A Hierarchical-Dealer-Centric Model of FX Swap Valuation

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This paper constructs a model of foreign exchange (FX) swap valuation based on dealers' behavior and the hierarchy of the global dollar funding system. International investors use these currency derivatives to synthetically fill their US-dollar funding gaps. In this model, three attributes of market structure drive the valuation of FX swaps: market-making costs (measured by dealers' bid-ask spreads), dollar funding liquidity risk (measured by CIP deviation and market imperfections), and FX swap market liquidity (measured by dealer competition). The goal is to understand how market design influences the cost of US dollar funding and its spillover effects. FX dealers are vital institutions in this ecosystem, as their balance sheets connect national monetary systems to the global dollar funding markets. For currencies with low FX turnover, central banks act as market makers, while private banks serve as dealers for currencies with the highest FX turnover. Studying the "dollar funding gap" through the lens of FX swap dealers is a crucial aspect often overlooked in international finance scholarship.

Keywords: foreign exchange, liquidity, international finance, dealers, microstructure, financial stability

INTRODUCTION

This paper relates to several strands of literature that study the emerging inter- connectedness between Foreign Exchange (FX) swaps and offshore dollar funding. FX swap price dynamics can generate systemic liquidity risk in the global dollar funding market.[1] The FX swap dealing system has become the pillar of financing the dollar funding gap caused by the decline in US bank lending activities. Nonetheless, monetary economics literature solely focuses on potential stresses in the wholesale cash markets, such as the US repurchase agreement (repo), when examining the dollar funding liquidity condition.[2] In international finance, in contrast, researchers focus on "correcting" FX swaps' mispricing, measured by the breakdown of the covered interest parity (CIP), and remain uninterested in liquidity conditions.[3] However, to monitor global funding and financial stability, we need to focus on the interrelation between these two markets. This paper attempts to fill this gap.

In particular, this paper evaluates the feedback loops between FX swap and dollar funding liquidities through the "dealers" channel. Rather than speculative arbitrageurs, the dealers are central institutions that link monetary jurisdictions in the international monetary system. Traditionally, US banks connected the US money market with the offshore Eurodollar market. However, more recently, US banks have started to reduce their lending activities, and FX swap dealers are becoming primary financiers of the dollar funding shortage. In this balance sheet problem, foreign investors' dollar liabilities, such as loans and bonds, are inadequate to finance their dollar assets. The institutions that absorb such imbalances into their balance sheets are the dealers. Nonetheless, classical inter- national finance theories tend to abstract from the role of dealers when exploring FX swaps' new function as indirect (synthetic) dollar funding.

This paper develops a model of FX swap valuation based on three dealer-centric fundamentals: FX swaps market liquidity (measured by dealers' competition), dollar funding liquidity risk (measured by CIP deviation), and market-making costs (measured by dealers' spread). This model is called the *"A Hierarchical-Dealer-Centric Model of FX Swap Valuation,"* or the HD model. Incorporating the private dealing system in asset pricing allows the model to capture two essential elements often overlooked in the literature. First, the wholesale money market rates directly affect FX swap valuation, which is the cost of borrowing dollars by investors (synthetic liquidity takers). Second, the international monetary system is hierarchical based on the institutions' proximity to the Fed, the issuer of the US dollar. FX swap dealers' (synthetic liquidity providers) status in the hierarchy determines their cost of funding and indirectly influences their FX swap quotations.

According to the model, US dollar funding liquidity constraints, invisible market-making costs, and FX swaps market liquidity determine the indirect cost of accessing dollar funding for foreign investors. The dealers' bid-ask spreads measure dealers' costs and profits. The FX swap dealers adjust their spot and forward bid and ask quotes when the cost of doing business increases. Additionally, the dealers' funding liquidity constraints—determined mainly by their proximity to the Fed—affect their bid-ask quotes. As funding liquidity becomes less available or more expensive, the implied rates deviate further from the CIP. CIP is considered the financial market's equilibrium pricing of currency forwards. Finally, the dealers' competition affects market liquidity and determines rates. When dealers' competition is low, international investors cannot execute large transactions and reverse them without changing the prices. When market liquidity dries up, the dealers' bid-ask quotes significantly change when traders execute large trades and reverse them instantly. Therefore, FX swaps market liquidity affects the extent of access to stable dollar funding for investors.

The HD model analyzes FX swap valuation, the costs of synthetic dollar borrowing, as the by-product of conditions in the FX swap dealing systems. This interpretation has financial stability implications. FX swaps and other currency derivatives are off-balance-sheet instruments, making the regulation and oversight of the derivatives market extremely complex.

The Fed's ability to support the international monetary system will be restricted in a synthetic dollar funding market. When faced with dollar shortages, the main options for other central banks have been to seek funds from the Fed by establishing swap lines or repo facilities. After the COVID-19 crisis, for example, foreign central banks used the Fed's foreign reserve repo facilities, called Foreign and International Monetary Authorities (FIMA) Repo facility, to stabilize the international monetary system. Unlike this liquidity cooperation, the international effort by the Basel Committee to regulate the derivatives market has not been successful.[4]

Furthermore, channeling dollars to the FX swap market is not straightforward. This problem will be amplified by the exit of dealers and the rise of prime brokerage firms. As banks reduce their market-making and dealing operations, the Fed loses willing intermediaries. In the presence of such operative restrictions, central banks usually employ unconventional tools, such as becoming the dealer of last resort in the FX swap market. Nonetheless, central banks face natural obstacles, both in principle and practice, to justify their role as market makers in the derivatives market—one of the most obscure corners of the financial system.

Section 2 lays out the FX swap synthetics and market microstructure from a dollar funding perspective. Section 3 introduces a conceptual model of FX swap valuation based on the dealers' financial positions and the hierarchical structure of the international monetary system. Finally, Section 4 concludes.

FX SWAP MARKET: SYNTHETICS AND MICROSTRUCTURE

International investors often have more immediate access to their domestic currency than to the world reserve currency, the US dollar, in the dollar funding market. If not resolved readily, this gap creates a mismatch between the supply and demand for the dollar. Traditionally, Eurodollar deposits, a type of bank loan, were the primary tool to fill the US dollar funding gap. However, after the Great Financial Crisis (GFC), the "offshore premium"—the extra cost for foreign investors to raise money in the Eurodollar market—increased dramatically. Faced with higher US dollar funding costs, these agents sought alternative sources of dollar finance. Consequently, they turned to FX swaps, which are synthetic USD-denominated loans, for overnight liquidity management. This shift from the Eurodollar to the FX swap market occurred because the funding costs implied in these synthetic loans were lower than money market rates.

Dollar finance exemplifies the use of synthetic assets. From a monetary economics perspective, the most distinctive feature of FX swap cash flows is that they replicate secured lending. A synthetic asset is a contract in which an agent takes various positions to create the same cash flow structures as holding a specific asset (also called an underlying asset). Similarly, an FX swap is a single portfolio of cash flows generated from spot FX transactions involving the sale and purchase of two currencies, offset by a forward trade later. Like a repo, an FX swap is a form of collateralized loan. In an FX swap contract, the collateral is the foreign currency used to secure funding in the dollar.

Synthetics: A Money Market Instrument

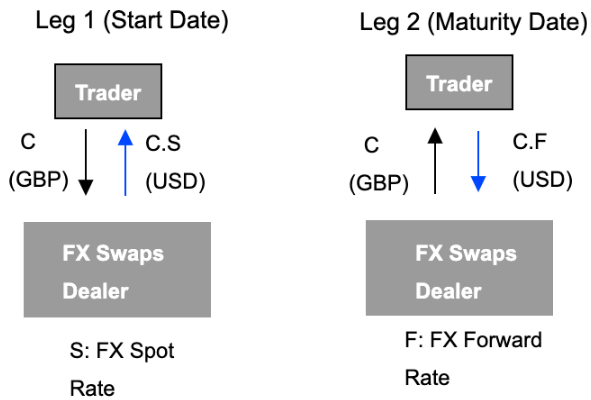
This paper applies three financial engineering tools—standard cash flow tables, analytical contractual equations, and balance sheets—to demonstrate that the use of FX swaps as a money market instrument is a deliberate feature of its engineering, not an accidental byproduct. Initially, FX swaps were employed to hedge foreign currency investments by financial institutions and customers, including multinational corporations engaged in foreign direct investment. They have also been used to hedge foreign currency borrowings, such as bonds de- nominated in foreign currencies. Most FX swaps are short-term, generally less than one year in maturity, mirroring the tenor of money market transactions.

However, the similarity between FX swaps and money market instruments extends beyond their maturity. A careful examination of an FX swap reveals inherent similarities with a repurchase agreement (repo), the backbone of money market lending. Both are forms of secured loans and are extensively used to raise US-dollar funding.

An FX swap transaction can be viewed as a form of money market collateralized lending. The key to understanding this point lies in reassembling an FX swap based on its cash flow synthesis rather than its risk structure. Figure 1 illustrates the flow of funds involved in a pound/US dollar swap. Suppose an investor uses cash in pounds (GBP) to buy dollars (C·S USD) in the FX market.[5] The agent then uses this cash to purchase a dollar-denominated asset. Simultaneously, they enter an outright forward contract to sell an equivalent amount of dollars for pounds at an agreed price (C·F USD) when the contract expires. Thus, the forward contract generates a commitment to purchase dol- lars (a liability), paired with the right to receive pounds (an asset), equal to the current value of the dollar-denominated asset. Consequently, the swap creates an implicit obligation to repay, or IOU, analogous to short-term debts in the money market.

The paper applies another cash flow engineering tool, called "analytical contractual equations," to show that an FX swap creates hybridity between the foreign exchange and money markets. By replicating an instrument with a portfolio of cash flows, we can write a contractual equation and create new synthetics. The tables below use such equations to demonstrate the similar construction of FX swaps and money market instruments. The right-hand side contract leads to the same cash flows generated jointly by the contracts on the left-hand side.

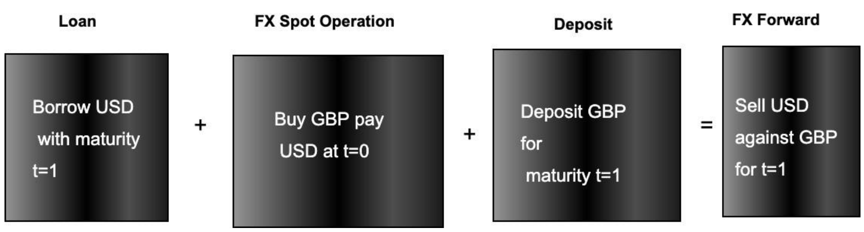
FIGURE 1
THE BASIC MECHANICS OF FX SWAP



Importantly, this does not necessarily mean that the monetary value of the two sides is always the same. One or more of the contracts shown on the left- hand side may not even exist explicitly. Instead, they are "implicit" swaps of IOUs (promises to pay), and the markets may not even have the opportunity to price them. Nevertheless, the equation indicates that the two sides' risk and cash flow attributes are the same. The only condition that ensures the value of the two sides of the contractual equation are the same is the absence of credit risk, transaction costs, and if the markets for all involved instruments are liquid. This condition is called the "no-arbitrage condition," which produces the CIP.[6]

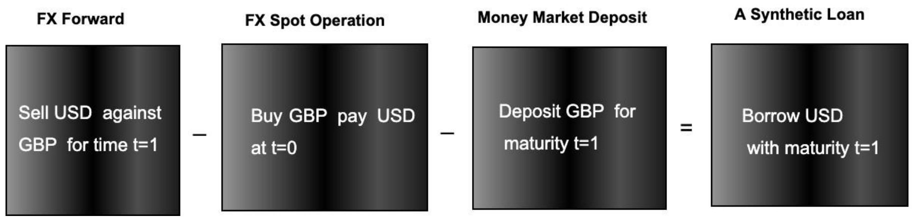
Figure 2 shows a standard FX swap contract. Contractual equations can be used to solve routine problems encountered in financial markets, although they have drawbacks. Ignoring these for the time being, we use an example to show why the FX swap is ultimately a desirable way to obtain US dollar funding. Suppose dollar loans were either too expensive or altogether unavailable in the traditional Eurodollar market. In that case, investors use the FX swap as a synthetic instrument to raise US dollar funding.

FIGURE 2
A CONTRACTUAL EQUATION OF FX SWAP



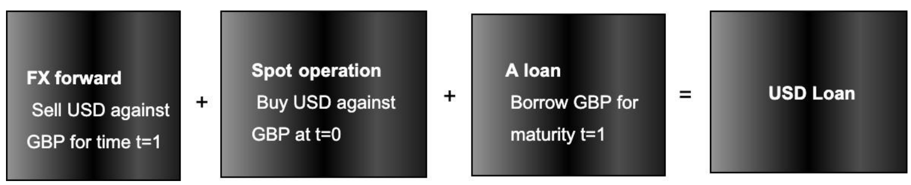
We manipulate this like an algebraic equation. Note that on the left-hand side, there is a money market loan contract. This is a "true" dollar loan, and it can be isolated on the right-hand side by rearranging the left-hand-side contracts. Figure 3 expresses the loan in terms of synthetic money market loans:

FIGURE 3
A CONTRACTUAL EQUATION OF A MONEY MARKET LOAN



Note that signs changed because we moved the deposit and the spot operation to the other side of the equality. In this context, a deposit with a minus sign would mean reversing the cash flow diagrams, and hence it becomes a loan. On the other hand, a spot operation with a minus sign would switch the currencies exchanged. Hence, Figure 4 contractual equation can finally be written as:

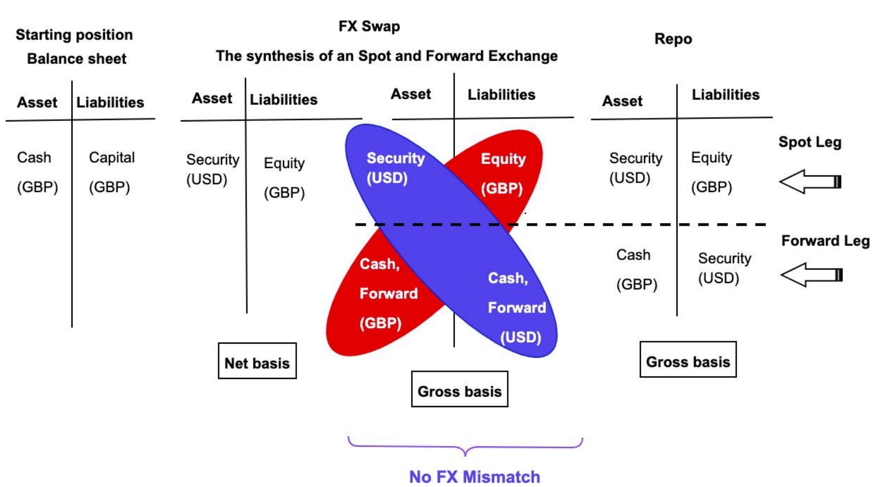
FIGURE 4
FINAL CONTRACTUAL EQUATION - A US-DOLLAR FUNDING LOAN



These contractual equations expose two ways of understanding an FX swap. First, the FX swap is a portfolio of money market "deposits" and "loans" in different currencies. The second interpretation is that an FX swap is a "collateralized debt" similar to the repurchase agreement (or repo). The FX swap allows two counterparties to sell and repurchase two currencies against each other at the beginning of the contract and the maturity date. Hence, there are significant money market qualities engineered in the design of an FX swap.

Figure 5 uses another financial tool, balance sheets, to expose the similarities between FX swap and the repo instrument, the most critical wholesale money market tool. These set of balance sheets show both the "implicit" and "explicit" assets and liabilities in both instruments:

FIGURE 5
A STYLIZED COMPARISON OF FX SWAP AND REPO



These balance sheets reveal the similarities between an FX swap and a repo as US-dollar funding instruments. To understand this point, assume that the agent raises US-dollar funding through the US repo market (right-hand panel) to purchase a dollar-denominated security. In this case, the investor funds the dollar-denominated security by selling the security "at purchase," effectively using it as collateral. Meanwhile, they pledge to buy it forward at an agreed price.[7] Similarly, FX swaps can be viewed as collateralized borrowing/lending. Like the repo, FX swaps have a spot leg and a forward leg. In the spot leg, the investor uses pounds to purchase dollars. In the forward leg, the investor reverses this transaction and repurchases the pound using dollars. Furthermore, even though rates are fixed in both instruments, the "repo rate" is explicit, while the FX swap rate (forward rate) is implied. The reason is that FX swaps are term loans of one currency collateralized with another currency. Therefore, the interest rate differentials between these two currencies will affect the forward rates. In contrast, the securities and cash in the repo market are denominated in the same currency.

Repo and FX swaps are inherently similar tools for raising US-dollar funding. Nonetheless, the "quality" of their underlying collaterals differs in two aspects. First, in a repo transaction, the collateral is *explicit*. This means the balance sheet of the cash lender reflects the acquisition of the collateral in a repo contract. In contrast, an FX swap has a *missing collateral* in the form of an implicit "net worth" on the balance sheet (Figure 6). Second, the collaterals that secure US-dollar funding through these instruments have different qualities in terms of liquidity and the creditworthiness of the issuers. As a result, they relate to separate layers of the financial instrument hierarchy. While dollar-denominated "securities" are used as collateral in the repo market, foreign "currency" positions serve as implicit collateral in the FX swap market. In a domestic money market, the liability of a government, a currency, is at a higher layer of the hierarchy of promises to pay than a private sector's security. However, in a global funding market, dollar-denominated private sector security (repo market collateral) is at a higher layer of the hierarchy than foreign currency (FX swap market collateral).

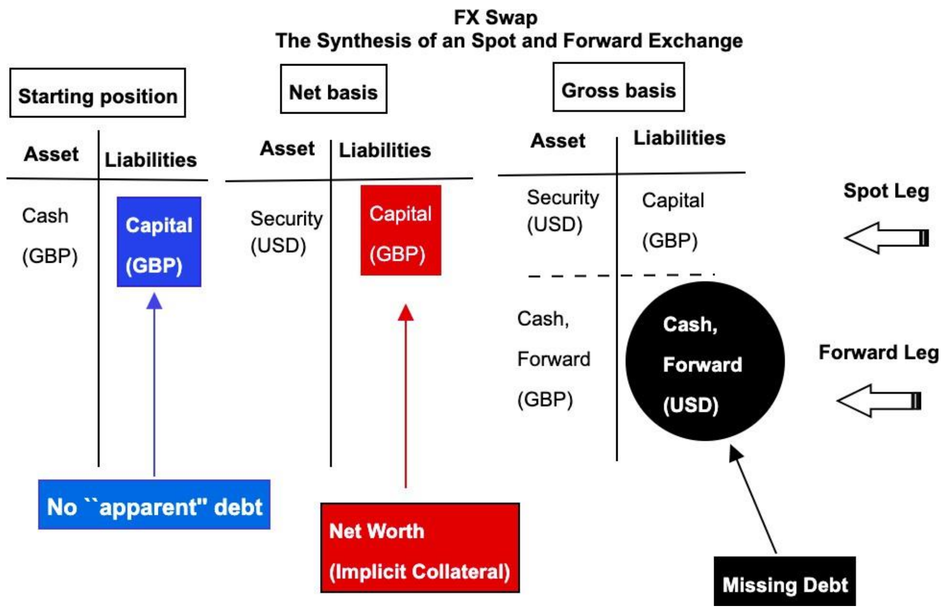
The "missing collateral" phenomenon results from an accounting convention. Current accounting principles require repo transactions to be reported on a gross basis, demonstrating that the balance sheet doubles in size. In contrast, the FX swap market is recorded on a net basis, and the forward leg of the transactions is kept as off-balance sheet instruments. This accounting practice has created significant misunderstandings about the attributes of FX swaps.

First, despite the widespread view, FX swaps do not expose investors to FX risks. When recorded on a net basis, the FX swap exposes the investor to FX risk (a form of currency mismatch between the assets and liabilities on the balance sheet). In Figure 5, for instance, in the "net basis" balance sheet position, the liabilities of the investor in the FX swap market are in pounds while the assets are denominated in dollars. However, as the figure shows, there is no currency mismatch once we record these transactions on a gross basis, where spot and forward obligations and assets are shown explicitly. The forward positions will offset the apparent FX risk of the spot transactions.

Second, the netting principle in FX swaps keeps the "forward liabilities" mostly off-balance sheet. Figure 6 exposes the "implicit forward obligations" in the FX swap markets. Borio et al. (2017) called this phenomenon "missing debts" and a significant threat to the stability of the international monetary system. The idea is that a simple accounting convention hides the debt accumulated in the FX swap market, even though it is a secured loan with a principal that should be repaid in full at maturity.

To understand these T-accounts, assume that a foreign investor purchases a dollar-denominated security and needs dollars. The agent enters the transaction holding her capital in the local currency, say pounds (left-hand panel), with no explicit debt. In the first case, represented by the middle balance sheets, the investor uses an FX swap to finance the purchase of the dollar-denominated security. The mechanism works *as if* she uses pound deposits to buy dollar deposits in the FX spot market, paying the spot rate for this transaction. Simultaneously, she enters an outright forward contract, committing to sell an equal amount of dollars (an implicit liability) balanced by the right to purchase pounds (an implicit asset) at maturity. The forward contract price is agreed upon from the beginning and is equal to the market value of her dollar security at maturity. The critical point, often missed through the accounting process, is that the promise to purchase pounds using dollars at maturity is a kind of debt. Since these promises to pay are implied in the contract, the swap's accounting convention considers these debts as off-balance-sheet.

FIGURE 6
FX SWAPS: MISSING DEBT AND COLLATERAL



Nonetheless, these promises to pay are hidden from balance sheets and regulatory accounting standards. This misconception is a result of the extensive use of netting in the FX swap market. The above balance sheets show two potential methods of recording the transaction: on a net basis and a gross basis. Gross accounting explicitly shows the implicit rights to collateral and commitments as assets and liabilities denoted by *forward*. Conventional rules, on the contrary, account for the transactions in the swap agreements by netting. Netting shows only the outcome of a series of transactions and makes it difficult to measure all the debt and funding involved. The resulting net positions are likely to underestimate the off-balance-sheet gross debt positions, especially for dealer banks. As a result, they lead to the rise of "missing debts" with significant implications for financial stability.

The application of netting and the rise of missing debts is due to an academic treatment of the FX swap as a typical derivative. From a financial perspective, however, an FX swap, in terms of pricing, cash flow, and risks, is more similar to debt security than a derivative. Swaps comprise one type of derivative. However, unlike other derivatives, their value is not derived from an underlying security or asset. Instead, the swap's value is based on cash flows. The first scholarly lapse is about an FX swap's cash flow stream. Unlike other types of swaps, an FX swap has no interim payments. Still, the most significant difference is about the final payment. As is the case for a debt security, such as a bond, there is nothing notional about the face value of an FX swap. Instead, the principal, or FX swap's face value, should be paid at maturity. On the contrary, for most other swaps, the buyer pays only a fraction of the total value of the principal. Thus, the face value only serves as a reference for the much smaller payment at maturity and is called the "notional amount." Economists tend to treat an FX swap identical to other derivatives that have a small total net cash outflows.[8]

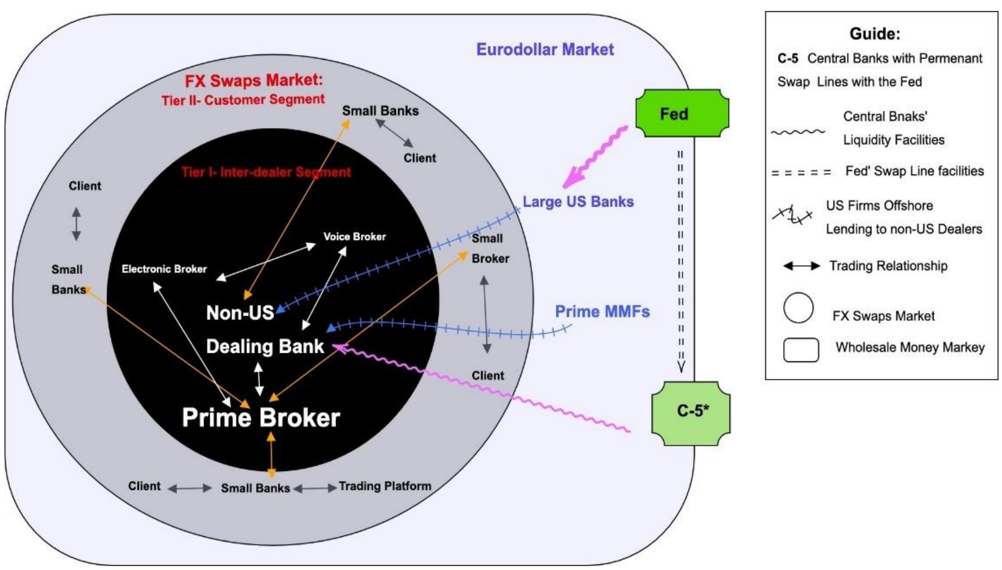
Furthermore, economists tend to misunderstand the risks of an FX swap. On the one hand, the netting shows an "apparent" currency mismatch: the security is in dollars, and the liability is in pounds. However, this FX mismatch neutralizes once the transaction is recorded on a gross basis, as the dollar-denominated security (asset) offsets the forward dollar liability. On the other hand, the standard FX swap pricing approaches overlook the risks associated with the hidden debt in an FX swap. The implicit debt includes risks connected with the counterparty's ability to fulfill her promises to pay the face value in the future. Standard debt security pricing theories include a risk premium to capture final payments' default, liquidity, and price risks. Similarly, FX swap dealers, the established price setters in the FX swap markets, have started to account for the possibility of the counterparty's default to pay the face value by widening their bid-ask spread.

This trend, the widening of dealers' bid-ask spreads to capture the FX swaps', implied final payments have accelerated after the COVID-19 pandemic. The process of including the default risk of principal in FX swap pricing is known as "credit value adjustment".[9] The associated price risk is called "FX collateral risk." Furthermore, the risks of defaults on final payments make the interest rate differentials necessary but not the sole component of FX swap pricing. Finally, dealers' compensation for counterparties' default on the debts that are "missing" from academic models can partially explain puzzles, such as the failure of CIP, in international finance scholarship.

Market Microstructure: A Hybridity With Wholesale Funding Market

A two-tier structure has characterized FX markets for a long time. The two segments are "inter-dealer" and "dealer-customer." To help clarify this system, figure 7 shows the stylized structure of the FX swap market and its interaction with the offshore wholesale funding market. The black and gray circles in the frame represent the interdealer market and the customer market in the FX swap market, respectively. The offshore US-dollar funding market is the box outside the circles:

FIGURE 7
STYLIZED MICROSTRUCTURE OF FX SWAP ECOSYSTEM



The FX swap market is a private dealing system despite being an "order-driven" market. In a typical order-driven market, prices are displayed and largely determined by buyers and sellers who wish to buy or sell a particular security. Therefore, it is "broker-centric," where buyers and sellers regularly trade without relying on the dealers' balance sheets.[10] In the FX swap market, this would imply that activities in the customer segment (Tier-II) set the prices. Nonetheless, over the past decade, transactions in the "interdealer" segment of the market (Tier-I) have determined prices in the FX swap market.[11]

In this two-tier market structure, most FX swap trades are intermediated by dealers. As a result, the dealers' balance sheets absorb any trade imbalances to ensure the smooth and continuous execution of trades. This process is called "internalization," which is a key aspect of market-making and liquidity provision. However, the FX swap market is still called an order-driven market because the dealers cannot choose clients. In other words, the FX swap dealers are "uninformed" traders. Uninformed traders prefer markets where they have substantial market shares and can set prices. This market structure splits participants into two distinct categories: "liquidity makers" and "liquidity takers." The current FX swap market structure designates dealers as the primary liquidity makers and price setters, while brokers and other participants are liquidity takers.

The FX swap dealers' credit lines with large US banks and access to cheap wholesale money market funding enable them to earn substantial revenue from liquidity provision for customers.[12] Generally, there is a hybrid relationship between the costs of raising US-dollar funding and the FX swap prices. The implied rates of FX swaps move in response to the dealers' costs to raise funding liquidity. Dealers or "market makers" emerged naturally in the FX swap market because these dealers, typically large non-US banks, had historical and long-lasting relationships with US banks. Access to cheap funding enabled them to provide liquidity regardless of the size and creditworthiness of their counter- parties, the liquidity takers. Dealers trade with any trader requiring FX swaps at a moment's notice.

To initiate an FX swap trade, an agent calls a dealer indicating the currency and quantity they want to trade and asks for the price. The dealer states a price they are willing to buy (the "bid") and a price they are willing to sell (the "ask"). The client then decides whether to buy, sell, or pass. The dealer is compensated for the burdens of liquidity provision, such as bearing inventory risk, by a positive gap between the quoted buy and sell prices, known as the "bid-ask spread." Dealers in this market structure, known as "over-the-counter" (or OTC), are under no formal obligation to provide liquidity. Nonetheless, they tend to continuously make the market because otherwise, their reliability—and potentially their market share—would deteriorate.

This structure has blurred somewhat over the years. However, after the GFC, significant developments in the FX swap and wholesale funding markets have restructured this setting. For instance, the list of key players in the FX swap market has expanded. Beyond central banks and FX swap dealers, prime brokerage firms have become major players in this market. Furthermore, large US banks have started to curb their lending activities in the offshore wholesale market. Instead, prime MMFs have replaced these banks as the primary funders of the FX swap dealing system. These changes in the FX swap market microstructure and their impacts on the costs of dollar funding have attracted central bankers' attention. In contrast, economists' attention has mainly been limited to examining the performance of CIP as a theory of FX swap pricing.

The Breakdown of the Classical FX Swap Pricing Theories

Finding the exact value of a swap is highly complicated. Many economists spent several years solving this problem before Fisher Black and Myron Scholes published their Nobel prize-winning Black-Scholes options pricing formula in 1973. In line with this paper's proposed FX swap valuation framework, the Black-Scholes equation calculates the theoretical value of derivatives, considering the impact of time and risk factors on the market-makers' balance sheets. Nonetheless, the derivation of the Black-Scholes options pricing formula requires complex stochastic calculus. In most cases, modern financial theories have circumvented this complexity by employing no-arbitrage and no-dealers rules. These assumptions enabled the researchers to estimate their models by employing simple arithmetic. For example, the economists derived exact swap prices in a binomial framework. With binomial option price models, the assumptions are that prices do not change, there is no arbitrage opportunity, and there are only two possible outcomes- the prices either increase or fall. Thus, the significant advantage of a binomial option pricing model is that they are mathematically simple. As a result, the binominal valuation model has been used more frequently in practice than the well-known Black-Scholes formula.

The CIP simplifies swaps pricing by requiring two synchronous identities. First, CIP holds that the extent of the interest rate disparity between two currencies in the cash markets should equal the differences between the forward and spot exchange rates. Otherwise, arbitrageurs could make a seemingly riskless profit. For example, in an FX swap market, if the dollar is cheaper in terms of yen in the forward market than stipulated by CIP, then anyone able to borrow dollars at prevailing cash market rates could profit by entering an FX swap - selling dollars for yen at the spot rate today and repurchasing them cheaply at the forward rate at a future date. In this case, the arbitrageur will keep trading until the return on different currencies equals the FX swaps implied rate. In doing so, the arbitrageurs price these synthetic assets (FX swaps) and create parity between the interest rate differentials and the FX swaps implied rates. Second, CIP creates parity between cash flow patterns and pricing of a replicating portfolio and its underlying assets. Therefore, this identity condition asserts that the price of an FX swap should depend on its generated cash flows.

Further, CIP allows valuation even under a "floating" FX regime. A floating FX regime significantly complicates the FX swap pricing for at least two reasons. First, when exchange rates float freely, each currency can have independent interest rates for various maturities. This means that there can be numerous forward rates at a given spot exchange rate for each future maturity date. Second, in a floating FX regime, the size and the timing of the cash flows for the spot and forward loans are uncertain. The CIP fixes the first issue by assuming that each forward rate must follow the interest parity theorem under the no-arbitrage condition even under such circumstances. In other words, for any spot rate and at any maturity date, there is a unique forward rate that follows the CIP condition. CIP also resolves the second problem. When CIP holds, an FX swap contract obligates an investor to pay dollars today and receive a fixed amount of dollars at maturity. Under no-arbitrage conditions, this should generate the same cash flows as a dollar-denominated fixed-income instrument, such as a bond. Nonetheless, this seemingly reliable no-arbitrage condition can only hold in a continuous liquid market with the absence of transaction costs, bid-ask spreads, credit risk, and counterparty risk.

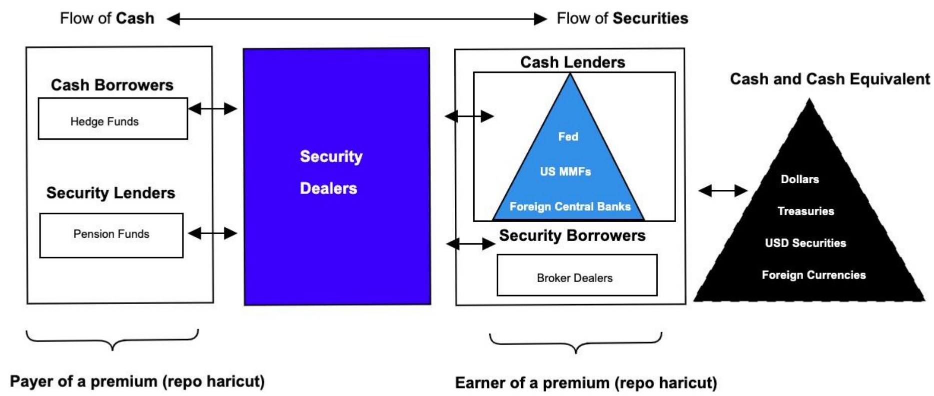
CIP, an inherently "dealer-less" condition, is the closest doctrine to physical law in the classical FX swap valuation theories. CIP predicts that US-dollar funding costs should be the same in the money and FX swap markets. For example, suppose today's interest rates on dollar and pound deposits are 1.6% and −0.4%. In that case, the CIP predicts that the cost of the *GBP/USD* currency swap to a foreign non-bank is 2% (i.e., it pays out 1.6% on the dollar interest but also pays out 0.4% on the pound interest because the pound interest rate is negative). If the US dollar lender quotes a basis of −50 bps due to a dollar shortage, then the cost of this swap to the firm would increase to 2.5% (1.6% dollar interest + 0.4% pound interest + 0.5% currency basis). In this scenario, the arbitrageurs enter the market, take advantage of the premium rates, and eliminate the deviations from the CIP.

Despite the theoretical value of the CIP, after the GFC, accounting for basis, an excess premium, in addition to the interest rate differential, has become a permanent feature of FX swap pricing (Song, 2016). In the literature, any deviation of the FX swaps implied rate (the "basis") from CIP is a form of "mispricing." This breakdown, however, suggests "limits to no-arbitrage conditions" as the arbitrageurs are reluctant to eliminate seemingly risk-free, economically significant returns through spread-narrowing trades. The CIP's failure, nonetheless, is the byproduct of its abstraction from the private dealing system and the hierarchical structure of the financial system. The dealers provide liquidity, absorb risks and quote bid-ask spreads[13]. Despite CIP's conjectures, these functions are neither cheap nor risk-free. Instead, dealers provide market liquidity, charge bid-ask spreads to offset their exposures to risks, and continuously monitor their access to funding liquidity. Further, the CIP breakdown also reflects the use of swaps to overcome US dollar funding shortages and the hierarchical structure of the international monetary system.

Lastly, the analogy in the financial engineering of the FX swap and the repo provides an extra tool to understand the CIP deviation. Whenever CIP breaks down, in effect, the pricing in the FX swap market starts to simulate that of the repo market closely. In this circumstance, one borrower of the US-dollar funding in the FX swap market ends up paying the basis, or a premium, on top of cash market rates. Similarly, in the repo market, the cash borrower pays an interest rate, repo rate, to the cash lender. In the meantime, the US-dollar funding provider, in effect, receives an equivalent discount when borrowing the foreign currency. As discussed in section 2.1, the foreign currency in the FX swap market acts as the de facto, yet implied, collateral. Hence, using the repo market analogy, the discount that the US-dollar lender ends up receiving when acquiring the foreign currency in the FX swap market can partially be understood as a form of "haircut" that the money-lender receives when lending US-dollar cash against securities in the repo market.

The main economic reasoning behind the existence of the haircut in the repo market is in the hierarchy of financial instruments. Figure 8 shows the effects of such hierarchy on the repo pricing. In this market, security dealers borrow cash from cash lenders who are willing to supply cash because of the extra security it offers them. Moreover, security dealers lend cash to cash borrowers who are willing to pledge securities. Thus, cash flows through dealers in one direction, and collateral flows through them in the other direction.

FIGURE 8
INHERENT HIERARCHY IN REPO PRICING



The point to emphasize is that the repo transaction is not entirely symmetric because the price at which the security is transferred is lower than its market price. This means that the cash lender gets control over more securities than a clean purchase would allow. This difference is a form of margin. In practice, the dealers set the margin. The primary dealers are the core of the lender/dealer system of first resort who absorb trade imbalances. If cash investors avoid particular collateral or particular counterparties, dealers take over that business (by increasing the margin), expanding their balance sheets on both sides. The margin works because the price of a security that is used as repo collateral is less than its market price by an amount called the haircut. Traditionally, in a repo transaction, the lender of money receives margin because it is lending the more liquid asset. This extra cost, or the premium, is called the "haircut" and is an integral part of the repo pricing. In other words, the asymmetry in the relative value of the two exchanged assets in the repo is a symptom of the money-credit hierarchy rather than mispricing. Similarly, the premium that traders pay, even during non-crisis periods, to raise dollars synthetically against foreign currencies is a symptom of the dollar's higher status in the hierarchy of national currencies. Essentially, the part of the CIP breakdown caused by the dollar's status in the international monetary system signifies accurate pricing of the US dollar rather than FX swap mispricing.

The dollar, the ultimate international means of payment, is at the apex of the hierarchy of currencies. There exists voluminous research on the new function of the FX swap and the gravity of the CIP condition, and this paper speaks to this literature. Assuming the no-arbitrage condition, CIP has formed an implicit view of international finance that the currency hierarchy is flat. Nonetheless, the centrality of the US dollar as the world's reserve currency has put the Fed at the top of the international monetary system. In this system, all other currencies promise to pay the dollar and are more peripheral. Therefore, the hierarchy implies that other currencies should pay a premium to be converted into the dollar. As the importance of an FX swap as a dollar funding instrument increases, the same premium applies to the price of an FX swap. Indeed, after the GFC, the dollar basis (a measure of the US dollar funding premium) in the forward market has widened. However, the current literature ignores the existence of such a hierarchy and considers the "premium" as a currency mispricing.

A HIERARCHICAL-DEALER-CENTRIC MODEL OF FX SWAP VALUATION

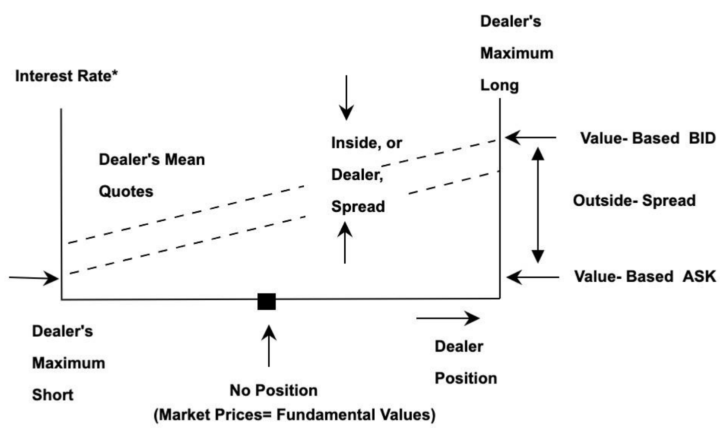
This section introduces a conceptual FX swap valuation model based on the hierarchy of dealers and the international monetary system. This framework, termed "A Hierarchical-Dealer-Centric Model of FX Swap Valuation" (HD model), uniquely formulates the CAPM theorem by incorporating dealers' balance sheets and the structure of the international financial market into asset valuation. This distinctive interpretation enables the HD model to directly connect the cost structure and financial system position of FX swap dealers with FX swap capital valuation.

In finance and economics, fundamentals represent the key characteristics and financial data essential for determining an asset's stability and price. The HD model identifies three dealer-centric fundamentals that drive FX swap valuation: market-making costs (measured by dealers' bid-ask spreads), access to dollar funding liquidity (measured by CIP deviation), and FX swap market liquidity (measured by dealer competition). The HD model formally quantifies these fundamentals and explains how their interactions are reflected in FX swap market pricing. The objective is to elucidate FX swap pricing trends (such as the persistence of the basis) and to understand the spillover effects between FX swaps and offshore dollar funding markets.

HD Model: Origin

One of the theoretical foundations of the HD model is Treynor's (1987) model of *The Economics of Dealer Function*. The Figure below combines the main elements of the Treynor Model in a diagram:

FIGURE 9
TREYNOR MODEL OF DEALERS' BEHAVIOR



Note*- In the original Treynor's Diagram, the vertical axis represents "prices." The dashed lines are downward sloping. However, in this formulation of the Treynor model, the paper has used "interest rates" than prices. Since interest rates and prices have an inverse relationship, the dashed lines are upward sloping.

In this model, two essential players constitute the private dealing system: dealers and value-based traders. Both act as market makers. Dealers provide market liquidity by intermediating between traders to whom time is essential, in exchange for a spread.[14] As a result, dealers charge buyers a higher price than they pay sellers. A value-based investor may also fulfill this function, typically at a wider spread than that imposed by the dealer. The model refers to the spreads of value-based investors and dealers as the outside spread and the inside spread, respectively.

In a private dealing system, the arithmetic mean of the dealer's bid-ask spread becomes the market price. Narrow bid-ask spreads require dealers' dynamic engagement in the price discovery process and their willingness to increase balance sheet risks and cost exposures. Dealers are essential to reducing spreads, as their actions make them the price-setters and suppliers of market liquidity. The dealers' commitment to trade and create a competitive market determines the sensitivity of their quoted spreads to the size of trades, a measure of market liquidity. This readiness depends on their cost of doing business, including balance sheet constraints such as regulatory requirements and the cost of raising US-dollar funding.

Dealers incur various costs, including salaries and other operational expenses. Unless these costs have a significant variable component, the dominant variable costs for dealers are the economic losses incurred during a firesale (or lay-off) of inventories to value-based dealers.[15] The primary reason for a firesale is the loss of access to cheap funding liquidity in modern finance. In this setting, as the dealers' prices are related to these variable costs, dealers' expectations about funding liquidity costs factor directly into asset prices. In the event of a liquidity drought that could lead to the dealers' departure from the market, traders would have to pay the entire outside spread.

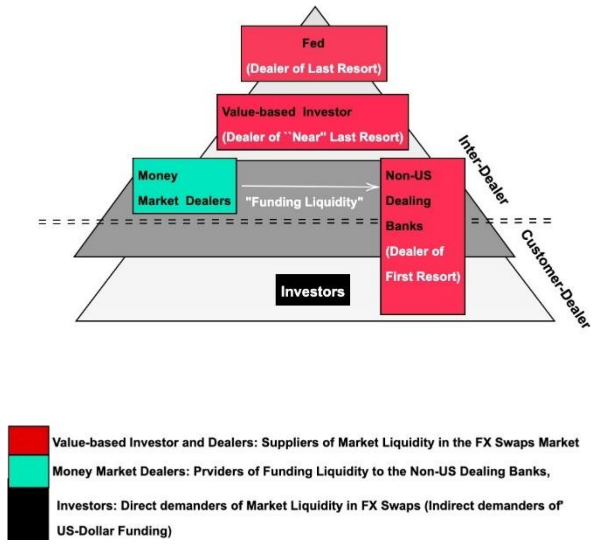
Financial factors related to the dealers' balance sheets influence and sometimes restrict their ability to provide market liquidity and set prices. For example, dealers increase their bid-ask spreads if they are nearing their balance sheet constraints. Additionally, dealers have limited capital and loss-absorbing capacity. Loss-absorbing capacity is the ability of a dealing bank to suffer losses without falling below the regulatory minimum of capital and requiring recapitalization or resolution. To manage this risk, dealers set limits on the level of inventories they are willing to hold. The Treynor diagram above labels these limits as maximum long and maximum short positions.

Another critical element is the cost of funding liquidity. Dealers require continuous access to cheap funding to finance their positions. When dealers' access to funding is restricted or the cost of liquidity increases, they adjust their spreads or cease providing services. Finally, dealers face firesale risk—the need to sell inventories at highly discounted prices. When dealers reach their maximum position, they may face economic losses, prompting them to firesale their inventories. They sell their positions to the only other transactor motivated by price—the value-based investor. Essentially, value-based traders, who have considerably more capital, act as dealers of last resort during standard times. However, during a financial crisis, value-based traders become only the dealers of "near last resort." The ultimate market-makers in the private dealing system are the central banks with their asset purchasing programs.

The private dealing system is hierarchical based on the extent of access to liquidity. Figure 10 stylizes this hierarchical system. Private dealers are the market makers of the first resort. They set market prices when their financial condition is favorable, and their loss-absorbing capacity allows them to absorb imbalances. Value-based investors are the dealers of "near last resort," meaning that once dealers exit the market, value-based dealers only act as market-makers if there is no widespread financial crisis. During a financial crisis, when continuous prices are needed the most, the Fed's balance sheet becomes the "only game in town."

The academic literature on market-making has long posited seemingly conflicting puzzles. The efficient market hypothesis, proposed by Fama (1970), asserts that markets are informationally efficient, and thus dealers cannot earn abnormal returns. Grossman and Stiglitz (1980) introduce the concept of "near efficiency," arguing that because information is costly, prices only partially reflect information. Therefore, arbitrageurs can make extra profits by gathering information. The literature has documented many trading strategies over the past several decades that generate positive risk-adjusted returns (alphas).[16] Simultaneously, the literature shows that most active investors have not been able to outperform passive investment strategies.[17]

FIGURE 10
THE HIERARCHY OF MARKET-MAKERS IN SECURITY MARKETS



Treynor offers insights into these matters in a series of articles. Generally, portfolio managers' actual returns fail to exceed market averages due to the dealer-based nature of capital markets and the presence of dealers' spreads. Any trade with a market-maker incurs the dealers' spread cost regardless of the trader's type. Dealers interact with three types of traders: information-based, liquidity-motivated, and noise traders.[18] Dealers lose to information-based traders and gain from liquidity-motivated and noise traders. The spread must be large enough to cover losses incurred while trading with informed traders to justify market-making and provide market liquidity. During non-crisis periods, the spread seems missing because fluctuations in the bid and ask prices are covered by constant fluctuations in the equilibrium value of the security.

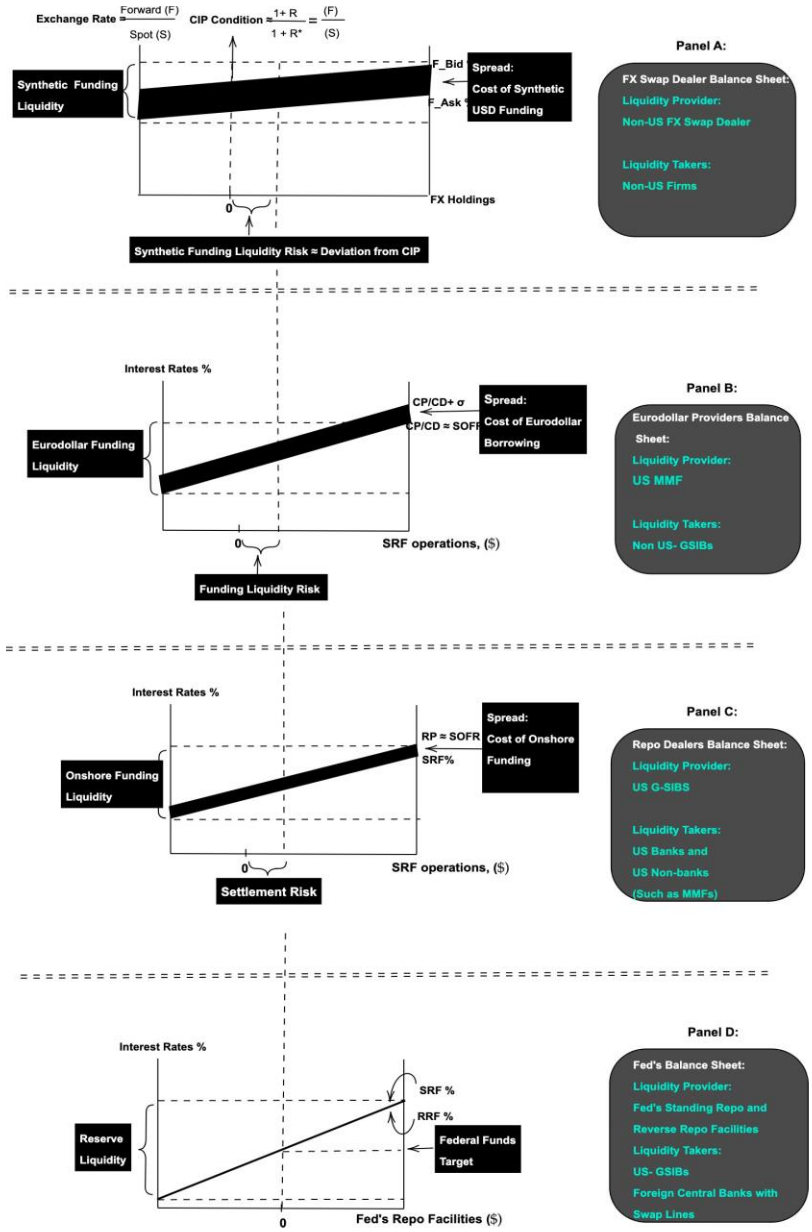
However, during a crisis, value-based dealers, motivated by the gap between the market price and fundamental value, make the dealers' spread too wide to remain obscure. Essentially, value-based investors act as liquidity providers of "last resort," but at extremely high costs to the market. The value-based investor's high buy-sell spread can be viewed as compensation for providing liquidity during such periods.[19]

Two inherent characteristics of Treynor's model of dealers' behavior make this theorem stand out compared to alternative interpretations of the CAPM. First, the model offers a hierarchical view of a private dealing system in line with the structure of the international monetary system. For example, after the GFC, the FX swap dealing banks have become the central providers of global US-dollar funding. In effect, US G-SIBs' behavior began to match that of value-based traders.[20] They supply US-dollar financing at a high price, primarily to bail out non-US dealers. Once dollar funding costs are considered too high and a threat to financial stability, the Fed intervenes and acts as the dealer of last resort for the international monetary system. Second, the model portrays the essential hybridity of the money market and capital market. In this asset pricing model, US-dollar funding liquidity directly affects market liquidity in the security markets and influences prices.

HD Model: Deep Fundamentals and Valuation

The HD Model is a conceptual framework for capital valuation based on the behavior of the *dealers* and the *hierarchy* of the international monetary system. It essentially applies the CAPM to international finance, uniquely formulating it around dealers' market-making activities. Figure 11 represents the schematic representation of this model:

FIGURE 11
A SCHEMATIC OF THE HIERARCHICAL-DEALER CENTRIC MODEL OF FX SWAP VALUATION



Panel A illustrates the dealers' behavior in the FX swap market. The horizontal axis represents the FX swap dealers' net position (holding) in foreign currencies (FX) and their exposure to dollar liquidity risk. When dealers lend US dollars synthetically in the FX swap market, they receive foreign currencies as "implied" collateral. Thus, as net US dollar lenders, dealers accumulate inventories in the foreign currency.[21] The vertical axis represents the forward (F) to spot (S) ratios and implied forward rates.[22] The diagram includes two upward-sloping price lines: the upper price curve represents the implied bid rates, while the lower curve outlines the ask rates.

FX dealers supply quotations for exchange rates upon demand. A quote consists of a bid and an ask on a designated quantity of currency. The *bid* is the price at which the dealer is willing to buy the indicated amount of dollars. The *ask* is the price at which the dealer is willing to sell the stated quantity of dollars. Generally, FX dealers' asked rates, quoted to synthetic US dollar borrowers (the buyers of FX swaps), are lower than their bid rates to synthetic lenders (sellers of FX swaps). A positive bid-ask spread indicates that the dealer buys the foreign currency at a lower price and sells it later at a higher price.[23] Like a typical dealer market, the effective rates, or prices, are the "mid" rates, which are the arithmetic mean of "bid" and "ask" prices.

Panel A explains the dynamics of FX swap pricing from the dealers' balance sheet perspective. Let us assume that dealers make the market for clients who have domestic currency, such as euros, and want to swap it into dollars. In this case, dealers sell dollars in the spot leg of the transaction at the spot rate (S) and simultaneously enter a forward agreement requiring the dealers to purchase dollars at a fixed forward rate at maturity. The forward rate implied in the FX swap or forward contract is the rate on synthetic dollar funding. The price curves are upward sloping, indicating that as dealers expand their balance sheets, they demand higher premiums from their clients to provide synthetic dollar funding (e.g., borrowing in euros and swapping into dollars) relative to direct dollar funding (i.e., borrowing dollars in the money market), resulting in CIP deviations. Dealers earn an extra premium by increasing the forward rates compared to spot rates. As $\frac{F}{S}$ increases, the relative cost of purchasing the US dollar at maturity compared to the spot contract falls. As dealers sell dollars in the spot market and buy them in the forward market, they can obtain more dollars with the same amount of foreign currency as the forward rate increases relative to the spot rate.

To understand this point, assume that a European bank wants to use cash in domestic currency, such as euros, to borrow dollars synthetically in the FX market. The European bank borrows $115 and lends €100 to the dealer. S, the FX spot rate, is 1.15 $\frac{\$}{e}$, and F, the FX forward rate, is 1.2$\frac{\$}{e}$. F is the FX forward rate determined at the beginning. At maturity, the outright forward contract obliges the dealer to sell the €100 to the bank and receive $120 in return. In this case, the $\frac{F}{S} \simeq 1.043$. Now, assume that the forward rate increases from 1.2$\frac{\$}{e}$ to 1.3$\frac{\$}{e}$.[24] In this case, the dealer lends $115 against €100 on the spot but receives $130, rather than $120, when trading the same amount of foreign currency, €100, at maturity.

The HD model argues that in reality, dealers are willing to expand their balance sheets and lend more US dollars synthetically only if counterparties are willing to pay even higher amounts of dollars at maturity to the dealer. The pricing dynamic that captures this behavior is that $\frac{F}{S}$ increases with the size of the dealers' book—even if the spot rate increases, the forward rate should increase even more (spot depreciates, but forward depreciates more).[25] More- over, even though dealers are acquiring foreign currencies (euros) as implied collaterals, they are lending in a currency (dollars) at the higher layer of the international monetary hierarchy. In effect, the extra premium reflects this "quality mismatch" between the loaned asset and the acquired collateral.

In this model, the dealers' behavior explains FX swaps' implied rates. Three dealer-centric fundamentals—US dollar funding liquidity risk, invisible market- making costs, and FX swap market liquidity—determine FX swap valuation. First, dealers adjust their quotations to capture the cost of doing business. Thus, the diagram represents dealers' profit as the spread between the bid-ask curves. Second, conditions in dollar funding liquidity spill over into the FX swap markets, as volatilities in the funding market increase dealers' exposure to funding liquidity risks and their ability to finance inventories. Dealers factor liquidity risk into their prices. However, the *sensitivity* of dealers' prices to funding liquidity depends on their proximity to the Fed and their status in the monetary hierarchy. Dealers with access to the Fed's liquidity facilities are more stable liquidity providers in the FX swap market, while peripheral dealers modify their quoting practices significantly to price in wholesale funding risks immediately. The space between the no-inventory point and the dealers' actual position on the horizontal axis outlines the funding liquidity exposures in panel A.

No-arbitrage and no-inventory conditions coincide as dealers usually man- age to hold zero inventories in the presence of dynamic and active arbitrageurs. Hence, in panel A, the extent of dealers' vulnerability to funding liquidity on the X-axis also reflects deviations from CIP, a no-arbitrage condition. Finally, the model assumes a strong relationship between the extent of FX swap market liquidity and prices. A deep market enables investors to trade large positions and reverse their transactions without significantly changing market prices. Conversely, an illiquid market would create significant price fluctuations from such activities. In panel A, the slope of the bid-ask curves represents the extent of FX swap market liquidity. When the bid-ask curves are steep, dealers' prices shift significantly when traders execute large trades and quickly reverse them. In contrast, as the curves flatten, traders can complete large transactions without significantly changing prices. This feature is analyzed as a characteristic of the highly competitive dealing system that leads to a liquid market. FX swaps' implied rates echo the interactions between these fundamentals.

US-Dollar Funding Liquidity Constraints

The dealers' costs of raising US dollar funding directly from the Eurodollar market influence the rates in the FX swap market. This spillover of funding liquidity conditions in the FX swap market can be explained through FX swap dealers' funding needs to finance their synthetic lending operations. Dealers act as the intermediaries connecting different segments of the international monetary system, as depicted in panels B, C, and D of Figure 11.

There is a segment of the international monetary system that is administered and funded by the Fed through a corridor-type monetary framework, depicted in panel D. The Fed intervenes in this market to establish effective ceilings and floors for the target risk-free overnight benchmark funding cost faced by large US dealing banks, hence the term "corridor." To maintain an effective floor, the Fed's current monetary policy framework includes the interest on reserve balances (IORB) and overnight reverse repurchase agreement (RRP) rates, which influence the federal funds rate and other short-term interest rates. In July 2021, the Fed introduced the domestic standing repurchase agreement (repo) facility (SRF) to enhance its corridor framework and set a ceiling on US domestic repo rates.

The SRF acts as a backstop in money markets, limiting pressures that could push the effective federal funds rate above the FOMC's target range. Through the SRF, the Fed offers daily overnight repos, allowing counterparties—primarily large US dealing banks—to obtain funds against U.S. Treasuries, agency debt, and agency mortgage-backed securities (MBS). The SRF's mini- mum bid rate is set above normal market rates to avoid unduly influencing price discovery in short-term funding markets while ensuring effective control of the federal funds rate. The SRF rate is currently set at 25 basis points, the top of the FOMC's target range. Including US banks as SRF counterparties pro- vides a backstop source of liquidity against high-quality assets, complementing the discount window. The SRF's acceptance of U.S. Treasuries, agency debt, and agency MBS allows it to address a broad range of repo market pressures, consistent with the Fed's historical open market operations practices.

In panel C, banks serve as market makers between the overnight and term (three-month) money markets, earning the spread that represents the liquidity premium. US G-SIBs borrow dollars cheaply through the Fed's facilities and lend these proceeds in the US repo market at a slightly higher repo rate (% RP). The primary liquidity takers in the repo market are other institutions and non-banks such as US investment funds. In panel B, US institutions lend the dollars raised in the repo market to non-US dealing banks in the Eurodollar market, albeit at a higher rate. Finally, in panel A, FX swap dealers use the cash raised directly from the wholesale funding market to supply dollars syn- thetically. FX swaps serve as a substitute instrument to the Eurodollar market, allowing market participants to place foreign currencies for a specified term in exchange for collateral denominated in dollars rather than the home currency. The interconnectedness of these various funding markets ultimately determines the costs in the FX swap markets.

In the international monetary system, financial institutions are not created equally. Foreign liquidity takers face highly unequal funding costs and have access to different funding markets based on their proximity to the Fed's balance sheet. For example, non-US FX swap dealing banks with indirect access to the Fed's balance sheet through their central banks' swap lines pay a moderate risk premium, σ, because they have an alternative source of US dollar funding via their central banks' dollar lending facilities. In contrast, more peripheral FX swap dealers face considerably higher premiums due to their central banks lacking swap lines with the Fed. The spread over the risk-free funding rate captures the risk and liquidity premium based on the institutions' proximity to the Fed and their status in the international monetary hierarchy.[26] The liquidity premium, therefore, measures an institutional detail—the liquidity takers' status in the international monetary system's hierarchy and their proximity to the Fed.

The international funding market is a hybrid of private and public actors, with a highly hierarchical structure. Figure 12 provides a schematic of the off- shore dollar funding hierarchy and its implications for dollar liquidity costs. This enhanced understanding of the hierarchical structure and interconnectedness of the international funding markets allows for a more comprehensive analysis of the factors influencing FX swap market dynamics and the cost of dollar liquidity.

FIGURE 12
THE HIERARCHY OF OFFSHORE SUPPLIERS OF US-DOLLAR FUNDING

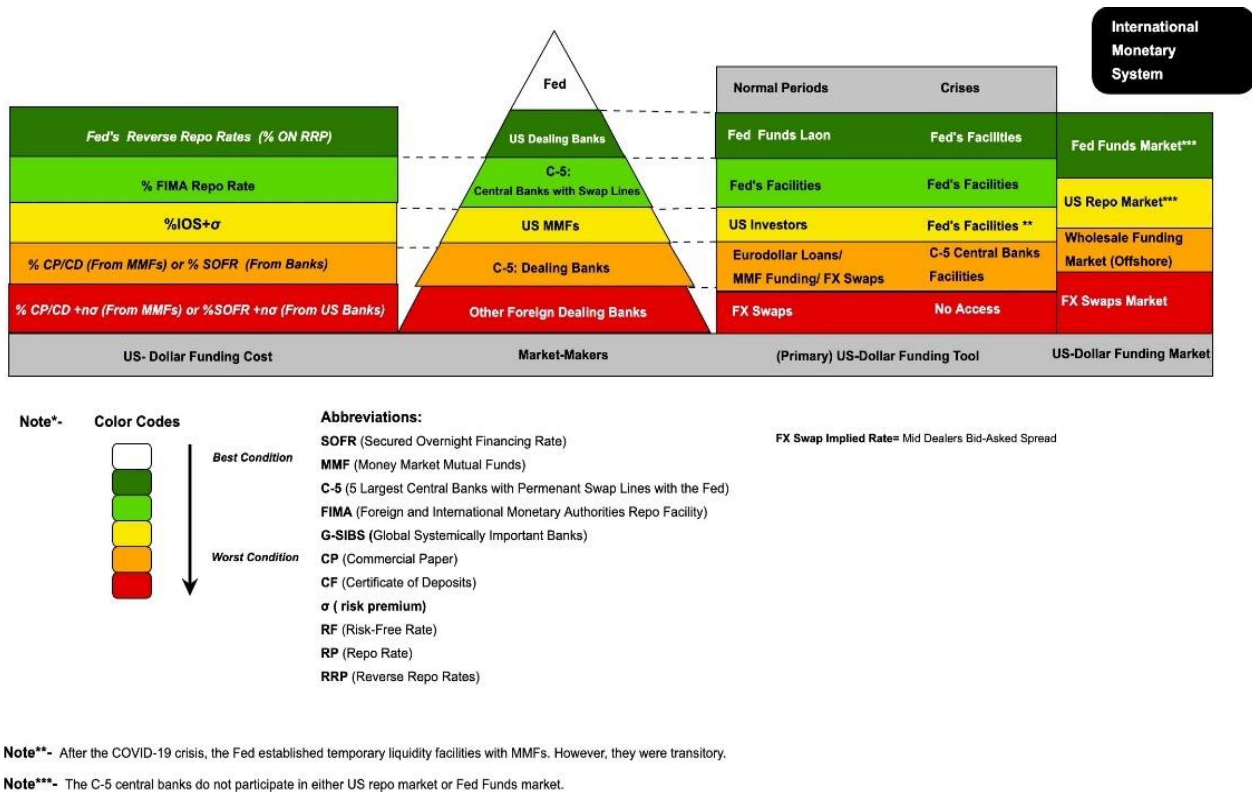


Figure 12 also highlights that, in addition to the hierarchy of liquidity takers, there is a hierarchy of liquidity providers. Whether US banks or non-banks become the primary providers of US funding to international dealers significantly influences the risk premium. In other words, the liquidity risk premium also reflects the stability of the liquidity providers. US banks' unique relationship with the Fed places them at the highest layer of private liquidity providers. On the other hand, the financial position of the money market fund (MMF) industry as liquidity providers is lower than that of banks because MMFs do not have direct access to the Fed's balance sheet.[27] Instead, MMFs raise dollar funding from their investors and lend the proceeds to non-US FX swap dealers at higher rates, $CP/CD + n\sigma$, than US banks. To illustrate the MMFs' lending rate, let us assume a non-US dealing bank wants to raise \$750M.

The first strategy is to borrow dollars directly from a US bank with access to the Fed's balance sheet. In this case, the cost of US dollar funding would be close to the risk-free rate, SOFR. A competing strategy would be to raise dollars indirectly through MMFs. In this scenario, the foreign bank would issue domestic currency-denominated unsecured debt instruments such as commercial papers (CPs) and certificates of deposit (CDs). The bank then uses these instruments to borrow fixed-rate dollars of the same term from MMFs, which are primary holders of such instruments. The cost of financing the dollar funding in this case, measured by $\frac{\%CP}{\%CD}$, even when economically viable, would be higher than SOFR. Additionally, the stability of MMF dollar funding provision depends on the MMFs' ability and willingness to continuously accept CP or CD issued by the foreign bank. If MMFs decide to withdraw from the CP or CD market, as occurred after the COVID-19 crisis, the cost of raising dollar funding becomes higher for this FX swap dealer.

The next step is to connect the FX swap dealers' funding costs to their pricing. Synthetic dollar lending exposes dealers to funding liquidity risks. The HD model uses two different measures to capture FX swap dealers' exposures to dollar liquidity risks: the *CIP deviation* and the *forward discount*. Graphically, the FX dealers' dollar liquidity risk is shown in panel A of Figure 11 as the distance between the no-inventory position and the dealers' "actual" position on the horizontal axis. This same space in the diagram also reflects the CIP deviation. The idea is that the only point in the dealer diagram representing the no-arbitrage condition is when the dealers have managed to hold no inventories[28]. In a typical dealer market, market-makers can establish such matched-book positions under two circumstances.

First, if they have successfully fulfilled the price discovery process, dealers can trade at fundamental value. The second situation is if the dealers can quickly move all unwanted inventories to the arbitragers' balance sheets. In reality, dealers rarely find the instruments' intrinsic value. Instead, they can maintain a relatively matched book whenever they proactively trade with arbitrageurs who simultaneously connect different markets for the same instruments. Therefore, the buildup of inventories by dealers often indicates the presence of un-arbitraged opportunities and the violation of no-arbitrage conditions such as CIP.29 As the FX swap dealers' inventories deviate from the no-inventory position, the implied forward rates deviate from the rates implied by the CIP condition. Therefore, as long as dealers have some exposure to dollar funding liquidity, the breakdown of CIP is a feature of FX swap pricing.

In other words, CIP holds only when dealers' exposure to funding liquidity is minimal,

$$\frac{1+R}{1+R^*} = \frac{F}{S} \tag{1}$$

where S is the spot exchange rate in units of US-dollar per foreign currency, F is the corresponding forward exchange rate, R is the US dollar interest rate, and R^* is the foreign currency interest rate[30].

However, as the dealers' actual position deviates from the no-inventory position, their exposure to the dollar funding liquidity increases. As a result, the dealers adjust quotations to factor liquidity risks into FX swap pricing. Typically, this implies that the US dollar holds a premium in FX swaps. Therefore, CIP breaks down as the trader lending US dollars via FX swap makes a higher or lower return than implied by the interest rate differential in the two currencies. In this case, rearranging the CIP the equation yields the following relationship between (F – S), R and R^*:

$$\underline{F - S > S(\frac{1+R^*}{1+R} - 1)} \tag{2}$$

In the equation, a positive ("wide") value of (F –S) indicates that the supplier of the US-dollar funding sells the foreign currency forward at a higher US-dollar price than justified by the interest differential (and CIP). For example, let us assume that a party is borrowing US-dollar fundings via an FX swap – say, to finance its debts- is essentially paying a higher interest rate on the swapped dollars, or through the synthetic borrowing than is paid i_n the cash market (or via direct borrowing). In other words, the FX swap implied US dollar rate, $\underline{\frac{F}{S}(1 + R^*)}$, exceeds the actual interest rate on the offshore US-dollar deposits, 1 + R[31]. By convention, the CIP deviation is negative when the synthetic US- dollar rate is higher than the actual USD money market rate.

We can rewrite the same equation based on the dealers' implied bid and ask prices. This approach allows us to factor the status of FX swap dealing banks and their specific exposure to the US-dollar funding liquidity risks into the CIP deviation. For simplicity, let us assume that R^* is sufficiently small so that $1 + R^* \sim= 1$. Then, denoting by S_{Ask} the spot ask rate and by F_{Bid} the forward bid rate, CIP deviations for every dealer will be given by:

$$CIP_{Dev} = \frac{F-S}{S} - (R - R^*) = \frac{F}{S} - \frac{F_{Bid}}{S_{Ask}} \tag{3}$$

In the HD model, the second measure that captures the impacts of US-dollar funding liquidity on FX swap pricing is the forward discount:

$$F_{Discount} = \frac{F-S}{S} \tag{4}$$

where F and S refer to the mid-price of forward and spot rates. $F_{Discount}$ is the difference between the spot price and the forward price. This measure implies that the pricing of FX swaps reflects the costs of obtaining dollars today at the spot rate S in exchange for foreign currency and reversing this transaction at maturity, usually in one month, at the pre-agreed forward exchange rate F. Notably, using the forward spread allows capturing the premium that the banks in peripheries pay to access dollar liquidity indirectly. The idea is that the reported swap points are significantly negative for these institutions, indicating that the dollar is trading at a forward discount compared to the quoted currency. In other words, for countries at the bottom of the currency hierarchy, the cost of borrowing US-dollar funding is significantly higher in the FX swap market than in the wholesale cash market. Nonetheless, the periphery's banks have switched to synthetic borrowing precisely because they lost access to the US banks' balance sheets.

Market-Makers' Invisible Costs and Profits

The other fundamental determining the dealers' valuation of an FX swap is the invisible market-making costs. These costs have often been omitted in classical interpretations of FX swap rates. However, in competitive dealer markets, the dealers' spreads ultimately depend on the costs of doing business. This section introduces a measure of FX swap market-making costs using the implied forward rates. Graphically, this fundamental is represented in panel A of Figure 11 as the "width of the bid-ask spread." In the FX swap private dealing system, the implied rate equals the market mid-price and can be calculated as the arithmetic mean of the bid-ask spread. In a dealer market, the bid-ask spread measures the dealer's invisible market-making costs, such as asymmetric information costs and transaction costs, including costs to shareholders' interest[32].

Given this microstructure, the HD model measures the dealers' cost com- ponent using bid-ask prices in the spot and forward markets. Spot dealers' bid-ask prices are conveniently obtained from FX exchange platforms. However, the bid-ask forward exchange rates are implied by the swap points quoted by the FX swap dealers.

The next step is to construct the implied forward rates. Following Banti and Phylaktis (2015), let us assume that a 1-month forward rate implied in FX swap points is defined as:

$$F = S + P \times 10^{-n} \tag{5}$$

S denotes the spot rate in these equations, and P is a 1-month FX swap point. The HD model uses this measure of forward rate to calculate the market- making costs in the FX spot and swap markets[33],

$$S_{Spread} = \frac{S_{Ask} - S_{Bid}}{S_{Mid}} \tag{6}$$

$$S_{Spread} = \frac{F_{Ask} - F_{Bid}}{F_{Mid}} \tag{7}$$

The mid-price is computed as the arithmetic mean between the ask and bid prices in each market. Additionally, the swap points quoted by FX swap dealers imply the bid and ask forward exchange rates, F_{Bid} and F_{Ask}.

FX dealers' market-making costs have been overlooked in classical theories of FX swap pricing. However, in competitive dealer markets, the dealers' spreads ultimately depend on the costs of doing business. For analytical purposes, the dealers' bid-ask spread can be decomposed into two components: "transaction cost" and "adverse selection." The transaction cost component compensates the dealers for their expenses such as financing inventories, order processing costs, wages for their staff, exchange membership dues, trading system development, clearing and settlement, and other items. Publicly traded FX swap dealing banks have also begun to consider less tangible costs, such as risks to shareholders' returns (interests), through a process called "Funding Valuation Adjustment" (FVA)[34].

The adverse selection component compensates the dealers for trading with "well-informed" traders. This component allows the dealers to earn from trading with uninformed traders and cover the losses from trading with informed traders. Together, these two components constitute the total spread and are part of the prices in the FX swap market. The dealers' spreads have to be wide enough to cover these costs of doing business.

FX Swaps Market Liquidity

The HD model uses dealers' trading activity to analyze market depth, a key feature of liquid markets. This measure of market liquidity aligns with Pastor- Stambaugh (2003), which captures FX swap market liquidity by assessing traders' ability to execute and reverse large trades immediately, even in the presence of risk-averse, profit-seeking market makers. In this setting, a market is liquid due to high competition among dealers, who are willing to execute large trades and reverse them without substantially changing prices.

Traditionally, the bid-ask spread is the most widely used measure of market liquidity in the literature. Stoll (1989) defines the relative importance of each component of the spread (transaction costs and adverse selection) based on the covariance of transaction returns. In the FX market, significant research has focused on the bid-ask spread35. However, Grossman and Miller (1988) highlight a limitation of using the bid-ask spread to measure market liquidity, noting that this proxy captures immediacy—a feature of market liquidity provided by the dealer—only in the simultaneous presence of buy and sell orders. Therefore, the spread is a good measure of market liquidity only when the dealer has zero inventories, which is seldom the case in reality.

The level of competition among dealers influences prices in the FX swap market. In this model, market liquidity is measured by considering quantity-based factors such as quoting activities and competition in the inter-dealer segment of the FX swap market. Thus, market liquidity is tracked by the total number of spot and forward quote submissions per hour in the FX swap market. To introduce this measure formally, let us denote the volumes of dealers' quotes per hour in spot and forward points as V_h^S and V_h^F , respectively. Additionally, let us denote the total number of active dealing banks within each hour as B_h^S and B_h^F for spot and forward points. By connecting these two variables, we can estimate quoting intensity as the ratio of submitted quotes to the level of activity of the dealing banks.

$$\frac{V\frac{S}{h}}{B\frac{S}{h}} \tag{8}$$

and

$$\frac{V\frac{F}{h}}{B\frac{F}{h}} \tag{9}$$

These measures can be interpreted as an indicator of dealer competition and market liquidity in an FX swap.

In panel A, figure 11, the slope of the bid-ask curves represents the extent of FX swaps market liquidity. The slope measures the *sensitivity* of the FX swap dealers' mean prices to changes in their positions, hence the market's "depth." In this paper, the sensitivity of the dealers' quotes to the size of trades depends on the competition among the dealers to trade and quote competitive prices. When the bid-ask curves are steep, the dealers' prices significantly change when traders want to execute large trades and reverse them immediately. In contrast, as the curves become flatter, the price difference between the large transactions, and their reversal, falls. In the above analysis, the model analyzed this behavior as a character of the highly competitive dealing system and a liquid market.

When examining the factors determining market liquidity in the FX swap market, researchers have primarily focused on external influences, such as the impacts of financial regulation. The prevailing idea is that financial requirements, like the "leverage ratio" requirement, constrain dealers' balance sheets and decrease their ability and willingness to compete in the market[36].

Nonetheless, an overlooked yet significant factor limiting the market-making capacity of dealing banks is the "FX collateral risk." FX collateral risk refers to the possibility that the dealers' counterparties might default on their dollar payments due at maturity. Since traders use FX swaps precisely due to liquidity shortages in the Eurodollar market, the risk that they might retain the borrowed dollars rather than returning them at maturity has increased. Typically, when risk factors rise, dealers either adjust their spreads or trade less, both of which reduce FX swap market liquidity.

To sum up, according to the HD model, three fundamentals determine FX swap valuation: US-dollar funding liquidity constraints, invisible market-making costs, and FX swaps market liquidity. First, market-making costs and profits are measured by dealers' bid-ask spreads. Dealers adjust their bid and ask quotes in both spot and forward points when the cost of doing business increases. Funding liquidity constraints, primarily determined by dealers' proximity to the Fed, also affect these quotes. As funding liquidity becomes less available or more expensive, the implied rates deviate further from CIP.

Finally, market liquidity impacts prices by determining the feasibility of traders executing and reversing large transactions without changing prices. In panel A of figure 11, market liquidity is represented as the slope of the bid- ask curves. When these curves are steep, dealers' bid-ask quotes significantly change with large trades and their reversals. Conversely, as the curves flatten, traders can execute and reverse large transactions without significantly altering prices. The HD model analyzes this behavior as characteristic of a highly competitive dealing system and a liquid market. The interactions between these fundamentals ultimately set prices in the FX swap market.

CONCLUSION

This paper presents an alternative model of FX swap valuation, termed the "Hierarchical-Dealer Centric Model of FX Swap Valuation" (HD model). This model is grounded in dealers' behavior and the international monetary hierarchy. The key fundamentals that determine the value of FX swaps in this model are FX swaps market liquidity (measured by dealers' competition), dollar funding liquidity risk (measured by CIP deviation), and market-making costs (measured by dealers' spreads). The HD model explicitly incorporates the inherent hierarchy of liquidity providers (such as FX swap dealers) into the costs faced by liquidity takers for dollar funding. This approach allows for a nuanced analysis of modern trends in the FX swap market, their impacts on dealers' balance sheets, and the cost of dollar liquidity.

The model asserts that FX swap dealers adjust FX swap implied rates in response to changes in the cost of doing business. When profits shrink or expenses, such as balance sheet costs, rise, dealers offer less attractive rates to dollar borrowers. Funding liquidity constraints, determined by dealers' proximity to the Fed during crises, also affect quotes. As funding liquidity becomes scarce or more expensive, implied rates deviate further from CIP, considered the financial market's equilibrium value of currency derivatives. Additionally, the level of competition among dealers influences market liquidity and rates. With low competition, global investors struggle to borrow large amounts of dollars without impacting prices. Therefore, FX swaps market liquidity significantly affects access to stable and affordable dollar funding.

The paper also explores the broader implications of investors switching to FX swaps to access dollars. This trend could potentially diminish the Fed's leverage over the international monetary system. The HD model examines FX swaps as a dollar funding tool, viewing their price dynamics as by-products of the dealers' function. This perspective has notable financial stability implications.

First, the "synthetic" nature of FX swaps poses significant challenges for the Fed, as central bankers are generally ill-equipped to regulate and stabilize swaps, which are off-balance-sheet instruments. Second, providing dollar liquidity to the FX swap market during a crisis will be challenging, particularly with the exit of traditional dealers and the rise of prime brokerage firms. As banks reduce their market-making and dealing operations, the Fed loses key intermediaries. In such restrictive conditions, central banks might resort to unconventional tools, such as acting as dealers in the derivatives market. However, the Fed would likely face severe public backlash against its role as a market maker in currency derivatives, one of the most obscure areas of the financial system.

ENDNOTES

1. Hasbrouck and Levich (2017) examine liquidity dynamics across large settlements in the US dollar funding market, complemented with high-frequency data on FX swaps quotes. Finally, Krohn and Sushko (2019) added to these studies by considering the spillover effects of liquidity conditions in the FX swaps and US dollar spot markets. Their findings show that the pricing of US dollar spot and FX swaps is intimately linked.
2. See, for instance, the Financial Stability Report (2020) that examined March 2020 Market Turmoil and the financial instability implications of the dollar funding conditions.
3. See, for instance, BIS (2021).
4. The Basel Committee on banking Supervision (BCBS) is the primary global standard setter for the prudential regulation of banks and provides a forum for regular cooperation on banking supervisory matters. Its 45 members compromise central banks and bank supervisors from 28 jurisdictions.
5. In this table, the subscript C means foreign currency positions, S is the FX spot rate, and F is the FX forward rate as of start.
6. The no-arbitrage condition and covered interest parity will be discussed extensively in the next section.
7. Here, I abstract from the haircut so that the security is altogether self-financing.
8. Total net cash outflows are defined as the total expected cash outflows minus total expected cash inflows.
9. Credit value adjustment is essentially equal to the present discounted value of the risk- neutral expectation of the market value of the notional amount in the event of a counterparty default (Duffie and Kan, 1996).
10. In an auction market, the trading rules formalize the trading process by which buyers seek the lowest prices and sellers seek the highest available prices. Economists call this the "price discovery process." The idea is that in an auction market, brokers smoothly match buyers to sellers and discover the "right price" in the process.
11. BIS 2019 Triennial Survey of FX and Over-the-counter (OTC) Derivatives Market.
12. In contrast, smaller dealers primarily earned income from customer service (Mende and Menkhoff, 2006).
13. See Cenedese et al. (2019), and also the collections of papers from BIS Symposium: "CIP - RIP", who identified the changes in the dealers' balance sheets and the asymmetric cost of access to US-dollar funding as the main drivers of the CIP breakdown after the GFC.
14. Market liquidity is the traders' ability to buy or sell assets quickly, cheaply, and without changing market prices.
15. A firesale is the sale of inventories at highly discounted prices.
16. See McLean and Pontiff (2014) for a recent summary of dozens of such strategies and their performance after publication in the public domain.
17. See Fama and French (2010) for a recent review and new evidence.
18. Noise traders are those who believe they have new information, but the information has already been included in the price.
19. Furthermore, traders still face transaction costs even without a dealer. The reason is that an active trader must know that the transactor on the other end of the trade is not randomly participating in the

trading.Instead, this trader has one of two motives: “information” or “value.” Information traders trade based on information, which affects the fundamental value of a security. The value-based investor, an essential player in the model, is driven by value traders’ perceived inconsistency between the market price and fundamental value. In addition, information-based traders are time-sensitive and demand quick execution before their possessed information is impounded into prices.

20. G-SIBs stands for global systemically important banks.

21. Conversely, when the dealer is a net synthetic US dollar borrower, it holds a short position in foreign currencies.

22. An exchange rate can be quoted in two ways: as the price of the foreign currency in terms of dollars (e.g., \$1.0612 per Euro or $1.0612\frac{\$}{e}$) or as its inverse, the price of dollars in terms of the foreign currency (e.g., €0.9424 per dollar or $0.9424\frac{\$}{e}$). The first of these exchange rate quotations (dollars per foreign currency unit) is in direct (or “American”) terms. In this example, €1 ≡ \$1.0612. All the exchange rates in this paper are direct quotes.

23. It is important to note that the exchange rates are quoted in “American” terms. Therefore, a higher rate implies the dollar is less valuable, while a lower exchange rate suggests that the dollar is worth more relative to the foreign currency. Hence, dealers are willing to sell the dollar at a lower exchange rate (ask) than they are willing to pay for it (bid).

24. In other words, the $\frac{F}{S}$ increases to $\simeq 1.13$.

25. It is essential to remember that the exchange rates are quoted in American terms. Therefore, as exchange rates increase, the US dollar depreciates relative to the foreign currency.

26. The Secured Overnight Financing Rate (SOFR) is a secured interbank overnight interest rate and reference rate established as an alternative to LIBOR, published in several currencies, and underpinning financial contracts worldwide.

27. Effective March 21, 2020, the Fed established the Money Market Mutual Fund Liquidity Facility to support the funding condition of MMFs. However, this program is not intended to be permanent.

28. This point is labeled as 0 on the horizontal axis.

29. The dealer offers synthetic US dollar liquidity to buyers and sellers who trade “at different times” in the “same market.” The arbitrageur, in contrast, offers such liquidity to buyers and sellers who trade at the same time but in a different market. When the arbitrageur is incapable or reluctant to fulfill this role, dealers consequently use their inventories to bridge time gaps between buyers and sellers.

30. In practice, the relationship between F and S is gathered from the market trades in FX instruments, notably FX swap. In an FX swap, one agent borrows US-dollars from and simultaneously lends another currency to a counterparty. The borrowed amounts are exchanged at the spot rate, S, and then repaid at maturity’s pre-agreed forward rate, F. The disparity between F and S determines the implicit rate of return in an FX swap, and the contract is typically quoted in forward points $(F - S)$.

31. The risk-free offshore US-dollar rate used to be LIBOR. However, the Secured Overnight Financing Rate (SOFR), a broad measure of the cost of borrowing cash overnight collateralized by Treasury securities, replaced this rate from 2022.

32. See Krohn and Sushko (2021) among others.

33. Banti and Phylaktis (2015) used this measure as an indicator of market liquidity. However, in this paper, the measures are used to capture the market-making costs.

34. FVA implies that the dealers’ cost of making the market in swaps is above the risk-free rate as the dealers have to borrow to finance their inventories. The higher leverage resulting from market-making activities might lead the dealing banks to reach the “debt-overhang” level. At this point, the dealers cannot increase their leverage anymore, and the shareholders should post higher capital that reduces the return on equity. Andersen, Duffie, and Song (2019) show that the spreads in inter-dealer segments of the FX swap market usually include FVAs.

35. See Bessembinder (1994), Bollerslev and Melvin (1994), and Hsieh and Kleidon (1996).

36. In the wake of the GFC, policymakers and regulators aimed to enhance the banking sector’s capacity to absorb capital losses. For example, international regulators introduced a minimum requirement on the leverage ratio, defined as capital over consolidated exposures, to serve as a backstop to the risk-weighted capital requirement (BCBS, 2014). The leverage ratio can strengthen the banking system’s resilience by reducing the risks of deleveraging in a downturn. However, some market researchers have argued that the leverage ratio may have increased market-making costs in many markets, including the FX swap (e.g.,

ESRB, 2016a,b). This is because the leverage ratio affects the size rather than the composition of a bank's balance sheet relative to its capital.

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