Offshore Dollar Funding Shocks and the Dollar Exchange Rate*

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Abstract

Deviations from covered interest rate parity (CIP) have persisted since the global financial crisis, reflecting a segmentation between onshore (US) and offshore dollar markets. This segmentation can give rise to dollar shortages in offshore markets during periods of financial stress. We propose a model with limited CIP and UIP arbitrage where the CIP deviation and exchange rate are jointly determined by equilibrium in the swap and spot FX markets. We consider offshore dollar funding shocks, where either the supply of dollar funding by the US to offshore markets declines or the demand for dollar funding in offshore markets rises. We show that this gives rise to dollar shortages, with a rise in the CIP deviation and appreciation of the dollar. In contrast to other models of exchange rate determination, the dollar appreciation is entirely due to imperfect CIP arbitrage.

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"...the global banking system suffered from an acute US dollar shortage. The cost of dollar funding in the global foreign exchange swap market soared. This shortage, and high dollar yields in the market, contributed to a sharp appreciation of the currency in late 2008. Companies around the world...found it hard to roll over maturing dollar debts and faced price incentives to draw on funding in other currencies to pay down such debts...one would expect dollar appreciation as these firms bought dollars in the spot market."
McCauley and McGuire (December 2009, BIS Quarterly Review)

1 Introduction

Prior to the Global Financial Crisis (GFC), the US dollar funding market was globally integrated, driven by effective international arbitrage. However, in the aftermath of the GFC, a significant transformation occurred, leading to a segmentation between onshore and offshore dollar markets. Non-US entities have limited direct access to the US dollar funding market, while deviations from covered interest parity (CIP) since the GFC have lead to a higher marginal cost of dollar funding in offshore markets than in the US market. This marginal cost corresponds to the synthetic dollar rate, which is the cost of borrowing in non-dollar currencies that are swapped into dollars using the FX (Foreign Exchange) swap market.

During periods of heightened financial stress, a reduction in dollar lending by the US to offshore markets can lead to dollar shortages that are associated with an increase in CIP deviations. An interesting question is whether such offshore dollar funding shocks, without any cross-currency reallocation, can imply an appreciation of the US dollar, as mentioned in the quote above. This paper explores this question in a model of segmented dollar markets.

Offshore dollar funding shocks occur when US financial institutions, such as money market funds or banks, reduce dollar lending to offshore markets. Such shocks were prominent during the GFC (e.g., McCauley and McGuire, 2009; McGuire and von Peter, 2009), the European debt crisis (e.g., Ivashina et al., 2015), the 2016 reform of US money market funds (e.g., Anderson et al., 2025; Iida et al., 2018) and the Covid crisis (e.g., Eren et al., 2020). Khetan (2024) shows that reduced offshore dollar lending by US money market funds increases CIP deviations. The shock can also take the form of reduced CIP arbitrage by US banks, reducing the supply of synthetic dollar funding to offshore markets. Central bank dollar liquidity swap lines, introduced since 2007 to address dollar shortages in offshore markets, operate in the exact opposite direction as negative offshore dollar funding shocks. As the Fed raises dollar lending to offshore markets through these swap lines, dollar shortages are reduced, which reduces CIP deviations.[1]

While these are all shocks to the supply of dollar funding by the US to offshore markets, the effect is analogous to an increase in demand for dollar funding in offshore markets. An example of an offshore dollar funding shock on the demand side is an increase in demand for synthetic dollar funding by non-US entities to hedge increased holdings of liquid US dollar assets during crisis times.

To analyze these issues, we develop a model of exchange rate determination that incorporates a limited capacity to arbitrage both CIP and uncovered interest rate parity (UIP) deviations.[2] Our theory leads to two equilibrium schedules, one for the spot market and one for the FX swap market. The exchange rate and CIP deviation are jointly determined by equilibrium in these two markets. For simplicity, we refer to the offshore market as Europe and the currency as the euro. European agents are dollar borrowers, but also hold liquid dollar assets. They have a standard FX portfolio, where the overall net dollar position depends on the expected excess return of dollars over euros. The relevant dollar interest rate is the marginal cost of dollar funding in offshore markets, which is the synthetic dollar rate.

A reduction in offshore dollar lending by US financial institutions drives up the cost of synthetic dollar funding. Although for given asset prices there is no change in demand for dollars on the spot market, in equilibrium the dollar appreciates. The higher synthetic dollar rate reduces dollar borrowing by European agents, who instead acquire the dollars directly on the spot market. The substitution of synthetic dollar funding with spot market purchases is the essence of the quote above by McCauley and McGuire (2009). Although synthetic dollar borrowing falls, these dollars are still needed, for example, to repay dollar-denominated debts

[1] For evidence of reduced CIP deviations as a result of central bank swap lines, see Bahaj and Reis (2022), Cerutti et al. (2021), Rime et al. (2022), Ferrara et al. (2022) and Goldberg and Ravazzolo (2022).

[2] A substantial literature has documented CIP deviations that have developed since 2008 and the role of various post-2008 regulations that have limited CIP arbitrage, implying market segmentation. See, for example, Du et al. (2018), Diamond and Van Tassel (2023), Rime et al. (2022), Boyarchenko et al. (2020) and Cenedese et al. (2021). Du and Schreger (2022) provide a survey of the literature on CIP deviations. Several papers, including Du et al. (2018) and Cenedese et al. (2021), provide evidence that tighter bank leverage regulations since the GFC have led to a higher cost of financial intermediation that is responsible for the CIP deviations since then.

or to purchase dollar-invoiced imports.

If there were perfect CIP arbitrage, there would be an unlimited supply of dollar funding to Europe at the US dollar rate that is controlled by the Fed. In other words, the role of the Fed as a lender of last resort of dollars is extended to Europe. Without a change in the synthetic dollar rate, the mechanism described above for the dollar appreciation does not apply. It is precisely the higher cost of synthetic dollar funding that causes an increased demand for dollars on the spot market and therefore the dollar appreciation.

The theory is consistent with recent evidence from dollar swap lines. These can be thought of as a positive offshore dollar funding shock, whereby the Fed increases dollar lending to offshore markets. This reduces dollar shortages, lowers the CIP deviation and depreciates the dollar. Kekre and Lenel (2024b) use high-frequency data on central bank swap announcements. They find that the swap line announcements on March 19 and 20, 2020, during the Covid crisis, reduced the CIP deviation and lead to a depreciation of the dollar. The theory tells us that such central bank swap lines would have no effect on the exchange rate under perfect CIP arbitrage.

The paper relates to a small literature that has considered models in which the exchange rate and CIP deviation are jointly determined, including Fang and Liu (2021), Liao and Zhang (2025) and Greenwood et al. (2023).[3] The shocks considered in these papers affect the exchange rate even under perfect CIP arbitrage. This is because they consider shocks that generate a cross-currency reallocation or a change in the unhedged FX position. In contrast, the offshore dollar funding shocks considered here do not involve a cross-currency reallocation, which is why the exchange rate is unaffected under perfect CIP arbitrage. For given asset prices, the unhedged dollar position of European agents remains unchanged.

In Fang and Liu (2021), an increase in uncertainty in US output reduces the risk-bearing capacity of financial institutions, reducing UIP arbitrage and therefore the FX position.[4] Liao and Zhang (2025) investigate the effect of an increase in exchange rate volatility, which changes the optimal hedge ratio and therefore the unhedged FX position. Greenwood et al. (2023) consider an increase in the US supply of long-term bonds in a model with both short-term and long-term bonds. In their framework, foreigners wish to take on an increased

[3]An older paper, Tsiang (1959), is similar in also assuming limited CIP arbitrage and the model is summarized by equilibrium in spot and forward markets.

[4]In a related framework, Bacchetta, Benhima, and Berthold (2023) analyze FX interventions with both UIP and CIP deviations.

unhedged FX position as a hedge against US long-term bond prices.

These papers jointly analyze the spot and forward markets, while we consider the spot and FX swap markets. This makes no difference for the solution, though for our purpose it is more intuitive to consider the swap and spot markets. In the context of the equilibrium swap and spot market schedules that we analyze, offshore dollar funding shocks only shift the swap market schedule. Since there is no cross-currency reallocation for given asset prices, the spot market schedule is unaffected. The shocks in the papers discussed above simultaneously shift both the spot and swap market schedules. In most exchange rate models there is perfect CIP arbitrage and only the spot market schedule shifts as there are only changes in unhedged FX positions.

The paper is also related to evidence that a rise in the CIP deviation tends to be associated with a dollar appreciation. This evidence of an unconditional relationship is developed in Avdjiev et al. (2019), Du and Schreger (2022), Diamond and Van Tassel (2023) and Engel and Wu (2023).[5] While such an unconditional relationship can have many explanations, it is at least consistent with the offshore dollar funding shocks that we study here. Related, Lilley et al. (2022) find that post-2007, but not pre-2007, the dollar appreciates during periods of financial stress. This is also consistent with the shocks we analyze, where the dollar appreciation only occurs as a result of imperfect CIP arbitrage, which is a post-2007 phenomenon.

Also related are recent influential works such as Gabaix and Maggiori (2015) and Itskhoki and Mukhin (2021), which highlight the role of financial frictions that limit arbitrage in the determination of exchange rates.[6] In these models, financial intermediaries have constrained risk-bearing capacity and demand expected excess returns to intermediate international financial flows. However, their focus is on UIP arbitrage. They do not allow for financial frictions that limit CIP arbitrage, which are key to our theory.

The remainder of the paper is organized as follows. Section 2 describes the model. Section

[5] Avdjiev et al. (2019) suggest an explanation where an exogenous dollar appreciation reduces CIP arbitrage and therefore raises the CIP deviation. In contrast, in our model the exchange rate is endogenous and changes in the CIP deviation lead to changes in the exchange rate.

[6] In the same spirit, other models of exchange rate determination with various financial frictions, such as market segmentation, informational frictions and portfolio adjustment costs, include Bacchetta and van Wincoop (2010, 2021), Gourinchas et al. (2024), Greenwood et al. (2023), Hau and Rey (2005), Jeanne and Rose (2002) and Koijen and Yogo (2024). Engel and Wu (2024) provide empirical evidence on models of exchange rate determination, including variables that the more recent literature has emphasized.

3 derives spot and swap market equilibrium equations and discusses a pre-shock equilibrium. Section 4 analyzes the implications of offshore dollar funding shocks. We also briefly discuss how these shocks are different from other shocks considered in the literature. Section 5 concludes.

2 Model Description

After discussing an overview of the model that also introduces notation, the remainder of this section discusses the goods market, money demand, portfolio decisions by European households and the portfolios of CIP and UIP arbitrageurs.

2.1 Model Overview

There are two countries (Home and Foreign). We think of the Home country (H) as the US and the Foreign country (F) as the rest of the world. For convenience, we will refer to the latter as Europe and the currency as the euro. Although there are three periods (0, 1 and 2), it is more like a two-period model (periods 1 and 2) as period 0 is the past. We take asset prices and financial holdings in period 0 as given. Our main focus will be on financial decisions and prices in period 1.

The assets are dollar and euro bonds, dollar and euro money balances and a synthetic dollar asset created by swapping the euro bond into dollars through the swap market. Dollar and euro money balances could also be liquid assets such as Treasuries. The agents are the two central banks (Fed and ECB), US and European households, CIP arbitrageurs and UIP arbitrageurs.

European households and both CIP and UIP arbitrageurs operate in FX markets and are central to our analysis. US households only hold dollar bonds and dollar money balances and therefore do not participate in FX markets. They are important only to the extent that they lend a limited exogenous amount of dollars to European households, which generates a source of dollar funding shocks in the model. Central banks mainly play a passive role, providing sufficient liquidity to domestic bond markets to target a constant policy interest rate that we take as given. The Fed also plays a role in lending dollars to offshore markets through central bank swap lines, which generates another source of offshore dollar funding shocks.

European households hold $B^{€}_{F,t}$ euro bonds and euro and dollar money balances of $M^{€}_{F,t}$ and $M^{\$}_{F,t}$. Dollar money balances are needed as a result of assumed dollarization of trade. European households borrow dollars from US households at the US dollar interest rate $i^{\$}$ targeted by the Fed, up to a limit of $D^{\$}_{F,t}$. The limited direct access by European households to the US dollar funding market reflects well-known frictions in accessing foreign credit markets. Without this friction there would be no segmentation between the onshore and offshore dollar market and the CIP deviation would be zero. European households also borrow $D^{\$}_{swap,t}$ from the ECB. These are dollars that the ECB obtains from the Fed through a swap line.[7]

European households borrow an additional $D^{\$,syn}_{F,t}$ dollars through synthetic dollar funding, which involves borrowing euros and swapping them into dollars by buying dollar swaps. The synthetic dollar rate is given by

$$1 + i^{\$,syn}_t = \frac{F_t}{S_t}\left(1 + i^{€}\right) \tag{1}$$

where S_t and F_t are the spot and forward exchange rates, which are dollars per euro. The right-hand side is obtained by taking 1 dollar, exchanging it for $1/S_t$ euros, investing in the euro bond, and then exchanging it back for dollars at the forward rate F_t.

We assume that parameters of the model are such that $D^{\$,syn}_{F,t} > 0$. This implies that US CIP arbitrageurs supply synthetic dollars to Europe. As a result of arbitrage frictions, they demand a profit that takes the form of a positive CIP deviation, consistent with the data since 2007. The synthetic dollar interest rate $i^{\$,syn}_t$ is therefore above the US dollar rate $i^{\$}$.

This implies that it is optimal for European households to borrow up to the limit of $D^{\$}_{F,t}$ from US households. The interest rate at which the ECB lends dollars to European households is the same as the interest rate $i^{\$,swap}$ of the swap line from the Fed, which corresponds to the US dollar rate $i^{\$}$ plus a small spread. We assume that $i^{\$,swap}$ is also below the synthetic dollar rate when such swap lines are in effect, so that European households will borrow up to the maximum $D^{\$}_{swap,t}$ from the ECB.

[7]The first dollar liquidity swap lines during the GFC were set up between the Fed and the ECB and the Swiss National Bank in December 2007. Swap lines between the Fed and the five major central banks (including the Bank of England, the Bank of Japan, and the Bank of Canada) were made permanent in 2013. On occasion swap lines have been extended to 9 smaller central banks as well.

The overall net dollar asset position of European households is $N^{\$}_{F,t} = M^{\$}_{F,t} - D^{\$}_{F,t} - D^{\$}_{swap,t} - D^{\$,syn}_{F,t}$. Its optimal level is determined by a mean-variance portfolio decision, so that $N^{\$}_{F,t}$ depends on the expected excess return of dollars over euros. Since $D^{\$}_{F,t}$ and $D^{\$}_{swap,t}$ are exogenously fixed, and $M^{\$}_{F,t}$ is also tied down through a cash in advance constraint, on the margin European households can only change $N^{\$}_{F,t}$ by changing synthetic dollar borrowing. The relevant dollar interest rate is therefore the synthetic dollar rate $i^{\$,syn}_t$. The relevant euro interest rate is $i^{€}$, which is set by the ECB.

CIP arbitrageurs lend $B^{\$}_{CIP,t}$ dollars synthetically to European households, while borrowing the same amount of dollars in the US. Synthetic dollar lending involves lending euros and swapping them into dollars by selling dollar swaps. They adopt a risk-free arbitrage position, but face a quadratic cost associated with their arbitrage position. This is meant to reflect financial regulations that limit CIP arbitrage. UIP arbitrageurs operate in the dollar and euro bond markets, but do not take positions in the swap market. They take a position $B^{\$}_{UIP,t}$ in dollar bonds. They take an opposite position in the euro bond, so that $S_t B^{€}_{UIP,t} = -B^{\$}_{UIP,t}$. For convenience we assume that both CIP and UIP arbitrageurs are US agents, though this is not critical.

The key endogenous variables in the model are the period 1 log exchange rate s_1 and CIP deviation $cip_1 = i^{\$,syn}_1 - i^{\$}$. Note that the CIP deviation is directly linked to the synthetic dollar rate as $i^{\$}$ is assumed fixed. From (1) the synthetic dollar rate is in turn directly linked to the forward discount or swap rate. Equilibrium in the spot and swap FX markets that is discussed in Section 3 will jointly determine these endogenous variables s_1 and cip_1.

2.2 Goods Market and Money Demand

We first discuss the period 1 goods market, where prices are set in advance, and then the period 2 goods market, where prices are flexible. Consumption demand in period 1 also leads to proportional money demand expressions. There is no money demand in period 2.

2.2.1 Period 1 Goods Market

Home and Foreign agents produce differentiated goods. Prices are preset at 1 in the currency of invoicing. We assume full trade dollarization in that both US and European goods that are exported are invoiced in dollars. Goods sold domestically are invoiced in the domestic currency. Euro invoicing therefore only applies to European goods sold in Europe. All other invoicing is in dollars.

The period 1 consumption index for households in the Home and Foreign country is[8]

$$C_{H,1} = \left((1-\omega)^{\frac{1}{\theta}} \left(C_{HH,1} \right)^{\frac{\theta-1}{\theta}} + \omega^{\frac{1}{\theta}} \left(C_{HF,1} \right)^{\frac{\theta-1}{\theta}} \right)^{\frac{\theta}{\theta-1}}$$
$$C_{F,1} = \left((1-\omega)^{\frac{1}{\theta}} \left(C_{FF,1} \right)^{\frac{\theta-1}{\theta}} + \omega^{\frac{1}{\theta}} \left(C_{FH,1} \right)^{\frac{\theta-1}{\theta}} \right)^{\frac{\theta}{\theta-1}}$$

The double country subscript refers to respectively the buyer and the seller. For example, $C_{HF,1}$ refers to consumption by Home households of goods produced in Foreign. Given these consumption indices, Home and Foreign consumer price indices in respectively dollars and euros are

$$P_1 = 1 \tag{2}$$
$$P_1^* = \left((1-\omega) + \omega S_1^{\theta-1} \right)^{\frac{1}{1-\theta}} \tag{3}$$

Optimal allocation across Home and Foreign goods by Home households is $C_{HH,1} = (1-\omega)C_{H,1}$ and $C_{HF,1} = \omega C_{H,1}$. Similarly, optimal allocation by Foreign households is

$$C_{FF,1} = (1-\omega) \left(\frac{1}{P_1^*} \right)^{-\theta} C_{F,1}; \quad C_{FH,1} = \omega \left(\frac{1}{S_1 P_1^*} \right)^{-\theta} C_{F,1} \tag{4}$$

The other agents (UIP and CIP arbitrageurs) are from the US and allocate their aggregate consumption in the same way across Home and Foreign goods as US households. Their consumption is indicated with a superscript o. Production of the goods corresponds to demand from all agents. The resulting income of Home households in dollars and Foreign households in euros is denoted respectively $Y_{H,1}$ and $Y_{F,1}$:

$$Y_{H,1} = C_{HH,1} + C_{FH,1} + C^o_{HH,1} \tag{5}$$
$$Y_{F,1} = C_{FF,1} + \frac{1}{S_1} C_{HF,1} + \frac{1}{S_1} C^o_{HF,1} \tag{6}$$

[8]This is analogous to Betts and Devereux (2000). One piece that we are not explicit about here is that goods are differentiated by agents producing them, giving them price-setting power. But all agents producing the same good will end up setting the same price, which we normalize to 1 in the currency of invoicing.

2.2.2 Money Demand

We assume that only households hold money balances. Their money demand in period $t = 1$ is equal to a fraction ψ of consumption of goods invoiced in the corresponding currency:

$$M_{H,1}^{\$} = \psi C_{H,1} \tag{7}$$

$$M_{F,1}^{\$} = \psi\omega \left(S_1 P_1^*\right)^{\theta} C_{F,1} \tag{8}$$

$$M_{F,1}^{€} = \psi(1-\omega) \left(P_1^*\right)^{\theta} C_{F,1} \tag{9}$$

Trade dollar dominance therefore also implies financial dollar dominance as money balances need to be held in the currency of invoicing. This is analogous to Gopinath and Stein (2021).[9]

2.2.3 Period 2 Goods Market

In period 2 prices are flexible. There is a Home good and a Foreign good, with aggregate endowments of

$$Q_{H,2} = e^{\kappa_H \epsilon_q}$$
$$Q_{F,2} = e^{-\kappa_F \epsilon_q}$$

where $\kappa_H + \kappa_F = 1$ and ϵ_q is a period 2 endowment shock with mean of zero. There is a CES period 2 consumption index with equal weight to both goods and an elasticity of substitution of θ. Central banks target a price of 1 of the domestic good in the domestic currency.

We leave further details regarding the period 2 goods market equilibrium to Appendix A. In equilibrium $s_2 = \epsilon_q/\theta$, where s_2 is the log exchange rate in period 2. Intuitively, a rise in ϵ_q raises the relative supply of Home goods, which lowers the relative price of Home goods. Since prices are 1 in the local currency, the Home currency must depreciate. It follows that $E(s_2) = 0$. The period 2 income of households in both countries in the domestic currency is

[9] Coppola et al. (2024) develop an alternative, liquidity-based, theory of financial dollar dominance in a model with endogenous search frictions, which does not rely on dollar dominance in trade invoicing. Another, more direct, approach is that taken by Kekre and Lenel (2024a), who model the perceived non-pecuniary benefits of liquid dollar assets through the utility function.

then

$$Y_{H,2} = e^{\kappa_H \theta s_2} \tag{10}$$

$$Y_{F,2} = e^{-\kappa_F \theta s_2} \tag{11}$$

European households have dollar exposure through their non-asset income, with a weaker dollar lowering their income when $\kappa_F > 0$.

2.3 Household Portfolios

Period 1 portfolios of European households are determined by maximizing a simple mean-variance objective related to period 2 consumption:

$$EC_{F,2} - 0.5\gamma var(C_{F,2}) \tag{12}$$

Since our focus is on financial markets, we simplify period 1 consumption decisions. After assuming that period 1 consumption is perfectly smoothed with expected period 2 consumption in a pre-shock equilibrium, we hold period 1 consumption constant after introducing shocks in Section 4.

Their period 2 budget constraint is

$$\begin{aligned} P_2^* C_{F,2} \quad = \quad & Y_{F,2} + \Pi_{FCB,2} + \frac{1}{S_2} M_{F,1}^{\$} + M_{F,1}^{€} + (1 + i^{€}) B_{F,1}^{€} \\ & - \frac{1 + i_1^{\$,syn}}{S_2} D_{F,1}^{\$,syn} - \frac{1 + i^{\$}}{S_2} D_{F,1}^{\$} - \frac{1 + i^{\$,swap}}{S_2} D_{swap,1}^{\$} \end{aligned} \tag{13}$$

Here $\Pi_{FCB,2}$ denotes profits from the European central bank on its euro bonds holdings that are transferred to European households.

The financial wealth of European households at the start of period 1, other than through money, is $W_{F,1}$. This is equal to their euro bond holdings minus their total dollar debt: $W_{F,1} = B_{F,1}^{€} - (1/S_1) \left(D_{F,1}^{\$,syn} + D_{F,1}^{\$} + D_{swap,1}^{\$} \right)$. We use this to substitute out the euro bond holdings in (13). We then linearize (13) around $s_2 = 0$, zero interest rates and $C_{F,2} = \bar{C}_{F,2}$, which is the pre-shock second period consumption level at $s_2 = 0$ discussed below. We then have[10]

$$C_{F,2} = 1 - \rho s_2 + \Pi_{FCB,2} + (1-s_2) M^{\$}_{F,1} + M^{€}_{F,1} + (1+i^{€}) W_{F,1}$$
$$-(i_1^{\$,syn} - i^{€} - s_2 + s_1) D^{\$,syn}_{F,1} - (i^{\$} - i^{€} - s_2 + s_1) D^{\$}_{F,1} - (i^{\$,swap} - i^{€} - s_2 + s_1) D^{\$}_{swap,1} \quad (14)$$

where $\rho = \kappa_F \theta - 0.5\bar{C}_{F,2}$. The last three terms are FX excess returns of dollars over euros with different dollar interest rates.

As discussed, European households first borrow from US households and the ECB as they offer lower interest rates. But on the margin they borrow in the synthetic dollar market. Their only portfolio choice variable is therefore $D^{\$,syn}_{F,1}$. Maximizing the mean-variance second period consumption objective (12) with respect to $D^{\$,syn}_{F,1}$ gives (see Online Appendix)

$$N^{\$}_{F,1} = M^{\$}_{F,1} - D^{\$,syn}_{F,1} - D^{\$}_{F,1} - D^{\$}_{swap,1} = -\rho + \frac{i_1^{\$,syn} - i^{€} + s_1}{\gamma \sigma^2} \quad (15)$$

where $\sigma^2 = var(s_2)$.

The left-hand side of (15) is the total net dollar position $N^{\$}_{F,1}$ of European households, which is equal to dollar assets minus dollar liabilities. The first term on the right-hand side is $-\rho$. A larger value of ρ implies more non-asset dollar exposure, both through period 2 non-asset income and the period 2 consumer price index. The optimal net dollar position will then be more negative as a hedge. The second term on the right-hand side of (15) is the expected excess return of dollars over euros. This is a standard term in an optimal FX portfolio, using that $E(s_2) = 0$. The dollar interest rate is the synthetic dollar rate, which is the marginal cost of dollar funding.

For given asset prices (exchange rate and interest rates), (15) determines the optimal net dollar position. Changes in $M^{\$}_{F,1}$, $D^{\$}_{F,1}$ and $D^{\$}_{swap,1}$ are offset by a change in synthetic dollar borrowing $D^{\$,syn}_{F,1}$ to keep the overall net dollar position $N^{\$}_{F,1}$ unchanged. For example, reduced dollar lending by US households to European households will be offset by increased synthetic dollar borrowing by European households. They simply reallocate one type of dollar debt to another type of dollar debt.

A change in the expected excess return generates a change in the net dollar position and

[10]This uses that the log Foreign period 2 price level in Appendix A is linearized as $-0.5s_2$ and second period income $Y_{F,2}$ is linearized as $1 - \kappa_F \theta s_2$.

a cross-currency reallocation. For example, a rise in the synthetic dollar rate raises the net dollar position $N^{\$}_{F,1}$, accomplished through a reduction in synthetic dollar borrowing $D^{\$,syn}_{F,1}$. The euro bond position $B^{€}_{F,1}$ then drops as[11]

$$B^{€}_{F,1} = W_{F,1} - \frac{1}{S_1} N^{\$}_{F,1} - \frac{1}{S_1} M^{\$}_{F,1} \tag{16}$$

European households switch from borrowing dollars to borrowing euros or holding fewer euro bonds.

2.4 CIP and UIP Arbitrageurs

CIP arbitrageurs borrow $B^{\$}_{CIP,1}$ in the US dollar funding market and lend the same quantity in the synthetic dollar market. This delivers a period 2 profit equal to the difference between the synthetic and US dollar rates times $B^{\$}_{CIP,1}$:

$$\Pi_{CIP,2} = \left(i^{\$,syn}_1 - i^{\$} \right) B^{\$}_{CIP,1} \tag{17}$$

UIP arbitrageurs similarly start out with zero wealth. They choose positions in the dollar and euro bonds, going long in one and short in the other, such that $B^{\$}_{UIP,1} + S_1 B^{€}_{UIP,1} = 0$. This yields profits of

$$\Pi_{UIP,2} = B^{€}_{UIP,1} \left(i^{€} - i^{\$} + s_2 - s_1 \right) \tag{18}$$

where the term in brackets is the log linearized excess return of euro bonds over dollar bonds.

For both CIP and UIP arbitrageurs, we assume that they maximize expected profits minus a quadratic cost. An alternative, leading to the same result, is to assume that intermediaries are subject to a credit constraint as in Gabaix and Maggiori (2015) or that UIP arbitrageurs have a mean-variance objective as in Itskhoki and Mukhin (2021). We assume that CIP arbitrageurs maximize $\Pi_{CIP,2}$ minus the quadratic cost $0.5\Gamma_{CIP} \left(B^{\$}_{CIP,1} \right)^2$. Similarly, UIP arbitrageurs maximize $E(\Pi_{UIP,2})$ minus the quadratic cost $0.5\Gamma_{UIP} \left(B^{€}_{UIP,1} \right)^2$. This leads to

[11]Note that the synthetic dollar rate does not affect beginning-of-period financial wealth $W_{F,1}$ or dollar money balances $M^{\$}_{F,1}$.

the following positions of CIP and UIP arbitrageurs:

$$B^{\$}_{CIP,1} = \frac{i_1^{\$,syn} - i^{\$}}{\Gamma_{CIP}} \tag{19}$$

$$B^{€}_{UIP,1} = \frac{i^{€} - i^{\$} - s_1}{\Gamma_{UIP}} \tag{20}$$

The higher Γ_{CIP} and Γ_{UIP}, the lower the arbitrage capacity of these intermediaries, which is their capacity to absorb financial flows. For UIP arbitrageurs this is referred to as risk-bearing capacity in Gabaix and Maggiori (2015), but CIP arbitrageurs face no exchange rate risk. Their arbitrage capacity is linked to regulations that limit CIP arbitrage. Arbitrage capacity is also linked to the overall financial health of financial institutions. We also define the arbitrage capacity of European households as $\Gamma_F = \gamma\sigma^2$.

3 Equilibrium

In this section we discuss the FX market equilibrium in both the swap market and the spot market. After that we discuss a pre-shock equilibrium of the model prior to introducing shocks in the next section. As will be more clear in Section 4, the FX market equilibrium in the swap and spot markets jointly determines s_1 and $cip_1 = i_1^{\$,syn} - i^{\$}$.

3.1 Swap Market Equilibrium

Synthetic dollar borrowing by European households leads to swap market transactions. A dollar swap market position of 1 involves buying 1 dollar at time t in exchange for $1/S_t$ euros and then buying $(1 + i^{€})/S_t$ euros at time $t + 1$ in exchange for $(1 + i^{€})(F_t/S_t) = 1 + i_t^{\$,syn}$ dollars. In order to borrow $D_{F,t}^{\$,syn}$ dollars synthetically, European households borrow $D_{F,t}^{\$,syn}/S_t$ euros in combination with buying $D_{F,t}^{\$,syn}$ dollar swaps. This amounts to receiving $D_{F,t}^{\$,syn}$ dollars at time t and paying $(1 + i_t^{\$,syn})D_{F,t}^{\$,syn}$ dollars at time $t + 1$.

The other agents entering the swap market are CIP arbitrageurs. As discussed, they borrow $B^{\$}_{CIP,t}$ in the US and lend the same quantity of dollars synthetically to Europe. This synthetic dollar lending involves buying $B^{\$}_{CIP,t}/S_t$ euro bonds in combination with selling $B^{\$}_{CIP,t}$ dollar swaps.

It then follows that swap market equilibrium is

$$B^{\$}_{CIP,t} = D^{\$,syn}_{F,t} \tag{21}$$

3.2 Spot Market Equilibrium

The spot market equilibrium is a little different from that in a model with a spot market and a forward market. Ultimately, the solution is identical, but when there is a swap market, the spot market does not include the spot component of swap market transactions. So we only include pure spot transactions.

Let $Q^{\$,spot}_{F,1}$ and $Q^{\$,spot}_{UIP,1}$ be spot market purchases of dollars in exchange for euros by Foreign households and UIP arbitrageurs. Spot market equilibrium is then

$$Q^{\$,spot}_{F,1} + Q^{\$,spot}_{UIP,1} = 0 \tag{22}$$

Note that CIP arbitrageurs do not buy or sell dollars on the spot market. The dollars that they borrow in the US are immediately lent out by selling dollar swaps. This involves selling dollars in exchange for euros in the spot component of the swap transaction, but not separately on the spot market. US households also do not transact on the spot market as all their transactions involve dollars. They do not hold euro assets and all exports are invoiced in dollars.

Purchases of dollars on the spot market by European households are

$$Q^{\$,spot}_{F,1} = dN^{\$}_{F,1} - Y^{\$}_{F,1} + C_{FH,1} + i^{\$,syn}_0 D^{\$,syn}_{F,0} + i^{\$} D^{\$}_{F,0} + i^{\$,swap} D^{\$}_{swap,0} \tag{23}$$

where $Y^{\$}_{F,1} = C_{HF,1} + C^{o}_{HF,1}$ are dollar revenues from European exports and $dX_1 = X_1 - X_0$. Consider the terms on the right hand side. A rise in desired net dollar assets raises demand for dollars. Dollar revenues from exports reduce demand for dollars. Dollar-invoiced imports $C_{FH,1}$ raise demand for dollars. For the three types of dollar borrowing, period 1 payments of interest on period 0 debt raise demand for dollars.

US UIP arbitrageurs receive $(1 + i^{€})B^{€}_{UIP,0}$ euros from their time 0 euro position and buy $B^{€}_{UIP,1}$ new euro bonds. In the spot market they sell $(1 + i^{€})B^{€}_{UIP,0} - B^{€}_{UIP,1}$ euros and therefore buy

$$Q^{\$,spot}_{UIP,1} = -S_1 dB^{€}_{UIP,1} + S_1 i^{€} B^{€}_{UIP,0} \tag{24}$$

dollars.

Substituting these dollar spot market purchases in (22), we obtain the following expression for the spot market equilibrium (see Online Appendix for details):

$$CA^{\$}_{H,1} + dN^{\$}_{F,1} - S_1 dB^{€}_{UIP,1} = 0 \tag{25}$$

where $CA^{\$}_{H,1}$ is the US current account. Substituting the swap market equilibrium $D^{\$,syn}_{F,1} = B^{\$}_{CIP,1}$, this can also be written as the familiar identity that the US current account is equal to net capital outflows (see Online Appendix).

3.3 Pre-Shock Equilibrium

Before introducing period 1 shocks, we solve the pre-shock equilibrium. Given any set of model parameters, including the values of period 0 variables that we take as given, we can solve for the period 1 equilibrium. However, we limit ourselves to parameters that generate a sort of pre-shock steady state, with the following features: (1) equilibrium period 1 variables are equal to period 0 variables, (2) consumption is smoothed in that period 1 consumption of European households is equal to period 2 consumption when the period 2 shock ϵ_q is zero. We normalize $s_0 = 0$, so that s_1 is zero as well in the pre-shock equilibrium. Appendix B discusses how the pre-shock equilibrium is computed.

Denote variables in the pre-shock equilibrium with a bar on top. The CIP deviation is $\overline{cip} = \bar{i}^{\$,syn} - i^{\$}$. The UIP deviation is the expected excess return of dollars over euros. Since the expected change in the exchange rate is zero, it is equal to the dollar minus euro interest rate: $i^d = i^{\$} - i^{€}$. Since this interest differential is controlled by central banks, we take it as exogenous.

Omitting period 0 and 1 time subscripts, the synthetic dollar borrowing by European households in the pre-shock equilibrium is

$$\bar{D}^{\$,syn}_{F} = \rho + \bar{M}^{\$}_{F} - \bar{D}^{\$}_{F} - \bar{D}^{\$}_{swap} - \frac{\overline{cip} + i^d}{\Gamma_F} \tag{26}$$

The position of CIP arbitrageurs is $\bar{B}^{\$}_{CIP} = \overline{cip}/\Gamma_{CIP}$. Imposing the swap market equilibrium, we then have

$$\overline{cip} = \frac{\Gamma_{CIP}}{\Gamma_{CIP} + \Gamma_F} \left[\Gamma_F \left(\rho + \bar{M}^{\$}_F - \bar{D}^{\$}_F - \bar{D}^{\$}_{swap} \right) - i^d \right] \tag{27}$$

We will assume that the term in the square brackets in (27) is positive, generating a positive CIP deviation as seen in the data since 2007. In the limit when $\Gamma_{CIP} \to 0$ this positive CIP deviation approaches zero. This is the case of perfect CIP arbitrage.

When $\Gamma_{CIP} > 0$, positive holdings of liquid dollar assets by European households contribute to a positive CIP deviation. They hedge these positions by borrowing dollars synthetically, which raises the CIP deviation. A positive ρ also contributes to a positive CIP deviation as European households borrow dollars synthetically to hedge non-asset income. The higher the borrowing of dollars from US households ($\bar{D}^{\$}_F$) or from the Fed through swap lines ($\bar{D}^{\$}_{swap}$), the less the need to borrow dollars synthetically, which lowers the CIP deviation. Assuming that the term in square brackets in (27) is positive, a higher value of Γ_{CIP} leads to a higher CIP deviation.[12]

Substituting (27) into (26), we have

$$\bar{D}^{\$,syn}_F = \frac{\Gamma_F}{\Gamma_F + \Gamma_{CIP}} \left(\rho + \bar{M}^{\$}_F - \bar{D}^{\$}_F - \bar{D}^{\$}_{swap} - \frac{i^d}{\Gamma_F} \right) \tag{28}$$

A positive CIP deviation implies that the term in brackets is positive, so that European households borrow a positive amount of dollars synthetically.

Net dollar exposure of European households outside of their synthetic dollar position is given by $\rho + \bar{M}^{\$}_F - \bar{D}^{\$}_F - \bar{D}^{\$}_{swap}$. Equation (28) tells us to what extent they choose to hedge this dollar exposure through synthetic dollar borrowing. When $i^d = 0$, the hedge ratio is $\Gamma_F/(\Gamma_F + \Gamma_{CIP})$. Imperfect CIP arbitrage ($\Gamma_{CIP} > 0$) leads to a positive CIP deviation, which makes hedging more expensive and therefore leads to a partial hedge ratio in equilibrium. Such partial equilibrium hedging of dollar exposure by foreign entities is consistent with empirical evidence in Du and Huber (2024). A positive i^d further reduces the hedge ratio as

[12] The CIP deviation is also affected by i^d. For a given CIP deviation, a higher dollar interest rate also implies a higher synthetic dollar interest rate. This reduces synthetic dollar borrowing by European households, which lowers the equilibrium synthetic dollar interest rate and therefore the CIP deviation.

for a given CIP deviation it further increases the cost of borrowing dollars.

4 Analysis of Response to Shocks

We now discuss how the exchange rate and CIP deviation are affected by a variety of shocks under imperfect CIP arbitrage. We first discuss the linearized spot and swap market equilibrium schedules and a graphical representation. After that we consider the effect of four offshore dollar funding shocks on the CIP deviation and the exchange rate. We also show that in a slightly modified version of the model the quantitative effect of these shocks on the exchange rate can be large. We finally consider other shocks that have been discussed in the literature, mainly to illustrate the difference relative to offshore dollar funding shocks.

4.1 Linearized Spot and Swap Market Schedules

Appendix C derives linearized spot and swap market equilibrium schedules. We have

$$\nu_1 s_1 + cip_1 = shock_1^{spot} \tag{29}$$

$$\nu_2 s_1 + \frac{\Gamma_{CIP} + \Gamma_F}{\Gamma_{CIP}} cip_1 = shock_1^{swap} \tag{30}$$

where $shock_1^{spot}$ and $shock_1^{swap}$ are defined below and the parameters ν_1 and ν_2 are

$$\nu_1 = \omega(1-\omega)\theta \bar{C}_{F,1}\Gamma_F + 1 + \frac{\Gamma_F}{\Gamma_{UIP}}$$

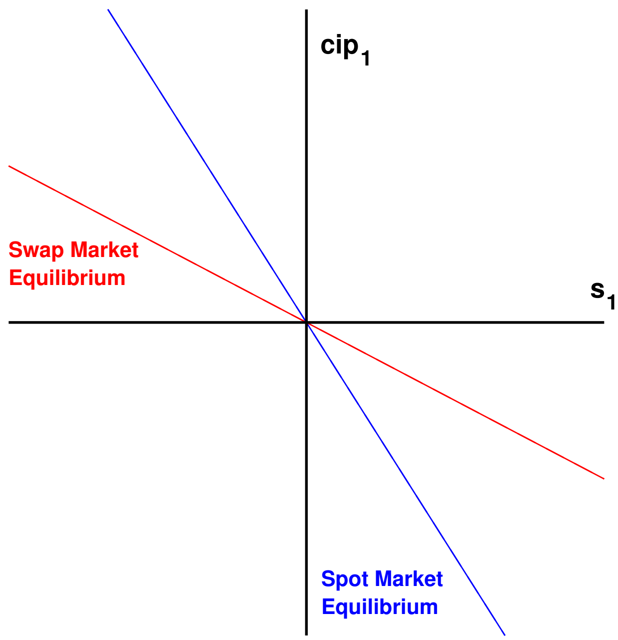
$$\nu_2 = 1 - \psi(1-\omega)\omega\theta \bar{C}_{F,1}\Gamma_F$$

Here the CIP deviation $cip_1 = i_1^{\$,syn} - i^{\$}$ is in deviation from its pre-shock level. Any change in the CIP deviation is directly related to a change in the synthetic dollar rate.

The two schedules are represented in Figure 1. First consider the spot market schedule. Since $\nu_1 > 0$, it is clearly negatively sloped. A higher synthetic dollar rate (raising cip_1) makes it more expensive for European households to borrow dollars. As we have seen, this leads to a cross-currency reallocation from borrowing dollars to borrowing euros (or holding fewer euro bonds). Since they acquire fewer dollars through dollar borrowing, they buy the needed dollars on the spot market, implying a dollar appreciation (drop in s_1).

The swap market schedule is also drawn as negatively sloped in Figure 1. The parameter ν_2 can be positive or negative. For our purpose of analyzing the offshore dollar funding shocks, it does not matter whether the slope of the swap market schedule is positive or negative. If it is negatively sloped, the slope is less negative than the spot market schedule. For concreteness, we assume this negative slope in what follows, but the analysis is unchanged if it is positively sloped.[13]

Figure 1: Spot and Swap Market Equilibrium Schedules



We next introduce shocks to the model. Any shock that leads to a cross-currency reallocation from dollars to euros will shift the spot market schedule to the right, so that the

[13]As we will discuss in Section 4.3.2, the slope of the swap market schedule does matter when we consider UIP shocks that affect the spot market schedule. Two factors drive the slope of the swap market schedule. Consider an increase in the synthetic dollar rate. This leads to an excess supply of synthetic dollars. To reestablish equilibrium in the swap market, we need to raise synthetic dollar borrowing. A dollar appreciation implies an expected dollar depreciation, which raises synthetic dollar borrowing. On the other hand, a dollar depreciation lowers the relative price of US goods, which raises imports from the US, which raises demand for dollar money balances, which also raises synthetic dollar borrowing.

dollar depreciates for a given synthetic dollar rate. Any shock that generates an excess demand for dollar swaps shifts the swap market schedule upward. Such a shock generates an excess demand for synthetic dollar funding, which raises the synthetic dollar rate for a given exchange rate. We will also refer to an excess demand for dollar swaps as a dollar shortage.

4.2 Offshore Dollar Funding Shocks

We focus on four offshore dollar funding shocks. Three of them are on the supply side, relating to dollar lending by the US to Europe. A drop in $D^{\$}_{F,1}$ reduces dollar lending by US households to European households. A rise in Γ_{CIP} reduces synthetic dollar lending by the US to Europe. A rise in $D^{\$}_{swap,1}$ is a positive dollar funding shock that raises dollar lending by the Fed to Europe through swap lines. We consider one offshore dollar funding shock on the demand side. This happens as a result of a rise in ψ, which raises demand for dollar money balances by European households. They hedge this through an increased demand for synthetic dollar funding.

All these offshore dollar funding shocks imply no change in the spot market schedule, so that $shock^{spot}_1 = 0$. This is because there is no change in unhedged FX positions and therefore no cross-currency reallocation. We have seen from (15) that for given asset prices a drop in $D^{\$}_{F,1}$ or a rise in $D^{\$}_{swap,1}$ do not change the overall net dollar position $N^{\$}_{F,1}$ of European households, as there is an offsetting change in synthetic dollar funding. The same is also the case when a rise in ψ implies increased demand for onshore dollar assets (US money balances).[14] There will be an equal increase in synthetic dollar borrowing to keep the overall net dollar position $N^{\$}_{F,1}$ unchanged. Finally, since CIP arbitrageurs do not hold an unhedged FX position, a rise in Γ_{CIP} also does not generate a cross-currency reallocation.

In contrast, all of these offshore dollar funding shocks shift the swap market schedule by changing the demand or supply of dollar swaps. Denoting deviations from the pre-shock level with a hat, we have

$$shock^{swap}_1 = \Gamma_F \omega \bar{C}_{F,1} \hat{\psi} - \Gamma_F \hat{D}^{\$}_{F,1} - \Gamma_F \hat{D}^{\$}_{swap,1} + \frac{\Gamma_F \overline{cip}}{\Gamma_{CIP}} \frac{\hat{\Gamma}_{CIP}}{\Gamma_{CIP}} \tag{31}$$

[14] A rise in ψ represents a flight to liquidity, including both dollar and euro money balances. As a result of the assumed dollar dominance, this raises demand by European households for dollar money balances in the US, while there is no change in euro money balances held by US households (which remain zero).

We have seen that a drop in $D_F^\$$ or rise in ψ raise demand for synthetic dollar funding and therefore demand for dollar swaps. This shifts the swap market schedule upward. A rise in Γ_{CIP} reduces the supply of synthetic dollar funding, which reduces the supply of dollar swaps. Similarly, it implies an excess demand for dollar swaps that shifts the swap market schedule upward. Finally, a rise in $D_{swap,1}^\$$ is a favorable dollar funding shock that reduces demand for synthetic dollar funding. It therefore lowers demand for dollar swaps, shifting the swap market schedule downward.

Appendix C provides algebraic expressions of the impact of these shocks on the CIP deviation and exchange rate. Here we focus on a graphical illustration. Figure 2 shows the impact of offshore dollar funding shocks that lead to dollar shortages, so that there is an excess demand for dollar swaps or an excess demand for synthetic dollar funding. This is the case for a drop in $D_{F,1}^\$$, a rise in Γ_{CIP} and a rise in ψ. They shift the swap market schedule upwards. Figure 2 shows that they imply an increased CIP deviation and an appreciation of the dollar. The exact opposite happens as a result of an increase in dollar swap lines, which shifts the swap market schedule downward, leading to a decreased CIP deviation and dollar depreciation.

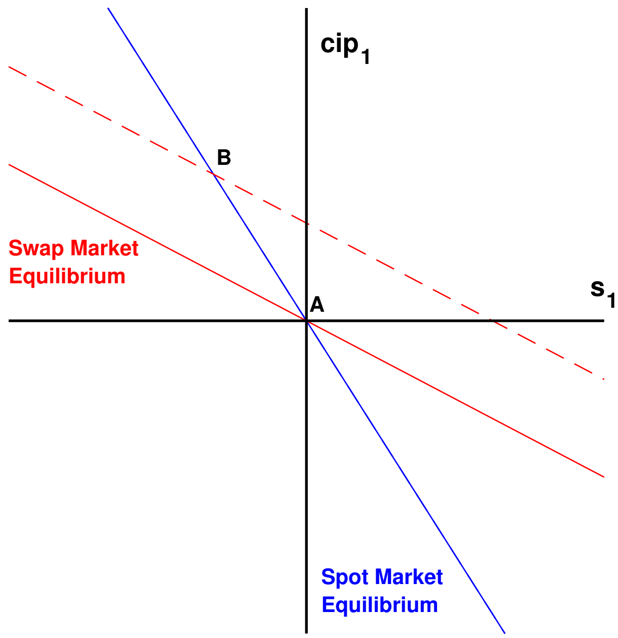
The intuition is straightforward. Offshore dollar funding shocks that generate dollar shortages lead to an excess demand for synthetic dollar funding that raises the synthetic dollar rate and therefore the CIP deviation. At a given synthetic dollar rate, the shocks do not change the desired unhedged dollar position $N_{F,1}^\$$ of European households. However, a higher synthetic dollar rate increases the desired unhedged dollar position $N_{F,1}^\$$, achieved by borrowing fewer dollars. European households then buy the needed dollars on the spot market, implying a dollar appreciation.

In terms of Figure 2, the shocks imply a movement along the spot market schedule rather than a shift of the spot market schedule. It is therefore the increase in the cost of synthetic dollar borrowing that causes the dollar to appreciate.

An increase in central bank swap lines has the exact opposite effect. European households reduce their synthetic dollar borrowing, reducing the synthetic dollar rate and CIP deviation. The optimal dollar position $N_{F,1}^\$$ falls as European households borrow more dollars. They will sell the additional dollars that they borrow on the spot market, giving rise to a dollar depreciation.

A key aspect of these results is that the exchange rate does not change under perfect

Figure 2: Offshore Dollar Funding Shock



CIP arbitrage. In that case the swap market equilibrium schedule is simply $cip_1 = 0$. It is a horizontal line that does not shift in response to any of these shocks. The synthetic dollar rate remains equal to the US dollar rate. Dollar shortages cannot arise and central bank swap lines have no effect on the exchange rate.

The algebraic solution in Appendix C shows that the impact of these shocks on the exchange rate is larger the more limited CIP arbitrage (the higher Γ_{CIP}). This is consistent with evidence reported by Krohn and Sushko (2022). They find that spot market liquidity is lower (price impact is higher) when CIP deviations are higher. But they consider the general price impact, not specifically associated with offshore dollar funding shocks.

More specifically related to our shocks, Kekre and Lenel (2024b) find that central bank swap lines lower the CIP deviation and depreciate the dollar. They focus on the exchange rate response in tight windows around eight swap lines announcements, using minute-by-minute data. They identify swap line announcements that were not accompanied by news regarding other policies and FOMC statements. Indeed, they find no change in the Fed funds rate in response to these announcements. They also find a substantially larger change in the exchange rate than the CIP deviation. In the main text they focus on swap line announcements on March 19 and 20, 2020, during the Covid crisis. They find that it leads to a dollar depreciation of $72bp$ relative to other G7 currencies and $117bp$ relative to emerging market currencies, while the CIP deviation fell by $18bp$. Cesa-Bianchi et al. (2024) report similar results.

Many of the offshore dollar funding shocks that we consider here are likely to be important during financial crises or periods of increased financial stress. A flight to liquidity is well known during periods of financial stress.[15] Cesa-Bianchi et al. (2023) refer to a dash-for-dollars during the COVID-19 pandemic. A decline in wholesale dollar funding by US financial institutions to non-US financial institutions during periods of financial stress is also typical, as discussed for example in McGuire and von Peter (2009, 2012) for the global financial crisis, Ivashina et al. (2015) for the European debt crisis and Eren et al. (2020) for the Covid pandemic. CIP arbitrage can also decline during periods of financial stress as a result of reduced bank capital and reduced short-term wholesale funding. Anderson et al. (2025) discuss the importance of short-term unsecured funding as a source of arbitrage capital for global banks.

In this context, another form of evidence consistent with the theory relates to the dollar exchange rate during periods of financial stress. Lilley et al. (2022) report that post-2007 the dollar appreciates during periods of financial stress, as captured by various measures of risk and risk aversion. This is not the case pre-2007. Similar evidence is reported in Bacchetta, Davis, and van Wincoop (2023). The offshore dollar funding shocks considered here indeed have no effect on the exchange rate under perfect CIP arbitrage. Prior to 2007 the Libor CIP deviation was close to zero.[16] CIP deviations started to arise as a result of the global financial crisis and new regulations after the global financial crisis that limited CIP arbitrage.

[15] Bianchi et al. (2021) refer to a flight to liquidity as "scrambling for dollars" during times of increased funding risk, where they have in mind both Treasury bills and reserves of banks at the Fed. In other contexts, it refers to an increased demand for assets that are easily convertible into money. This is the case in Longstaff (2004) and Vayanos (2004), who both refer to it as a "flight to liquidity" in uncertain times. While these papers consider investors and banks, we also see an increased demand for cash by firms during increased uncertainty. See, for example, Li (2019).

[16] Jiang et al. (2021) show that Libor CIP deviations have been close to zero between the late 1980s and 2007, with the exception of two idiosyncratic events related to Sweden and Japan.

It is hard to give a quantitative assessment of the effect of these shocks on the exchange rate within the context of a three-period model. Since the expected log exchange rate in period 2 is zero, the expected dollar depreciation is $-s_1$, which varies a lot with the current exchange rate. A very small dollar appreciation then implies a substantial expected dollar depreciation that will increase the demand for synthetic dollar funding and re-establish equilibrium in the swap market in response to negative offshore dollar funding shocks. Since the spot market schedule has a slope that is more negative than -1 (see (29)), the exchange rate will change less than the CIP deviation in equilibrium.

This can be different in a more dynamic model, where expected changes in the exchange rate are much smaller. In that case, the exchange rate will also be affected by changes in expected future CIP deviations. In reality, exchange rate changes are very hard to predict. Du and Huber (2024) assume that agents similar to our European households form exchange rate expectations based on the interest differential. In our context, this is analogous to random walk expectations as the interest differential is constant. In Appendix C we show that when the expected change in the exchange rate by European households is zero, in response to offshore dollar funding shocks we have approximately

$$\hat{s}_1 = -\frac{\Gamma_{UIP}}{\Gamma_F}\hat{cip}_1 \tag{32}$$

If the risk-bearing capacity of UIP arbitrageurs is much less than that of the European households ($\Gamma_{UIP} > \Gamma_F$), the exchange rate changes much more than the CIP deviation, consistent with Kekre and Lenel (2024b). The risk-bearing capacity of UIP arbitrageurs is reduced when they are subject to intermediary constraints, such as in Gabaix and Maggiori (2015). In addition, it is possible that UIP arbitrageurs manage much less wealth than agents operating in the FX swap market, also reducing their overall risk-bearing capacity. Gourinchas et al. (2024) identify UIP arbitrageurs as hedge funds, which manage a limited amount of wealth.

4.3 Other Shocks

Here we examine some other shocks considered in the literature and draw contrasts to the offshore dollar funding shocks analyzed above. The first is a shock to the hedge ratio as in

Liao and Zhang (2025), which shifts both the spot and swap market schedules. The second is a shock to the spot market schedule. Appendix C shows how these shocks affect the spot and swap market schedules, the equilibrium exchange rate and CIP deviation.

4.3.1 Shock to the Hedge Ratio

Liao and Zhang (2025) consider an increase in the variance of the exchange rate, which raises Γ_F, reducing the risk-bearing capacity of European households. Assuming $i^d + \overline{cip} > 0$, the pre-shock expected excess return on dollars is positive, so that European households hold a positive unhedged dollar position $N^{\$}_{F,1}$. They wish to hedge their dollar exposure to a greater extent when Γ_F rises, lowering $N^{\$}_{F,1}$. The effect is the same as for an increase in ρ, which leads to an increased hedge of non-asset dollar exposure. In this case we have

$$shock_1^{spot} = shock_1^{swap} = \left(\overline{cip} + i^d\right) \frac{\hat{\Gamma}_F}{\Gamma_F} \tag{33}$$

This shock has in common with the offshore dollar funding shocks that the swap market schedule shifts up. But the difference is that the spot market schedule shifts as well. When Γ_F increases, European households buy more dollar swaps to hedge their dollar exposure. But it also has a direct effect on the spot market as they reduce their unhedged dollar position $N^{\$}_{F,1}$, implying a cross-currency reallocation from dollars to euros. The dollars received from buying additional dollar swaps are sold on the spot market. In contrast, with offshore dollar funding shocks, there is no change in the optimal unhedged dollar position $N^{\$}_{F,1}$. There is simply a reshuffling of the components of $N^{\$}_{F,1}$.

The impact of an increase in Γ_F is illustrated in Chart A of Figure 3. The increase in demand for dollar swaps shifts the swap market schedule up, while the cross-currency reallocation from dollars to euros shifts the spot market schedule to the right. The dollar depreciates and the CIP deviation increases.

While Chart A is drawn with a downward sloping swap market schedule, Appendix C shows that the dollar depreciation and rise in CIP deviation hold generally. The rise in the CIP deviation is a result of increased synthetic dollar borrowing. As the dollars obtained from the synthetic dollar borrowing are sold on the spot market, the dollar depreciates.

These results are consistent with Liao and Zhang (2025).[17]

Figure 3: Hedging shock

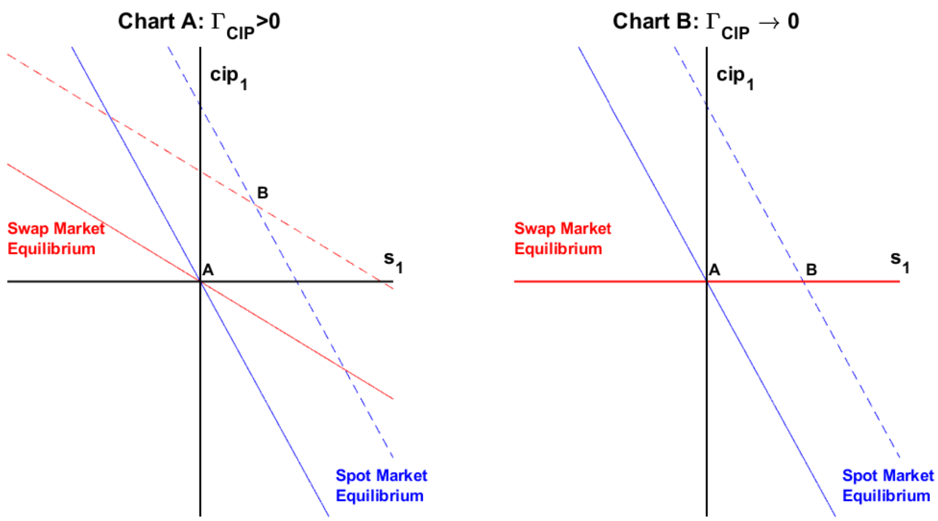


Chart B of Figure 3 shows that even under perfect CIP arbitrage this shock to the hedge ratio causes a dollar depreciation. An increased hedge ratio changes the unhedged FX position of European households regardless of the synthetic dollar rate. In contrast, offshore dollar funding shocks have no effect on the exchange rate under perfect CIP arbitrage as they have no direct effect on the unhedged dollar position.

4.3.2 Shock to the Spot Market Schedule

In most exchange rate models, there is perfect CIP arbitrage. Then all shocks that affect the exchange rate are shocks to the spot market schedule, which are unhedged FX demand shocks. Typical examples are noise trader shocks, shocks to the arbitrage capacity of UIP arbitrageurs or foreign exchange intervention by central banks. Such shocks feature in the

[17]They also consider the case where "Europe" in our model has a negative net dollar position, which happens when $i^d + \overline{cip} < 0$. In that case the dollar appreciates and the CIP deviation becomes smaller.

seminal contributions by Gabaix and Maggiori (2015) and Itskhoki and Mukhin (2021). Another example are shocks that change the relative convenience yield.[18]

For illustrative purposes, we consider shocks to the arbitrage capacity of UIP arbitrageurs when $i^d < 0$. This means that UIP arbitrageurs borrow dollars and lend euros. A reduction in their arbitrage capacity (increase in Γ_{UIP}) reduces the size of this FX position, generating a cross-currency reallocation from euros to dollars. In the Online Appendix we also consider noise trader shocks, which have the same effect.

In this case, Appendix C shows that $shock_1^{swap} = 0$ and

$$shock_1^{spot} = \frac{\Gamma_F}{\Gamma_{UIP}} i^d \frac{\hat{\Gamma}_{UIP}}{\Gamma_{UIP}}$$

The impact of a rise in Γ_{UIP} is shown in Figure 4. The cross-currency reallocation from euros to dollars shifts the spot market schedule to the left, while the swap market schedule does not shift.

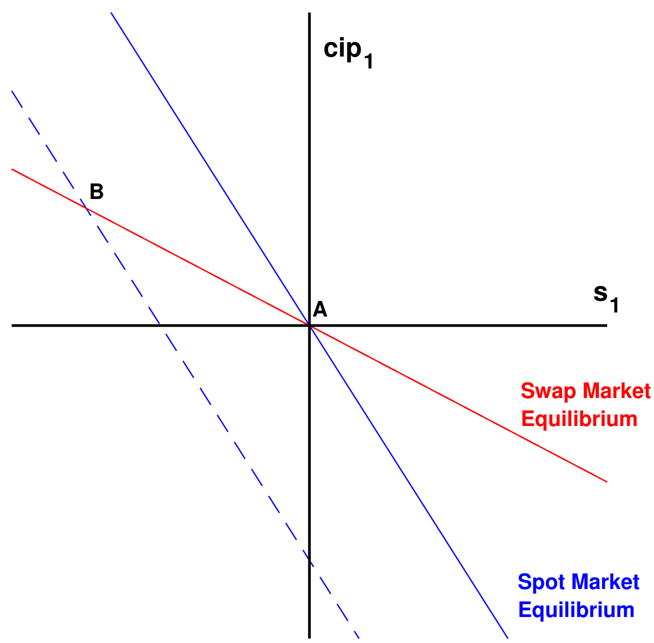
The reallocation towards dollars appreciates the dollar. The same would happen under perfect CIP arbitrage, where the swap market schedule is horizontal. This again contrasts with offshore dollar funding shocks. We also see that the CIP deviation rises under imperfect CIP arbitrage. However, this result is not robust. When the swap market schedule is upward sloping the CIP deviation falls. The effect on the CIP deviation results from a feedback from the spot market to the swap market. It depends on how the exchange rate affects demand in the swap market. As discussed earlier, a dollar appreciation can raise or lower synthetic dollar borrowing, representing, respectively, a downward and upward sloping swap market schedule.

5 Conclusion

We have developed a model that captures the segmentation between onshore and offshore dollar markets that has developed since 2007. This segmentation is reflected in persistent and time-varying deviations from CIP. The model is used to show that offshore dollar funding

[18] See Valchev (2020), Kekre and Lenel (2024a), Engel and Wu (2023), Jiang et al. (2024), Jiang et al. (2021), Bianchi et al. (2021) and Devereux et al. (2023).

Figure 4: Spot Market Shift to Dollars: rise in Γ_{UIP}



shocks affect the dollar exchange rate. We have shown that without this market segmentation, under perfect CIP arbitrage, such shocks have no effect on the exchange rate.

These shocks occur frequently during periods of increased financial stress, as we have seen during the global financial crisis, the European debt crisis and the Covid-19 pandemic. This generates dollar shortages in offshore dollar markets that raise the synthetic dollar interest rate and cause the dollar to appreciate. Although offshore dollar funding shocks themselves do not involve any cross-currency reallocation, the higher cost of synthetic dollar funding that results from these shocks generates a cross-currency reallocation towards dollars that leads to an appreciation. Non-US residents increase their net dollar position by reducing synthetic dollar borrowing. They buy the dollars that they need on the spot market when borrowing dollars synthetically becomes more expensive.

One natural extension is to consider a multi-country framework. CIP deviations vary significantly across countries. While the cross-currency basis is negative (CIP deviation is positive) for most currencies relative to the dollar, the opposite is the case for the Australian and New Zealand dollar. Reallocation between the US and a specific offshore dollar market like Europe may spill over to other offshore dollar markets, affecting their exchange rate relative to the dollar. Another extension is to explicitly model offshore banks, since a lot of offshore dollar funding directly or indirectly involves non-US banks that have significant dollar liabilities to US financial institutions. A final extension is to consider a fully dynamic model to better quantify the magnitude of the effect of offshore dollar funding shocks on the exchange rate.

Appendix

A Period 2 Goods Market Equilibrium

Country h households receive an endowment of $Q_{h,2}$ of the good of country h. The period 2 consumption index for households from country h is

$$C_{h,2} = \left((0.5)^{\frac{1}{\theta}} C_{hH,2}^{\frac{\theta-1}{\theta}} + (0.5)^{\frac{1}{\theta}} C_{hF,2}^{\frac{\theta-1}{\theta}} \right)^{\frac{\theta}{\theta-1}} \tag{A.1}$$

Here $C_{hH,2}$ is consumption of the Home good by country h households and $C_{hF,2}$ is consumption of the Foreign good by country h households. The parameter θ is the elasticity of substitution among the two goods. Central banks target a price of $P_{H,2} = 1$ for the Home good in dollars and a price of $P_{F,2} = 1$ for the Foreign good in euros. The price index of consumption in dollars is then

$$P_2 = \left(0.5 + 0.5 S_2^{1-\theta} \right)^{\frac{1}{1-\theta}} \tag{A.2}$$

and the price index in euros is $P_2^* = P_2/S_2$. The standard intratemporal first-order conditions imply consumption of Home and Foreign goods of

$$C_{hH,2} = 0.5 \left(\frac{1}{P_2} \right)^{-\theta} C_{h,2} \tag{A.3}$$

$$C_{hF,2} = 0.5 \left(\frac{S_2}{P_2} \right)^{-\theta} C_{h,2} \tag{A.4}$$

for agents from both countries.

The “other” agents (CIP arbitrageurs and UIP arbitrageurs) have the same consumption index. Using the expressions for the supply Q_H and Q_F of Home and Foreign goods, period

2 goods market clearing then implies

$$e^{\kappa_H \epsilon_q} = 0.5 \left(\frac{1}{P_2}\right)^{-\theta} (C_{H,2} + C_{F,2} + C^o_{H,2}) \tag{A.5}$$

$$e^{-\kappa_F \epsilon_q} = 0.5 \left(\frac{S_2}{P_2}\right)^{-\theta} (C_{H,2} + C_{F,2} + C^o_{H,2}) \tag{A.6}$$

Denote with a bar the levels of second period consumption when $s_2 = 0$, so that $S_2 = 1$. In that case $P_2 = 1$. Linearizing (A.5)-(A.6) around $\epsilon_q = s_2 = 0$, we get

$$1 + \kappa_H \epsilon_q = 0.5(C_{H,2} + C_{F,2} + C^o_{H,2}) + 0.25(\bar{C}_{H,2} + \bar{C}_{F,2} + \bar{C}^o_{H,2})\theta s_2$$
$$1 - \kappa_F \epsilon_q = 0.5(C_{H,2} + C_{F,2} + C^o_{H,2}) - 0.25(\bar{C}_{H,2} + \bar{C}_{F,2} + \bar{C}^o_{H,2})\theta s_2$$

First set $\epsilon_q = 0$. It follows immediately by first subtracting and then adding these equations that $s_2 = 0$ and

$$\bar{C}_{H,2} + \bar{C}_{F,2} + \bar{C}^o_{H,2} = 2 \tag{A.7}$$

Using this equation, taking the difference between the two market clearing conditions (using $\kappa_H + \kappa_F = 1$) gives $\epsilon_q = \theta s_2$ or $s_2 = \epsilon_q/\theta$.

B Pre-Shock Equilibrium

Period 1 variables are equal to period 0 variables. For the exchange rate this implies $s_1 = s_0 = 0$. This also implies that $P_1 = P_1^* = 1$. Consumption is smoothed in that period 1 consumption by households is equal to period 2 consumption when $s_2 = 0$. We denote pre-shock period 1 variables with a bar. They are equal to corresponding period 0 variables.

In the pre-shock equilibrium household wealth is the same in period 1 as in period 0. This implies that saving of Home and Foreign households is zero, so that

$$\bar{C}_{H,1} = \bar{Y}_{H,1} + \bar{\Pi}_{HCB,1} + i^{\$} W_{H,0} \tag{B.1}$$

$$\bar{C}_{F,1} = \bar{Y}_{F,1} + \bar{\Pi}_{FCB,1} - i_0^{\$,syn} D_{F,0}^{\$,syn} - i^{\$} D_{F,0}^{\$} - i^{\$,swap} D_{swap,0}^{\$} + i^{€} B_{F,0}^{€} \tag{B.2}$$

This sets period 1 consumption equal to income, which is the sum of income from production and interest income and transfers of central bank profits back to the households. Here $\bar{\Pi}_{HCB,1} = i^{\$} M_0^{\$}$ and $\bar{\Pi}_{FCB,1} = i^{€} M_0^{€}$. One of these equations is redundant as aggregate world saving is zero. We therefore remove the last equation.

In the pre-shock equilibrium we also have consumption smoothing: $\bar{C}_{h,1} = \bar{C}_{h,2}$. Substituting this into the period 2 budget constraints, we have

$$\bar{C}_{H,1} = 1 + \bar{\Pi}_{HCB,2} + \bar{M}^{\$}_{H,1} + (1 + i^{\$})\bar{W}_{H,1} \tag{B.3}$$

$$\begin{aligned}\bar{C}_{F,1} &= 1 + \bar{\Pi}_{FCB,2} + \bar{M}^{\$}_{F,1} + \bar{M}^{€}_{F,1} + (1 + i^{€})\bar{W}_{F,1} \\ &\quad -(\bar{i}_1^{\$,syn} - i^{€})\bar{D}^{\$,syn}_{F,1} - (i^{\$} - i^{€})\bar{D}^{\$}_{F,1} - (i^{\$,swap} - i^{€})\bar{D}^{\$}_{swap,1}\end{aligned} \tag{B.4}$$

The last two equations needed to derive the pre-shock equilibrium are

$$\bar{C}_{H,1} + \bar{C}_{F,1} + \bar{C}^o_{H,1} = 2 \tag{B.5}$$

$$\bar{B}^{\$}_{CIP,1} = \bar{D}^{\$,syn}_{F,1} \tag{B.6}$$

These correspond to the period 2 world goods market equilibrium (A.7), replacing $\bar{C}_{h,2} = \bar{C}_{h,1}$, and the period 1 swap market equilibrium. We then have a total of 5 equations: (B.1) and (B.3)-(B.6). This system can be solved by substituting expressions for money balances, portfolio holdings, central bank profits and period 1 production, setting $\bar{i}_1^{\$,syn} = i_0^{\$,syn}$, $s_1 = s_0 = 0$, $\bar{D}^{\$}_{F,1} = D^{\$}_{F,0}$, $\bar{D}^{\$}_{swap,1} = D^{\$}_{swap,0}$ and $\bar{W}_{h,1} = W_{h,0}$. We then have 5 equations in 5 variables: the 2 period 1 consumption levels, the 2 initial wealth levels $W_{h,0}$ and $\overline{cip}$. As shown in the Online Appendix, after these substitutions, we obtain 5 equations in $\bar{C}_{H,1}$, $\bar{C}_{F,1}$, $W_{H,0}$, $W_{F,0}$ and $\overline{cip}$.

C Linearized Model

When linearizing, we allow for the four offshore dollar funding shocks ($\hat{\psi}$, $\hat{D}^{\$}_{F,1}$, $\hat{D}^{\$}_{swap,1}$, $\hat{\Gamma}_{CIP}$), as well as the other shocks considered in Section 4.3. The latter include shocks to ρ and Γ_F that affect the hedge ratio as well as a shock to Γ_{UIP}.

We first linearize the spot market equilibrium. Using $N^{\$}_{F,1} = M^{\$}_{F,1} - D^{\$,syn}_{F,1} - D^{\$}_{F,1} - D^{\$}_{swap,1}$, the spot market equilibrium (25) can be written as

$$CA_{H,1}^{\$} + dM_{F,1}^{\$} - dD_{F,1}^{\$,syn} - dD_{F,1}^{\$} - dD_{swap,1}^{\$} - S_1 dB_{UIP,1}^{€} = 0 \tag{C.1}$$

In the Online Appendix we show that

$$CA_{H,1}^{\$} = TA_{H,1}^{\$} + i_0^{\$,syn} D_{F,0}^{\$,syn} + i^{\$} D_{F,0}^{\$} + i^{\$,swap} D_{swap,0}^{\$} + S_1 i^{€} B_{UIP,0}^{€} \tag{C.2}$$

It is equal to the trade account plus four terms that capture net investment income. The first three investment income terms are constant (only depend on time 0 variables). The fourth term depends on S_1. However, we can replace S_1 with S_0 and then add $(S_1 - S_0) i^{€} B_{UIP,0}^{€}$. This is a third-order term, the product of the change in the exchange rate, euro interest rate and euro bond position by UIP arbitrageurs that itself depends on an expected excess return. So we ignore it (we only consider first-order terms). We then have $\widehat{CA}_{H,1}^{\$} = \widehat{TA}_{H,1}^{\$}$.

Regarding the trade account, we have $TA_{H,1}^{\$} = Y_{H,1} - C_{H,1} - C_{H,1}^{o}$. $C_{H,1}$ is held constant and $C_{H,1}^{o}$ is equal to the period 1 profits of Home UIP and CIP arbitrageurs based on period 0 interest rates and portfolio positions. Specifically

$$C_{H,1}^{o} = \left(i_0^{\$,syn} - i^{\$} \right) B_{CIP,0}^{\$} + (i^{€} - i^{\$} + s_1) B_{UIP,0}^{€} \tag{C.3}$$

Following Itskhoki and Mukhin (2021), we abstract from the effect of s_1 on the consumption of UIP arbitrageurs as this effect is second-order. The last term is the product of an excess return and an expected excess return that determines the euro bond position of UIP arbitrageurs.

We therefore have $\widehat{TA}_{H,1}^{\$} = \hat{Y}_{H,1}$. Using

$$Y_{H,1} = C_{HH,1} + C_{FH,1} + C_{HH,1}^{o} = (1-\omega)\left(C_{H,1} + C_{H,1}^{o}\right) + \omega \left(S_1 P_1^*\right)^{\theta} C_{F,1} \tag{C.4}$$

and $\hat{p}_1^* = -\omega \hat{s}_1$, it follows that

$$\widehat{TA}_{H,1}^{\$} = \hat{Y}_{H,1} = \omega(1-\omega)\theta \bar{C}_{F,1} \hat{s}_1 \tag{C.5}$$

Clearly therefore a dollar depreciation raises the US trade account.

We have

$$\hat{M}^{\$}_{F,1} - \hat{D}^{\$,syn}_{F,1} - \hat{D}^{\$}_{F,1} - \hat{D}^{\$}_{swap,1} = -\hat{\rho} + \frac{\hat{cip}_1 + \hat{s}_1}{\Gamma_F} - \frac{\overline{cip} + i^d}{\Gamma_F}\frac{\hat{\Gamma}_F}{\Gamma_F} \tag{C.6}$$

Next, consider UIP arbitrageurs. We can write

$$-S_1 dB^{€}_{UIP,1} = -S_0 dB^{€}_{UIP,1} - (S_1 - S_0) dB^{€}_{UIP,1}$$

We ignore the last term. It is second-order as it is the product of the change in the exchange rate and the change in the euro position of UIP arbitrageurs. We have

$$-S_0 dB^{€}_{UIP,1} = -\hat{B}^{€}_{UIP,1} = \frac{\hat{s}_1}{\Gamma_{UIP}} - \frac{i^d}{\Gamma_{UIP}}\frac{\hat{\Gamma}_{UIP}}{\Gamma_{UIP}} \tag{C.7}$$

Combining all terms, we can write the spot market equilibrium as

$$\nu_1 \hat{s}_1 + \hat{cip}_1 = shock^{spot}_1 \tag{C.8}$$

where

$$shock^{spot}_1 = \Gamma_F \hat{\rho} + \left(\overline{cip} + i^d\right)\frac{\hat{\Gamma}_F}{\Gamma_F} + i^d \frac{\Gamma_F}{\Gamma_{UIP}}\frac{\hat{\Gamma}_{UIP}}{\Gamma_{UIP}} \tag{C.9}$$

and

$$\nu_1 = \omega(1-\omega)\theta \bar{C}_{F,1}\Gamma_F + 1 + \frac{\Gamma_F}{\Gamma_{UIP}} \tag{C.10}$$

Next, consider the swap market equilibrium

$$B^{\$}_{CIP,1} = D^{\$,syn}_{F,1} \tag{C.11}$$

From (C.6) we have

$$\hat{D}^{\$,syn}_{F,1} = \hat{\rho} + \hat{M}^{\$}_{F,1} - \hat{D}^{\$}_{F,1} - \hat{D}^{\$}_{swap,1} - \frac{\hat{cip}_1 + \hat{s}_1}{\Gamma_F} + \frac{\overline{cip} + i^d}{\Gamma_F}\frac{\hat{\Gamma}_F}{\Gamma_F} \tag{C.12}$$

We also have

$$\hat{M}^{\$}_{F,1} = \omega \bar{C}_{F,1}\hat{\psi} + \psi(1-\omega)\omega\theta \bar{C}_{F,1}\hat{s}_1 \tag{C.13}$$

and

$$\hat{B}^{\$}_{CIP,1} = \frac{\hat{cip}_1}{\Gamma_{CIP}} - \frac{\overline{cip}}{\Gamma_{CIP}}\frac{\hat{\Gamma}_{CIP}}{\Gamma_{CIP}} \tag{C.14}$$

Therefore the swap market equilibrium becomes

$$\nu_2 \hat{s}_1 + \left(1 + \frac{\Gamma_F}{\Gamma_{CIP}}\right) \hat{cip}_1 = shock_1^{swap} \tag{C.15}$$

where

$$shock_1^{swap} = \Gamma_F \hat{\rho} + \Gamma_F \omega \bar{C}_{F,1} \hat{\psi} + \left(\overline{cip} + i^d\right) \frac{\hat{\Gamma}_F}{\Gamma_F} + \frac{\Gamma_F}{\Gamma_{CIP}} \overline{cip} \frac{\hat{\Gamma}_{CIP}}{\Gamma_{CIP}} - \Gamma_F \hat{D}^{\$}_{F,1} - \Gamma_F \hat{D}^{\$}_{swap,1} \tag{C.16}$$

and

$$\nu_2 = 1 - \psi(1-\omega)\omega\theta \bar{C}_{F,1} \Gamma_F \tag{C.17}$$

Algebraically, the effect of these shocks is as follows. For the offshore dollar funding shocks we have

$$\hat{s}_1 = \frac{\Gamma_F}{\nu_1 \left[1 + (\Gamma_F / \Gamma_{CIP})\right] - \nu_2} \left(-\omega \bar{C}_{F,1} \hat{\psi} + \hat{D}^{\$}_{F,1} + \hat{D}^{\$}_{swap,1} - \frac{\overline{cip}}{\Gamma_{CIP}} \frac{\hat{\Gamma}_{CIP}}{\Gamma_{CIP}} \right) \tag{C.18}$$

$$\hat{cip}_1 = \frac{\nu_1 \Gamma_F}{\nu_1 \left[1 + (\Gamma_F / \Gamma_{CIP})\right] - \nu_2} \left(\omega \bar{C}_{F,1} \hat{\psi} - \hat{D}^{\$}_{F,1} - \hat{D}^{\$}_{swap,1} + \frac{\overline{cip}}{\Gamma_{CIP}} \frac{\hat{\Gamma}_{CIP}}{\Gamma_{CIP}} \right) \tag{C.19}$$

The denominator of the term in front of the big bracket is clearly positive since $\nu_1 > 1$ and $\nu_2 < \nu_1$.

For the shocks that affect the hedge ratio we have

$$\hat{s}_1 = \frac{\Gamma_F / \Gamma_{CIP}}{\nu_1 \left[1 + (\Gamma_F / \Gamma_{CIP})\right] - \nu_2} \left(\Gamma_F \hat{\rho} + \left(\overline{cip} + i^d\right) \frac{\hat{\Gamma}_F}{\Gamma_F} \right) \tag{C.20}$$

$$\hat{cip}_1 = \frac{\nu_1 - \nu_2}{\nu_1 \left[1 + (\Gamma_F / \Gamma_{CIP})\right] - \nu_2} \left(\Gamma_F \hat{\rho} + \left(\overline{cip} + i^d\right) \frac{\hat{\Gamma}_F}{\Gamma_F} \right) \tag{C.21}$$

For the $\hat{\Gamma}_{UIP}$ shocks that only affect the spot market schedule we have

$$\hat{s}_1 = \frac{1}{\nu_1\left[1+(\Gamma_F/\Gamma_{CIP})\right]-\nu_2}\left(1+\frac{\Gamma_F}{\Gamma_{CIP}}\right)\frac{\Gamma_F}{\Gamma_{UIP}}i^d\frac{\hat{\Gamma}_{UIP}}{\Gamma_{UIP}} \tag{C.22}$$

$$\hat{cip}_1 = \frac{-1}{\nu_1\left[1+(\Gamma_F/\Gamma_{CIP})\right]-\nu_2}\nu_2\frac{\Gamma_F}{\Gamma_{UIP}}i^d\frac{\hat{\Gamma}_{UIP}}{\Gamma_{UIP}} \tag{C.23}$$

We also discuss an extension where the dollar position of European households does not depend on the expected change in the exchange rate. This implies that we need to remove $\hat{s}_1$ from (C.6) and (C.12). This affects the slopes of both the spot and swap market schedules. We then have

$$\nu_1 = \omega(1-\omega)\theta\bar{C}_{F,1}\Gamma_F + \frac{\Gamma_F}{\Gamma_{UIP}} \tag{C.24}$$

$$\nu_2 = -\psi(1-\omega)\omega\theta\bar{C}_{F,1}\Gamma_F \tag{C.25}$$

The solutions for the exchange rate and CIP deviation remain the same, but with these new values of ν_1 and ν_2. For offshore dollar funding shocks we then have

$$\frac{\hat{s}_1}{\hat{cip}_1} = -\frac{1}{\nu_1} \tag{C.26}$$

The first term in the expression for ν_1 is very small. It is the product of two small numbers: the change in the trade to GDP ratio in response to a 1% increase in the exchange rate and $\Gamma_F = \gamma var(s_2)$. Ignoring this term, we have $1/\nu_1 = \Gamma_{UIP}/\Gamma_F$.

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