction, the returns of our forward CIP trading strategy are also the (negative of) innovations to the magnitude of the cross-currency basis.[32] Our forward CIP trading strategy earns 4.8 bps per month on average in the post-GFC period. Take the Intermediary Equity return as the tradable proxy for intermediary wealth returns; the mean excess return of Intermediary Equity from 1970 to 2018 is 60 bps per month. Defining λ as the vector containing these mean excess returns, we can extract estimates of γ and ξ (the coefficients in the SDF of Equation (1)) by multiplying these means by the inverse of the variance-covariance matrix (Σ) of the two factors (see Cochrane (2009)). We estimate the standard deviation of the AUD-JPY forward CIP return at 12 bps per month, and the standard deviation of the Intermediary Equity return at 6.7% per month. The correlation between these two factors is 0.19 in our post-GFC sample, meaning that the basis tends to

[32]We focus on the AUD-JPY cross-currency basis in part because its sign essentially does not change over our sample, allowing us to ignore issues related to absolute values.

shrink when intermediary equity returns are positive. Using these estimates,

$$\begin{bmatrix} \gamma \\ \xi \end{bmatrix} = \Sigma^{-1}\lambda = \begin{bmatrix} 0.66 \\ 305 \end{bmatrix}.$$

Our results are consistent with $\gamma < 1$ in two ways. First, our direct estimate of the γ parameter is less than one. Second, the sign of our estimate of ξ is greater than zero, which should be expected if $\gamma < 1$. Note that these are point estimates and subject to estimation error.[33]

Our estimate of $\xi > 0$ (implying $\gamma < 1$) is driven by the fact that the forward CIP strategy achieves a risk premium that is larger than would be expected given its beta to the intermediary equity factor. Recall that a large basis indicates better future investment opportunities. Intermediaries will view exposure to basis shocks as risky if they prefer to hoard wealth to take advantage of those better investment opportunities, which occurs when $\gamma < 1$. We emphasize that this is not a quirk of our model, but rather a general fact about investment opportunities and intertemporal hedging.[34]

However, we cannot rule out the alternative possibility that the forward CIP return is a better proxy for the true intermediary wealth return. If the risk premia we document is caused entirely by this effect and not inter-temporal hedging, the forward CIP return must be a much better proxy for the true intermediary wealth return than the HKM intermediary equity measure. Suppose that $\gamma = 1$, so there is no intertemporal hedging concern. Our Sharpe ratio estimate for forward CIP trading strategy implies (by the Hansen-Jagannathan bound) that the true intermediary wealth return must have an annual volatility of at least 138%, far higher than the annualized volatility of the Intermediary Equity return. Suppose instead that $\gamma > 1$. In this case, the intermediary manager should view the forward CIP trading strategy as not being very risky at all, because it offers low returns only when there are future arbitrage opportunities. To overcome this intertemporal hedging effect, we would have to suppose that our forward CIP trading returns are strongly correlated with the true intermediary wealth returns.[35]

[33]See Internet Appendix H for a discussion of the estimation and standard errors.

[34]See, for example, pg. 1157 of Kondor and Vayanos (2019). Note also that Adrian et al. (2014) rely on a risk-neutral (γ=0) model to interpret their results, implicitly imposing $\gamma < 1$.

[35]Given the persistence of the cross-currency basis, which causes the intertemporal term to be large, it is not obvious that even perfect correlation with the intermediary wealth return solves the problem. However,

We believe our results are interesting regardless of which of these interpretations is preferred. Either intertemporal hedging considerations are large and can be proxied for by the forward CIP return, or the forward CIP return is a better way of measuring intermediary wealth returns (the main component of the SDF). Under either of these interpretations, we would be justified in using the forward CIP return as an asset pricing factor.

5.4 Cross-sectional Asset Pricing

We next present a cross-sectional analysis, which provides an additional test of our theory. If the SDF in Equation (1) is correctly specified and the traded factors are good proxies of the true factors, the prices of risk estimated from the cross-section of asset returns should be the same as the unconditional risk premia of the traded factors.

We view this analysis as a complement to our earlier direct estimates of the forward arbitrage return. The key advantage our model and approach enjoy over other empirical intermediary asset pricing exercises is that we are able to directly estimate the price of the risk that constraints tighten. The cross-sectional exercise allows us to verify that the price of risk we directly estimate is consistent with the price of risk we infer from the cross-section. Because we are focused on the post-GFC sample, the power of our cross-sectional exercise is limited. Despite this limitation, we are in some cases (when pooling across asset classes) able to reject the hypothesis of a zero risk price. However, we are never able to reject the hypothesis that the risk price in the cross-section matches the risk price we directly estimate.

Our exercise builds directly on HKM. We study equities (FF6, the Fama-French 6 size by value portfolios, Fama and French (1993)), currencies (FX, developed and EM currencies sorted on forward premia, Lustig et al. (2011)), US bonds (US, six maturity-sorted CRSP "Fama Bond Portfolios" of Treasury bonds and five Bloomberg corporate bond indices), sovereign bonds (Sov, sorted on credit rating and beta to the market, Borri and Verdelhan (2015)), equity options (Opt, eighteen portfolios of S&P 500 calls and puts, Constantinides et al. (2013)), credit default swap indices (CDS, five traded CDS indices), and commodities (Comm, twenty three commodity futures return indices). We also study single-currency forward CIP returns with OIS and IBOR rates (FwdCIP), excluding AUD and JPY.

Note that many of these test portfolios have a factor structure to their returns. For example, the currency portfolios of Lustig et al. (2011) can be summarized by the "carry"

without an exact quantification of the intertemporal terms, we cannot rule out this possibility.

and "dollar" factors. Following HKM, we do not include these factors as additional factors in our model. That is, we are asking whether the risk premium associated with the carry trade is explained by its exposure to intermediary wealth and the forward CIP return, not whether the proposed factors of the SDF predict the part of currency returns that is not explained by the carry and dollar factors.

The conjecture we are testing, which follows from our hypothesized form of the stochastic discount factor[36], is that

$$E[R^i_{t+1} - R^f_t] = \alpha + \beta^i_w \lambda_w + \beta^i_x \lambda_x, \tag{12}$$

where β^i_w is the beta of asset i to the intermediary wealth return and β^i_x is the beta to the negative of the forward CIP return. These betas can be estimated in the standard way using a time series regression,

$$R^i_{t+1} - R^f_t = \mu_i + \beta^i_w (R^w_{t+1} - R^f_t) + \beta^i_x r^{|x|}_{t+1} + \epsilon^i_{t+1}, \tag{13}$$

where $r^{|x|}_{t+1}$ is the negative of the AUD-JPY forward CIP return.[37]

Our preferred specification uses the Intermediary Equity return as our proxy for R^w_{t+1}. As discussed in Cochrane (2009), with tradable factors, if we included the factors as test assets and used GLS or two-step GMM to estimate the risk prices λ_x and λ_w, we would recover the mean excess returns of those factors. We ask instead whether the price of risk implied by the cross-section of other asset returns is consistent with the mean excess returns on our tradable factors. For this reason, we do not include our factors as test assets. We estimate Equation (12) as an OLS regression, with GMM standard errors to account for the estimation of the betas in Equation (13), following chapter 12 of Cochrane (2009).[38] Both regressions use monthly data. For each asset class, and for a combination of six asset classes,

[36]Our hypothesis is expressed as a linear form for the log SDF, but we test a linear SDF to stay closer to the procedure of He et al. (2017).

[37]Our model implies that the risk-free rate in this time-series regression is misspecified, and should include an adjustment proportional to x_t (see Internet Appendix Equation (A2)). However, because x_t has almost no ability to predict $R^w_{t+1} - R^f_t$ or $r^{|x|}_{t+1}$, omitting it has almost no effect our results. See Internet Appendix Table A17 for a version of Table 6 with a risk-free rate adjustment.

[38]More efficient (in an asymptotic sense) procedures estimate equations (12) and (13) jointly as moment conditions. These procedures have advantages and disadvantages relative to the cross-sectional approach; see Cochrane (2009).

we report the "H1 p-value" from testing whether λ_w and λ_x are equal to the mean excess return of the corresponding factor (as described in the previous sub-section). This p-value, as opposed to the usual test of whether the coefficients are zero, is the focus of our analysis.

One difference between our main specification and the textbook procedure is that the samples we use to estimate the betas and the mean excess returns are different. Our model argues that the cross-currency basis enters the SDF because it measures the degree to which regulatory constraints bind, a viewpoint relevant for the post-GFC period. Eight years of data, however, is generally too short to reliably determine whether one test portfolio has a higher expected return than another test portfolio. To overcome this difficulty, we estimate the cross-sectional regression using the longest available sample for each test portfolio, while estimating the betas using only the post-GFC sample. This approach increases the likelihood of rejecting our "H1" hypothesis (biasing against our main finding), and is valid if the long-sample expected excess returns are also the expected excess returns in the post-crises period. We present qualitatively similar results using only post-GFC data in the Internet Appendix Table A22.[39]

Because we use a short sample to estimate our betas, there is the potential for weak identification in our setting. Weak identification arises when there is not significant cross-sectional variation in the betas of the test assets to the factors. Kleibergen and Zhan (2020) develop a "pre-test" that tests whether the estimated betas of the test assets are different from each other. We report the p-value associated with this test. Low p-values suggest rejection of the hypothesis that the betas are equal.[40] Note that the primary focus of our exercise is whether we can reject our "H1" hypothesis. Spurious rejection induced by weak identification makes it harder for us to find cross-sectional results that are consistent with

[39] One difference between our main results and our results using post-GFC means is the risk price of the basis shock with FX test assets. We find that carry trade returns are correlated with the basis shock, but in the post-GFC period, carry trade returns are roughly zero. This example illustrates the costs and benefits of using the full sample for mean returns. If we believe carry still earns a risk premium, but happens to have done poorly during the post-GFC period, using the long sample provides a better estimate of the price of risk for the basis shock. If instead we believe that carry no longer earns a risk premium, then using only the post-GFC sample is preferable.

[40] Specifically, we use the multi-factor version of the test described in the appendix of Kleibergen and Zhan (2020). We report the F test associated with their statistic to account for the "large N, small T" nature of some of our regressions. We modify their test slightly to account for the fact that when we pool asset classes, we have one intercept for each asset class in the asset-pricing equation as opposed to a single intercept. Unfortunately, the other robust inference methods described by Bryzgalova (2020) and Kleibergen and Zhan (2020) could not be directly applied to our setting.

our direct estimates of the risk premia for our tradable factors.

Note that our estimates depart in a variety of ways from HKM. Our results are estimated on monthly data, and our betas are estimated only in the post-GFC period. Our test portfolios in each asset class are also different, in some cases only slightly and in some cases more substantially. We describe these details in the Internet Appendix, Section J.

Our main cross-sectional results are shown in Table 6. These results use the two-factor specification of Equation (12), with the Intermediary Equity return as the empirical proxy for R^w_{t+1}. The first eight columns show results for individual asset classes. For most asset classes, we cannot reject the hypothesis of weak identification, and the problem is particularly severe for equities and commodities.[41] Pooling the first six asset classes (i.e. everything except equities and commodities) improves identification, and we report pooled results in column (9).

Our main outcome of interest is the H1 hypothesis that the prices of risk are equal to the mean excess returns of Intermediary Equity and negative of the forward CIP return (roughly 0.6 %/mo. and -0.05 %/mo.). We are unable to reject this hypothesis with $p \leq 0.1$ in any asset class or when we pool across six asset classes to achieve more precise identification. Our point estimates in the pooled specification ($\lambda_w = 0.728, \lambda_x = -0.0725$) are in fact quite close to the mean excess returns.

Internet Appendix Table A13 presents results that add in Market as an additional factor (as in HKM). Our H1 hypothesis now requires that all three risk prices be consistent with the mean excess returns of those tradable factors. We again are unable to reject our hypothesis at the 10% level. Internet Appendix Tables A14 and A15 present versions of Tables 6 and A13 that do not include the basis shock (i.e. specifications found in HKM). When the basis shock is not included, the point estimates for the price of intermediary equity risk are generally higher, in some cases to the point that we are able to reject the hypothesis that the prices of risk are consistent with the returns on the intermediary equity. We interpret this result as again suggesting that either the basis shock is captures something about intermediary wealth that the equity return omits or that it captures an intertemporal hedging consideration that

[41] Our results about the disconnect between cross-sectional equity risk premia and intermediary health measures echo the results of Haddad and Muir (2020), who find that intermediary health measures only weakly predict equity returns but strongly predict returns in other asset classes. They are also consistent with certain results in HKM, who also have difficulty pricing equities in their monthly data, and with the view espoused by those authors that intermediaries are unlikely to be the marginal agents in equity markets.

is significant in its own right.

The Internet Appendix also presents a number of other variants on Table 6. There is a variant (Table A16) in which we use the HKM capital ratio innovation (along with the Market and forward CIP return), which is non-tradable and is the primary specification in HKM. In this case, we can only test whether the risk prices of the traded factors are consistent with their excess returns, and our results are noisier both in terms of standard errors and with respect to the weak identification test. The Internet Appendix also contains variants that use alternative measures in the place of the AUD-JPY forward CIP return. Table A18 uses USD-JPY, and Tables A19, A20, and A21 use the portfolios of forward CIP returns described in Table 3. Table A23 replaces the forward CIP return in Table 6 with the AR(1) innovation (following HKM) of the first principal component of the near-arbitrages described in Section 5.1, scaled to match the volatility of the AUD-JPY forward CIP return. These variants generate results that are similar to those of Table 6.

6 Discussion and Conclusion

We provide direct evidence that the AUD-JPY and other cross-currency bases are correlated with the SDF. These results are consistent with our motivating hypothesis, derived from an intermediary-based asset pricing framework and intertemporal hedging considerations. They are also consistent with the correlation between the basis and other near-arbitrages, the correlation between the basis and measures of intermediary wealth, and with our cross-sectional asset pricing tests. Taken together, we view our results as strongly supportive of intermediary asset pricing theory.

More broadly, we view this paper as beginning an investigation in the dynamics and pricing of arbitrages induced by regulatory constraints. If intermediaries play a central role in both asset pricing and the broader economy, then the question of how to measure the constraints they face and the properties of those constraints is of first-order importance.

References

Adrian, T., Etula, E., and Muir, T. (2014). Financial intermediaries and the cross-section of asset returns. *The Journal of Finance*, 69(6):2557–2596.

Anderson, A., Du, W., and Schlusche, B. (2019). Arbitrage capital of global banks. Working paper.

Avdjiev, S., Du, W., Koch, C., and Shin, H. S. (2019). The dollar, bank leverage, and deviations from covered interest parity. *American Economic Review: Insights*, 1(2):193–208.

Bai, J. and Collin-Dufresne, P. (2019). The cds-bond basis. *Financial Management*, 48(2):417–439.

Barillas, F. and Shanken, J. (2018). Comparing asset pricing models. *Journal of Finance*, 73(2).

Borio, C. E., McCauley, R. N., McGuire, P., and Sushko, V. (2016). Covered interest parity lost: understanding the cross-currency basis. *BIS Quarterly Review September*.

Borri, N. and Verdelhan, A. (2015). Sovereign risk premia. Working paper.

Boyarchenko, N., Eisenbach, T. M., Gupta, P., Shachar, O., and Van Tassel, P. (2018). Bank-intermediated arbitrage. Working paper.

Brunnermeier, M. K. and Pedersen, L. H. (2009). Market liquidity and funding liquidity. *The review of financial studies*, 22(6):2201–2238.

Bryzgalova, S. (2020). Spurious factors in linear asset pricing models. Working paper.

Burnside, C., Eichenbaum, M., Kleshchelski, I., and Rebelo, S. (2010). Do peso problems explain the returns to the carry trade? *The Review of Financial Studies*, 24(3):853–891.

Burnside, C., Eichenbaum, M., and Rebelo, S. (2011). Carry trade and momentum in currency markets. *Annual Review of Financial Economics*, 3(1):511–535.

Campbell, J. (1993). Intertemporal asset pricing without consumption data. *American Economic Review*, 83(3):487–512.

Campbell, J. Y. (2017). *Financial decisions and markets: a course in asset pricing*. Princeton University Press.

Campbell, J. Y., Giglio, S., Polk, C., and Turley, R. (2018). An intertemporal capm with stochastic volatility. *Journal of Financial Economics*, 128(2):207–233.

Campbell, J. Y. and Shiller, R. J. (1991). Yield spreads and interest rate movements: A bird's eye view. *The Review of Economic Studies*, 58(3):495–514.

Chib, S., Zeng, X., and Zhao, L. (2020). On comparing asset pricing models. *The Journal of Finance*, 75(1):551–577.

Cochrane, J. H. (2009). *Asset pricing: Revised edition*. Princeton university press.

Constantinides, G. M., Jackwerth, J. C., and Savov, A. (2013). The puzzle of index option returns. *Review of Asset Pricing Studies*, 3(2):229–257.

Correa, R., Du, W., and Liao, G. Y. (2020). Us banks and global liquidity. *NBER Working Paper No.27491*.

Di Tella, S. (2017). Uncertainty shocks and balance sheet recessions. *Journal of Political Economy*, 125(6):2038–2081.

Du, W., Im, J., and Schreger, J. (2018a). The us treasury premium. *Journal of International Economics*, 112:167–181.

Du, W., Tepper, A., and Verdelhan, A. (2018b). Deviations from covered interest rate parity. *The Journal of Finance*, 73(3):915–957.

Duarte, J., Longstaff, F. A., and Yu, F. (2007). Risk and return in fixed-income arbitrage: Nickels in front of a steamroller? *The Review of Financial Studies*, 20(3):769–811.

Duffie, D. (2010). Presidential address: Asset price dynamics with slow-moving capital. *The Journal of finance*, 65(4):1237–1267.

Epstein, L. and Zin, S. (1989). Substitution, risk aversion, and the temporal behavior of consumption and asset returns: A theoretical framework. *Econometrica*, 57(4):937–69.

Fama, E. F. and French, K. R. (1993). Common risk factors in the returns on stocks and bonds. *Journal of financial economics*, 33(1):3–56.

Fang, X. (2018). Intermediary leverage and currency risk premium. Working paper.

Fleckenstein, M. and Longstaff, F. A. (2018). Shadow funding costs: Measuring the cost of balance sheet constraints. Working paper.

Fleckenstein, M., Longstaff, F. A., and Lustig, H. (2014). The tips-treasury bond puzzle. *the Journal of Finance*, 69(5):2151–2197.

Gabaix, X. and Maggiori, M. (2015). International liquidity and exchange rate dynamics. *The Quarterly Journal of Economics*, 130(3):1369–1420.

Garleanu, N. and Pedersen, L. H. (2011). Margin-based asset pricing and deviations from the law of one price. *The Review of Financial Studies*, 24(6):1980–2022.

Haddad, V. and Muir, T. (2020). Do intermediaries matter for aggregate asset prices. Working paper.

He, Z., Kelly, B., and Manela, A. (2017). Intermediary asset pricing: New evidence from many asset classes. *Journal of Financial Economics*, 126(1):1–35.

He, Z. and Krishnamurthy, A. (2011). A model of capital and crises. *The Review of Economic Studies*, 79(2):735–777.

He, Z. and Krishnamurthy, A. (2017). Intermediary Asset Pricing and the Financial Crisis. *Annual Review of Financial Economics*, pages 1–37.

Hébert, B. (2018). Externalities as Arbitrage. Working paper.

Hu, G. X., Pan, J., and Wang, J. (2013). Noise as information for illiquidity. *The Journal of Finance*, 68(6):2341–2382.

Jegadeesh, N. (1990). Evidence of predictable behavior of security returns. *The Journal of finance*, 45(3):881–898.

Jegadeesh, N. and Titman, S. (1995). Short-horizon return reversals and the bid-ask spread. *Journal of Financial Intermediation*, 4(2):116–132.

Jermann, U. (2019). Negative swap spreads and limited arbitrage. *The Review of Financial Studies*, pages 0893–9454.

Jiang, Z., Krishnamurthy, A., and Lustig, H. (2018). Foreign safe asset demand and the dollar exchange rate. Working paper.

Kleibergen, F. and Zhan, Z. (2020). Robust inference for consumption-based asset pricing. *The Journal of Finance*, 75(1):507–550.

Kondor, P. and Vayanos, D. (2019). Liquidity risk and the dynamics of arbitrage capital. *The Journal of Finance*, 74(3):1139–1173.

Krishnamurthy, A. and Lustig, H. N. (2019). Mind the gap in sovereign debt markets: The us treasury basis and the dollar risk factor. In *2019 Jackson Hole Economic Symposium*.

Lettau, M., Maggiori, M., and Weber, M. (2014). Conditional risk premia in currency markets and other asset classes. *Journal of Financial Economics*, 114(2):197–225.

Liao, G. Y. (2019). Credit migration and covered interest rate parity. Working paper.

Liu, J. and Longstaff, F. A. (2003). Losing money on arbitrage: Optimal dynamic portfolio choice in markets with arbitrage opportunities. *The Review of Financial Studies*, 17(3):611–641.

Lo, A. W. (2002). The statistics of sharpe ratios. *Financial analysts journal*, 58(4):36–52.

Longstaff, F. A. (2002). The flight-to-liquidity premium in us treasury bond prices. Working paper.

Lustig, H., Roussanov, N., and Verdelhan, A. (2011). Common risk factors in currency markets. *The Review of Financial Studies*, 24(11):3731–3777.

Menkhoff, L., Sarno, L., Schmeling, M., and Schrimpf, A. (2012). Carry trades and global foreign exchange volatility. *The Journal of Finance*, 67(2):681–718.

Newey, W. K. and West, K. D. (1987). A simple, positive semi-definite, heteroskedasticity and autocorrelation consistent covariance matrix. *Econometrica*, 55(3):703–708.

Newey, W. K. and West, K. D. (1994). Automatic lag selection in covariance matrix estimation. *The Review of Economic Studies*, 61(4):631–653.

Pasquariello, P. (2014). Financial Market Dislocations. *The Review of Financial Studies*, 27(6).

Rime, D., Schrimpf, A., and Syrstad, O. (2019). Covered interest parity arbitrage. Working paper.

Roll, R. (1984). A simple implicit measure of the effective bid-ask spread in an efficient market. *The Journal of finance*, 39(4):1127–1139.

Schwarz, K. (2018). Mind the gap: Disentangling credit and liquidity in risk spreads. *Review of Finance*, 23(3):557–597.

Shleifer, A. and Vishny, R. W. (1997). The limits of arbitrage. *The Journal of finance*, 52(1):35–55.

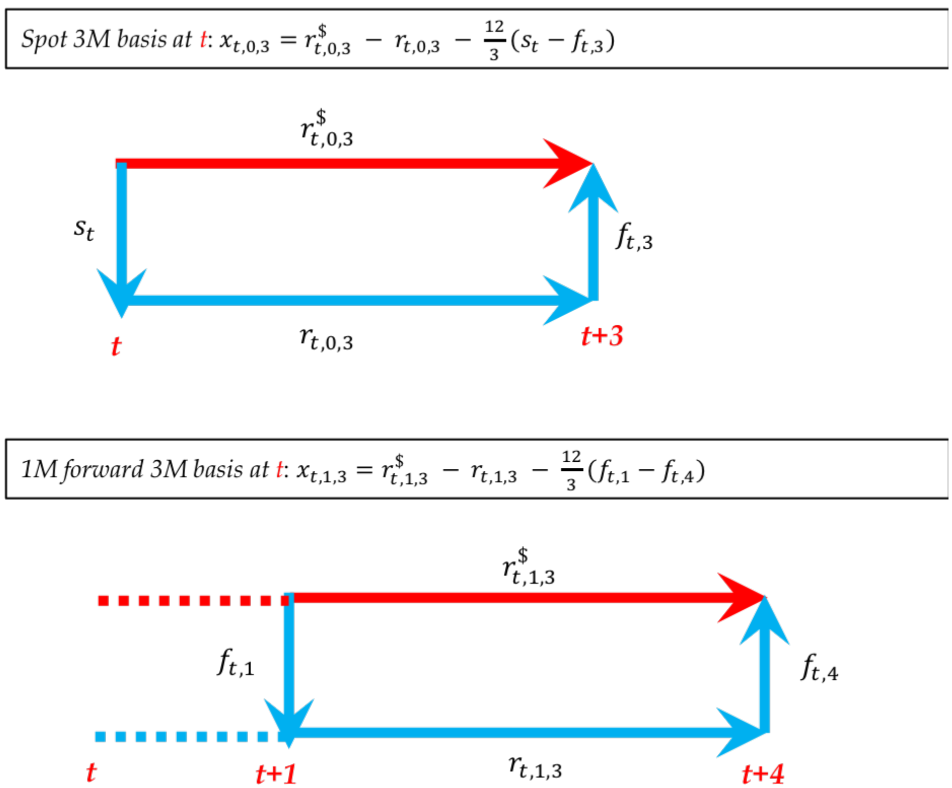
Stock, J. and Yogo, M. (2005). *Testing for Weak Instruments in Linear IV Regression*, pages 80–108. Cambridge University Press, New York.

Wallen, J. (2020). Markups to financial intermediation in foreign exchange markets. Working

paper.
Yang, F. (2013). Investment shocks and the commodity basis spread. *Journal of Financial Economics*, 110(1):164–184.

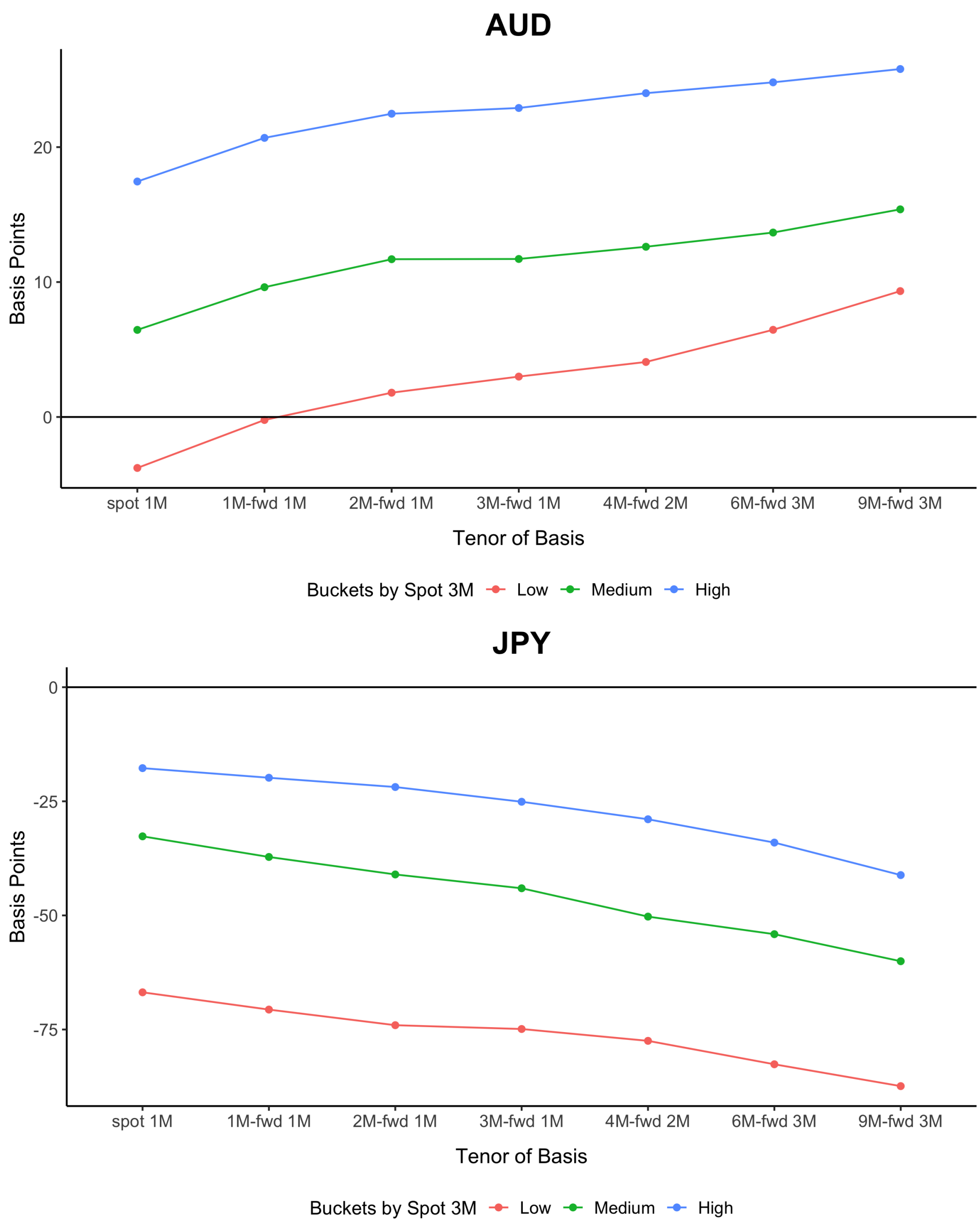
Figures and Tables

Figure 1: **Illustration of spot vs. forward cross-currency basis**



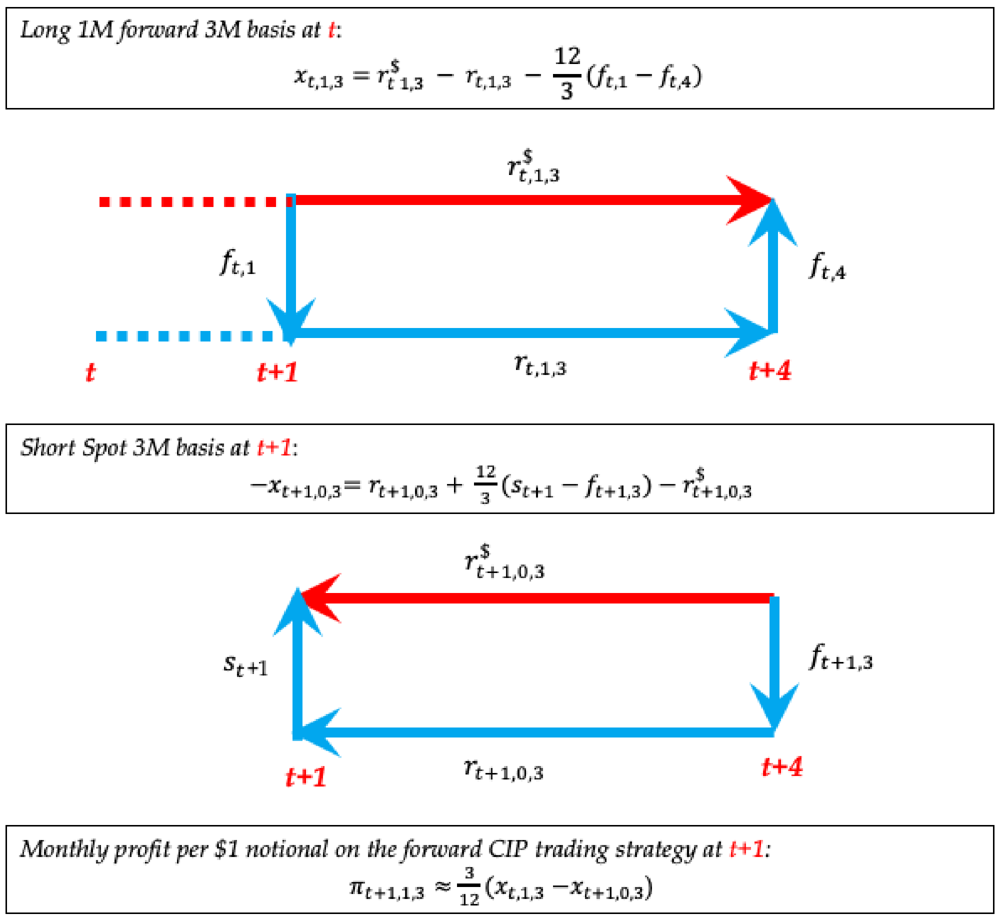
Notes: This figure illustrates the spot 3M cross-currency basis and the 1M-forward 3M cross-currency basis. The spot basis is $x_{t,0,3}$ as defined in the text, and the forward basis is $x_{t,1,3}$ as defined in the text.

Figure 2: **Term Structure of the Forward Cross-Currency Basis**



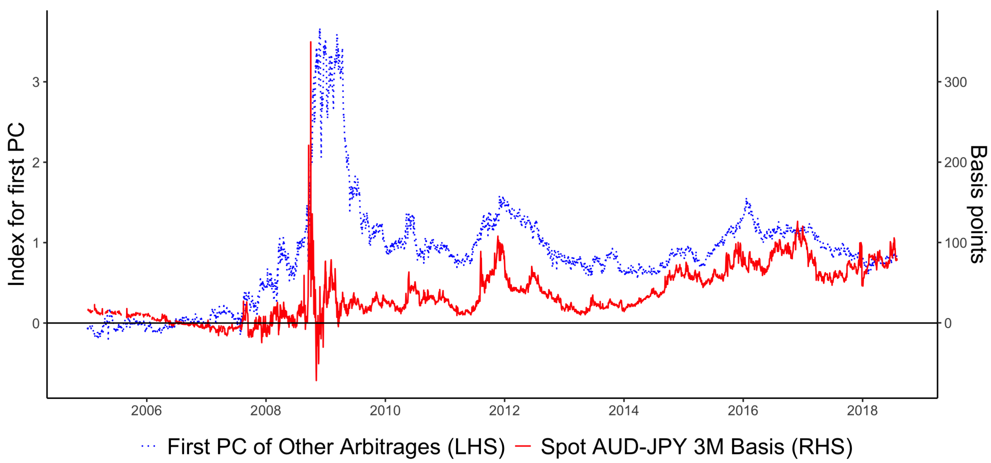
Notes: This figure illustrates the time series average spot and forward-starting cross-currency bases in AUD and JPY, vis-à-vis the USD, respectively, as defined in Equation (8). For each currency, the sample from July 2010 to August 2018 is split into three sub-samples based on the tercile of the level of the spot 3M OIS cross-currency basis. Within each sub-sample, the time series average of the relevant spot/forward OIS cross-currency basis is shown.

Figure 3: **Illustration of the forward CIP trading strategy**



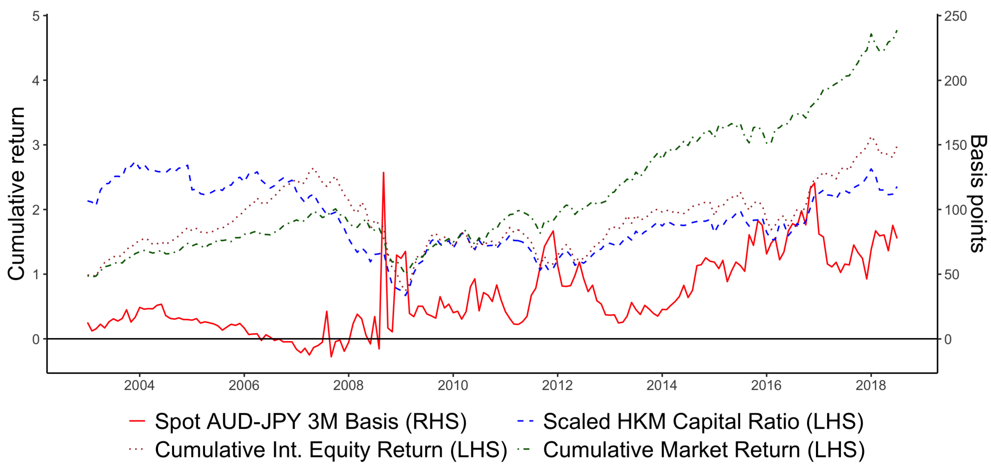
Notes: This figure illustrates the return on a 1M-forward 3M forward CIP trading strategy. At time t, the trader enters the forward basis, $x_{t,1,3}$, which is the forward direct interest less the forward synthetic interest. At time $t+1$, the trader unwinds the spot basis, $-x_{t+1,0,3}$, which is the spot synthetic interest less the spot direct interest. The realized monthly profit per dollar notional on this forward CIP trading strategy is approximately the sum of the two bases: $x_{t,1,3} + (-x_{t+1,0,3})$, normalized by the duration 3/12.

Figure 4: **Cross-Currency Basis and Other Near-Arbitrages**



Notes: This figure plots the daily spot 3M AUD-JPY cross-currency basis and the first principal component of seven other near-arbitrages: the bond-CDS basis, the CDS-CDX basis, the US Libor tenor basis, the 30-year Treasury-swap spread, the Refco-Treasury spread, the KfW-Bund spread, and the TIPS-Treasury spread. The details of these other near-arbitrages are given in Internet Appendix G.

Figure 5: **Cross-Currency Basis and Intermediary Wealth**



Notes: This figure plots the monthly spot 3M AUD-JPY cross-currency basis and measures of intermediary wealth from 2003 to 2018. The HKM Capital Ratio is the equity capitalization ratio of the primary dealers, scaled by 1000. The cumulative intermediary equity return and the cumulative market return are calculated from January 2003, and are based on the value-weighted return of the equity of primary dealers and the entire US stock market, respectively.

Table 1: **Forward CIP Trading Profits and Additional Properties for USD-Based Currency Pairs**

Panel A: Summary Statistics of Returns on OIS 1M-fwd 3M Forward CIP Trading Strategy

	Mean			Sharpe Ratio		
	Pre-GFC	GFC	Post-GFC	Pre-GFC	GFC	Post-GFC
AUD_USD	1.06	3.71	4.73	0.28	0.10	0.90
	(0.98)	(19.41)	(1.78)	(0.27)	(0.50)	(0.37)
CAD_USD	-0.93	1.50	5.56	-0.26	0.05	1.10
	(1.57)	(15.50)	(1.57)	(0.44)	(0.48)	(0.32)
GBP_USD	-1.47	9.27	4.26	-0.48	0.27	0.84
	(0.77)	(16.13)	(1.67)	(0.27)	(0.42)	(0.31)
EUR_USD	-1.15	14.29	-1.35	-0.60	0.34	-0.17
	(0.60)	(20.07)	(2.54)	(0.30)	(0.40)	(0.33)
CHF_USD	-1.34	5.97	-3.60	-0.35	0.14	-0.25
	(0.86)	(18.14)	(4.72)	(0.26)	(0.40)	(0.36)
JPY_USD	-1.97	8.18	-9.53	-0.81	0.17	-1.04
	(0.97)	(22.78)	(3.11)	(0.39)	(0.44)	(0.33)

Panel B: Post-GFC Properties

	Mean Fwd CIP Trad. Ret.	Average Basis	Average Slope	Avg. Interest Diff. vs. USD	Corr SPX and FX
AUD_USD	4.73	9.14	5.81	2.27	0.51
CAD_USD	5.56	-8.64	5.63	0.48	0.49
GBP_USD	4.26	-14.78	4.34	0.02	0.31
EUR_USD	-1.35	-33.65	-1.22	-0.33	0.15
CHF_USD	-3.60	-51.96	-3.69	-0.62	-0.07
JPY_USD	-9.53	-42.48	-8.98	-0.37	-0.31

Notes: Panel A of this table reports the annual profits and annualized Sharpe ratios from the OIS 1M-forward 3M forward CIP trading strategy vis-à-vis the USD. All statistics are reported by period: Pre-GFC is 2003-01-01 to 2007-06-30, GFC is 2007-07-01 to 2010-06-30, and Post-GFC is 2010-07-01 to 2018-08-31. Newey-West standard errors are reported in parentheses, where the bandwidth is chosen by the Newey and West (1994) selection procedure. Panel B of this table reports additional characteristics the USD-based currency pairs post-GFC. "Mean Fwd CIP Trad. Ret." is the annualized profit from the forward CIP trading strategy; "Average Basis" is the average spot 3M OIS cross-currency basis; "Average Slope" is the average spread between the 1M-forward 3M and spot 3M OIS cross-currency basis; "Avg. Int. Rate Diff." is the average spread between the 3M foreign OIS rate and the US OIS rate; and "Corr SPX and FX" is the correlation between weekly currency returns of going long the foreign currency and shorting the USD and the weekly returns on the S&P 500 index.

Table 2: **Summary Statistics of Currency Pair Returns on OIS 1M-forward 3M Forward CIP Trading Strategy**

	Mean			Sharpe Ratio			Post-GFC Metrics	
	Pre-GFC	GFC	Post-GFC	Pre-GFC	GFC	Post-GFC	Avg Basis	Int. Rate Diff.
AUD_CHF	2.47	-1.92	9.82	0.50	-0.06	0.64	60.37	2.89
	(1.06)	(10.49)	(5.15)	(0.26)	(0.34)	(0.40)		
AUD_JPY	2.44	-4.37	14.27	0.61	-0.16	1.38	51.63	2.64
	(1.37)	(10.40)	(3.40)	(0.35)	(0.36)	(0.35)		
USD_CHF	1.34	-5.97	3.60	0.35	-0.14	0.25	51.96	0.62
	(0.86)	(18.14)	(4.72)	(0.26)	(0.40)	(0.36)		
CAD_CHF	1.01	-4.37	9.08	0.20	-0.16	0.67	44.34	1.09
	(1.78)	(8.41)	(4.39)	(0.39)	(0.29)	(0.40)		
AUD_EUR	2.27	-10.27	6.06	0.62	-0.41	0.68	42.79	2.60
	(0.88)	(9.01)	(2.93)	(0.24)	(0.32)	(0.35)		
USD_JPY	1.97	-8.18	9.53	0.81	-0.17	1.04	42.48	0.37
	(0.97)	(22.78)	(3.11)	(0.39)	(0.44)	(0.33)		
GBP_CHF	0.16	3.17	8.16	0.04	0.14	0.61	38.58	0.64
	(0.91)	(7.03)	(4.29)	(0.20)	(0.33)	(0.39)		
CAD_JPY	-0.08	-6.66	15.01	-0.02	-0.23	1.69	33.84	0.85
	(1.41)	(11.11)	(2.89)	(0.37)	(0.36)	(0.35)		
USD_EUR	1.15	-14.29	1.35	0.60	-0.34	0.17	33.65	0.33
	(0.60)	(20.07)	(2.54)	(0.30)	(0.40)	(0.33)		
GBP_JPY	0.10	1.09	13.70	0.03	0.05	1.70	27.70	0.40
	(0.89)	(9.61)	(2.65)	(0.27)	(0.41)	(0.30)		

Standard errors in parentheses

Notes: This table reports the annual profits and annualized Sharpe ratios from the OIS 1M-forward 3M forward CIP trading strategy for the ten currency pairs with the largest average Post-GFC spot 3M bases. All statistics are reported by period: Pre-GFC is 2003-01-01 to 2007-06-30, GFC is 2007-07-01 to 2010-06-30, and Post-GFC is 2010-07-01 to 2018-08-31. "Avg. Basis" is the average spot 3M OIS cross-currency basis post-GFC, and "Int. Rate Diff." is the average spread between the 3M foreign OIS rate and the US OIS rate post-GFC. Newey-West standard errors are reported in parentheses, where the bandwidth is chosen by the Newey and West (1994) selection procedure.

Table 3: **Summary Statistics of Portfolio Returns on OIS 1M-forward 3M Forward CIP Trading Strategy**

	Mean			Sharpe Ratio		
	Pre-GFC	GFC	Post-GFC	Pre-GFC	GFC	Post-GFC
Classic Carry (AUD-JPY)	2.44	-4.37	14.27	0.61	-0.16	1.38
	(1.37)	(10.40)	(3.40)	(0.35)	(0.36)	(0.35)
3 Currency Carry	0.32	-4.59	9.77	0.14	-0.24	1.28
	(0.88)	(7.09)	(2.59)	(0.39)	(0.33)	(0.41)
Dynamic Top5 Basis	1.83	0.18	11.36	0.79	0.01	1.11
	(0.76)	(14.21)	(3.33)	(0.34)	(0.44)	(0.41)
Top 10 Basis	0.84	-5.32	9.00	0.38	-0.21	1.06
	(0.72)	(10.01)	(2.86)	(0.36)	(0.36)	(0.40)
Simple Dollar	-0.95	7.37	-0.06	-0.51	0.20	-0.01
	(1.09)	(18.17)	(1.86)	(0.56)	(0.45)	(0.35)

Standard errors in parentheses

Notes: This table reports the annual profits and annualized Sharpe ratios from the OIS 1M-forward 3M forward CIP trading strategy. All statistics are reported by period: Pre-GFC is 2003-01-01 to 2007-06-30, GFC is 2007-07-01 to 2010-06-30, and Post-GFC is 2010-07-01 to 2018-08-31. The Classic Carry portfolio is the forward CIP trading strategy for the AUD-JPY pair. The 3 Currency Carry portfolio longs the forward CIP trading strategy in AUD, CAD, and GBP and shorts the forward CIP trading strategy in JPY, CHF, and EUR; all individual currency trades are vis-à-vis USD and weighted equally. The Dynamic Top5 Basis portfolio has equal weight in the 5 currency pairs that exhibit the highest spot 3M basis, rebalanced monthly. The Top 10 Basis portfolio has equal weights in the ten currency pairs with the largest average spot 3M basis post-GFC shown in Table 2. The Simple Dollar portfolio puts equal weights on the forward CIP trading strategy for all sample currencies vis-à-vis the USD. Newey-West standard errors are reported in parentheses, where the bandwidth is chosen by the Newey and West (1994) selection procedure.

Table 4: **Returns on ON-TN Forward CIP Trade and Quarter-Ends**

	(1) ON basis	(2) Lagged TN basis	(3) ON-TN Forward Profit
QE Dummy	145.6	215.2	69.54
	(41.48)	(47.99)	(29.15)
Constant	7.911	11.64	3.733
	(0.740)	(0.635)	(0.689)
Observations	3,273	3,273	3,273
R-squared	0.095	0.183	0.034

Notes: This table reports regression results for the overnight CIP deviations (Column 1), one-day lagged tomorrow/next CIP deviations (Column 2) and the return on the ON-TN forward CIP trade (Column 3), or the difference between Column 2 and Column 3. The independent variable is a quarter-end (QE) dummy, which is equal to one if the date is equal to the last business date of the quarter. The sample currencies include CHF, EUR and JPY. The CIP deviations are calculated as the difference between swapped foreign central bank deposit rate into U.S. dollars and the U.S. interest rate on excess reserves. The sample period is post-GFC from 2010-07-01 to 2018-08-31. Robust standard errors are reported in the parentheses. Details on the ON and TN CIP deviations can be found in Internet Appendix F.

Table 5: **Forward CIP Returns and Intermediary Wealth**

	Panel A: Pricing Fwd CIP Returns with Intermediary Wealth					
	Daily Overlapping Returns				Monthly Returns	
	(1)	(2)	(3)	(4)	(5)	(6)
Market		0.007		−0.0003		−0.001
		(0.004)		(0.004)		(0.005)
Int. Equity			0.006	0.006		
			(0.002)	(0.003)		
HKM Factor						0.004
						(0.003)
Constant	0.048	0.038	0.042	0.042	0.053	0.052
	(0.011)	(0.012)	(0.011)	(0.012)	(0.013)	(0.014)
Observations	2,099	2,030	2,030	2,030	98	98

Standard errors in parentheses

Panel B: Bayesian Posterior Likelihood of SDF Models

Factor Space	Model	Probability
{Market, Fwd. CIP Ret.}	Market + Fwd. CIP Ret.	0.979
	Market Only	0.021
{Int. Equity, Fwd. CIP Ret.}	Int. Equity + Fwd. CIP Ret.	0.996
	Int. Equity Only	0.004
{Int. Equity, Market, Fwd. CIP Ret.}	Int. Equity + Market + Fwd. CIP Ret.	0.987
	Int. Equity + Market	0.005
	Int. Equity + Fwd. CIP Ret.	0.007
	Int. Equity Only	0.000
{HKM Factor, Market, Fwd. CIP Ret.}	HKM Factor + Market + Fwd. CIP Ret.	0.980
	HKM Factor + Market	0.010
	HKM Factor + Fwd. CIP Ret.	0.010
	HKM Factor Only	0.000

Notes: In Panel A, we regress returns of the AUD-JPY 1M-forward 3M CIP trading strategy on a constant and the intermediary wealth proxies described in the text: Market, Intermediary Equity and the HKM Factor. Regressions (1) through (4), which use overlapping monthly returns from daily data, report Newey-West standard errors, with the bandwidth is chosen by the Newey and West (1994) selection procedure. Regressions (5) and (6), which use monthly data, report heteroskedasticity-robust standard errors. In Panel B, we report posterior probabilities for factor models that do and do not include the forward CIP return, using the method of Barillas and Shanken (2018) and Chib et al. (2020) (see Internet Appendix I for details).

Table 6: **Cross-sectional Asset Pricing Tests, 2-Factor.**

	(1) US	(2) Sov	(3) FX	(4) Opt	(5) CDS	(6) FwdCIP	(7) FF6	(8) Comm	(9) 1-6
Int. Equity	0.182	1.363	1.845	1.485	2.330	-0.0337	0.301	1.031	0.728
	(0.746)	(1.565)	(0.639)	(0.996)	(1.016)	(2.206)	(4.148)	(0.694)	(0.466)
Neg. Fwd CIP Ret.	-0.174	-0.0784	-0.0718	-0.126	-0.0274	-0.0621	0.0839	-0.0171	-0.0725
	(0.114)	(0.0661)	(0.0508)	(0.0492)	(0.0660)	(0.0371)	(0.341)	(0.0277)	(0.0332)
Intercepts	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
MAPE (%/mo.)	0.030	0.022	0.060	0.034	0.017	0.007	0.106	0.363	
H1 p-value	0.436	0.716	0.150	0.289	0.144	0.955	0.186	0.373	0.813
KZ p-value	0.079	0.379	0.107	0.035	0.355	0.226	0.780	0.780	0.041
N (assets)	11	6	11	18	5	9	6	23	60
N (beta, mos.)	98	98	98	98	98	98	98	98	
N (mean, mos.)	360	283	418	272	170	98	1106	331	

Standard errors in parentheses

Notes: This table reports estimates for the price of risk (λ in Equation (12)) from the various asset classes described in Internet Appendix Section J. "Neg. Fwd. CIP Ret." is the negative of the return on the AUD-JPY 1M-fwd 3M forward CIP trading strategy and "Int. Equity" is the intermediary equity return of He et al. (2017). Intercepts indicates an intercept is used for each asset class (one intercept per column, with six in (9), which pools the first six asset classes). MAPE is mean absolute pricing error of monthly returns. H1 p-value tests whether the price of the Fwd. CIP Ret. and Int. Equity risks are equal to the mean excess returns of those trading strategies. KZ p-value is the p-value of the Kleibergen and Zhan (2020) test rejecting reduced rank for the betas of the test assets. Standard errors are computed using GMM with the Newey-West kernel and a twelve-month bandwidth. Units are in percentage points.

Internet Appendix (not for publication)

"Are Intermediary Constraints Priced?"

Wenxin Du Benjamin Hébert Amy W. Huber

A List of Tables and Figures

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B Model Details

In this Internet Appendix section we present a more detailed description of the model outlined in Section 2, and a more formal statement of the key results.

Our model adopts the approach of He and Krishnamurthy (2011) and the subsequent intermediary asset pricing literature (surveyed in He et al. (2017)), and in particular the idea that the manager of the intermediary is an agent whose SDF should price assets. The model is a discrete time version of He and Krishnamurthy (2011). We add to He and Krishnamurthy (2011) a variety of assets, including both "cash" assets and derivatives, and a regulatory constraint. We study a manager with CRRA or Epstein-Zin preferences (rather than focus on log preferences), because these preferences will allow us to discuss the role that intertemporal hedging concerns play in the model.[42]

The model is based on He and Krishnamurthy (2011), but is partial equilibrium in that it considers only that intermediary manager's problem and not market clearing conditions. In this sense, the model follows the spirit of the standard consumption-based asset pricing approach. Our maintained assumption is that asset prices are consistent with the manager's Euler equations. This assumption has a particularly significant implication in the presence of arbitrage opportunities: it implies that arbitrage can exist if and only if constraints prevent the intermediary from taking advantage of the arbitrage.[43]

The manager is endowed with the ability to run an intermediary that survives for a single period. In the beginning of the period, the manager will raise funds from households in the form of both debt and equity, subject to various constraints, and choose how much of her own wealth to contribute. The manager then invests these funds in a variety of assets. At the end of the period, returns realize and the intermediary is dissolved. The manager receives a payout based on her equity share in the intermediary. This payout, plus any savings the manager holds outside the intermediary, determine the manager's wealth entering into the next period.

Let W_t^M denote the manager's wealth at the beginning of period t, and let z_t be a state variable that determines the conditional (on time t information) distribution of asset returns. These two variables are the state variables of the manager's optimization problem and are the relevant portions of the manager's information set. Expectations should be understood as conditioning on these two variables,

$$E_t[\cdot] = E[\cdot|W_t^M, z_t].$$

At the beginning of the period, the manager must decide on a contractual structure for the intermediary she runs. The intermediary begins by raising equity capital $N_t \geq 0$. Of

[42] In augmenting the He and Krishnamurthy (2011) model with Epstein-Zin preferences, we are building on Di Tella (2017) among others.

[43] We would like to thank Andreas Stathopoulos very a helpful discussion on this point.

the initial equity capital, N_t^M is contributed by the manager, with the remainder coming from households. The manager receives a share ϕ_t of the wealth that will be liquidated when the intermediary is dissolved at the end of the period, with the remainder going to households. Note that the share ϕ_t is not necessarily equal to the proportion of the equity that the manager contributes; define the fee

$$f_t^m \equiv \frac{\phi_t N_t}{N_t^M}$$

as the ratio of what the manager receives to what she contributes.

The manager raises equity and debt from households in a competitive market. Let M_{t+1}^H be the household's SDF, and let $\hat{N}_{t+1}$ be the value of the intermediary's equity after returns are realized and the debt is repaid (we define this variable in more detail below). Let B_t be the face value of the intermediary's debt, and let $R_t^b = \exp(r_t^b)$ be its interest rate. For any capital structure $(\phi_t, N_t^M, N_t, B_t, R_t^b)$ proposed by a manager with wealth W_t^M in state z_t, households will be willing to purchase the equity if

$$N_t - N_t^M \leq (1 - \phi_t) E[M_{t+1}^H \hat{N}_{t+1} | z_t, W_t^M, (\phi_t, N_t^M, N_t, B_t, R_t^b)].$$

The intermediary's debt must also be priced by the household's SDF,

$$1 = E_t[M_{t+1}^H R_t^b].$$

Note that the expectation relevant for the equity purchase decision is conditional on the state variables z_t, W_t^M and the capital structure of the intermediary, but not on the intermediary's asset allocation (which we define below). That is, the household must form a conjecture about how the manager will choose to invest, and price the equity accordingly; the manager cannot commit. This is a key friction, which is also employed by He and Krishnamurthy (2011).

We have assumed that the intermediary is risk-free. We are ignoring the possibility of default; the model of He and Krishnamurthy (2011) that we are building on is developed in continuous time with continuous price processes, and hence also excludes the possibility of default. We develop a discrete time model to make the intuition behind our hypothesized SDF clear, and have found that incorporating the possibility of default obfuscates that intuition.[44]

We next turn to the intermediary's budget constraints. We allow the manager of the intermediary to divert resources from the intermediary instead of investing them. Let $\Delta_t \geq 0$ be the resources diverted. In equilibrium, households will ensure that diversion does not occur by ensuring that ϕ_t, the manager's claim on the assets, is sufficiently high.

[44]Note, however, that incorporating the possibility of default is necessary for the model to speak to issues like whether it is to preferable to examine OIS or IBOR bases.

Let I be the set of all assets available to the intermediary. We partition this set into "cash" and "derivative" assets, I^c and I^d, assuming that the former require an upfront cash investment whereas the latter are contracts entered into with zero initial net-present-value. Cash assets affect the intermediary's initial budget constraint, whereas the derivatives do not. Let α_t^i be the dollar amount (cash) or notional (derivative) invested in asset i, scaled by the initial non-diverted intermediary equity N_t.

The intermediary's initial budget constraint is

$$N_t + B_t = \Delta_t + N_t \sum_{i \in I^c} \alpha_t^i.$$

The excess return (cash assets) or profit per unit notional (derivative assets) of asset i is defined as $R_{t+1}^i - R_t^b$. The distribution of these returns is a function of z_t, and the returns are realized at the end of the period. The intermediary's net worth when it is liquidated at the end of the period is therefore

$$\hat{N}_{t+1} = -R_t^b B_t + N_t \sum_{i \in I^c} \alpha_t^i R_{t+1}^i + N_t \sum_{i \in I^d} \alpha_t^i (R_{t+1}^i - R_t^b),$$

which can be re-written as

$$\hat{N}_{t+1} = R_t^b (N_t - \Delta_t) + N_t \sum_{i \in I} \alpha_t^i (R_{t+1}^i - R_t^b).$$

Using this definition, we can rewrite the household's equity participation constraint as

$$\begin{aligned} N_t - N_t^M \leq & (1 - \phi_t)(N_t - \Delta_t^*) \\ & + N_t (1 - \phi_t) E_t[M_{t+1}^H \sum_{i \in I} \alpha_t^{i*} (R_{t+1}^i - R_t^b)]), \end{aligned}$$

where Δ_t^* and α_t^{i*} are the policies that the household conjectures based on observing the state variables and capital structure.

Lastly, as described in the text, we assume that the intermediary operates under a regulatory constraint that affects only cash assets:

$$1 \geq \sum_{i \in I^c} k^i |\alpha_t^i|.$$

Note that we have assumed that the regulatory constraint cannot limit the cashflow diversion of the manager.[45]

[45] Our model inherits from He and Krishnamurthy (2017) the somewhat awkward assumption that the

These constraints describe the operation of the intermediary. We next turn to the decisions and preferences of the manager. We assume the manager has Epstein-Zin preferences (Epstein and Zin (1989)), with risk-aversion parameter γ, intertemporal elasticity of substitution parameter ψ, and a subjective discount factor of β, and define $\theta = \frac{1-\gamma}{1-\psi^{-1}}$. Whatever wealth she does not consume or invest in the intermediary, plus any resources she diverts from the intermediary, is saved in risk-free assets, but the manager cannot borrow. When the manager diverts Δ_t resources from the intermediary, she receives only $(1+\chi)^{-1}\Delta_t$, which she can save in the risk-free asset. As a result, her wealth entering the next period is

$$W_{t+1}^M = R_t^b(W_t^M - C_t^M - N_t^M + \frac{\Delta_t}{1+\chi}) + \phi_t \hat{N}_{t+1},$$

where the first term represents the intermediary's outside savings and the second her share of the intermediary's liquidation value.

We now define the Bellman equation describing the manager's problem. The manager solves

$$\begin{aligned} V(W_t^M, z_t) = & \max_{C_t^M \geq 0, N_t^M \geq 0, N_t \geq 0, \phi_t \in [0,1], \Delta_t \geq 0, \{\alpha_t^i\}_{i \in I}} \\ & \{(C_t^M)^{1-\psi^{-1}} + \beta E_t[V(W_{t+1}^M, z_{t+1})^{1-\gamma}]^{\theta^{-1}}\}^{\frac{1}{1-\psi^{-1}}}, \end{aligned}$$

subject to

$$\begin{aligned} \hat{N}_{t+1} &= R_t^b(N_t - \Delta_t) + N_t \sum_{i \in I} \alpha_t^i (R_{t+1}^i - R_t^b), \\ W_{t+1}^M &= R_t^b(W_t^M - C_t^M - N_t^M + \frac{\Delta_t}{1+\psi}) + \phi_t \hat{N}_{t+1}, \\ C_t^M + N_t^M &\leq W_t^M, \\ N_t - N_t^M &\leq (1-\phi_t)(N_t - \Delta_t^*) \\ &\quad + N_t(1-\phi_t)E_t[M_{t+1}^H \sum_{i \in I} \alpha_t^{i*}(R_{t+1}^i - R_t^b)], \\ \sum_{i \in I^c} k^i |\alpha_t^i| &\leq 1, \\ N_t^M &\leq N_t. \end{aligned}$$

In defining this problem, we have eliminated the debt level B_t as a choice variable by substituting out the initial budget constraint, and we have assumed that the manager will choose

manager cannot commit when choosing an asset allocation, even though the regulator can limit the manager's asset allocation.

to offer a capital structure acceptable to households. This assumption is without loss of generality, as the manager can always set $N_t^M = N_t$, $\phi_t = 1$, which is equivalent to having her offer rejected. Note also that this problem is part of an equilibrium of a capital raising game. That is, the households expectations Δ_t^* and α_t^{i*} are functions of the proposed capital structure and must be consistent with the manager's ultimate choices given that capital structure.[46]

We next describe a lemma that collects a number of simplifying results, in particular focusing on an equilibrium in which no cashflow diversion occurs in equilibrium and the anticipated asset allocation depends only in the investment opportunities. These results are essentially identical to statements contained in He and Krishnamurthy (2011).

Lemma 1. *In the manager's problem, there exists an equilibrium in which:*

1. *The optimal allocation α_t^{i*} is a function only of the state vector z_t, and satisfies*

$$-1 < E_t[M_{t+1}^H \sum_{i \in I} \alpha_t^{i*}(R_{t+1}^i - R_t^b)] < \frac{1}{\chi},$$

2. *There is no diversion, $\Delta_t = \Delta_t^* = 0$, and the manager's share satisfies $\phi_t^* \geq (1+\chi)^{-1}$,*

3. *The household equity participation constraint binds,*

4. *The manager invests all savings in the intermediary, $C_t^M + N_t^M = W_t^M$, with $N_t^M > 0$,*

5. *The manager's share ϕ_t^* and fee f_t^M are functions only of z_t, with*

$$f_t^M(z_t) = \frac{\phi_t^*(z_t)}{\phi_t^*(z_t) - (1-\phi_t^*(z_t))E_t[M_{t+1}^H \sum_{i \in I} \alpha_t^{i*}(R_{t+1}^i - R_t^b)]}.$$

6. *$f_t^M(z_t) \geq 1$, strictly if and only if $E_t[M_{t+1}^H \sum_{i\in I} \alpha_t^{i*}(R_{t+1}^i - R_t^b)] > 0$, and $\phi_t^* = (1+\chi)^{-1}$ if $f_t^M > 1$.*

Proof. See below. □

With these results, the manager's final wealth is

$$\begin{aligned} W_{t+1}^M &= \phi_t \hat{N}_{t+1} \\ &= (W_t^M - C_t^M) f_t^M(z_t)(R_t^b + \sum_{i \in I} \alpha_t^i (R_{t+1}^i - R_t^b)), \end{aligned}$$

[46] Formally, we do not require that this equilibrium be subgame perfect. This simplification allows us to focus directly on an equilibrium in which the manager puts all her savings in the intermediary. He and Krishnamurthy (2011) Lemma 2 proves (in the context of their model; our model is essentially the discrete time version) that this outcome holds in all equilibria.

and the manager's problem can be written as

$$V(W_t^M, z_t) = \max_{C_t^M \geq 0, \{\alpha_t^i\}_{i \in I}} \{(C_t^M)^{1-\psi^{-1}} + \beta E_t[V(W_{t+1}^M, z_{t+1})^{1-\gamma}]^{\theta^{-1}}\}^{\frac{1}{1-\psi^{-1}}},$$

subject to

$$W_{t+1}^M = (W_t^M - C_t^M) f_t^M(z_t)(R_t^b + \sum_{i \in I} \alpha_t^i (R_{t+1}^i - R_t^b)),$$

$$\sum_{i \in I^c} k^i |\alpha_t^i| \leq 1.$$

It is useful to define the log return on the manager's wealth,

$$\begin{aligned} r_{t+1}^w &= \ln(f_t^M) + \ln(R_t^b + \sum_{i \in I} \alpha_t^i (R_{t+1}^i - R_t^b)) \\ &= \ln(\frac{W_{t+1}^M}{W_t^M - C_t^M}). \end{aligned}$$

This definition includes the fee f_t^M, unlike the usual definition of the return on wealth. As shown in Lemma 1, this fee will be positive if and only the intermediary's portfolio earns an abnormal return under the household's SDF, and in this case the "inside equity" constraint $\phi_t^* \geq (1+\chi)^{-1}$ will bind. This is natural, but not guaranteed, in the presence of arbitrage opportunities.

For example, if the intermediary can only 1) engage in arbitrage or 2) buy assets that are also priced under the household's SDF, and arbitrage opportunities exist, then it must the case that $f_t^M > 1$. However, if the intermediary can also buy assets that are "expensive" from the household's perspective, then even in the presence of arbitrage opportunities it is not necessarily the case that $f_t^M > 1$. This kind of indifference occurs in He and Krishnamurthy (2011) when the inside equity constraint does not bind (normal times).

In the main text, we assume that $f_t^M = 1$ to illustrate the point that the regulatory constraint can bind even if the inside equity constraint does not. In the remainder of this Internet Appendix, we present results that include f_t^M. Note also that f_t^M can vary over time (in particular, when the economy transitions from "normal" to "crisis" times), and that the increase in f_t^M in crisis times generates an additional intertemporal hedging motive.[47]

We next derive the Euler equation for consumption and the first-order conditions for

[47]Exploring the interactions between intertemporal hedging and the non-linearity in intermediary asset pricing models is an interesting avenue for future research. We thank David Chapman for pointing out this possibility.

portfolio choice in the usual way, following Epstein and Zin (1989). The only complications that our model introduces relative to Epstein and Zin (1989) are the fee f_t^M, which alters the definition of the wealth return, and the constraint, which introduces a multiplier into the portfolio choice problem but does not change the consumption Euler equation. We summarize these equations in the lemma below, and for completeness provide a derivation at the end of this section.

Lemma 2. *Define* $\Delta c_{t+1}^M = \ln(C_{t+1}^M) - \ln(C_t^M)$, *and* $m_{t+1} = \theta \ln(\beta) + (\theta - 1) r_{t+1}^w - \frac{\theta}{\psi} \Delta c_{t+1}^M$. *For the manager's problem, the first-order condition associated with the consumption-savings decision is*

$$1 = E_t[\exp(m_{t+1} + r_{t+1}^w)]$$

and the first-order condition for α_t^i *is*

$$E_t[\exp(m_{t+1})(R_{t+1}^i - R_t^b)] = \lambda_t^{RC} k^i sgn(\alpha_t^i),$$

Proof. See below. □

Consider in particular the first-order conditions associated with a foreign currency risk-free bond and with a forward contract on the exchange rate. The return on the foreign currency bond is $R_t^c \frac{S_t}{S_{t+1}}$, and the profit of the forward (a derivative) is $\frac{S_{t+1} - F_{t,1}}{S_{t+1}}$ per dollar notional. The two first-order conditions are

$$E_t[\exp(m_{t+1})(R_t^c \frac{S_t}{S_{t+1}} - R_t^b)] = \lambda_t^{RC} k^c sgn(\alpha_t^c)$$

and

$$E_t[\exp(m_{t+1})(\frac{S_{t+1} - F_{t,1}}{S_{t+1}})] = 0.$$

Combining these two equations yields

$$E_t[\exp(m_{t+1})(R_t^c \frac{S_t}{F_{t,1}} - R_t^b)] = \lambda_t^{RC} k^c sgn(\alpha_t^c),$$

or

$$E_t[\exp(m_{t+1})] R_t^b (\exp(-x_{t,1}) - 1) = \lambda_t^{RC} k^c sgn(\alpha_t^c),$$

where $x_{t,1}$ is defined as in the main text. Taking absolute values gives Equation (4).

Combining this equation with the first-order condition for an arbitrary asset i, we have

$$E_t[\exp(m_{t+1})(R_{t+1}^i - R_t^b(1 + sgn(\alpha_t^i) \frac{k^i}{k^c} |1 - \exp -x_{t,1}|)] = 0.$$

We conclude that, holding risk premia constant, the absolute value of the cross-currency basis should predict asset returns, at least for those assets the intermediary is consistently long or short. However, the "holding risk premia" constant caveat is potentially quite important. It may very well be the case that the cross-currency basis co-moves with other variables in z_t that predict changing variances and co-variances, and hence risk premia and expected returns.

We should also emphasize that this prediction is difficult to test. Return predictability regressions often require long time series, but our theory only applies to the period in which regulatory constraints create CIP violations (essentially the post-financial-crisis period). It may be possible to construct stronger tests even in short data samples by imposing structure on the coefficients k^i/k^c, by taking a stand on the nature of the regulatory constraint. For example, a pure leverage constraint might set all of these coefficients to unity for all assets i. Our approach focuses on a different prediction of the model, which we derive next.

Let us consider the first-order condition associated with the wealth portfolio. We have

$$E_t[\exp(m_{t+1})(\sum_{i\in I}\alpha_t^{i*}(R_{t+1}^i - R_t^b))] = \lambda_t^{RC}\sum_{i\in I}\alpha_t^{i*}k^i sgn(\alpha_t^i),$$

which is

$$E_t[\exp(m_{t+1})(\exp(r_{t+1}^w - \ln(f_t^M)) - R_t^b)] = \lambda_t^{RC}.$$

This simplifies to Equation (5) in the $f_t^M = 1$ case.

We next apply the log-normality approximation used by Campbell (1993), and assume that all conditional variances and covariances are constant (i.e. that the model is homoskedastic). Under these assumptions, and using the first-order approximation

$$\ln(1 + \frac{k^i}{k^c}sgn(\alpha_t^i)|1 - \exp(-x_{t,1})|) \approx \frac{k^i}{k^c}sgn(\alpha_t^i)|x_{t,1}|,$$

we can simplify the Euler equation for asset i to

$$E_t[r_{t+1}^i] - r_t^b + \frac{1}{2}(\sigma^i)^2 = \frac{\theta}{\psi}\sigma^{ic} + (1-\theta)\sigma^{iw} + \frac{k^i}{k^c}sgn(\alpha_t^i)|x_{t,1}|, \tag{A1}$$

where $r_{t+1}^i = \ln(R_{t+1}^i)$, $(\sigma^i)^2$ is the conditional variance of the log return, σ^{ic} is the conditional covariance of the log return and log consumption growth, and σ^{iw} is the conditional covariance of the log return and the log wealth return. Compared to the textbook formula (Campbell (2017)), the expected excess return now includes an effect of the cross-currency basis, scaled by the relative risk-weights between asset i and the foreign-currency bond. This result is essentially the "margin-based CCAPM" result of Garleanu and Pedersen (2011), except that we have used a cross-currency basis to measure that shadow value of the constraint and employed Epstein-Zin preferences instead of CRRA utility.

Using the standard approximation for the return of the wealth portfolio (Campbell (2017)), and accounting for the possibility of extra fee income, we have

$$\begin{aligned} E_t[r^w_{t+1} - \ln(f^M_t)] - r^b_t + \frac{1}{2}(\sigma^w)^2 &= \sum_{i\in I} \alpha^i_t (E_t[r^i_{t+1}] - r^b_t + \frac{1}{2}(\sigma^i)^2) \\ &= \frac{\theta}{\psi}\sigma^{wc} + (1-\theta)\sigma^{w^2} + \frac{1}{k^c}|x_{t,1}|. \end{aligned}$$

It follows by the homoskedasticity assumption and the law of iterated expectations that

$$(E_{t+1} - E_t)[r^w_{t+1+j}] = (E_{t+1} - E_t)[r^b_{t+j} + \ln(f^M_{t+j}) + \frac{1}{k^c}|x_{t,1}|].$$

We next combine the log-linear approximation of the intertemporal budget constraint developed by Campbell (1993) and the Euler equation for the consumption-savings decision derived in Lemma 2. These two equations together show that

$$\Delta c^M_{t+1} - E_t[\Delta c^M_{t+1}] = r^w_{t+1} - E_t[r^w_{t+1}] + (1-\psi)\sum_{j=1}^{\infty} \rho^j (E_{t+1}[r^w_{t+1+j}] - E_t[r^w_{t+1+j}]).$$

Note that this formula is identical to a result in Campbell (1993), because the Euler equation for the consumption-savings is not distorted by the regulatory constraint (which only affects the asset allocation).

Plugging our equation for the expected return on the wealth portfolio into this equation, and then the resulting expression for consumption growth into the equation defining the return of an arbitrary asset i (equation (A1)), leads to our main result.

Theorem 3. *The expected arithmetic excess return of an arbitrary asset i can be written as*

$$E_t[r^i_{t+1}] - r^b_t + \frac{1}{2}(\sigma^i)^2 = \gamma\sigma^{iw} + (\gamma - 1)\sigma^{ih} + \frac{k^i}{k^c} sgn(\alpha^i_t)|x_{t,1}|, \tag{A2}$$

where σ^{iw} is the conditional covariance with the wealth portfolio and

$$\sigma^{ih} = Cov_t[r^i_{t+1}, \sum_{j=1}^{\infty} \rho^j (E_{t+1} - E_t)(\frac{1}{k^c}|x_{t+j,1}| + \ln(f^M_{t+j}) + r^b_{t+j})]. \tag{A3}$$

This theorem arrives at the usual conclusion that, if $\gamma > 1$, the manager will be concerned about hedging her investment opportunities, and will demand a risk premium for assets whose returns co-vary with those investment opportunities. Conversely, if $\gamma < 1$, the manager prefers assets whose returns co-vary with her investment opportunities, because those assets allow the manager to better take advantage of those investment opportunities.

Future arbitrage opportunities are a particularly stark example of an investment opportunity, and indicative of the expected returns on the wealth portfolio, and hence returns that negatively co-vary with future arbitrages should have a high risk premium if $\gamma < 1$ and a low risk premium if $\gamma > 1$.

The last piece of our argument is the conjecture (which is verified in the data) that arbitrage opportunities are likely to be persistent. As a result, shocks to the cross-currency basis at time $t+1$ are likely to be indicative of shocks to the arbitrage at later dates. For illustrative purposes only (and ignoring issues about negative numbers), suppose that $|x_{t,1}|$ follows an AR(1) process,

$$|x_{t+1,1}| = \bar{x} + \phi|x_{t,1}| + \sigma^{|x|}\epsilon_{t+1},$$

where ϵ_{t+1} is an I.I.D. standard normal shock. In this case, we have

$$\sum_{j=1}^{\infty} \rho^j (E_{t+1}[\cdot|z_{t+1}] - E[\cdot|z_t])\frac{1}{k_c}|x_{t+j,1}|) = \frac{1}{k_c}\frac{1}{1-\rho\phi}\sigma^{|x|}\epsilon_{t+1}.$$

Under very strong assumptions (i.e. that borrowing rates r^b_{t+j} and fees f^m_{t+j} are uncorrelated with ϵ_{t+1}), the constant $\frac{1-\gamma}{k_c}\frac{1}{1-\rho\phi}\sigma^{|x|}$ is equal to the value of ξ defined in our hypothesized functional form for the log SDF. More generally, projecting the revisions in expectations found in Equation (A3) onto the current innovation in the cross-currency basis, under the assumption that such innovations are persistent, generates our hypothesized functional form for the log SDF, Equation (1).

B.1 Proof of Lemma 1

First, observe that diversion does not change α^{i*}_t in the conjectured equilibrium. Consequently, the net benefit of stealing is proportional to

$$\beta R^b_t E_t[V(W^M_{t+1}, z_{t+1})^{-\gamma} V_W(W^M_{t+1}, z_{t+1})](\frac{1}{1+\chi} - \phi_t),$$

and by the usual arguments $V_W(W^M_{t+1}, z_{t+1}) > 0$. If $\frac{1}{1+\chi} > \phi_t$, stealing has a net benefit, and this benefit does not diminish. Consequently, there cannot be a solution with outside equity ($N^M_t > N_t$). Conversely, if $\frac{1}{1+\chi} \leq \phi_t$, diversion has a weakly negative net benefit, and it is without loss of generality to suppose diversion does not occur in equilibrium. By the argument in the main text, it is without loss of generality to suppose $\frac{1}{1+\chi} \leq \phi_t$ and there is no equilibrium stealing.

Now consider a perturbation which increases N_t but shrinks α^i_t so that $\alpha^i_t N_t$ remains constant for all assets. If the household participation constraint does not bind, this generates a strict welfare improvement for the manager and is always feasible. Therefore, the household participation constraint binds,

$$\phi_t N_t (1 - \frac{(1-\phi_t)}{\phi_t} E_t[M^H_{t+1} \sum_{i \in I} \alpha_t^{i*}(R^i_{t+1} - R^b_t)]) = N^M_t.$$

Note by assumption that

$$-1 < E_t[M^H_{t+1} \sum_{i \in I} \alpha_t^{i*}(R^i_{t+1} - R^b_t)] < \frac{1}{\chi} \leq \frac{\phi_t}{1-\phi_t}$$

and hence that positive values of N^M_t and N_t are feasible. Observe that if $N^M_t = N_t = 0$, the manager is taking no risk, which cannot be optimal by the principle of participation. Therefore these values are strictly positive.

Under these assumptions, the manager's fee f^M_t is a function of z_t and ϕ_t,

$$f^M_t(\phi_t, z_t) = \frac{\phi_t}{\phi_t - (1-\phi_t) E[M^H_{t+1} \sum_{i \in I} \alpha_t^{i*}(R^i_{t+1} - R^b_t)|z_t]},$$

Moreover, the manager's final wealth is

$$W^M_{t+1} = R^b_t (W^M_t - C^M_t - N^M_t) + N^M_t f^M_t(\phi_t, z_t)(R^b_t + \sum_{i \in I} \alpha^i_t (R^i_{t+1} - R^b_t)).$$

Note that $f^M_t(\phi_t, z_t)$ is strictly increasing in ϕ_t if $E_t[M^H_{t+1} \sum_{i \in I} \alpha_t^{i*}(R^i_{t+1} - R^b_t)] < 0$ and strictly decreasing if $E_t[M^H_{t+1} \sum_{i \in I} \alpha_t^{i*}(R^i_{t+1} - R^b_t)] > 0$. In the increasing case, we must have $\phi^*_t = 1$ and in this case $f^M_t = 1$; in the decreasing case, $f^M_t \geq 1$, strictly if $E_t[M^H_{t+1} \sum_{i \in I} \alpha_t^{i*}(R^i_{t+1} - R^b_t)] > 0$, and therefore $f^M_t \geq 1$ always. It also follows that ϕ^*_t is purely a function of z_t, and hence the fee f^M_t is also purely a function of z_t.

Now consider a perturbation that increasing N^M_t while scaling down α^i_t so that $N^M_t f^M_t(\phi_t, z_t)\alpha^i_t$ remains constant for all $i \in I$. This perturbation has a weak net benefit, as it increases W^M_{t+1}, and hence it is without loss of generality to suppose $N^M_t = W^M_t - C^M_t$.

We have demonstrated the stated properties conditional in the conjectured that α^{i*}_t is a function only of z_t. We now show that this an equilibrium. We scale variables by wealth. Define $c^m_t = \frac{C^M_t}{W^M_t}$. The problem is

$$V(W^M_t, z_t) = \max_{c^M_t \geq 0, \{\alpha^i_t\}_{i \in I}} \{(W^M_t)^{1-\psi^{-1}} (c^M_t)^{1-\psi^{-1}} + \beta E_t[V(W^M_{t+1}, z_{t+1})^{1-\gamma}]^{\theta^{-1}}\}^{\frac{1}{1-\psi^{-1}}},$$

subject to

$$\frac{W_{t+1}^M}{W_t^M} = f_t^M(z_t)R_t^b(1-c_t^M) + (1-c_t^M)f_t^M(z_t)\sum_{i\in I}\alpha_t^i(R_{t+1}^i - R_t^b),$$

$$\sum_{i\in I^c} k^i|\alpha_t^i| \leq 1.$$

We can immediately (following Epstein and Zin (1989)) conjecture and verify that $V(W_t^M, z_t)$ is linear in wealth,

$$V(W_t^M, z_t) = W_t^M J(z_t)$$

for some function $J(z_t)$, and that as a result the optimal policies do not depend on wealth (or any capital structure variables), verifying the conjecture.

B.2 Proof of Lemma 2

Define

$$R_{t+1}^w = f_t^M(z_t)(R_t^b + \sum_{i\in I}\alpha_t^i(R_{t+1}^i - R_t^b)).$$

Using homotheticity, $V(W_t^M, z_t) = W_t^M J(z_t)$, and writing the problem in Lagrangean form,

$$\begin{aligned} J(z_t) = & \max_{c_t^M\geq 0, \{\alpha_t^i\}_{i\in I}} \min_{\hat{\lambda}_t^{RC}\geq 0} \\ & \{(c_t^M)^{1-\psi^{-1}} + \beta E_t[((1-c_t^M)R_{t+1}^w)^{(1-\gamma)}J(z_{t+1})^{1-\gamma}]^{\theta^{-1}}\}^{\frac{1}{1-\psi^{-1}}} \\ & + \hat{\lambda}_t^{RC}(1 - \sum_{i\in I^c} k^i|\alpha_t^i|). \end{aligned}$$

The Euler equation is derived in the usual way. Taking the FOC with respect to c_t^M,

$$(c_t^M)^{-\psi^{-1}} = \beta(1-c_t^M)^{-\psi^{-1}}E_t[(R_{t+1}^w)^{(1-\gamma)}J(z_{t+1})^{1-\gamma}]^{\theta^{-1}},$$

and plugging this back into the Bellman equation,

$$\begin{aligned} J(z_t) &= \{(c_t^M)^{1-\psi^{-1}} + (1-c_t^M)(c_t^M)^{-\psi^{-1}}\}^{\frac{1}{1-\psi^{-1}}} \\ &= \{(c_t^M)^{-\psi^{-1}}\}^{\frac{1}{1-\psi^{-1}}}. \end{aligned}$$

Therefore, the Euler equation is reads

$$(c_t^M)^{-\psi^{-1}} = \beta(1-c_t^M)^{-\psi^{-1}}E_t[(R_{t+1}^w)^{(1-\gamma)}\{(c_{t+1}^M)^{-\psi^{-1}}\}^{\theta}]^{\theta^{-1}}.$$

We can rearrange this to

$$1 = E_t[(R^w_{t+1})^{(1-\gamma)}\{\beta(1-c^M_t)^{-\psi^{-1}}(\frac{c^M_{t+1}}{c^M_t})^{-\psi^{-1}}\}^{\frac{1-\gamma}{1-\psi^{-1}}}],$$

and then substitute $c^M_t = \frac{C^M_t}{W^M_t}$ and $c^M_{t+1} = \frac{C^M_{t+1}}{W^M_{t+1}}$,

$$1 = E_t[(R^w_{t+1})^{(1-\gamma)}\{\beta(1-c^M_t)^{-\psi^{-1}}(\frac{W^M_t}{W^M_{t+1}})^{-\psi^{-1}}\frac{C^M_{t+1}}{C^M_t})^{-\psi^{-1}}\}^{\theta}].$$

Using the budget constraint $\frac{W^M_{t+1}}{W^M_t} = (1-c^M_t)R^w_{t+1}$, we have

$$1 = E_t[(R^w_{t+1})^{(1-\gamma)}\{\beta(R^w_{t+1})^{\psi^{-1}}(\frac{C^M_{t+1}}{C^M_t})^{-\psi^{-1}}\}^{\theta}].$$

Noting that

$$(1-\gamma)(1+\frac{\psi^{-1}}{1-\psi^{-1}}) = \theta,$$

we conclude that the standard consumption Euler equation applies,

$$1 = E_t[(R^w_{t+1})^{\theta}\{\beta\frac{C^M_{t+1}}{C^M_t})^{-\psi^{-1}}\}^{\theta}].$$

The FOC for asset i is

$$\begin{aligned}\frac{1}{1-\psi^{-1}}\{(c^M_t)^{1-\psi^{-1}} + \beta E_t[((1-c^M_t)R^w_{t+1})^{(1-\gamma)}J(z_{t+1})^{1-\gamma}]^{\theta^{-1}}\}^{\frac{1}{1-\psi^{-1}}-1}\times \\ \theta^{-1}(1-\gamma)E_t[\beta^{\theta}((1-c^M_t)R^w_{t+1})^{(1-\gamma)}J(z_t)^{1-\gamma}]^{\theta^{-1}-1}\times \\ (1-c^M_t)^{1-\gamma}E_t[\beta^{\theta}(R^w_{t+1})^{-\gamma}J(z_{t+1})^{1-\gamma}(R^i_{t+1}-R^b_t)] = \hat{\lambda}^{RC}_t k^c sgn(\alpha^c_t).\end{aligned}$$

We can substitute

$$
\begin{aligned}
&E_t[\beta^\theta (R^w_{t+1})^{-\gamma} J(z_{t+1})^{1-\gamma}(R^i_{t+1}-R^b_t)] = \\
&(c^M_t)^{-\psi^{-1}\theta} E_t[\beta^\theta (R^w_{t+1})^{-\gamma} (\frac{c^M_{t+1}}{c^M_t})^{-\psi^{-1}\theta}(R^i_{t+1}-R^b_t)] = \\
&(c^M_t)^{-\psi^{-1}\theta} E_t[\beta^\theta (R^w_{t+1})^{-\gamma} (\frac{W^M_t}{W^M_{t+1}}\frac{C^M_{t+1}}{C^M_t})^{-\psi^{-1}\theta}(R^i_{t+1}-R^b_t)] = \\
&(1-c^M_t)^{\psi^{-1}\theta}(c^M_t)^{-\psi^{-1}\theta} E_t[\beta^\theta (R^w_{t+1})^{\psi^{-1}\theta-\gamma} (\frac{C^M_{t+1}}{C^M_t})^{-\psi^{-1}\theta}(R^i_{t+1}-R^b_t)] = \\
&(1-c^M_t)^{\psi^{-1}\theta}(c^M_t)^{-\psi^{-1}\theta} E_t[\beta^\theta (R^w_{t+1})^{\theta-1} (\frac{C^M_{t+1}}{C^M_t})^{-\psi^{-1}\theta}(R^i_{t+1}-R^b_t)].
\end{aligned}
$$

Re-scaling $\hat{\lambda}_t$ to λ_t results in the FOC in the lemma,

$$
E_t[\beta^\theta (R^w_{t+1})^{\theta-1} (\frac{C^M_{t+1}}{C^M_t})^{-\psi^{-1}\theta}(R^i_{t+1}-R^b_t)] = \lambda^{RC}_t k^c sgn(\alpha^c_t).
$$

C Equivalent definition of the Forward CIP basis

In this section, we show the equivalence between the two definitions for the forward cross-currency basis given by equations (8) and (9), under the assumption of no-arbitrage between forward interest swap rates and term structure of spot interest swap rates.

$$
\begin{aligned}
x_{t,h,\tau} &= r^\$_{t,h,\tau} - r^c_{t,h,\tau} - \frac{12}{\tau}(f_{t,h+\tau} - f_{t,h}) \\
&= \left(\frac{h+\tau}{\tau} r^\$_{t,0,h+\tau} - \frac{h}{\tau} r^\$_{t,0,\tau}\right) - \left(\frac{h+\tau}{\tau} r^c_{t,0,h+\tau} - \frac{h}{\tau} r^c_{t,0,\tau}\right) - \frac{12}{\tau}(f_{t,h+\tau} - f_{t,h}) \\
&= \frac{h+\tau}{\tau}\left[(r^\$_{t,0,h+\tau} - r^c_{t,0,h+\tau}) - \frac{12}{h+\tau}(f_{t,h+\tau} - s_t)\right] \\
&- \frac{h}{\tau}\left[(r^\$_{t,0,h+\tau} - r^c_{t,0,h+\tau}) - \frac{12}{\tau}(f_{t,\tau} - s_t)\right] \\
&= \frac{h+\tau}{\tau} x_{t,0,h+\tau} - \frac{h}{\tau} x_{t,0,h},
\end{aligned}
$$

where the second equality follows no arbitrage between forward interest swap rates and the term structure of spot interest swap rates. This no-arbitrage condition likely holds in practice because arbitrage between interest rate derivatives is not strongly affected by most real-world regulatory constraints. It holds in our model under the assumption that derivatives are not subject to the regulatory constraint.

D Profit Calculations

In this section we detail the calculation of profits for the forward CIP trading strategy, and then show how that can be mapped to the cross-currency basis variables we have defined. We will use yen as our example currency.

At time t, the strategy

1. receives fixed (pays floating) on one dollar notional of a h-month forward-starting τ-month interest-rate swap in dollars at annualized fixed rate $R^{\$}_{t,h,\tau}$,
2. enters into a h-month forward agreement to sell $F_{t,h}$ yen in exchange for one dollar,
3. pays fixed (receives floating) on $F_{t,h}$ yen notional of a h-month forward-starting τ-month interest-rate swap in dollars at rate $R^{c}_{t,h,\tau}$, and
4. enters into a $h+\tau$-month forward agreement to buy $F_{t,h}(R^{c}_{t,h,\tau})^{\frac{\tau}{12h}}$ yen in exchange for dollars at the exchange rate $F_{t,h+\tau}$.

At time $t+h$, the strategy is unwound. The trader

1. unwinds the receive-fixed dollar swap, earning $(\frac{R^{\$}_{t,h,\tau}}{R^{\$}_{t+h,0,\tau}})^{\frac{\tau}{12h}} - 1$ dollars,
2. cash-settles the h-month forward, earning $\frac{S_{t+h}-F_{t,h}}{S_{t+h}}$ dollars,
3. unwinds the pay-fixed swap, earning $\frac{F_{t,h}}{S_{t+h}}(1-(\frac{R^{c}_{t,h,\tau}}{R^{c}_{t+h,0,\tau}})^{\frac{\tau}{12h}})$ dollars, and
4. unwinds the $h+\tau$-month forward, earning $(\frac{1}{F_{t+h,\tau}} - \frac{1}{F_{t,h+\tau}})\frac{F_{t,h}(R^{c}_{t,h,\tau})^{\frac{\tau}{12h}}}{(R^{\$}_{t+h,0,\tau})^{\frac{\tau}{12h}}}$.

In this last expression, we have used $R^{\$}_{t+h,0,\tau}$ as the discount rate on the forward profits (converted to dollars). In our model, because derivatives are unaffected by the regulatory constraint, the dollar risk-free rate is in indeed the correct discount rate for the forward profits. If net derivative profits affected the regulatory constraint, the appropriate discount rate would depend on questions like whether the trader could unwind or net the derivatives instead of simply taking an offsetting position. However, as a practical matter, the choice of discount rate has a minuscule effect on the computed profits.

Therefore, total profit per dollar notional (i.e. the excess return) is

$$\Pi^{c}_{t+h,h,\tau} = (\frac{R^{\$}_{t,h,\tau}}{R^{\$}_{t+h,0,\tau}})^{\frac{\tau}{12h}} - \frac{F_{t,h}}{S_{t+h}}(\frac{R^{c}_{t,h,\tau}}{R^{c}_{t+h,0,\tau}})^{\frac{\tau}{12h}} + (\frac{1}{F_{t+h,\tau}} - \frac{1}{F_{t,h+\tau}})(\frac{R^{c}_{t,h,\tau}}{R^{\$}_{t+h,0,\tau}})^{\frac{\tau}{12h}} F_{t,h}.$$

Recall the definition of the cross-currency basis,

$$(R^c_{t+h,0,\tau})^{\frac{\tau}{12h}} S_{t+h} = \frac{(R^{\$}_{t+h,0,\tau})^{\frac{\tau}{12h}} F_{t+h,\tau}}{(1 + X^c_{t+h,0,\tau})^{\frac{\tau}{12h}}}$$

and

$$(R^c_{t,h,\tau})^{\frac{\tau}{12h}} F_{t,h} = \frac{(R^{\$}_{t,h,\tau})^{\frac{\tau}{12h}} F_{t,h+\tau}}{(1 + X^c_{t,h,\tau})^{\frac{\tau}{12h}}}.$$

Plugging in these definitions,

$$\Pi^c_{t+h,h,\tau} = (\frac{R^{\$}_{t,h,\tau}}{R^{\$}_{t+h,0,\tau}})^{\frac{\tau}{12h}} \left\{ 1 - \frac{F_{t,h+\tau}}{F_{t+h,\tau}} (\frac{1 + X^c_{t+h,0,\tau}}{1 + X^c_{t,h,\tau}})^{\frac{\tau}{12h}} + (\frac{F_{t,h+\tau}}{F_{t+h,\tau}} - 1) \frac{1}{(1 + X^c_{t,h,\tau})^{\frac{\tau}{12h}}} \right\}.$$

This exact profit formula is complicated by a variety of discounting effects that arise in the presence of arbitrage. Note, however, that all of these effects (deviations of interest rates and forward exchange rates from their previous forward values) are typically at most a few hundred basis points. In the presence of cross-currency basis values that on the order of basis points, these discounting effects will be a couple percent of some basis points, and hence for the most part negligible.

We therefore employ a first-order approximation. Define

$$\epsilon^F_{t+h,h,\tau} = \ln(\frac{F_{t+h,\tau}}{F_{t,h+\tau}}),$$
$$\epsilon^R_{t+h,h,\tau} = \ln(\frac{R^{\$}_{t+h,\tau}}{R^{\$}_{t,h,\tau}}).$$

Taking a first-order expansion around $x^c_{t,h,\tau} = x^c_{t+h,\tau} = \epsilon^F_{t+h,h,\tau} = \epsilon^R_{t+h,h,\tau} = 0$, we have

$$\Pi^c_{t+h,h,\tau} \approx \pi^c_{t+h,h,\tau} = \frac{\tau}{12h}(x^c_{t,h,\tau} - x^c_{t+h,0,\tau}).$$

Annualizing these monthly profits gives the formula employed in the main text.

E Forward CIP Trading Strategy's Return Predictability

In this Internet Appendix section, we consider whether the returns of our forward CIP trading strategy are predictable. In the context of the model, as usual, return predictability implies time variation in either the quantity or price of cross-currency basis risk.[48]

We find suggestive evidence that forward CIP trading strategy returns are predictable, in a manner that is analogous to findings of return predictability in the term structure literature (e.g. Campbell and Shiller (1991)). Our approach is inspired by Figure 2; the unconditional returns of the forward CIP trading strategy can be viewed as stating that the increase in the spot bases implied by the forward curves does not end up happening, on average. This result is similar to the familiar concept of a term premium in the term structure literature.

As demonstrated by Campbell and Shiller (1991), the slope of the term structure predicts the excess returns on longer maturity bonds. That is, not only is there a term premium, but it varies over time and variation in the term premium is a significant portion of the variation in the slope of the term structure. We find that a similar fact holds for the term structure of cross-currency bases. In other words, the slope of the term structure predicts forward CIP trading strategy returns.

The return predictability regressions we run are presented in Internet Appendix Table A9. The regressions estimate equations of the form

$$x^c_{t,h,\tau} - x^c_{t+h,0,\tau} = \beta(x^c_{t,h,\tau} - x^c_{t,0,\tau}) + \gamma w_t + \epsilon_{t+h}, \tag{A4}$$

where w_t are other controls. We use three-month tenors ($\tau = 3$) and look at one-month forward differences between the forward basis and the spot basis that is actually realized ($h = 1$). We use the "classic carry" AUD-JPY basis in all regressions, although we find but do not report similar results for various currencies vis-à-vis USD. We estimate the regressions in daily data and rely on a Newey-West HAC kernel with the Newey and West (1994) bandwidth selection procedure to correct the standard errors for overlap in the sample.[49] Note that our outcome variable is not exactly the profit per dollar notional defined in equation (11), because we do not scale the outcome variable by the duration $\frac{\tau}{12}$. This is analogous to regressing yield changes on yields instead of price changes on yields.

The first column of Table A9 simply regresses the outcome variable on a constant. We estimate an unconditional mean of 5 basis points and a root mean squared error of 12 basis points. In other words, on average, the one-month forward implied three-month classic carry basis is 5 basis points higher than the spot three-month basis one month in the future. The ratio of these two, scaled by $\sqrt{12}$, is essentially our point estimate for the annual Sharpe ratio of the unconditional forward CIP trading strategy. The next four columns of Table A9 present the estimations of equation (A4) with various permutations of two controls, the current level of the spot basis ($x^c_{t,\tau}$) and a constant. Column (4), which uses the spread and the spot basis as predictors, appears to offer a low RMSE while using fewer variables than

[48] In Internet Appendix F, we explore a different kind of predictability, and find that quarter-end or year-end crossings do not systematically predict abnormal returns in forward CIP trading strategy.

[49] The results are similar when using only non-overlapping month-end data.

the specification of column (5).[50] The specification in column (4) has the appealing property that, in a world in which both the spot and forward bases are zero (covered interest parity holds), we should expect no return on our forward CIP trading strategy.

Our return predictability results must be interpreted with caution. We usually expect return predictability regressions to require long time series to find significant results. Yet this intuition stems in part from the prior that "good deals" are not available, and that return predictors are very persistent. We find that spreads are not very persistent, and hence that it is possible to find predictability even in our comparatively small sample.

However, this lack of persistence raises another issue. The forward basis $x^c_{t,h,\tau}$ enters both sides of equation (A4), and is surely measured with some bid-offer induced noise. This issue is exactly analogous to the role of a price in a regression of return on lagged return (as in Roll (1984)). A standard approach to dealing with these issues is to avoid using the current value of the forward basis as a predictor value, and replace it with a lagged value instead (see, e.g., Jegadeesh (1990)). We adopt this approach, employing a lagged value of the spread, $x^c_{t-k,h,\tau} - x^c_{t-k,\tau}$, as an instrument for the current value of the spread. Columns (6), (7), and (8) of Table A9 repeat the specification of column (4), using a spread lagged 1, 5, and 10 trading days as an instrument for the current spread value. Our return predictability results continue to hold with this approach, and our point estimates remain similar across specifications, although our standard errors increase in the length of the lag.

We should emphasize that this lag approach is not a panacea (Jegadeesh and Titman (1995)). We have no theory on what causes the spread to vary over time, and hence cannot say decisively that the "real" variation dominates the micro-structure induced variation over a one or two-week period.

F Overnight (ON) and Tomorrow/Next (TN) CIP Deviations

In this Internet Appendix, we demonstrate how to calculate ON and TN CIP deviations. The standard formula for spot and forward CIP deviations (equations (6) and (8) in the paper) do not apply for these short-dated deviations because the spot exchange rate generally settles with T+2 convention, making the spot contract effectively a two-day forward contract. The ON calculation follows the formula in Correa et al. (2020). We use central bank deposit rates as the cash market interest rates, as these administered rates do to change outside central bank meetings. We use spot exchange rates and ON and TN forward points from Bloomberg <BFIX> based on quotes at 8:00 AM New York time.

To calculate the ON CIP deviation, we use the following formula:

$$x^{ON} = ((1 + r * N^{ON}/d) * (S - \phi_{TN}/D)/(S - \phi_{TN}/D - \phi_{ON}/D) - 1) * (d/N^{ON}) - r^{\$},$$

[50] Formally, the column (4) specification has the lowest value of the Akaike Information Criterion (AIC), where the AIC is computed with a sample size of 98 months to account for overlapping data.

where r is the foreign interest rate on foreign central bank deposit, $r^{\$}$ is the interest on reserves paid by the Federal Reserve, S is the spot exchange rate (defined as units of foreign currency per dollar), ϕ_{TN} and ϕ_{ON} are the forward points on the ON and TN contracts, respectively, $d = 360$ is the day count convention, D is the forward point multiplier (10000 for EUR and CHF, and 100 for JPY), and N^{ON} is the number of calendar days between the trading date and the ON contract settlement date (T+1).

To calculate the TN CIP deviation, we use the following formula:

$$x^{TN} = ((1 + r * N^{TN}/d)/S * (S - \phi_{TN}/D) - 1) * (d/N^{TN}) - r^{\$},$$

where N^{TN} is the number of calendar days from between the ON contract settlement date (T+1) and the TN contract settlement date (T+2).

G Definitions of Other Near-Arbitrages

We define the seven near-arbitrages as follows.

- **Bond-CDS basis**: the spread between the yield on the 5-year North America investment grade bonds over their corresponding credit default swaps (CDS). The series is from the J.P. Morgan Markets DataQuery.

- **CDS-CDX basis**: the spread between the composite of 125 single-name CDS spreads in the North America investment grade credit default swap index (CDX.NA.IG) and the quoted spread on the CDX.NA.IG. The series is from the J.P. Morgan Markets DataQuery.

- **US Libor tenor basis**: the spread in fixed rates between a 5-year interest rate swap indexed to one-month US Libor and a 5-year interest rate swap indexed to three-month US dollar Libor. The series is from the J.P. Morgan Markets DataQuery.

- **Swap-Treasury spread**: the spread between the 30-year US Libor interest swap rate and the 30-year US Treasury yield. The series is from Bloomberg.

- **Refco-Treasury spread**: the spread between the yield on the 5-year resolution funding corporation strip (fully backed by the U.S. government) and the 5-year US Treasury bond. The series is from Bloomberg.

- **KfW-Bund spread**: the spread between the yield on the 5-year euro-denominated bonds issued by Kreditanstalt für Wiederaufbau (fully backed by the German government) and the 5-year German bund yield. The series is from Bloomberg.

- **TIPS-Treasury spread**: the spread between the yield on the asset swap package combining a 5-year Treasury bond and an inflation swap and the yield on the 5-year Treasury inflation protected security (TIPS). The series is from Bloomberg.

In Internet Appendix Table A24, we summarize the mean and standard deviation of these near-arbitrages, together with the AUD-JPY spot cross-currency basis, by the pre-GFC, GFC and post-GFC period.

H Estimating the SDF from Prices of Risk

Our hypothesized SDF (Equation (1)) postulates that $m_{t+1} = \mu_t - \gamma r^w_{t+1} + \xi|x_{t+1,1}|$. Let $\lambda = [\lambda_{r_w}, \lambda_{|x|}]$ be the price of risk on the two factors, the wealth portfolio return and the magnitude of the cross-currency basis, respectively, and Σ be the variance-covariance matrix between these two factors. We can estimate the SDF parameters as[51]

$$\begin{bmatrix} \gamma \\ \xi \end{bmatrix} = \Sigma^{-1} \begin{bmatrix} \lambda_{r_w} \\ \lambda_{|x|} \end{bmatrix}.$$

The parameter λ is proportional to the single regression coefficient of the true SDF on the two factors. It therefore can be estimated from the realized market risk premium on the two factor's factor-mimicking portfolios. If we use the He et al. (2017) value-weighted intermediary return on equity as the factor-mimicking portfolio for intermediary wealth returns, and use the returns on the forward CIP trading strategy as a direct measure of the risk premium on the cross-currency basis, then we can estimate λ and, by extension, the SDF parameters γ and ξ.

We estimate the price of risk on intermediary equity return from monthly excess returns from January 1970 to August 2018, the longest panel of returns that we have. The average monthly excess return is about 0.61%, which implies an annual excess return of about 7.3%. We estimate the price of risk on the forward CIP trading strategy from the Post-GFC sample. Given the short sample, we use daily observations of the monthly returns on the 1M-forward 3M AUD-JPY forward CIP trading strategy. The average monthly return is 4.76 basis points, which corresponds to an annual profit of 14.3 basis points on the notional.

To calculate the SDF parameters, we also need the variance-covariance between the two factors. We estimate Σ using monthly returns on the intermediary equity and the 1M-forward 3M AUD-JPY forward CIP trading strategy in the Post-GFC period (July 2010 to August 2018). Together with estimates of λ, we find an estimate of γ of 0.66 and an estimate of ξ of 305. While the estimate of a positive ξ is statistically significant at conventional significance

[51] The signs in this equation are slightly non-standard. The factor in the SDF is $-|x_{t+1}|$, and the forward CIP return is positive when this factor increases (i.e. the basis shrinks).

levels, the estimate of γ is imprecise, and we cannot reject that the true γ is greater than 1. We summarize these results in Internet Appendix Table A25.

I Bayesian Test of Asset Pricing Models

In this Internet Appendix section we describe the Bayesian asset pricing methodology of Barillas and Shanken (2018) and Chib et al. (2020).

Let M_j be a candidate factor model and $\mathcal{ML}_j$ be the marginal likelihood of M_j. The posterior probability of observing a model is

$$P(M_j|Data) = \{\mathcal{ML}_j \times P(M_j)\} \times \left\{\sum_i \mathcal{ML}_i \times P(M_i)\right\}^{-1},$$

where the denominator sums across all models under consideration.

Which models are compared? Consider a set of n factors. One of the n factors (the only one that does not need to be tradable) is the "baseline factor" f_0, and is assumed to be present in all specifications. The remaining $n-1$ tradable factors could be included in the factor model (f) or excluded (f^*), in which case they are treated as test assets. For example, in the first specification in Panel B of Table 5, f_0 is the Market and the only other factor is the Fwd CIP return. In this case, the exercise compares the model using only the Market to the model containing both factors.

For each model M_j, the marginal likelihood is

$$\mathcal{ML}_j = P(R|f) = \int\int P(R|f,\alpha,\beta,\Sigma)P(\alpha|\beta,\Sigma)P(\beta,\Sigma)d\alpha d\beta d\Sigma,$$

where R is the excess returns of the test assets (f^*), f are the factors included in model M_j, and α, β, and Σ are from

$$R_t = \alpha + \beta f_t + \Sigma\epsilon_t.$$

Here, the regression residuals ϵ_t are assumed to be IID across time and normally distributed.

Barillas and Shanken (2018) suggest the prior that all models are equally likely ex-ante ($P(M_j) = P(M_{j'})$), and construct a prior $P(\alpha|\beta,\Sigma)$ based on bounds for Sharpe ratios. Using these priors and an appropriately constructed improper prior for the nuisance parameters $P(\beta,\Sigma)$ (Chib et al. (2020)), we can compute the relative likelihood of each candidate model M_j, $P(M_j|Data)$. We implement this procedure using the software of Chib et al. (2020).

These probabilities depend primarily on the Sharpe ratios of the excluded factors f^* given the factor model (f_0, f). If model M_j with only f is sufficient, then α^* from $f^*_t = \alpha^* + \beta^* f + \epsilon^*$

should be 0. In other words, the marginal likelihood of a model is high when the model is correctly specified relative to all available potential factors.

J Cross-Sectional Asset Pricing Details

In this Internet Appendix section, we provide more details about the cross-sectional asset pricing exercise of Section 5. We begin by describing our test asset portfolios, then discuss the differences between our exercise and He et al. (2017) (HKM).

Internet Appendix Tables A12, A15, and A14 show cross-sectional asset pricing results for our test asset classes with the HKM factors. These tables can be compared (noting the differences in asset class definitions and sample) with Tables 14 and 17 of He et al. (2017).

J.1 Factors and Test Assets

As discussed in the main text, our choice of test assets is inspired by HKM, but for various reasons the exact portfolios we use in each asset class differ slightly from their counterparts in HKM. Below, we describe the data used for each asset class. We truncate all of our series at the end of August 2018.

The Market and the Risk-Free Rate

The equity return we use is the Market factor provided on Ken French's website (originally from CRSP). We also use, for most of our sample, the 1-month t-bill rate provided on Ken French's website (and due to Ibbotson and Associates, Inc.). These are the same data sources used by HKM. However, as discussed on Ken French's website, the Market return was changed in October 2012 and as a result there are some differences between our series and the one originally used by HKM.

We also adjust the risk-free rate in the post-crisis period (as defined in our main text, July 2010 onwards) to use one-month OIS swap rates instead of 1-month t-bill rates. We make this adjustment to be consistent with the risk-free rates we used to compute the cross-currency basis and forward CIP returns. This adjustment has a minimal impact on our results.

The HKM Intermediary Wealth Returns

In our equity-return only specification (Table 6), we use as an equity return the "intermediary value-weighted investment return" of HKM, obtained from Asaf Manela's website. When we use the original HKM specification, perhaps augmented with our basis shock (Internet Appendix Tables A12 A16), we use our market return described above and the "intermediary capital risk factor" of HKM, obtained from Asaf Manela's website.

Equities (FF6)

Our test equity portfolios are the monthly return series of the "6 Portfolios Formed on Size and Book-to-Market (2x3)" available on Ken French's website, building on Fama and French (1993). The series begins in July 1926.

HKM use the 25 portfolio version of these series, with data from 1970 onwards. We use six portfolios instead of twenty five to mitigate the possibility of spurious results arising from the presence of large bank stocks on both sides of the regression. This issue causes, in our post-crisis sample, an unusually strong correlation between the HKM intermediary value-weighted investment return and one particular Size-by-Value 25 portfolio (Large Value). Using only six portfolios instead of twenty five allows us to capture the factor structure of equity returns documented by Fama and French (1993) while mitigating this issue.

There also appear to be a variety of small differences between the returns we obtained from Ken French's website in 2018 and the returns HKM obtained in 2012. Many of these differences are small enough that they can be attributed to rounding, but some are not. Ken French's website does mention a variety of changes in CRSP between 2012 and the present, but none seem directly applicable to the size-and-value portfolios.

US Bonds (US)

Our U.S. bond portfolios include both government and corporate bonds. The government bonds are the five CRSP "Fama Maturity Portfolios" defined in twelve-month intervals, plus the two longer-maturity portfolios (60-120 months and >120 months). We drop the shortest maturity portfolio, because of the similarity between its returns and the risk-free rate, and end up with six government bond portfolios. The corporate bonds are five Bloomberg corporate bond indices, which correspond to US corporate bonds with ratings of AAA, AA, A, B, and high yield.[52]

To include the returns for a particular month, we require that the returns for all six government bond maturity buckets and all five corporate bond indices be available. As a result, our data starts in September 1988. Four of our government portfolios are groupings of the Fama bond portfolios studied by HKM, who use the six-month interval portfolios and do not exclude the shortest maturities or include the longer maturity portfolios. Our corporate bond indices are different from the ones studied by HKM, and were chosen because they are readily available.

Sovereign Bonds (Sov)

Our sovereign bond portfolio construction follows the procedure of Borri and Verdelhan (2015). Those authors consider all countries in the JP Morgan EMBI index, and sort bonds

[52] The tickers are LU3ATRUU Index, LU2ATRUU Index, LU1ATRUU Index, LUBATRUU Index, and LF98TRUU Index.

into six portfolios. They first divide countries into two groups, depending on whether their bonds have a low or high beta to US equity market returns, and then within each of these groups split bonds into three sub-groups based on their S&P rating. HKM use exactly the data of Borri and Verdelhan (2015), as those two papers are roughly contemporaneous.

We implement this procedure with updated data. However, three countries have been dropped from the EMBI index, and do not have returns available for the post-crisis period. These countries are omitted from our entire analysis, and as a result there is an imperfect (80%) correlation between our portfolio returns and the original Borri and Verdelhan (2015) returns.

Foreign Exchange Portfolios (FX)

We use the 11 forward-premium-sorted portfolios of Lustig et al. (2011). These portfolios consist of up to 34 currencies on each date. Six these portfolios contain all currencies, sorted by forward premia. Five contain only developed-country currencies, sorted by forward premia. These returns series are updated regularly and available from Hanno Lustig's website.

In contrast, HKM use six portfolios sorted by forward premia from Menkhoff et al. (2012) and six portfolios sorted by interest rate differential from Lettau et al. (2014).[53] Because covered interest parity holds for most of the sample, these two groups of portfolios should be essentially identical. However, the two papers differ on data sources and samples (Menkhoff et al. (2012) have up to 48 currencies from 1983 to 2009, Lettau et al. (2014) have up to 53 from 1974 to 2010), and consequently the two sets of portfolios to do not exactly span each other.

Equity Options Portfolios (Opt)

We construct equity options portfolios using the procedure of Constantinides et al. (2013) to generate portfolios of puts and calls sorted by moneyness and maturity. We form eighteen portfolios (nine of calls and nine of puts), for three different maturities (30-day, 60-day, and 90-day), and three different levels of moneyness (in-, at-, and out-of-the-money). The underlying data source is OptionMetrics via WRDS.

The OptionMetrics data needs to be cleaned extensively, as discussed at length in Constantinides et al. (2013). We follow their procedure as closely as feasible and are able to construct portfolios whose returns closely track the portfolios of Constantinides et al. (2013) in their original sample.

HKM also use 18 portfolios based on the original portfolios of Constantinides et al. (2013). However, they use nine different moneyness levels for calls and puts, collapsing the three different maturities into a single portfolio for each moneyness. We have found

[53] The published version of Menkhoff et al. (2012) describes only five portfolios, and two other portfolios that are linear combinations of the five.

that collapsing into nine moneyness-by-maturity buckets reduces the correlation between the return series.

We follow Constantinides et al. (2013) in "leverage-adjusting" the option portfolio returns by mixing the original return with some amount of the risk-free return to ensure that the Black-Scholes-implied beta to the market of each portfolio is one. The advantage of this approach is that the return distribution of the options is closer to normal. The disadvantage of this approach is that, by construction, all of the option portfolios have a beta to the Market factor that is close to one. This leads to weak identification, as can be seen in the KZ p-value of column (4) in Internet Appendix Table A13. In the pooled specification (column (9) of that table), other assets help identify the price of Market risk. In our main specification (Table 6), the Market is not included as a factor, and this particular weak identification problem does not arise.

Credit Default Swaps (CDS)

Our CDS returns series consists of returns for five major CDS indices. The indices are CDX.NA.IG (North American investment grade), CDX.NA.HY (North American high yield), CDX.NA.XO (North American cross-over, between investment grade and high-yield), CDX.EM (emerging markets), and iTraxx Europe. These indices are available from Markit and via Bloomberg, with all five series having data from July 2004 onwards.

In contrast, HKM use portfolios of single name CDS returns constructed from Markit data on single-name CDS. We obtained this data and attempted to construct similar portfolios, but were unable to approximately match the return series used by HKM. Using the index returns instead of the single name returns reduces the likelihood of errors in our calculations and should make it easier for other researchers to replicate our results.

Commodity Futures (Comm)

We follow HKM and build on the work of Yang (2013). Specifically, we use the same twenty three commodities used by HKM. We obtain the total return index for that commodity from Bloomberg. These indices aggregate the returns of several short-maturity futures for each commodity. All twenty three commodities are available starting in February 1991.

HKM use instead data from the Commodities Research Bureau, which has the advantage of going back further in time. They also use a slightly different method of aggregating the various short-maturity futures contract returns into a single index for each commodity. Nevertheless, on the shared part of the sample, our returns and theirs are virtually identical.

OIS and IBOR Forward CIP Returns (FwdCIP)

We use OIS and IBOR forward CIP returns in four currencies (CAD, GBP, EUR, CHF) as test assets. Note that this list excludes AUD and JPY, which we used to construct the Classic

Carry forward CIP returns, our proposed factor in the SDF. Consequently, our SDF factor is not spanned by the portfolio of test assets. Our OIS returns include both 1-month forward 1-month and 1-month forward 3-month returns, whereas the IBOR returns are restricted to 3-month tenors due a lack of available data.

For all of these assets, we study as an excess return

$$x^c_{t,h,\tau} - x^c_{t+h,0,\tau},$$

which is the profit per dollar notional, normalized by the duration.

We construct the OIS forward CIP returns as described in the text. IBOR forward CIP returns are constructed in an essentially identical fashion, using 3M spot IBOR rates and FRA agreements with 3M IBOR as the underlying rate. For all returns, we consider only the post-crisis period.

We exclude CHF OIS returns due to problems with the OIS data (and hence use only IBOR for CHF), and exclude CAD IBOR returns due to missing data (and hence use only OIS returns for CAD). As a result, we combine three IBOR-based forward CIP returns with three OIS-based one-month tenor and three OIS-based three-month tenor forward CIP returns, for a total of nine test assets.

J.2 Estimation and Standard Errors

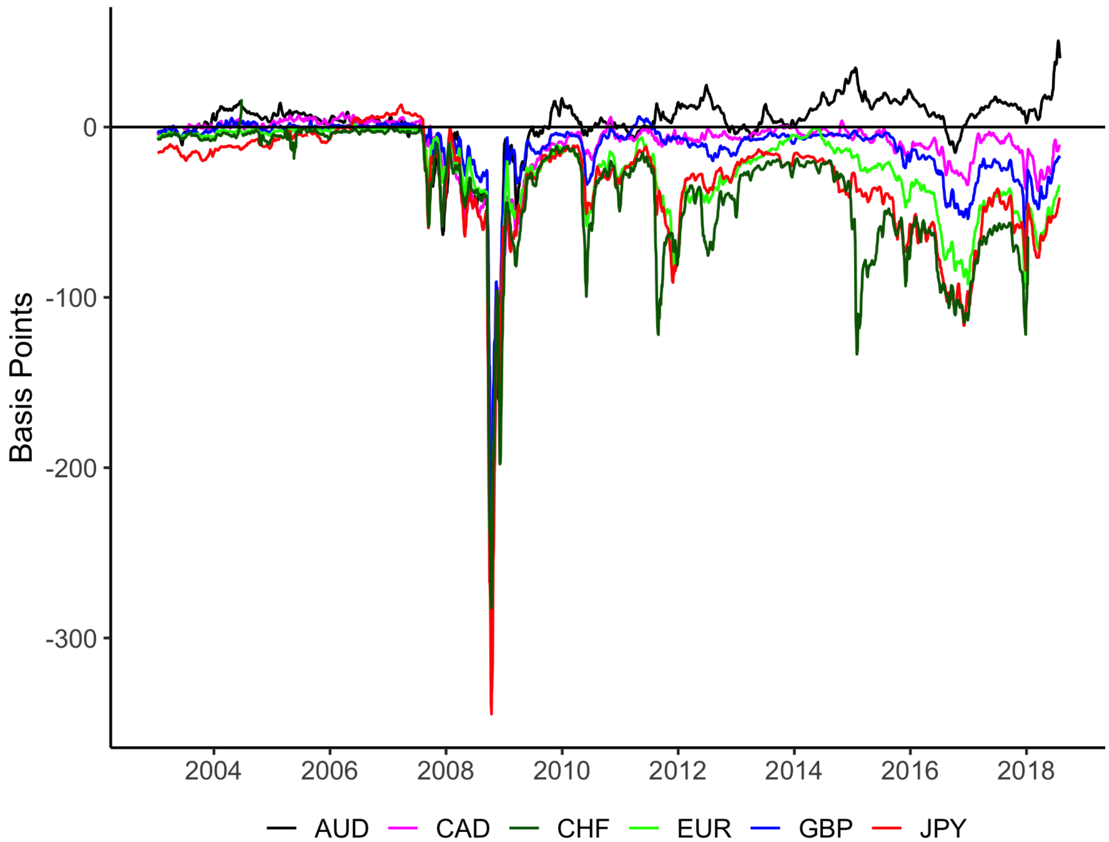
Our analysis is the GMM version of a traditional two-pass regression to estimate the price of various risk-factors, as described in chapter 12 of Cochrane (2009). Our point estimate come from an exactly identified single-step GMM estimation procedure, as described on pages 241-243 of Cochrane (2009). We use a Newey-West kernel with a twelve-month bandwidth (Newey and West (1987)) to construct standard errors that are robust to heteroskedasticity and autocorrelation.

The one key difference between our procedure and the textbook procedure is that we allow the samples for the estimation of the betas and the means to differ.[54] To implement this, we introduce as parameters in our GMM equations a mean-return parameter for each asset and an extra equation for each asset stating that the difference of the mean parameter and the asset excess return is zero in expectation. We then write our cross-sectional asset pricing equation (12) entirely as a function of parameters, with no data. These changes, and allowing our GMM estimator to use different samples for different equations, implement the desired outcome that the mean and beta samples can differ.

[54]For this reason, we do not use an automatic bandwidth selection procedure for our standard errors. We have found that the standard errors are insensitive to the bandwidth choice, likely because returns exhibit small amounts of auto-correlation.

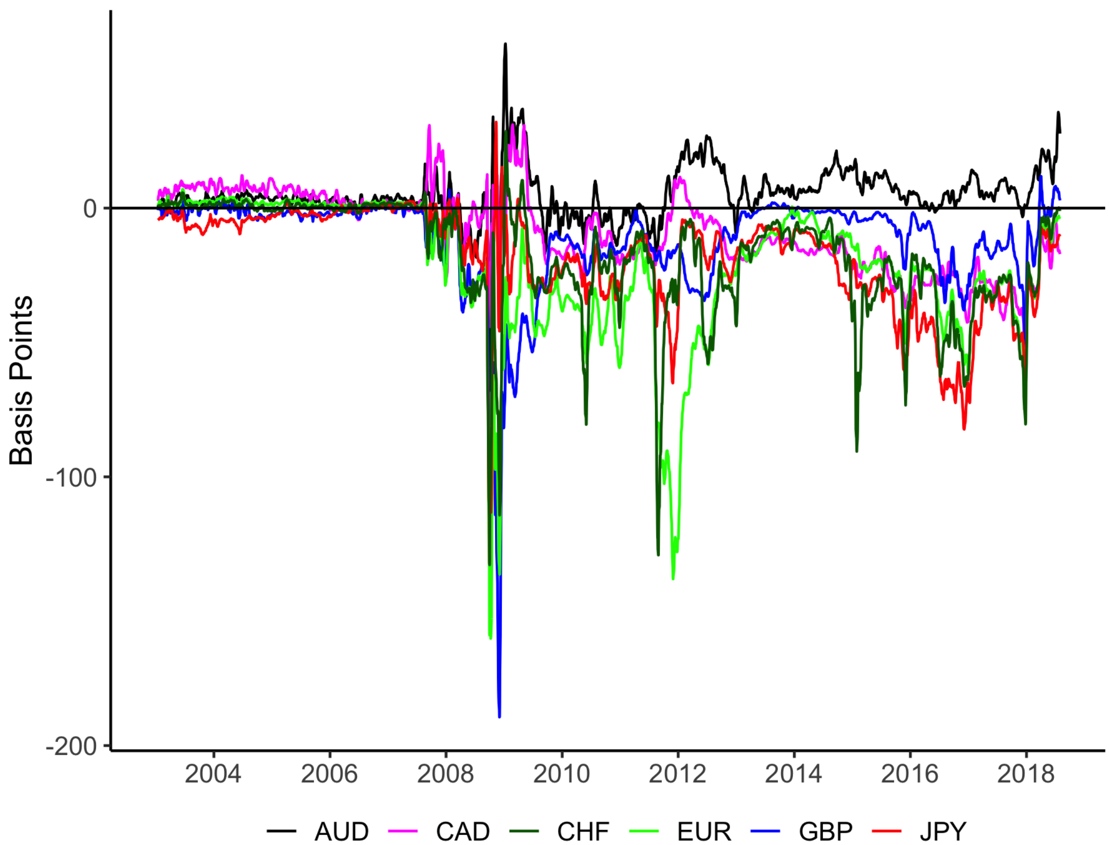
K Additional Figures and Tables

Figure A1: **Three-month OIS-based Cross-Currency Bases**



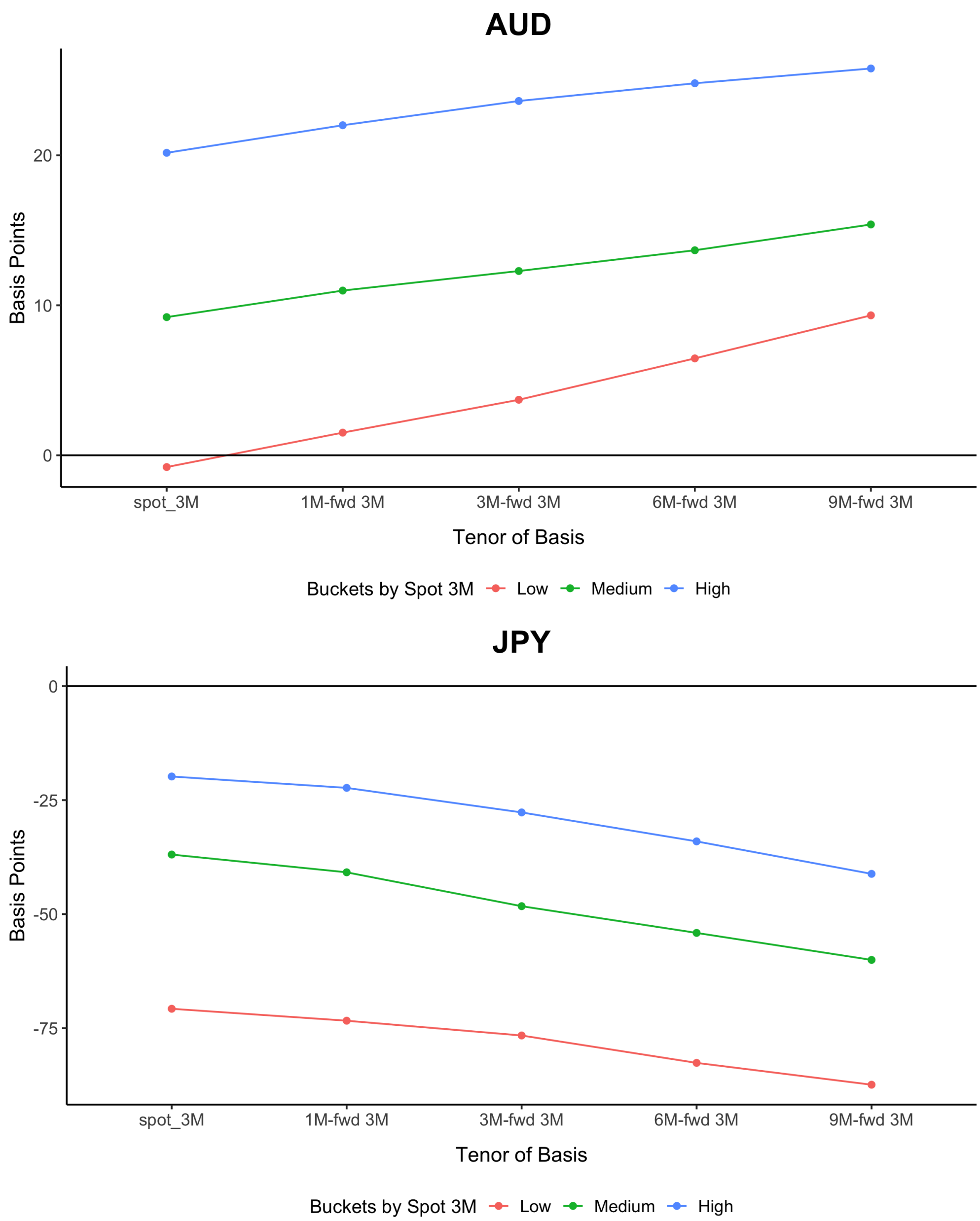
Notes: This figure plots the 10-day moving average of daily spot 3M OIS cross-currency basis vis-à-vis the USD, measured in basis points, for the six sample currencies. The spot OIS basis is $x^c_{t,0,3}$, as defined in Equation (6).

Figure A2: **Three-month IBOR-based Cross-Currency Bases**



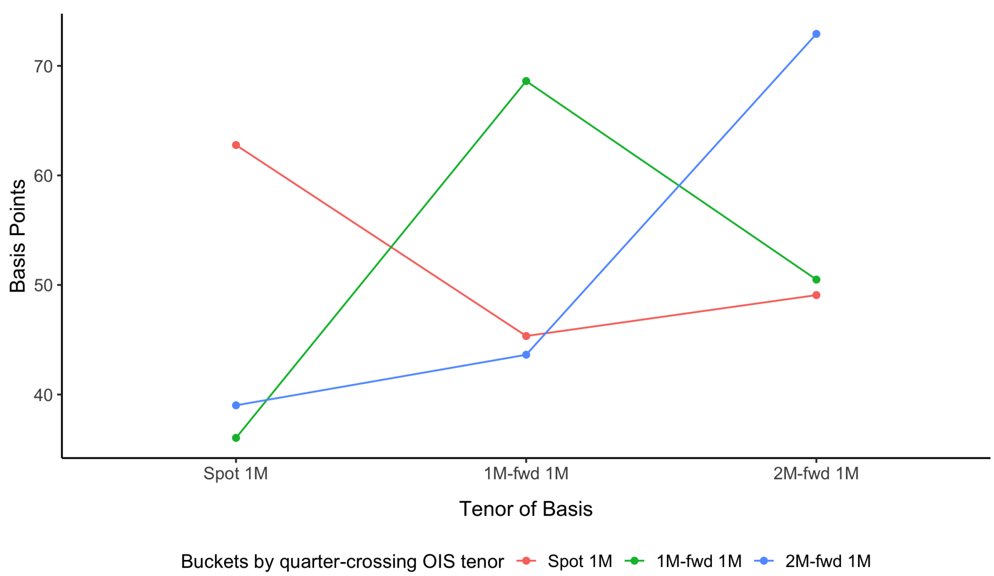
Notes: This figure plots the 10-day moving average of daily spot 3M IBOR cross-currency basis vis-à-vis the USD, measured in bps, for the six sample currencies. The spot IBOR basis is $x^c_{t,0,3}$, as defined in Equation (6).

Figure A3: **Term Structure of the Forward Cross-Currency Basis (Alternative Forward Tenors)**



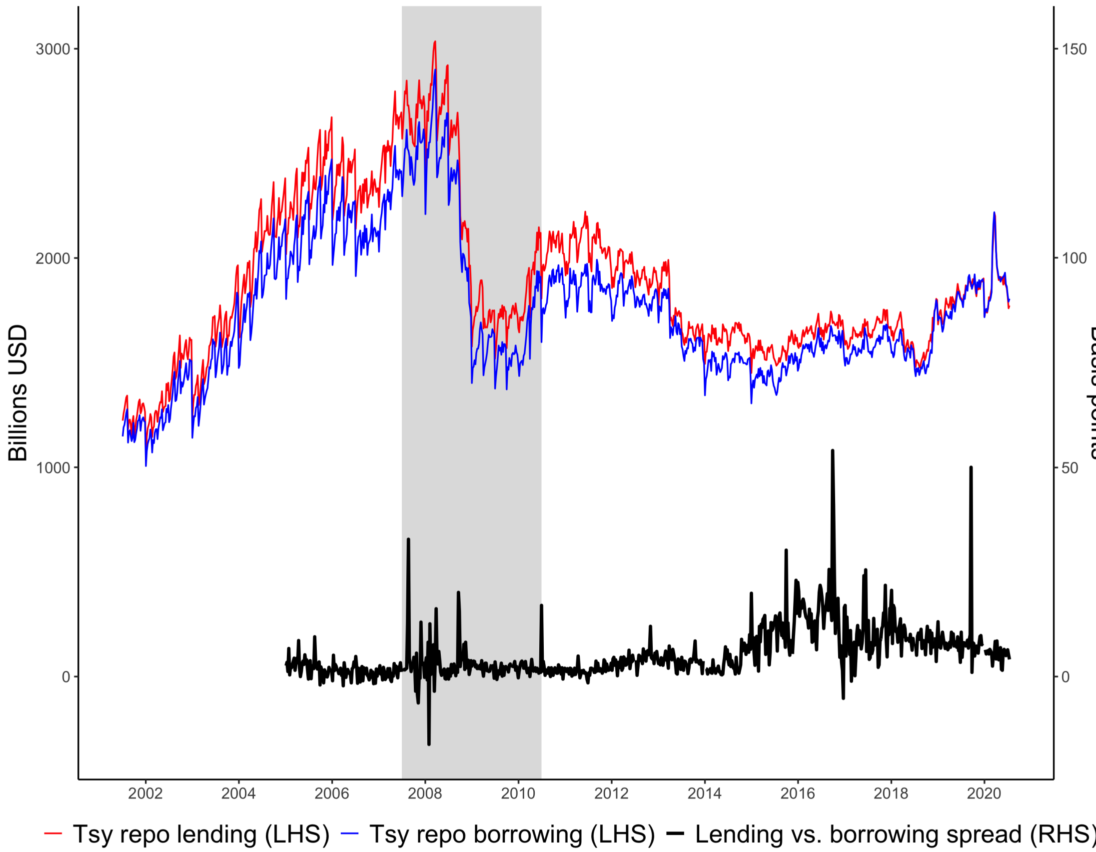
Notes: This figure illustrates the time series average spot and forward-starting cross-currency bases in AUD and JPY, vis-à-vis the USD, as defined in Equation (8). For each currency, the sample from July 2010 to August 2018 is split into three sub-samples based on the tercile of the level of the spot 3M OIS cross-currency basis. Within each sub-sample, the time series average of the relevant spot/forward OIS cross-currency basis is shown. Compared to Figure 2, this Figure plots a different set of forward tenors and use only OIS contracts of 3M tenor.

Figure A4: **Quarter-end-crossing in spot and forward cross-currency bases**



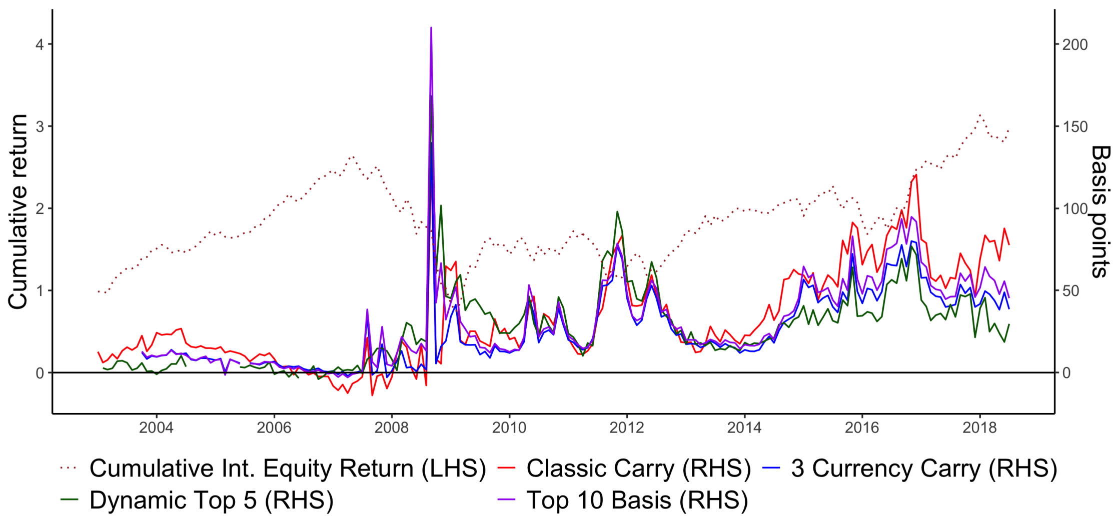
Notes: This figure illustrates the time series average of spot, 1M-forward 1M, and 2M-forward 1M AUD-JPY cross-currency bases. The sample from July 2010 to August 2018 is split into three sub-samples based which of the three bases has its OIS interest tenor crossing the quarter end. The three lines correspond to the three sub-samples, and each point shows the time series averages of the OIS cross-currency bases within the sub-sample. More details on the quarter-end behavior of the forward CIP trade can be found in Section 4.4.

Figure A5: **Treasury repo outstanding and rate**



Notes: This figure plots the time series of amounts outstanding and spreads on Treasury repurchase agreements (repos) by primary dealers. "Tsy repo borrowing" refers to primary dealers' borrowing in the Treasury repo market, and "Tsy repo lending" refer primary dealers' lending in the Treasury repo market, as reported in the Primary Dealer Statistics published by the Federal Reserve Bank of New York. "Lending vs. borrowing spread" refers to the difference between DTCC's GCF's median Treasury repo rate and (1) Bank of New York Mellon's median Triparty Treasury repo rate after August 2012; (2) Federal Reserve Bank of New York's historical primary dealer average Treasury repo financing rate before August 2012. The repo spread measures the spread between primary dealers' lending rate and borrowing rate in the Treasury repo market. The shaded area marks the period between July 1, 2007 and July 1, 2010.

Figure A6: **Cross-Currency Bases vs. Intermediary Equity**



Notes: This figure plots the monthly spot 3M OIS-based cross-currency bases and a measure of intermediary wealth from 2003 to 2018. The cumulative intermediary equity return is calculated from January 2003, and is based on the value-weighted return of the equity of primary dealers. Four versions of the cross-currency bases are plotted. "Classic Carry" is the spot cross-currency basis for the AUD-JPY pair; "3 Currency Carry" is the average spot cross-currency basis on the portfolio going long in AUD, CAD and GBP and shorting EUR, CHF and JPY. "Dynamic Top 5" has equal weight in the 5 currency pairs that exhibit the highest spot 3M basis, rebalanced monthly. "Top 10 Basis" has equal weight in the ten currency pairs with the largest CIP deviations post-GFC basis shown in Table 2.

Table A1: **OIS and IBOR Conventions for Sample Currencies**

Panel A: OIS		
Currency	Indexed Rate	Day Count
AUD	Reserve Bank of Australia Interbank Overnight Cash Rate	ACT / 365
CAD	Canadian Overnight Repo Rate Average (CORRA)	ACT / 365
CHF	Tomorrow/Next Overnight Indexed Swaps	ACT / 360
EUR	EMMI Euro Overnight Index Average (EONIA)	ACT / 360
GBP	Sterling Overnight Index Average (SONIA)	ACT / 365
JPY	Bank of Japan Estimate Unsecured Overnight Call Rate	ACT / 365
USD	US Federal Funds Effective Rate	ACT / 360
Panel B: IBOR		
Currency	Interbank Rate	Day Count
AUD	Australia Bank Bill Swap Rate (BBSW)	ACT / 365
CAD	Canada Bankers' Acceptances Rate	ACT / 365
CHF	ICE LIBOR CHF	ACT / 360
EUR	Euribor	ACT / 360
GBP	ICE LIBOR GBP	ACT / 365
JPY	ICE LIBOR JPY	ACT / 360
USD	ICE LIBOR USD	ACT / 360

Notes: This table reports the Overnight Index Swap and IBOR conventions for sample currencies. The Overnight Rate refers to the reference rate used to calculate the interest on the floating leg, against the expectation of which, the rate on the fixed leg is determined. The Day Count specifies how interests are calculated from the quoted annualized rate. For example, with a quoted annualized rate of 2%, a 32-day contract with a day count of ACT/360 would earn an interest of $(1 + 0.02 \times 32/360) - 1$.

Table A2: **Summary Statistics of Portfolio Returns on OIS 1M-forward 1M Forward CIP Trading Strategy**

	Mean			Sharpe Ratio		
	Pre-GFC	GFC	Post-GFC	Pre-GFC	GFC	Post-GFC
Classic Carry (AUD-JPY)	1.94	-0.52	6.43	1.09	-0.04	1.32
	(0.71)	(3.41)	(1.44)	(0.43)	(0.26)	(0.32)
3 Currency Carry	2.91	-4.05	4.56	1.39	-0.44	1.24
	(1.18)	(2.93)	(1.10)	(0.37)	(0.22)	(0.37)
Dynamic Top5 Basis	3.15	-0.01	5.39	1.48	0.00	1.04
	(1.09)	(6.82)	(1.54)	(0.36)	(0.44)	(0.37)
Top 10 Basis	3.55	-2.80	4.12	1.45	-0.25	0.99
	(1.44)	(4.28)	(1.25)	(0.36)	(0.31)	(0.36)
Simple Dollar	-1.62	1.38	0.09	-1.28	0.08	0.03
	(0.83)	(8.48)	(0.91)	(0.48)	(0.48)	(0.32)

Standard errors in parentheses

Notes: This table reports the annual profits and annualized Sharpe ratios from the OIS 1M-forward 1M forward CIP trading strategy. All statistics are reported by period: Pre-GFC is 2003-01-01 to 2007-06-30, GFC is 2007-07-01 to 2010-06-30, and Post-GFC is 2010-07-01 to 2018-08-31. The Classic Carry portfolio is the forward CIP trading strategy for the AUD-JPY pair. The 3 Currency Carry portfolio longs the forward CIP trading strategy in AUD, CAD, and GBP and shorts the forward CIP trading strategy in JPY, CHF, and EUR; all individual currency trades are vis-à-vis USD and weighted equally. The Dynamic Top5 Basis portfolio has equal weight in the 5 currency pairs that exhibit the highest spot 3M basis, rebalanced monthly. The Top 10 Basis portfolio has equal weights in the ten currency pairs with the largest CIP deviations post-GFC basis shown in Table 2. The Simple Dollar portfolio puts equal weights on the forward CIP trading strategy for all sample currencies vis-à-vis the USD. Newey-West standard errors are reported in parentheses, where the bandwidth is chosen by the Newey-West (1994) selection procedure.

Table A3: **Summary Statistics of Portfolio Returns on OIS 3M-forward 3M Forward CIP Trading Strategy**

	Mean			Sharpe Ratio		
	Pre-GFC	GFC	Post-GFC	Pre-GFC	GFC	Post-GFC
Classic Carry (AUD-JPY)	0.62	0.74	9.99	0.15	0.05	1.04
	(1.02)	(3.84)	(2.36)	(0.26)	(0.25)	(0.27)
3 Currency Carry	-0.71	2.46	6.89	-0.23	0.26	0.94
	(1.03)	(2.62)	(1.84)	(0.28)	(0.31)	(0.30)
Dynamic Top5 Basis	-0.27	0.94	7.42	-0.08	0.05	0.78
	(1.17)	(6.57)	(2.31)	(0.32)	(0.36)	(0.29)
Top 10 Basis	-0.94	0.11	6.32	-0.26	0.01	0.78
	(1.34)	(4.30)	(2.01)	(0.30)	(0.32)	(0.28)
Simple Dollar	1.25	6.84	-0.08	0.33	0.28	-0.01
	(1.58)	(9.07)	(1.36)	(0.32)	(0.34)	(0.25)

Standard errors in parentheses

Notes: This table reports the annual profits and annualized Sharpe ratios from the OIS 3M-forward 3M forward CIP trading strategy. All statistics are reported by period: Pre-GFC is 2003-01-01 to 2007-06-30, GFC is 2007-07-01 to 2010-06-30, and Post-GFC is 2010-07-01 to 2018-08-31. The Classic Carry portfolio is the forward CIP trading strategy for the AUD-JPY pair. The 3 Currency Carry portfolio longs the forward CIP trading strategy in AUD, CAD, and GBP and shorts the forward CIP trading strategy in JPY, CHF, and EUR; all individual currency trades are vis-à-vis USD and weighted equally. The Dynamic Top5 Basis portfolio has equal weight in the 5 currency pairs that exhibit the highest spot 3M basis, rebalanced monthly. The Top 10 Basis portfolio has equal weights in the ten currency pairs with the largest CIP deviations post-GFC basis shown in Table 2. The Simple Dollar portfolio puts equal weights on the forward CIP trading strategy for all sample currencies vis-à-vis the USD. Newey-West standard errors are reported in parentheses, where the bandwidth is chosen by the Newey-West (1994) selection procedure.

Table A4: **Summary Statistics of Portfolio Returns on IBOR 1M-forward 3M Forward CIP Trading Strategy**

	Mean			Sharpe Ratio		
	Pre-GFC	GFC	Post-GFC	Pre-GFC	GFC	Post-GFC
Classic Carry (AUD-JPY)	4.60	-12.56	14.70	1.09	-0.47	1.58
	(1.48)	(9.80)	(2.80)	(0.33)	(0.35)	(0.30)
3 Currency Carry	4.00	-10.27	8.95	1.60	-0.67	1.05
	(0.91)	(5.15)	(3.37)	(0.40)	(0.29)	(0.50)
Dynamic Top5 Basis	2.69	-20.51	6.50	0.86	-0.96	0.73
	(1.17)	(8.38)	(2.87)	(0.36)	(0.24)	(0.37)
Top 10 Basis	1.77	-13.47	3.04	0.76	-0.91	0.46
	(0.85)	(5.61)	(2.12)	(0.33)	(0.24)	(0.34)
Simple Dollar	0.11	1.09	2.22	0.06	0.06	0.40
	(0.62)	(8.63)	(2.16)	(0.33)	(0.45)	(0.36)

Standard errors in parentheses

Notes: This table reports the annual profits and annualized Sharpe ratios from the IBOR 1M-forward 3M forward CIP trading strategy. All statistics are reported by period: Pre-GFC is 2003-01-01 to 2007-06-30, GFC is 2007-07-01 to 2010-06-30, and Post-GFC is 2010-07-01 to 2018-08-31. The Classic Carry portfolio is the forward CIP trading strategy for the AUD-JPY pair. The 3 Currency Carry portfolio longs the forward CIP trading strategy in AUD, CAD, and GBP and shorts the forward CIP trading strategy in JPY, CHF, and EUR; all individual currency trades are vis-à-vis USD and weighted equally. The Dynamic Top5 Basis portfolio has equal weight in the 5 currency pairs that exhibit the highest spot 3M basis, rebalanced monthly. The Top 10 Basis portfolio has equal weights in the ten currency pairs with the largest CIP deviations post-GFC basis shown in Table 2. The Simple Dollar portfolio puts equal weights on the forward CIP trading strategy for all sample currencies vis-à-vis the USD. Newey-West standard errors are reported in parentheses, where the bandwidth is chosen by the Newey-West (1994) selection procedure.

Table A5: **Summary Statistics of Portfolio Returns on IBOR 3M-forward 3M Forward CIP Trading Strategy**

	Mean			Sharpe Ratio		
	Pre-GFC	GFC	Post-GFC	Pre-GFC	GFC	Post-GFC
Classic Carry (AUD-JPY)	1.61	-1.02	10.40	0.53	-0.07	1.43
	(0.67)	(3.22)	(1.69)	(0.28)	(0.22)	(0.31)
3 Currency Carry	1.05	0.79	7.24	0.56	0.10	1.04
	(0.44)	(2.12)	(1.72)	(0.33)	(0.27)	(0.34)
Dynamic Top5 Basis	1.27	-7.05	4.46	0.62	-0.56	0.61
	(0.42)	(4.03)	(1.78)	(0.27)	(0.25)	(0.29)
Top 10 Basis	0.75	-6.25	1.78	0.49	-0.68	0.32
	(0.34)	(2.80)	(1.33)	(0.27)	(0.23)	(0.27)
Simple Dollar	0.33	4.92	1.16	0.29	0.43	0.25
	(0.22)	(3.70)	(1.12)	(0.17)	(0.33)	(0.23)

Standard errors in parentheses

Notes: This table reports the annual profits and annualized Sharpe ratios from the IBOR 3M-forward 3M forward CIP trading strategy. All statistics are reported by period: Pre-GFC is 2003-01-01 to 2007-06-30, GFC is 2007-07-01 to 2010-06-30, and Post-GFC is 2010-07-01 to 2018-08-31. The Classic Carry portfolio is the forward CIP trading strategy for the AUD-JPY pair. The 3 Currency Carry portfolio longs the forward CIP trading strategy in AUD, CAD, and GBP and shorts the forward CIP trading strategy in JPY, CHF, and EUR; all individual currency trades are vis-à-vis USD and weighted equally. The Dynamic Top5 Basis portfolio has equal weight in the 5 currency pairs that exhibit the highest spot 3M basis, rebalanced monthly. The Top 10 Basis portfolio has equal weights in the ten currency pairs with the largest CIP deviations post-GFC basis shown in Table 2. The Simple Dollar portfolio puts equal weights on the forward CIP trading strategy for all sample currencies vis-à-vis the USD. Newey-West standard errors are reported in parentheses, where the bandwidth is chosen by the Newey-West (1994) selection procedure.

Table A6: **Summary Statistics of Non-Overlapping Monthly Portfolio Returns on OIS 1M-forward 3M Forward CIP Trading Strategy**

	Mean			Sharpe Ratio		
	Pre-GFC	GFC	Post-GFC	Pre-GFC	GFC	Post-GFC
Classic Carry (AUD-JPY)	0.84	2.54	15.26	0.22	0.09	1.44
	(1.85)	(15.27)	(3.70)	(0.49)	(0.58)	(0.34)
3 Currency Carry	2.08	-9.82	9.57	0.88	-0.39	1.23
	(1.23)	(14.31)	(2.73)	(0.46)	(0.47)	(0.38)
Dynamic Top5 Basis	2.00	-8.99	9.24	0.87	-0.22	0.90
	(1.20)	(23.00)	(3.61)	(0.49)	(0.50)	(0.41)
Top 10 Basis	2.31	-10.85	7.82	1.15	-0.32	0.90
	(1.04)	(19.02)	(3.03)	(0.48)	(0.49)	(0.37)
Simple Dollar	-0.94	11.73	2.00	-0.46	0.27	0.37
	(1.06)	(25.08)	(1.91)	(0.53)	(0.50)	(0.34)

Standard errors in parentheses

Notes: This table reports the annual profits and annualized Sharpe ratios from the OIS 1M-forward 3M forward CIP trading strategy based on non-overlapping month-end daily observations. All statistics are reported by period: Pre-GFC is 2003-01-01 to 2007-06-30, GFC is 2007-07-01 to 2010-06-30, and Post-GFC is 2010-07-01 to 2018-08-31. The Classic Carry portfolio is the forward CIP trading strategy for the AUD-JPY pair. The 3 Currency Carry portfolio longs the forward CIP trading strategy in AUD, CAD, and GBP and shorts the forward CIP trading strategy in JPY, CHF, and EUR; all individual currency trades are vis-à-vis USD and weighted equally. The Dynamic Top5 Basis portfolio has equal weight in the 5 currency pairs that exhibit the highest spot 3M basis, rebalanced monthly. The Top 10 Basis portfolio has equal weights in the ten currency pairs with the largest CIP deviations post-GFC basis shown in Table 2. The Simple Dollar portfolio puts equal weights on the forward CIP trading strategy for all sample currencies vis-à-vis the USD. Robust standard errors are reported in parentheses.

Table A7: **Summary Statistics of Split Sample Portfolio Returns on OIS 1M-forward 3M Forward CIP Trading Strategy**

	Mean				Sharpe Ratio			
	Pre-GFC	GFC	Pre-2015	Post-2015	Pre-GFC	GFC	Pre-2015	Post-2015
Classic Carry (AUD-JPY)	2.44	-4.37	12.80	16.12	0.61	-0.16	1.27	1.51
	(1.37)	(10.40)	(4.75)	(4.82)	(0.35)	(0.36)	(0.51)	(0.46)
3 Currency Carry	0.32	-4.59	8.99	10.77	0.14	-0.24	1.04	1.73
	(0.88)	(7.09)	(4.01)	(2.73)	(0.39)	(0.33)	(0.53)	(0.51)
Dynamic Top5 Basis	1.83	0.18	11.62	11.03	0.79	0.01	1.06	1.19
	(0.76)	(14.21)	(4.88)	(4.17)	(0.34)	(0.44)	(0.58)	(0.47)
Top 10 Basis	0.84	-5.32	8.61	9.48	0.38	-0.21	0.94	1.27
	(0.72)	(10.01)	(4.22)	(3.46)	(0.36)	(0.36)	(0.54)	(0.51)
Simple Dollar	-0.95	7.37	-1.64	1.94	-0.51	0.20	-0.37	0.31
	(1.09)	(18.17)	(1.86)	(3.40)	(0.56)	(0.45)	(0.43)	(0.54)

Standard errors in parentheses

Notes: This table reports the annual profits and annualized Sharpe ratios from the OIS 1M-forward 3M forward CIP trading strategy. All statistics are reported by period: Pre-GFC is 2003-01-01 to 2007-06-30, GFC is 2007-07-01 to 2010-06-30, Pre-2015 is 2010-07-01 to 2014-12-31, and Post-2015 is 2015-01-01 to 2018-08-31. The Classic Carry portfolio is the forward CIP trading strategy for the AUD-JPY pair. The 3 Currency Carry portfolio longs the forward CIP trading strategy in AUD, CAD, and GBP and shorts the forward CIP trading strategy in JPY, CHF, and EUR; all individual currency trades are vis-à-vis USD and weighted equally. The Dynamic Top5 Basis portfolio has equal weight in the 5 currency pairs that exhibit the highest spot 3M basis, rebalanced monthly. The Top 10 Basis portfolio has equal weights in the ten currency pairs with the largest CIP deviations post-GFC basis shown in Table 2. The Simple Dollar portfolio puts equal weights on the forward CIP trading strategy for all sample currencies vis-à-vis the USD. Newey-West standard errors are reported in parentheses, where the bandwidth is chosen by the Newey-West (1994) selection procedure.

Table A8: **Summary Statistics of Portfolio Returns on OIS 1M-forward 3M Forward CIP Trading Strategy for Longer Sample Covering the COVID-19 Pandemic**

	Mean			Sharpe Ratio		
	Pre-GFC	GFC	Post-GFC	Pre-GFC	GFC	Post-GFC
Classic Carry	2.44	-4.37	13.17	0.61	-0.16	1.00
	(1.37)	(10.40)	(3.72)	(0.35)	(0.36)	(0.42)
3 Currency Carry	0.32	-4.59	9.12	0.14	-0.24	1.01
	(0.88)	(7.09)	(2.60)	(0.39)	(0.33)	(0.41)
Dynamic Top5 Basis	1.83	0.18	10.06	0.79	0.01	0.83
	(0.76)	(14.21)	(3.40)	(0.34)	(0.44)	(0.39)
Top 10 Basis	0.84	-5.32	7.81	0.38	-0.21	0.73
	(0.72)	(10.01)	(3.05)	(0.36)	(0.36)	(0.40)
Simple Dollar	-0.95	7.37	1.54	-0.51	0.20	0.22
	(1.09)	(18.17)	(2.06)	(0.56)	(0.45)	(0.26)

Standard errors in parentheses

Notes: This table reports the annual profits and annualized Sharpe ratios from the OIS 1M-forward 3M forward CIP trading strategy for an extended sample period covering the COVID-19 pandemic. All statistics are reported by period: Pre-GFC is 2003-01-01 to 2007-06-30, GFC is 2007-07-01 to 2010-06-30, and Post-GFC is 2010-07-01 to 2019-03-31. The Classic Carry portfolio is the forward CIP trading strategy for the AUD-JPY pair. The 3 Currency Carry portfolio longs the forward CIP trading strategy in AUD, CAD, and GBP and shorts the forward CIP trading strategy in JPY, CHF, and EUR; all individual currency trades are vis-à-vis USD and weighted equally. The Dynamic Top5 Basis portfolio has equal weight in the 5 currency pairs that exhibit the highest spot 3M basis, rebalanced monthly. The Top 10 Basis portfolio has equal weights in the ten currency pairs with the largest CIP deviations post-GFC basis shown in Table 2. The Simple Dollar portfolio puts equal weights on the forward CIP trading strategy for all sample currencies vis-à-vis the USD. Newey-West standard errors are reported in parentheses, where the bandwidth is chosen by the Newey-West (1994) selection procedure.

Table A9: **Forward CIP Trading Strategy Return Predictability**

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1mFwd3m-3m Spread		0.710	0.554	0.509	0.584	0.507	0.588	0.772
		(0.127)	(0.122)	(0.106)	(0.113)	(0.127)	(0.194)	(0.303)
Spot Basis 3m				0.0534	0.0945	0.0533	0.0469	0.0339
				(0.0208)	(0.0396)	(0.0225)	(0.0272)	(0.0355)
Constant	0.0476		0.0202		-0.0300			
	(0.0113)		(0.0111)		(0.0207)			
RMSE	0.119	0.115	0.114	0.112	0.112	0.112	0.112	0.114
R^2	0.137	0.196	0.211	0.237	0.246	0.237	0.237	0.218
NW BW (bus. days)	40	40	40	40	40	40	40	40
1st Stage F						1005.0	153.0	61.48
Instrument Lag (bus. days)						1	5	10
Observations	2099	2099	2099	2099	2099	2092	2092	2092

Standard errors in parentheses

Notes: This table reports return predictability regressions for the classic carry (AUD-JPY) forward CIP trading strategy. The outcome variable in all columns is the one-month return of the three-month OIS forward CIP trading strategy. All data is daily and post-GFC (2010-07-01 to 2018-08-30). 1mFwd3m-3m Spread is the spread between the 1-month forward three-month AUD-JPY basis and the spot three-month AUD-JPY basis. Spot Basis 3m is the spot three month AUD-JPY basis. RMSE is the root-mean-squared error, R^2 is the un-centered R^2, NW BW is the bandwidth chosen by the Newey-West bandwidth selection procedure, 1st Stage F is the F-statistic from the first stage for the IV regressions (see Stock and Yogo (2005)), and Instrument Lag is the number of business days the spread variable is lagged in the IV regression. Units are in percentage points.

Table A10: **Returns on Quarter- and Year-end Crossing Forward CIP Trading Strategy Returns**

	OIS 1M-Forward 1M Returns							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
QE Cross: Interest Tenor		−0.024		−0.033				−0.036
		(0.027)		(0.030)				(0.029)
QE Cross: Forward Horizon			−0.001	−0.017				−0.032
			(0.023)	(0.024)				(0.026)
YE Cross: Interest Tenor					−0.007		−0.003	0.013
					(0.069)		(0.069)	(0.072)
YE Cross: Forward Horizon						0.050	0.049	0.062
						(0.046)	(0.044)	(0.047)
Constant	0.064	0.072	0.065	0.080	0.065	0.060	0.060	0.080
	(0.013)	(0.014)	(0.017)	(0.019)	(0.013)	(0.014)	(0.013)	(0.020)
F-stat				0.626			0.621	0.753
Observations	2,106	2,106	2,106	2,106	2,106	2,106	2,106	2,106
R^2	0.000	0.005	0.00000	0.006	0.0001	0.007	0.007	0.015
Residual Std. Error	0.169	0.169	0.169	0.169	0.169	0.169	0.169	0.168

Standard errors are in parentheses

Notes: This table reports regressions of the classic-carry (AUD-JPY) forward CIP trading strategy return on indicators of quarter-ends and year-ends. The outcome variable in all columns is the one-month return of the one-month forward CIP trading strtegy. All data are daily and post-GFC (2010-07-01 to 2018-08-31). Quarter-end (QE) and year-end (YE) dummies indicate whether the 1M OIS interest-tenor or the 1M forward horizon crosses QE or YE. Newey-West standard errors are reported in parentheses, where the bandwidth is chosen by the Newey-West (1994) selection procedure.

Table A11: **Transaction Costs of USD-JPY Forward CIP Trade (Basis Points)**

(1) 1M-Forward 3M Forward		(2) 3M-Forward 3M Forward	
(A) Initiate forward CIP position			
Long 1Mv4M JPY OIS	0.50	Long 3M6M JPY OIS	0.33
Short 1Mv4M USD OIS	0.12	Short 3M6M USD OIS	0.13
Long USD-JPY 1Mv4M	0.61	Long USD-JPY 3M6M	0.66
(B) Unwind forward at the spot CIP			
Sell 3M JPY OIS	0.19	Sell 3M JPY OIS	0.19
Long 3M USD OIS	0.12	Long 3M USD OIS	0.12
Short USD-JPY 3M	0.22	Short USD-JPY 3M	0.22
(C) Estimated transaction costs vs profits			
Total cost per trade	1.76	Total cost per trade	1.63
Number of trades per year	12	Number of trades per year	4
Annual costs	21.09	Annual costs	6.52
Annual profits post-GFC	9.53	Annual profits post-GFC	7.35

Notes: This table shows the estimated transaction costs on USD-JPY forward CIP trade for the one-month horizon in Column 1 and three-month horizon in Column 2. All transaction costs in Panel A and Panel B are equal to the mean half bid-ask spreads on the corresponding instrument from Bloomberg. The sample period is post-GFC from 2010-07-01 to 2018-08-31.

Table A12: **Cross-sectional Asset Pricing Tests, HKM 2-Factor Non-Tradable**

	(1) US	(2) Sov	(3) FX	(4) Opt	(5) CDS	(6) FwdCIP	(7) FF6	(8) Comm	(9) 1-6
Market	1.087	0.0839	2.231	1.907	1.062	4.518	0.877	0.982	1.128
	(0.803)	(0.671)	(0.781)	(1.211)	(0.646)	(2.154)	(0.703)	(0.787)	(0.515)
HKM Factor	-1.480	2.400	3.292	4.071	3.341	3.275	2.582	0.336	0.881
	(1.513)	(3.101)	(2.174)	(14.29)	(3.163)	(2.340)	(1.707)	(1.114)	(0.898)
Intercepts	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
MAPE (%/mo.)	0.031	0.051	0.062	0.088	0.048	0.009	0.155	0.369	
H1 p-value	0.585	0.370	0.045	0.308	0.529	0.075	0.746	0.680	0.349
KZ p-value	0.000	0.053	0.521	0.003	0.080	0.393	0.000	0.023	0.003
N (assets)	11	6	11	18	5	9	6	23	60
N (beta, mos.)	360	283	418	272	170	98	584	331	
N (mean, mos.)	360	283	418	272	170	98	1106	331	

Standard errors in parentheses

Notes: This table reports estimates for the price of risk (λ in Equation (12)) from the various asset classes described in Internet Appendix Section J. “Market” is the CRSP market return, and “HKM factor” is the intermediary capital ratio innovation of He et al. (2017). Intercepts indicates an intercept is used for each asset class (one intercept per column, with six in (9), which pools the first six asset classes). MAPE is mean absolute pricing error of monthly returns. H1 p-value tests whether the price of the Market risk is equal to its mean excess return. KZ p-value is the p-value of the Kleibergen and Zhan (2020) test rejecting reduced rank for the betas of the test assets. Standard errors are computed using GMM with the Newey-West kernel and a twelve-month bandwidth. Units are in percentage points.

Table A13: **Cross-sectional Asset Pricing Tests, 3-Factor**

	(1) US	(2) Sov	(3) FX	(4) Opt	(5) CDS	(6) FwdCIP	(7) FF6	(8) Comm	(9) 1-6
Market	0.901	0.486	0.907	0.511	1.104	-3.556	-0.998	0.634	0.840
	(0.819)	(0.695)	(0.357)	(0.715)	(0.498)	(5.825)	(4.892)	(0.373)	(0.412)
Int. Equity	-0.647	1.580	1.264	1.898	1.947	-2.551	-1.701	0.667	-0.0104
	(0.572)	(3.680)	(0.958)	(10.47)	(2.005)	(5.286)	(7.964)	(0.812)	(0.763)
Neg. Fwd CIP Ret.	-0.0651	-0.0715	-0.0602	-0.122	-0.0316	-0.0689	0.228	-0.00433	-0.0781
	(0.0767)	(0.101)	(0.0501)	(0.0951)	(0.0827)	(0.0480)	(0.538)	(0.0387)	(0.0311)
Intercepts	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
MAPE (%/mo.)	0.008	0.023	0.059	0.035	0.013	0.006	0.107	0.345	
H1 p-value	0.192	0.883	0.814	0.391	0.685	0.831	0.616	0.298	0.689
KZ p-value	0.061	0.757	0.235	0.911	0.210	0.713	0.871	0.778	0.085
N (assets)	11	6	11	18	5	9	6	23	60
N (beta, mos.)	98	98	98	98	98	98	98	98	
N (mean, mos.)	360	283	418	272	170	98	1106	331	

Standard errors in parentheses

Notes: This table reports estimates for the price of risk (λ in Equation (12)) from the various asset classes described in Internet Appendix Section J. "Neg. Fwd. CIP Ret." is the negative of the return on the AUD-JPY 1M-fwd 3M forward CIP trading strategy, "Market" is the CRSP market return, and "Int. Equity" is the intermediary equity return of He et al. (2017). Intercepts indicates an intercept is used for each asset class (one intercept per column, with six in (9), which pools the first six asset classes). MAPE is mean absolute pricing error of monthly returns. H1 p-value tests whether the price of the Fwd. CIP Ret., Market, and Int. Equity risks are equal to the mean excess returns of those trading strategies. KZ p-value is the p-value of the Kleibergen and Zhan (2020) test rejecting reduced rank for the betas of the test assets. Standard errors are computed using GMM with the Newey-West kernel and a twelve-month bandwidth. Units are in percentage points.

Table A14: **Cross-sectional Asset Pricing Tests, HKM 1-Factor**

	(1) US	(2) Sov	(3) FX	(4) Opt	(5) CDS	(6) FwdCIP	(7) FF6	(8) Comm	(9) 1-6
Int. Equity	0.639	1.027	3.646	3.962	2.337	2.150	0.949	1.326	1.701
	(0.742)	(0.935)	(1.180)	(1.706)	(0.927)	(1.297)	(1.589)	(1.016)	(0.701)
Intercepts	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
MAPE (%/mo.)	0.065	0.071	0.061	0.088	0.049	0.009	0.166	0.396	
H1 p-value	0.967	0.639	0.007	0.037	0.036	0.231	0.832	0.454	0.064
KZ p-value	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000
N (assets)	11	6	11	18	5	9	6	23	60
N (beta, mos.)	360	283	418	272	170	98	584	331	
N (mean, mos.)	360	283	418	272	170	98	1106	331	

Standard errors in parentheses

Notes: This table reports estimates for the price of risk (λ in Equation (12)) from the various asset classes described in Internet Appendix Section J. "Int. Equity" is the intermediary equity return of He et al. (2017). Intercepts indicates an intercept is used for each asset class (one intercept per column, with six in (9), which pools the first six asset classes). MAPE is mean absolute pricing error of monthly returns. H1 p-value tests whether the price of the Int. Equity risk is equal to its mean excess return. KZ p-value is the p-value of the Kleibergen and Zhan (2020) test rejecting reduced rank for the betas of the test assets. Standard errors are computed using GMM with the Newey-West kernel and a twelve-month bandwidth. Units are in percentage points.

Table A15: **Cross-sectional Asset Pricing Tests, HKM 2-Factor Tradable**

	(1) US	(2) Sov	(3) FX	(4) Opt	(5) CDS	(6) FwdCIP	(7) FF6	(8) Comm	(9) 1-6
Market	1.365	0.171	1.219	1.931	0.620	0.267	0.857	0.939	0.924
	(1.038)	(0.756)	(0.983)	(0.965)	(1.042)	(7.363)	(0.663)	(0.848)	(0.525)
Int. Equity	-1.602	1.701	5.198	7.161	4.779	1.679	2.201	0.949	1.611
	(1.640)	(2.773)	(2.761)	(16.22)	(2.902)	(4.954)	(1.409)	(1.261)	(0.818)
Intercepts	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
MAPE (%/mo.)	0.034	0.059	0.053	0.079	0.039	0.009	0.152	0.382	
H1 p-value	0.397	0.789	0.080	0.338	0.140	0.300	0.116	0.915	0.372
KZ p-value	0.000	0.157	0.569	0.076	0.091	0.411	0.000	0.220	0.000
N (assets)	11	6	11	18	5	9	6	23	60
N (beta, mos.)	360	283	418	272	170	98	584	331	
N (mean, mos.)	360	283	418	272	170	98	1106	331	

Standard errors in parentheses

Notes: This table reports estimates for the price of risk (λ in Equation (12)) from the various asset classes described in Internet Appendix Section J. "Market" is the CRSP market return, and "Int. Equity" is the intermediary equity return of He et al. (2017). Intercepts indicates an intercept is used for each asset class (one intercept per column, with six in (9), which pools the first six asset classes). MAPE is mean absolute pricing error of monthly returns. H1 p-value tests whether the price of the Market and Int. Equity risks are equal to the mean excess returns of those trading strategies. KZ p-value is the p-value of the Kleibergen and Zhan (2020) test rejecting reduced rank for the betas of the test assets. Standard errors are computed using GMM with the Newey-West kernel and a twelve-month bandwidth. Units are in percentage points.

Table A16: **Cross-sectional Asset Pricing Tests, 3 Factor Non-Tradable**

	(1) US	(2) Sov	(3) FX	(4) Opt	(5) CDS	(6) FwdCIP	(7) FF6	(8) Comm	(9) 1-6
Market	1.014	0.459	0.887	0.435	1.114	-3.608	-1.012	0.627	0.819
	(0.828)	(0.660)	(0.301)	(1.188)	(0.507)	(7.600)	(4.931)	(0.369)	(0.365)
HKM Factor	-1.222	1.712	0.399	2.447	1.956	-2.205	-1.267	0.766	-0.339
	(0.810)	(3.392)	(1.442)	(13.81)	(3.345)	(5.347)	(6.847)	(0.891)	(0.942)
Neg. Fwd CIP Ret.	-0.0483	-0.0605	-0.0588	-0.119	-0.0306	-0.0818	0.228	-0.00635	-0.0705
	(0.0868)	(0.107)	(0.0409)	(0.0874)	(0.0913)	(0.0638)	(0.544)	(0.0339)	(0.0351)
Intercepts	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
MAPE (%/mo.)	0.010	0.021	0.062	0.035	0.013	0.006	0.109	0.349	
H1 p-value	0.902	0.952	0.793	0.257	0.660	0.848	0.746	0.340	0.777
KZ p-value	0.058	0.636	0.174	0.986	0.246	0.723	0.868	0.780	0.127
N (assets)	11	6	11	18	5	9	6	23	60
N (beta, mos.)	98	98	98	98	98	98	98	98	
N (mean, mos.)	360	283	418	272	170	98	1106	331	

Standard errors in parentheses

Notes: This table reports estimates for the price of risk (λ in Equation (12)) from the various asset classes described in Internet Appendix Section J. "Neg. Fwd. CIP Ret." is the negative of the return on the AUD-JPY 1M-fwd 3M forward CIP trading strategy, "Market" is the CRSP market return, and "HKM Factor" is the intermediary capital ratio innovation of He et al. (2017). Intercepts indicates an intercept is used for each asset class (one intercept per column, with six in (9), which pools the first six asset classes). MAPE is mean absolute pricing error of monthly returns. H1 p-value tests whether the price of the Fwd. CIP Ret. and Market risks are equal to the mean excess returns of those trading strategies. KZ p-value is the p-value of the Kleibergen and Zhan (2020) test rejecting reduced rank for the betas of the test assets. Standard errors are computed using GMM with the Newey-West kernel and a twelve-month bandwidth. Units are in percentage points.

Table A17: **Cross-sectional Asset Pricing Tests, with Risk-Free Rate Adjustment**

	(1) US	(2) Sov	(3) FX	(4) Opt	(5) CDS	(6) FwdCIP	(7) FF6	(8) Comm	(9) 1-6
Int. Equity	0.176	1.429	1.855	1.328	2.325	0.195	-0.211	1.056	0.738
	(0.742)	(1.546)	(0.635)	(0.975)	(0.994)	(2.254)	(4.290)	(0.703)	(0.470)
Neg. Fwd CIP Ret.	-0.170	-0.0694	-0.0658	-0.132	-0.0228	-0.0576	0.124	-0.0208	-0.0696
	(0.108)	(0.0574)	(0.0503)	(0.0541)	(0.0559)	(0.0381)	(0.335)	(0.0302)	(0.0332)
Intercepts	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
MAPE (%/mo.)	0.032	0.026	0.063	0.035	0.019	0.007	0.094	0.360	
H1 p-value	0.423	0.731	0.147	0.319	0.151	0.982	0.338	0.473	0.844
KZ p-value	0.079	0.379	0.107	0.035	0.355	0.226	0.780	0.780	0.041
N (assets)	11	6	11	18	5	9	6	23	60
N (beta, mos.)	98	98	98	98	98	98	98	98	
N (mean, mos.)	360	283	418	272	170	98	1106	331	

Standard errors in parentheses

Notes: This table reports estimates for the price of risk (λ in Equation (12)) from the various asset classes described in Internet Appendix Section J. Betas are estimated from a modified version of (13), $R^i_{t+1} - R^f_t = \mu_i + \beta^i_w(R^w_{t+1} - R^f_t) + \beta^i_x r^{|x|}_{t+1} + \beta^i_s|x_t| + \epsilon^i_{t+1}$. "Neg. Fwd. CIP Ret." is the negative of the return on the AUD-JPY 1M-fwd 3M forward CIP trading strategy and "Int. Equity" is the intermediary equity return of He et al. (2017). Intercepts indicates an intercept is used for each asset class (one intercept per column, with six in (9), which pools the first six asset classes). MAPE is mean absolute pricing error of monthly returns. H1 p-value tests whether the price of the Fwd. CIP Ret. and Int. Equity risks are equal to the mean excess returns of those trading strategies. KZ p-value is the p-value of the Kleibergen and Zhan (2020) test rejecting reduced rank for the betas of the test assets. Standard errors are computed using GMM with the Newey-West kernel and a twelve-month bandwidth. Units are in percentage points.

Table A18: **Cross-sectional Asset Pricing Tests, USD-JPY**

	(1) US	(2) Sov	(3) FX	(4) Opt	(5) CDS	(6) FwdCIP	(7) FF6	(8) Comm	(9) 1-6
Int. Equity	0.893	1.715	1.997	0.947	2.319	0.635	-0.734	1.047	0.900
	(1.053)	(1.542)	(0.609)	(1.036)	(1.012)	(1.749)	(1.786)	(0.672)	(0.470)
Neg. Fwd CIP Ret. (JPYUSD)	-0.227	-0.0844	-0.0541	-0.123	-0.0348	-0.0516	0.126	0.00411	-0.0676
	(0.154)	(0.0750)	(0.0465)	(0.0568)	(0.120)	(0.0226)	(0.148)	(0.0328)	(0.0260)
Intercepts	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
MAPE (%/mo.)	0.034	0.016	0.067	0.036	0.018	0.007	0.088	0.368	
H1 p-value	0.384	0.429	0.076	0.274	0.088	0.446	0.565	0.442	0.195
KZ p-value	0.226	0.446	0.064	0.024	0.770	0.024	0.635	0.977	0.002
N (assets)	11	6	11	18	5	9	6	23	60
N (beta, mos.)	98	98	98	98	98	98	98	98	
N (mean, mos.)	360	283	418	272	170	98	1106	331	

Standard errors in parentheses

Notes: This table reports estimates for the price of risk (λ in Equation (12)) from the various asset classes described in Internet Appendix Section J. "Neg. Fwd. CIP Ret." is the negative of the return on the USD-JPY 1M-fwd 3M forward CIP trading strategy and "Int. Equity" is the intermediary equity return of He et al. (2017). Intercepts indicates an intercept is used for each asset class (one intercept per column, with six in (9), which pools the first six asset classes). MAPE is mean absolute pricing error of monthly returns. H1 p-value tests whether the price of the Fwd. CIP Ret. and Int. Equity risks are equal to the mean excess returns of those trading strategies. KZ p-value is the p-value of the Kleibergen and Zhan (2020) test rejecting reduced rank for the betas of the test assets. Standard errors are computed using GMM with the Newey-West kernel and a twelve-month bandwidth. Units are in percentage points.

Table A19: **Cross-sectional Asset Pricing Tests, Three Currency Carry**

	(1) US	(2) Sov	(3) FX	(4) Opt	(5) CDS	(6) FwdCIP	(7) FF6	(8) Comm	(9) 1-6
Int. Equity	-0.407	1.399	2.171	1.585	2.345	-0.378	0.625	1.008	0.767
	(1.188)	(1.707)	(0.769)	(0.949)	(1.270)	(1.731)	(0.933)	(0.707)	(0.450)
Neg. Fwd CIP Ret.	-0.200	-0.0608	-0.0311	-0.0715	-0.0223	-0.0225	0.0237	0.0216	-0.0263
	(0.143)	(0.0473)	(0.0404)	(0.0259)	(0.0643)	(0.0110)	(0.0451)	(0.0466)	(0.0132)
Intercepts	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
MAPE (%/mo.)	0.054	0.033	0.067	0.031	0.017	0.008	0.091	0.351	
H1 p-value	0.534	0.665	0.023	0.285	0.180	0.255	0.075	0.246	0.640
KZ p-value	0.165	0.464	0.052	0.002	0.499	0.221	0.518	0.943	0.000
N (assets)	11	6	11	18	5	9	6	23	60
N (beta, mos.)	98	98	98	98	98	98	98	98	
N (mean, mos.)	360	283	418	272	170	98	1106	331	

Standard errors in parentheses

Notes: This table reports estimates for the price of risk (λ in Equation (12)) from the various asset classes described in Internet Appendix Section J. "Neg. Fwd. CIP Ret." is the negative of the return on the 3 Currency Carry 1M-fwd 3M forward CIP trading strategy and "Int. Equity" is the intermediary equity return of He et al. (2017). Intercepts indicates an intercept is used for each asset class (one intercept per column, with six in (9), which pools the first six asset classes). MAPE is mean absolute pricing error of monthly returns. H1 p-value tests whether the price of the Fwd. CIP Ret. and Int. Equity risks are equal to the mean excess returns of those trading strategies. KZ p-value is the p-value of the Kleibergen and Zhan (2020) test rejecting reduced rank for the betas of the test assets. Standard errors are computed using GMM with the Newey-West kernel and a twelve-month bandwidth. Units are in percentage points.

Table A20: **Cross-sectional Asset Pricing Tests, Dynamic Top Five Basis**

	(1) US	(2) Sov	(3) FX	(4) Opt	(5) CDS	(6) FwdCIP	(7) FF6	(8) Comm	(9) 1-6
Int. Equity	-0.822	1.464	2.162	1.508	2.136	0.668	-0.241	1.023	0.762
	(0.724)	(1.580)	(0.731)	(0.971)	(1.374)	(1.301)	(1.844)	(0.705)	(0.445)
Neg. Fwd CIP Ret.	-0.228	-0.0746	-0.0347	-0.105	-0.0393	-0.0262	0.0887	0.0211	-0.0320
	(0.140)	(0.0530)	(0.0406)	(0.0404)	(0.0678)	(0.0139)	(0.141)	(0.0495)	(0.0165)
Intercepts	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
MAPE (%/mo.)	0.047	0.028	0.068	0.032	0.018	0.009	0.074	0.363	
H1 p-value	0.098	0.513	0.024	0.176	0.171	0.618	0.451	0.286	0.921
KZ p-value	0.157	0.324	0.028	0.024	0.207	0.051	0.617	0.839	0.000
N (assets)	11	6	11	18	5	9	6	23	60
N (beta, mos.)	98	98	98	98	98	98	98	98	
N (mean, mos.)	360	283	418	272	170	98	1106	331	

Standard errors in parentheses

Notes: This table reports estimates for the price of risk (λ in Equation (12)) from the various asset classes described in Internet Appendix Section J. "Neg. Fwd. CIP Ret." is the negative of the return on the Dynamic Top Five Basis 1M-fwd 3M forward CIP trading strategy and "Int. Equity" is the intermediary equity return of He et al. (2017). Intercepts indicates an intercept is used for each asset class (one intercept per column, with six in (9), which pools the first six asset classes). MAPE is mean absolute pricing error of monthly returns. H1 p-value tests whether the price of the Fwd. CIP Ret. and Int. Equity risks are equal to the mean excess returns of those trading strategies. KZ p-value is the p-value of the Kleibergen and Zhan (2020) test rejecting reduced rank for the betas of the test assets. Standard errors are computed using GMM with the Newey-West kernel and a twelve-month bandwidth. Units are in percentage points.

Table A21: **Cross-sectional Asset Pricing Tests, Top 10 Basis**

	(1) US	(2) Sov	(3) FX	(4) Opt	(5) CDS	(6) FwdCIP	(7) FF6	(8) Comm	(9) 1-6
Int. Equity	-0.313	1.325	2.147	1.385	2.197	0.209	0.390	1.001	0.768
	(1.186)	(1.753)	(0.741)	(0.935)	(1.223)	(1.412)	(1.226)	(0.712)	(0.446)
Neg. Fwd CIP Ret.	-0.237	-0.0688	-0.0323	-0.0824	-0.0359	-0.0252	0.0384	0.0246	-0.0306
	(0.162)	(0.0522)	(0.0412)	(0.0325)	(0.0645)	(0.0130)	(0.0683)	(0.0526)	(0.0162)
Intercepts	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
MAPE (%/mo.)	0.044	0.030	0.068	0.029	0.018	0.008	0.082	0.355	
H1 p-value	0.436	0.563	0.036	0.249	0.150	0.907	0.205	0.330	0.905
KZ p-value	0.171	0.491	0.033	0.006	0.376	0.096	0.632	0.944	0.000
N (assets)	11	6	11	18	5	9	6	23	60
N (beta, mos.)	98	98	98	98	98	98	98	98	
N (mean, mos.)	360	283	418	272	170	98	1106	331	

Standard errors in parentheses

Notes: This table reports estimates for the price of risk (λ in Equation (12)) from the various asset classes described in Internet Appendix Section J. “Neg. Fwd. CIP Ret.” is the negative of the return on the Top 10 Basis 1M-fwd 3M forward CIP trading strategy and “Int. Equity” is the intermediary equity return of He et al. (2017). Intercepts indicates an intercept is used for each asset class (one intercept per column, with six in (9), which pools the first six asset classes). MAPE is mean absolute pricing error of monthly returns. H1 p-value tests whether the price of the Fwd. CIP Ret. and Int. Equity risks are equal to the mean excess returns of those trading strategies. KZ p-value is the p-value of the Kleibergen and Zhan (2020) test rejecting reduced rank for the betas of the test assets. Standard errors are computed using GMM with the Newey-West kernel and a twelve-month bandwidth. Units are in percentage points.

Table A22: **Cross-sectional Asset Pricing Tests, Common Sample**

	(1) US	(2) Sov	(3) FX	(4) Opt	(5) CDS	(6) FwdCIP	(7) FF6	(8) Comm	(9) 1-6
Int. Equity	0.618	0.508	0.457	3.042	3.474	-0.0337	-0.523	0.806	0.913
	(1.142)	(1.267)	(0.799)	(1.190)	(1.884)	(2.206)	(3.971)	(0.806)	(0.655)
Neg. Fwd CIP Ret.	-0.276	-0.0850	0.0193	-0.0956	0.0838	-0.0621	0.0109	0.00918	-0.0714
	(0.173)	(0.0680)	(0.0375)	(0.0652)	(0.135)	(0.0371)	(0.315)	(0.0399)	(0.0335)
Intercepts	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
MAPE (%/mo.)	0.062	0.010	0.087	0.033	0.037	0.007	0.077	0.460	
H1 p-value	0.414	0.887	0.049	0.073	0.234	0.886	0.616	0.223	0.861
KZ p-value	0.079	0.379	0.107	0.035	0.355	0.226	0.780	0.780	0.041
N (assets)	11	6	11	18	5	9	6	23	60
N (beta, mos.)	98	98	98	98	98	98	98	98	
N (mean, mos.)	98	98	98	98	98	98	98	98	

Standard errors in parentheses

Notes: This table reports estimates for the price of risk (λ in Equation (12)) from the various asset classes described in Internet Appendix Section J, using only Post-GFC data. "Neg. Fwd. CIP Ret." is the negative of the return on the AUD-JPY 1M-fwd 3M forward CIP trading strategy and "Int. Equity" is the intermediary equity return of He et al. (2017). Intercepts indicates an intercept is used for each asset class (one intercept per column, with six in (9), which pools the first six asset classes). MAPE is mean absolute pricing error of monthly returns. H1 p-value tests whether the price of the Fwd. CIP Ret. and Int. Equity risks are equal to the mean excess returns of those trading strategies. KZ p-value is the p-value of the Kleibergen and Zhan (2020) test rejecting reduced rank for the betas of the test assets. Standard errors are computed using GMM with the Newey-West kernel and a twelve-month bandwidth. Units are in percentage points.

Table A23: **Cross-sectional Asset Pricing Tests, 2-Factor. 1st PC**

	(1) US	(2) Sov	(3) FX	(4) Opt	(5) CDS	(6) FwdCIP	(7) FF6	(8) Comm	(9) 1-6
Int. Equity	-0.252	1.145	1.653	3.020	2.431	-0.544	1.249	1.176	0.880
	(0.441)	(1.402)	(0.658)	(1.156)	(0.939)	(2.623)	(1.270)	(0.760)	(0.509)
PC1 Residual	-0.0694	-0.0813	0.0410	-0.132	-0.00903	-0.0970	-0.0231	-0.0238	-0.0558
	(0.0334)	(0.0488)	(0.0376)	(0.100)	(0.0651)	(0.0576)	(0.149)	(0.0336)	(0.0257)
Intercepts	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
MAPE (%/mo.)	0.054	0.046	0.070	0.088	0.018	0.005	0.121	0.352	
H1 p-value	0.036	0.690	0.113	0.026	0.029	0.653	0.612	0.463	0.538
KZ p-value	0.021	0.079	0.652	0.013	0.105	0.654	0.178	0.232	0.005
N (assets)	11	6	11	18	5	9	6	23	60
N (beta, mos.)	98	98	98	98	98	98	98	98	
N (mean, mos.)	360	283	418	272	170	98	1106	331	

Standard errors in parentheses

Notes: This table reports estimates for the price of risk (λ in Equation (12)) from the various asset classes described in Internet Appendix Section J. PC1 Residual is the AR(1) residual of the first principal components of the arbitrages described in Section 5.1, scaled to have the same volatility as the AUD-JPY forward CIP return, and "Int. Equity" is the intermediary equity return of He et al. (2017). Intercepts indicates an intercept is used for each asset class (one intercept per column, with six in (9), which pools the first six asset classes). MAPE is mean absolute pricing error of monthly returns. H1 p-value tests whether the price of the Int. Equity risk is equal to its mean excess return. KZ p-value is the p-value of the Kleibergen and Zhan (2020) test rejecting reduced rank for the betas of the test assets. Standard errors are computed using GMM with the Newey-West kernel and a twelve-month bandwidth. Units are in percentage points.

Table A24: **Summary Statistics of AUD-JPY Cross-Currency Basis and Other Near-Arbitrages**

Period	AUD-JPY Basis	Bond-CDS	CDS-CDX	Tenor basis	Tsy-swap spread	Refco-Tsy spread	KfW-Bund spread	TIPS-Tsy spread
Pre-GFC	3.1	-2.3	-1.0	0.1	-52.7	4.7	11.1	27.9
	(8.2)	(5.6)	(1.8)	(0.4)	(6.5)	(8.1)	(2.8)	(7.0)
GFC	17.9	75.5	6.7	6.3	-11.4	60.9	51.3	50.1
	(25.8)	(80.2)	(12.6)	(3.4)	(35.9)	(35.2)	(20.5)	(35.9)
Post-GFC	51.6	20.2	3.7	10.0	24.0	41.6	29.8	29.8
	(25.8)	(13.2)	(3.8)	(3.3)	(15.5)	(12.0)	(19.4)	(6.9)

Notes: This table reports the mean and standard deviation of the AUD-JPY cross-currency basis and seven near-arbitrages, in basis points. “AUD-JPY Basis” denotes the OIS-based 3M tenor classic carry (AUD-JPY) cross-currency basis. “Bond-CDS” denotes the 5-year spread between North American investment grade corporate bonds and CDS spreads. “CDS-CDX” denotes the 5-year spread between the composite sperad of 125 constituents of the NA.IG.CDX index and the quoted spread on the CDX index. "Tenor Basis" denotes the 5-year 1-month versus 3-month Libor tenor basis swap spread. “Tsy-swap spread” denotes the 30-year spread between the U.S. Treasury over the interest rate swap. “Refco-Tsy” denotes the 5-year spread between the yield on Resolution Financing Corporation and the US Treasury. “KfW-Bund” denotes the 5-year spread between the yield on euro-denominated KfW bonds and German bunds. “TIPS-Tsy” refers the 5-year spread between the yield on the TIPS and the yield on the asset swap package consisting of nominal Treasurys and inflation swaps. All statistics are reported by period: Pre-GFC is 2005-01-01 to 2007-06-30, GFC is 2007-07-01 to 2010-06-30, and Post-GFC is 2010-07-01 to 2018-08-31. More details on these near-arbitrages can be found in Internet Appendix G.

Table A25: **Prices of Risk and SDF Parameters**

	Intermediary Equity Return	Forward CIP Trading Strategy Return
Price of risk	0.610	0.048
	(0.288)	(0.011)
SDF parameters	0.658	305
	(1.768)	(91.7)

Standard errors in parentheses

Notes: This table reports the estimated price of risk and SDF parameters on the two proposed factors. Price of risk is reported in percentage points. The price of risk on intermediary equity return is estimated using monthly return from January 1970 through August 2018. The price of risk on the forward CIP trading strategy return is estimated using daily observations of monthly return from 2010-07-01 to 2018-08-31. Newey-West standard errors are reported in parentheses, where the overlapping bandwidth is chosen by the Newey-West (1994) selection procedure. More details on the estimation can be found in Internet Appendix H.