The Monetary Model of CIP Deviations

Ibhagui, Oyakhilome

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Oyakhilome Ibhagui

Abstract

A large amount of currencies has over time exhibited persistent deviations from covered interest rate parity, resulting in non-zero cross-currency basis swap spreads. The relationship between these deviations and standard macroeconomic variables, however, remains unknown. In this paper, we document a long-run relationship between cross-currency basis swap spreads and macroeconomic variables (relative money supply and relative real output). After presenting a simple model where we relax the no-arbitrage CIP assumption in a monetary model framework, we empirically show that, in the long run, tighter cross-currency basis swap spreads are associated with higher relative real output for non-European currencies, while a rise in relative money supply does not widen the cross-currency basis swap spreads associated with European currencies. Our main results are robust to different estimation techniques and the inclusion of control variables. We also perform an error-correction analysis which suggests that the mechanism governing the adjustment to equilibrium is not the same for European and non-European currencies. More generally, we show that, when there is a move away from equilibrium, it is mostly the cross-currency basis swap spreads that adjust to ensure a return to equilibrium, across all maturities and samples.

JEL classification: C3, E5, F3, G1, G2

1a. Introduction

A striking similarity among most studies on deviations from covered interest rate parity (CIP) is the development and estimation of models linking market-related variables - such as rates, spreads and issuance volumes - to CIP deviations, and the failure of these models to account for possible long run links between CIP deviations and macroeconomic variables such as money supply and real output. In an influential paper, Ivashina et al. (2015) attempt to connect CIP deviations to the real side of the economy. They develop a testable theoretical model that links the marginal product of lending to CIP violations. However, the possible links between CIP deviations, money supply and real output, which is the main gauge of real economic performance, is yet to be understood in a formal theoretical or empirical sense - making these links an unexplored area in the literature. In this article, we attempt to fill this gap. To do this, we incorporate CIP deviations into existing monetary models of exchange rate. This gives rise to a simple theoretical framework that provides a benchmark model for empirically testing the long-run impact of the macroeconomic fundamentals on CIP deviations.

The CIP deviations enter the model as the non-zero cross-currency basis swap spreads while the macroeconomic variables are the monetary fundamentals – relative money supply and relative real output – as well as the bilateral nominal exchange rates. We call this model the monetary model of cross-currency basis swap spreads. Although existing monetary models of exchange rate determination are built in parts on the assumption of no arbitrage or no CIP violations, in this paper, we relax this assumption. Such relaxation implies that the CIP deviations are no more negligible. This enables us to incorporate the non-zero CIP deviations into the monetary models of exchange rate, giving us the leeway to express the cross-currency basis swap spreads in terms of the macroeconomic fundamentals that make up the monetary models. Different variants of the model, based on the assumptions of the model parameters, are discussed, and an empirical analysis is performed for a collection of 11 currencies at the 1-, 5-, 10- and 20-year maturity of the cross-currency basis swaps.

In the literature, it is generally accepted that most models developed in the previous decades often impose a no-arbitrage assumption. Notable among such no-arbitrage conditions is the CIP. In international finance, one of the major building blocks of monetary models is the CIP assumption often imposed to ensure that the no-arbitrage requirement is satisfied. Essentially, this condition implies that realized interest rate in the cash market should coincide with the corresponding interest rate implied in foreign exchange (FX) swap market, where the implied interest rate in the FX swap market is that obtained when realized interest in a foreign currency is swapped into a domestic currency following an investment in a foreign asset. In order words, cash market and swap market interest rates, when expressed in the same domestic currency, should be equal. In such a case, the difference between the interest rates, known as CIP deviations or cross-currency basis swap spreads, is zero. Thus, investors should be indifferent about investing domestically versus investing abroad as income or returns generated from investing abroad, when expressed or converted to domestic currency, is equivalent to that which can be generated from a domestic investment. For example, an American citizen buying US T-bills should earn the same return on investment as another American who prefers buying Japanese T-bills hedged into dollars.

Looking at the evolution of CIP deviations, it is well known that prior to the last decade, especially before the global financial crises, most deviations from CIP were extremely small and statistically indifferent from zero. Further, profit opportunities implied by arbitrage from the mild CIP deviations were relatively small, with only very few instances of notable CIP deviations. However, since the global financial crisis, the dynamics seem to have changed. One of the most noteworthy anomaly in the global financial markets since the crisis, and in recent years, has been the significant deviations from CIP. We now live in a world of CIP deviations, evidenced by persistent non-zero cross-currency basis swap spreads for most currencies. While these CIP deviations are positive for a few currencies, which implies holders of these currencies will access the dollar at a discount or receive a premium for providing their currencies, for most currencies, the deviations are negative and signify, among others, that foreign corporates and institutions have become keener to hold the dollar and are ready to pay a premium or receive the least compensation or receive discount and give up their advantages in return for getting dollars. Also, it can imply that investors, more than ever before, have become more interested to hedge currency risks and so demand high FX hedging activities. At the time of the financial crisis, it was rationalized that the astronomical demand for USD caused the breakdown of the CIP condition at the height of the crisis. But even after the crisis, the breakdown of CIP remained pronounced quantitatively for a diverse collection of currencies. Many studies have attempted to explain away why these deviations have lingered on, even after the crisis. It is not our objective to explain the origins of the deviations and why the deviations have persisted. Instead, in this paper, we take the CIP deviations as a given – we are in a world of CIP deviations – and we attempt to examine further potential long run drivers of the deviations by linking them to macroeconomic fundamentals.

After investigating the theoretical implications of our model, we empirically test its postulates on a collection of 11 liquid currencies. In particular, we ask how the macroeconomic fundamentals are related to CIP deviations in the long run. This question is important in light of the observation that it is unclear how macroeconomic outcomes impact CIP deviations. Building on our framework, we also empirically investigate whether CIP deviations of currencies associated with Europe countries bear a similar long run relationship with the macroeconomic fundamentals compared to the non-European currencies. To test the relationship between CIP deviations and monetary fundamentals, we focus on periods covering 2008 – 2015 due to data constraints, and our sampling frequency is quarterly. Our results indicate that the strength of the real economy - measured as relative real output - bears a positive long run relationship with the cross-currency basis swap spreads for non-European currencies. This evidence also suggests that if the US economy plunges into a recession while the non-European economies hold firm, the cross-currency bases of the currencies associated with the resilient non-European economies are likely to tighten. Conversely, with an accelerating US economy relative to the rest of the world, the cross-currency basis tends to widen. We also show that an expansion in central bank liability, via an increase in money supply, leads to tighter cross-currency basis swap spreads for European currencies.

This relationship between monetary fundamentals and CIP deviations holds for most maturities of the cross-currency basis swaps considered, but it is particularly strong for the 5- and 10-year maturities. It is generally robust to the inclusion of control variables such as the implied volatility of S&P 500 index options (VIX), which track the level of global risk sentiment, and implied volatility of FX options (VOL), which control for the risk-neutral volatility of FX movements, and is robust to the use of different estimation techniques that correct for possible bias emanating from endogeneity and serial correlation. Through this channel, we argue that, in a world of CIP violations, the long-run impact of monetary fundamentals on cross-currency basis swap spreads is not the same across countries and so policies aimed at shrinking CIP deviations are likely to be heterogeneous in the long run. As CIP deviations imply the existence of arbitrage opportunities, our results suggest that arbitrage opportunities can be suppressed or become negligible with an appropriate policy on money supply and real output growth. We also conduct an error-correction analysis which suggests that the mechanism governing the adjustment to equilibrium is not the same for European and non-European currencies. More generally, we document that, when there is a move away from equilibrium, it is mostly the cross-currency basis swap spreads, rather than the macroeconomic variables, that adjust to ensure a return to equilibrium, across all maturities and samples.

Going back to our theoretical framework, our empirical results only partially agree with the a priori expectations from the simple theoretical models. First, the evidence that CIP deviations tighten when foreign central banks increase their liabilities via a rise in relative money supply, partially agrees with the theoretical framework built on the back of the Frenkel (1976) and Bilson (1978) monetary models. Second, the finding that an increase in relative real output tightens the cross-currency basis is partly in line with the postulate of the framework based on Frankel (1979). Overall, the linkages between macroeconomic fundamentals and CIP deviations point to the role that money supply management and activities in the real economy plays in the evolution of cross-currency basis swap spreads in a world of CIP deviations. Our simple model of cross-currency swap spread determination not only provides a theoretical underpinning for understanding the drivers of cross-currency swap spreads, but also helps to formally establish an empirical connection between CIP deviations and macroeconomic fundamentals – especially in a way that connects CIP deviations to the real economy – and this helps to show that not only are CIP deviations sensitive to vagaries in the financial markets, they also respond to shocks in the real economy.

Our paper contributes to the literature by extending the drivers of cross-currency basis swap spreads to include macroeconomic fundamentals. The main contribution of our paper is to highlight and then establish a previously overlooked connection between monetary fundamentals and CIP deviations, to examine the empirical plausibility of this connection and to investigate how the connections might change for European versus non-European currencies. Our paper investigates the long-run links between macroeconomic fundamentals and CIP deviations through the lens of the monetary models, particularly connecting monetary fundamentals to CIP deviations in a theoretical framework and testing the empirical implications of the model. To the best of our knowledge, it provides fresh perspectives in ways that have not previously been explored.

Two natural questions emerge from our main empirical findings. First, why do CIP deviations tighten for non-European currencies when relative real output levels increase. Second, why do they tighten for European currencies even after a rise in relative money supply?

For the first question, there are several mechanisms through which a rise in relative real output tightens cross-currency basis swaps. On the one hand, it is well known that an acceleration in real output drives capital inflows. As such, an improvement in relative real output is a catalyst for improved capital flows and enhanced financial market performance as output growth improves returns on the assets of countries experiencing the real output acceleration, which in turn further attract capital flows to these countries – particularly banking and portfolio flows, Koepke (2015). This rise in capital flows invariably increases supply of hedging activities, consequently tightening the cross-currency basis swaps associated with the currencies of countries experiencing the higher relative real output. So, an increase in relative real output affects the cross-currency basis swaps via the capital-flows channels: increased capital inflows drive demand for local currency assets, which stimulate the financial markets, increases supply of hedging activities and shrinks the CIP deviations. Moreover, a rise in relative real output often drives corporate profits and lowers the credit risks of corporates, which makes it increasingly more feasible for corporates to directly access dollars at favourable rates rather than rely on synthetic dollars which involves the use of the swap markets. Ultimately, the lower dependence on synthetic dollars reduces deviations from CIP.

In another way, the positive link between relative real output and CIP deviations for non-European currencies can work according to the following mechanism: when the real output accelerates, this necessitates a tight policy response from central banks in order to rein in possible inflation, causing yields to increase in line with interest rate, and credit spreads tighten. The rise in yields means it becomes more expensive for non-European entities to raise funds or issue domestically. Perhaps it is relatively cheaper to issue in the Yankee bond market given the relatively lower interest rate in the US (on the back of a relatively slower growth in real output). Thus, the foreign (non-European) entities issue Yankee bonds in the US. Given the benign macro backdrop in the non-European countries, American investors become eager to purchase the Yankee bonds as a way of gaining entrance into these countries/markets with favourable relative output. Thus, they lend willingly to these non-European entities. The dollars raised by the foreign entities from issuance of Yankee bonds in the US are then swapped into their respective currencies, tightening their cross-currency basis swap spreads and hence reducing the CIP deviations.

Turning to the second question, the somewhat puzzling evidence of a positive long-run link between relative money supply and cross-currency basis swap spreads suggests that only a small portion of the rise in money supply finds its way to the US for investment in dollar assets. This in turn reduces the demand of European entities for hedging activities.

One plausible explanation for such reduced flow is that a significant portion of the increased money supply is consumed or saved in Europe, with less left for investment in assets outside the shores of Europe. We interpret this evidence to mean that in the long run an increase in money supply in Europe will not necessarily increase the demand for hedging activities by European entities or incentivize an increase in the issuance of reverse Yankee bonds in Europe by US or other non-European entities, to be asset swapped into the USD. The state of the US domestic monetary policy, for instance, might make it favorable to raise direct dollars domestically rather than issue a reverse Yankee bond in a European currency to asset swap into synthetic dollars.

1b. Related literature

We now provide reviews of the literature on CIP deviations that are most relevant to this paper, enabling us to present an overview of related studies that have investigated the drivers of cross-currency basis swaps spreads.

In the literature, the cross-currency basis is generally accepted as a variable that measures CIP deviations and determines the extent or size of arbitrage opportunities available in the market. As has been motivated in the introduction, it is the difference between the interest realized in the cash market and the swap market interest. To put it in context, it is the difference between the direct dollar interest rate obtained from the domestic cash market and the synthetic dollar interest rate obtained by swapping proceeds in foreign currency, realized from foreign investment, into the US dollars. This is called synthetic dollars. One reason for the existence of the CIP deviations is that agents such as financial intermediaries during and after the crisis have been constrained by tough, new and stringent regulations which have prevented them from supplying currency hedging that is required to arbitrage away the CIP deviations[1].

Generally, positive basis swap spreads are associated with higher direct dollar interest compared to the synthetic dollar interest rate; inversely, negative basis swap spreads imply the direct dollar interest is beneath the synthetic dollar interest. If CIP holds, these rates are isometric, and the basis swap spread is zero. Apart from providing negligible arbitrage opportunities, one major implication of a zero-basis swap spread is that the logarithmic difference between the forward rate and the spot rate, that is the forward point, roughly equates the difference in interest rates or interbank offered rates for a given pair of currencies across countries, a condition which was violated during the peak of the most recent financial crises.

Many previous studies in the literature prior to the recent global financial and European sovereign debt crisis document the validity of the CIP condition. Some of these studies include a direct examination of the CIP condition as in Frenkel and Levich (1975, 1977), Deardorff (1979), Dooley and Isard (1980), Callier (1981), Bahmani-

Oskooee and Das (1985), and Clinton (1988). The consensus of these studies is that, by and large, no significant deviations from the CIP condition existed in those years prior to the crises. Following the global financial crisis, a number of papers have reexamined the validity of the CIP condition during the crisis. Most of them document persistent deviations from CIP condition both during and after the global financial crisis and the European debt crisis (see, for example, Baba et.al (2008), Baba et.al (2009), Coffey et.al (2009), Griffolli and Ranaldo (2011), Bottazzi et al. (2012), and Ivashina et.al (2015)).

One view in the literature is that CIP deviations are a consequence of the financial crisis. Several attempts have been made to explain the cause of these deviations. Studies such as Baba and Packer (2009), Goldberg et al. (2011), McGuire and von Peter (2012) argue that the large CIP deviations during the crisis are linked to a severe dollar funding shortage. These studies also find that after reaching heightened level, the deviations lessened due to relevant steps taken such as the establishment of Fed swap lines with various foreign central banks – a move which eased dollar shortage, and significantly lessened cross-currency basis. However, the deviations have not eroded.

Du et.al (2018) investigate CIP deviations in the post-crisis era and find that risk-free arbitrage opportunities from CIP deviations are not a direct consequence of credit risk or transaction costs alone but are also driven by bank balance sheet costs and asymmetric monetary policy shocks. To unearth this evidence, they investigate CIP deviations on issues that are known to be free of credit risks and still find large deviations from CIP.

Du et.al (2018) show that CIP deviations, measured as Libor cross-currency bases, have persisted among the G10 currencies even after the crises, and remains large in magnitude. They also show that the persistence is not limited to Libor bases with inherent credit risk. Using Kreditanstalt fur Wiederaufbau (KfW) bonds and general collateral repurchase agreements (repo) contracts - both of which are either fully collateralized or fully government-backed and thus exhibit negligible credit risks - to construct KfW- and repo-based swap spreads for the G10 currencies, they show that CIP deviations exist even for these credit-risk-free issues. Particularly, repo and forward contracts highlight CIP deviations at the short end of the yield curves, while KfW bonds and swaps focus on longer maturities. This leads to persistent arbitrage opportunities - with zero conditional volatility and infinite Sharpe ratios - free from credit and exchange rate risks, unlike Libor-based CIP deviations which, though free from exchange rate risk, are not necessarily free from credit risk. Thus, they argue that the CIP deviations must be driven by other factors different from credit risk. These are the factors which they attribute to bank balance sheet costs and asymmetric monetary policy shocks.

Avdjiev et al. (2018) document a triangular relationship wherein a stronger dollar, represented as a rise in Federal Reserve Board broad dollar index, is associated with larger CIP deviations and contractions of cross border bank lending in dollars. Rime et.al (2017) examine the impact of money market segmentation on CIP deviations and show how persistent arbitrage profits arises as an equilibrium outcome due to market segmentation, abundance of excess reserves and their remuneration in central banks' deposit facilities. Kohler and Muller (2018) show that CIP deviations are much smaller when calculated based on cross-currency repo rates instead of standard interest rates such as OIS or LIBOR, a finding they attribute to the nearly identical risk characteristics of foreign exchange swaps and cross-currency repos. They also argue that CIP violations are due to the presence of relative funding liquidity risk, which arises because markets prefer holding US dollars over most other currencies. Sushko et al. (2016) show that net hedging demand of different national banking systems are consistent with cross-sectional variations in CIP deviations. Liao (2016), on the other hand, focuses on corporate issuance patterns and finds that CIP deviations are linked to strategic funding cost arbitrage across currencies.

As CIP deviations remain even after the crisis, we take as a given the existence of CIP deviations and we analyze the drivers of these deviations for major currencies. Our work focuses on extending the drivers of cross-currency bases or CIP deviations and is builds on the literature on the monetary models of exchange rate in that it relaxes the no arbitrage conditions implied by these models and uses the condition to derive a close form model that explicitly expresses CIP deviations as a function of macroeconomic factors such as relative money supply and relative real output. Thus, on the theory side, our work builds on the framework of conventional monetary models in international finance such as Dornbusch (1976), Frenkel (1976), Mussa (1976), Bilson (1978), and Frankel (1978). Perhaps closest to our paper on the empirical side are Baran and Witzan (2017), Du et al. (2018), and Avdjiev (2018) et.al. Baran and Witzany (2017) investigate the drivers of CIP deviations in the euro basis swaps and find that the most important drivers appear to be short- and medium-term EU financial sector credit risk indicators and, to a slightly lesser extent, short- and medium-term US financial sector credit risk indicators. Another important driver is market volatility for the short-end basis spread, and the EUR/USD exchange rate for the medium-term basis spread, and to a lesser extent, the Fed/ECB balance sheet ratio.

While these studies highlight observed market data in the fixed income market such as rates and volatility indices as the major drivers of the cross-currency basis swap spreads, our paper stresses fundamental macroeconomic variables covering the real economy and monetary management as plausible drivers of CIP deviations. We also control for other potential drivers of CIP deviations that have been found to correlate with the cross-currency swap spreads. Our analysis extends existing studies as we provide a fresh long-run perspective on the drivers of CIP deviations, and this allows us to isolate real economic drivers of the cross-currency basis swaps from other market-based drivers.

Overall, though the literature on deviations from CIP is generally still recent, most studies have focused on the characteristics of CIP deviations. However, they have not particularly examined the long-run links between CIP deviations and their macroeconomic drivers. Also, to our knowledge, it remains unexplored how the cross-currency basis swaps are linked to the performance of the real side of the economy. Our paper adds to the growing literature on CIP deviations by arguing that fundamental variables such as relative money supply and relative real output are relevant drivers of the deviations. We show that these fundamentals are important drivers of the basis and that the relative real output, a proxy for the performance of the real economy, is strong and robust in explaining CIP deviations for non-European currencies. Our paper builds on the monetary model of exchange rate determination. The main contribution of our paper is that we highlight a previously unknown connection between monetary fundamentals and CIP deviations, examine the empirical plausibility of this connection and investigate how a currency's association with European countries influences the link between the fundamentals and CIP deviations.

The rest of the paper is structured as follows. Section 2 presents the modelling framework and discusses the connection between the macroeconomic fundamentals and CIP deviations. Section 3 tests the empirical validity of the established relationship between macroeconomic fundamentals and CIP deviations. Section 4 separates European and non-European currencies and examines how this affects the relationship between macroeconomic fundamentals and CIP deviations. Section 5 analyzes error-correction models to gain insights into the mechanism of the adjustment process of the long-run equilibrium relations between cross-currency basis swap spreads and macroeconomic fundamentals. Section 6 concludes, with further pointers to plausible future research questions.

2. The Model

The model is a fusion of CIP deviations and the other assumptions of the monetary models of exchange rate determination. It incorporates CIP deviations into these monetary models. That is, it relaxes the assumption of no-CIP deviations normally imposed on the monetary model of exchange rates. This allows us to incorporate the existence of non-zero cross-currency basis swap spreads into the monetary model in a way that enables us to generate a simple and testable theoretical model that expresses CIP deviations in terms of the macroeconomic fundamentals that make up the monetary model of exchange rate determination.

Therefore, in constructing the simple model, we first present an exposition of CIP. Next, we discuss the implications of CIP deviations. Then we present a brief explanation of the standard monetary models of exchange rates determination. Finally, we link CIP deviations to the monetary models and we solve the resulting simple linear equation to express the CIP determinations in terms of the fundamentals of the monetary models, mainly relative money supply capturing the monetary side of the economy and relative real output which is a proxy for the real economy. In all cases, each country's fundamentals are relative to the US fundamentals, so the US fundamentals are taken as the numeriare or domestic variables while the fundamentals of the other countries are the foreign variables. This yields a model which we term that monetary model of CIP deviations. We discuss the theoretical implications of this model and test its empirical validity in the subsequent part.

A. Covered Interest Rate Parity (CIP)

Consider a collection of economies with relatively liquid currencies and developed financial markets. Suppose i_t and i_t^* represent domestic and foreign one-period riskless interest rates at time t, where, as it is understood, the domestic interest rate is that associated with the US dollars while the foreign interest rate is the interest rate associated with each of the other currencies. It is important to note that we make no assumption that i_t^* is the same for all currencies in this paper. It is for exposition that we first consider a representative foreign currency. Let S_t be the spot exchange rate of the representative foreign currency at time *t*. In our notation, S_t is expressed as the number of units of foreign currency per unit of the domestic currency being the US\$, so an increase in S_t is understood as an appreciation of the US\$ or a depreciation of the foreign currency. Suppose, also, that the one-period forward exchange accompanying the spot exchange rate at time *t* is F_t, where the forward rate is agreed at time *t,* to be implemented one-period later.

Given the above market variables, a profit maximizing, return-seeking investor with investible US dollars in hand has two possible investment strategies to choose from. For simplicity, suppose this investor has a cash of \$1. First, she can invest the \$1 at time t in the domestic fixed income market and generate a total amount (principal plus interest) of $\$1(1 + i_t)$. Alternatively, the investor might exchange her \$1 to a foreign currency at the spot exchange rate S_t, enter a swap contract agreement (to be exercised at the end of the investment horizon), and then invest the foreign currency in the foreign fixed income market paying i_t^*. At the end of the investment horizon, i.e. one period later, she swaps the total amount realized in the foreign currency back to the domestic currency (i.e. US dollars) at the forward rate F_t previously agreed at time *t*. At the spot exchange rate S_t, \$1 is equivalent to S_t in the foreign currency. Investing this sum in the foreign fixed income market yields a total amount of $S_t(1+i_t^*)$ in foreign currency one period later. Swapping back to the domestic currency (i.e. US\$) at the forward rate F_t previously agreed at time t yields $S_t(1+i_t^*)/F_t$ in US\$. This is called synthetic US dollars.

If CIP holds in these markets, then both investment strategies must generate the same total amount in US\$, so that the opportunity to arbitrage is negligible. In other words, if CIP holds, it must be true that

$$1(1+i_t) = S_t(1+i_t^*)/F_t$$

or, using the identity

$$(1+\delta) \cong e^{\delta}, \text{ for small values of } \delta \text{ in the interval } 0 < \delta < 1,$$

and taking logs, the above condenses to

$$f_t - s_t = i_t^* - i_t$$

So, if CIP holds, the forward premium point $(f_t - s_t)$ must be the same as the interest rate differentials $(i_t^* - i_t)$ between the two currencies, which means that the forward rate itself must be/is set to fully account for differences in interest rates between two currencies. This also suggests that there is no additional profit of loss that can be made from the transactions that has not been fully reflected in the forward rate when it was set. In order words, $(f_t - s_t) - (i_t^* - i_t) = 0$.

B. Deviations from CIP

In an ideal world of no arbitrage opportunity, any deviations from CIP which presents an opportunity to make a riskless profit is immediately arbitraged away, so that the forward rate reflects exactly the differential in interest rates when expressed in the same currency (that is the difference in interest rate on the direct dollars (cash market) and synthetic dollars (swap market)) – and nothing more or less. This is the classical no-arbitrage opportunity discussed in part A. However, since the global financial crisis, the world of financial markets has become less-than-ideal. CIP deviations have persisted and puzzlingly not been arbitraged away for most currencies. We now operate in a world where deviations from CIP are a given. Thus, taking these deviations as a given, this paper attempts to look at the fundamental drivers of the deviations in a world of arbitrage opportunities.

In a world of CIP deviations, the forward rate associated with each currency does not exactly reflect the differentials in interest rates. It reflects either more or less of the differences in interest rates and the above equality does not hold. That extra non-zero addition to the interest rate differential is the magnitude of deviation from the CIP condition which represents an additional spread recognized in the market as the cross-currency basis swap spread. The higher the spread, the higher the magnitude of CIP deviations, the more the CIP condition fails and the higher the arbitrage opportunities in the market. Put another way, if this spread were zero, CIP deviations would be zero; in such instance, CIP would hold fully, and arbitrage opportunities would be negligible.

When the cross-currency basis swap spread is very different from zero, this suggests that there are some deviations presenting additional gains or losses that are not fully captured by the forward rates. At any time, t, these gains or losses lead to an arbitrage opportunity in investing or funding and implies that the previous equality is no more feasible and deviations from CIP is no more zero. The implication is that $(f_t - s_t) - (i_t^* - i_t) \neq 0$, suggesting that there exists a variable x_t, the non-zero cross currency swap spreads, which must be added to the non-dollar leg of the above inequality, to achieve equality. Essentially, this implies

$$x_t = (f_t - s_t) - (i_t^* - i_t) \text{ for } x_t \neq 0.$$

This gives an expression for the cross-currency basis swap spreads which also can be used to estimate the extent of deviations from CIP. If $x_t < 0$, then $i_t^* > (f_t - s_t) + i_t$, i.e. foreign market investment is better than domestic. An arbitrageur can earn a guaranteed profit even if she has no access to investible dollars. She can borrow from the domestic direct dollar market and make arbitrage profits by converting the dollars to foreign currency, investing the foreign currency in the foreign market to earn the foreign risk-free rate, and swapping the total proceeds back to the domestic currency (US$) at an earlier agreed forward rate contract. The higher is the magnitude of x_t, the higher is the return that such arbitrage trade would generate. If $x_t > 0$, then $i_t > (s_t - f_t) + i_t^*$, i.e. direct investment in the domestic (dollar) market is better than investing in the foreign market. An arbitrageur can earn a guaranteed profit using a reverse strategy even if she has no access to investible dollars or investible foreign currency. To achieve this arbitrage profit, she can borrow foreign currency, convert it at the spot exchange rate to the US dollars, this gives synthetic US dollars. Invest the synthetic US dollars in the US domestic market, earn the dollar risk free rate and enter a forward contract to swap those dollars back to the foreign currency. The amount of arbitrage profit earned from this strategy also grows with an increase in the magnitude of x_t, the deviations from CIP.

Having established a compact expression for determining the extent of CIP deviations, we turn now to the main part of this section which is to briefly present the monetary model of exchange rate determination and synthesize CIP deviations into the model.

C. Monetary Models of Exchange Rate and CIP Deviations

There are different versions of the monetary model of exchange rate determination. But all of them have one thing in common – they assume zero CIP deviations. In this paper, we construct a simple model from existing monetary models to capture the non-zero deviations from CIP. This enables expressing cross-currency basis swap spreads in terms of relative money supply, relative real output levels and spot exchange rate. On the basis of the model, we perform a series of empirical analyses to examine the relation between monetary fundamentals and cross-currency basis swap spreads.

Standard money models, for example Dornbusch (1976), Frenkel (1976), Bilson (1978) and Frankel (1979), are based conventional stable money demand functions for domestic and foreign countries given by

$$m_t - p_t = \psi_1 i_t + \psi_2 y_t \tag{1.1}$$

$$m_t^* - p_t^* = \psi_1 i_t^* + \psi_2 y_t^* \tag{1.2}$$

where m_t, p_t, i_t, and y_t denote domestic money supply, price level, interest rate and output respectively, at time t, while asterisks denote foreign variables, where foreign means all other countries excluding the US (which is the domestic country), and ψ_1 and ψ_2 denote the interest rate semi-elasticity and income elasticity of money demand, respectively. Except for the interest rate, all other variables are expressed in logarithm.

The assumption on ψ_1 and ψ_2 is important because it is what distinguishes one variant of monetary models from another. While Frenkel (1976) and Bilson (1978) argue that ψ_1 should be negative, Dornbusch (1976) and Frankel (1979) show that ψ_1 should in fact be positive. Frankel (1979) argues that an increase in interest rate, for a given expected inflation rate, should attract capital inflows that raise demand for a country's currencies and assets. Frenkel (1976) and Bilson (1978) however argue that a rise in interest rates may not be enough to encourage investors to hold a country's currency or assets in a high inflation environment. Frankel (1979) shows that the assumption for which $\psi_1 > 0$ is more in line with normal asset market outcomes. Frenkel (1976) and Bilson (1978) contend that it is in fact $\psi_1 < 0$ that better characterizes the money market equilibrium. An example of this view occurred recently in Argentina, with an inflation rate of close to 35%. Even after the benchmark interest rates were raised several times, eventually reaching the highest level in the world at 60%, demand for Argentine assets or currency did not improve steadily.

Taking the difference between (1.1) and (1.2) yields

$$(m_t^* - m_t) - (p_t^* - p_t) = \psi_1(i_t^* - i_t) + \psi_2(y_t^* - y_t) \qquad (1.3)$$

Meanwhile, standard purchasing power parity implies that, if s_t represents the spot exchange rate measured in the number of units of foreign currency per unit of domestic currency (US$), then it follows that

$$s_t = p_t^* - p_t, \qquad (1.4)$$

where, as before, the lower-case letters denote log-levels. From (1.1) to (1.3), e_t becomes

$$s_t = (m_t^* - m_t) - \psi_1(i_t^* - i_t) - \psi_2(y_t^* - y_t) \qquad (1.5)$$

If CIP holds, then, following Gardeazabal and Regúlez (1992), we have $(f_t - s_t) = (i_t^* - i_t)$, and so $s_t = (m_t^* - m_t) - \psi_1(f_t - s_t) - \psi_2(y_t^* - y_t)$.

Now, because of CIP deviations, we know that $x_t = (f_t - s_t) - (i_t^* - i_t)$, for $x_t \neq 0$. Combining CIP deviations and the monetary model, we obtain a model linking monetary fundamentals to cross-currency basis swap spread, i.e.

$$x_t = \left(\frac{1}{\psi_1} - 1\right)s_t - \frac{1}{\psi_1}(m_t^* - m_t) + \frac{\psi_2}{\psi_1}(y_t^* - y_t) + f_t \qquad (1.6a)$$

This equation presents a simple theoretical framework that leads to testable implications for the long-run relation between cross-currency basis swap spreads and monetary fundamentals – relative money supply and relative real output.

Taking first derivates, we have

$$\frac{\partial x_t}{\partial s_t} = \left(\frac{1}{\psi_1} - 1\right) <> 0, \qquad \frac{\partial x_t}{\partial(m_t^* - m_t)} = -\frac{1}{\psi_1}, \qquad \frac{\partial x_t}{\partial(y_t^* - y_t)} = \frac{\psi_2}{\psi_1} \qquad (1.6b)$$

Before proceeding to the empirical strategy, we provide some stylized facts deduced from (1.6b). As the derivatives show, the relation between CIP deviations and monetary fundamentals depends on ψ_1.

If we go by Frankel (1979) parameter assumptions, where $\psi_1 > 0$, and $\psi_2 > 0$, then we have

$$\frac{\partial x_t}{\partial s_t} = \left(\frac{1}{\psi_1} - 1\right) <> 0, \qquad \frac{\partial x_t}{\partial(m_t^* - m_t)} = -\frac{1}{\psi_1} < 0, \qquad \frac{\partial x_t}{\partial(y_t^* - y_t)} = \frac{\psi_2}{\psi_1} > 0, \qquad (1.7a)$$

implying that an increase in relative money supply would widen CIP deviations, increase in relative real out would tighten the deviations and currency depreciation would either widen or tighten the cross-currency basis swaps, depending on whether $\psi_1 > 1$ or $0 < \psi_1 < 1$.

According to Frenkel-Bilson assumptions, $\psi_1 < 0$, and $\psi_2 > 0$, suggesting that

$$\frac{\partial x_t}{\partial s_t} = \left(\frac{1}{\psi_1} - 1\right) < 0, \qquad \frac{\partial x_t}{\partial (m_t^* - m_t)} = -\frac{1}{\psi_1} > 0, \qquad \frac{\partial x_t}{\partial (y_t^* - y_t)} = \frac{\psi_2}{\psi_1} < 0, \qquad (1.7b)$$

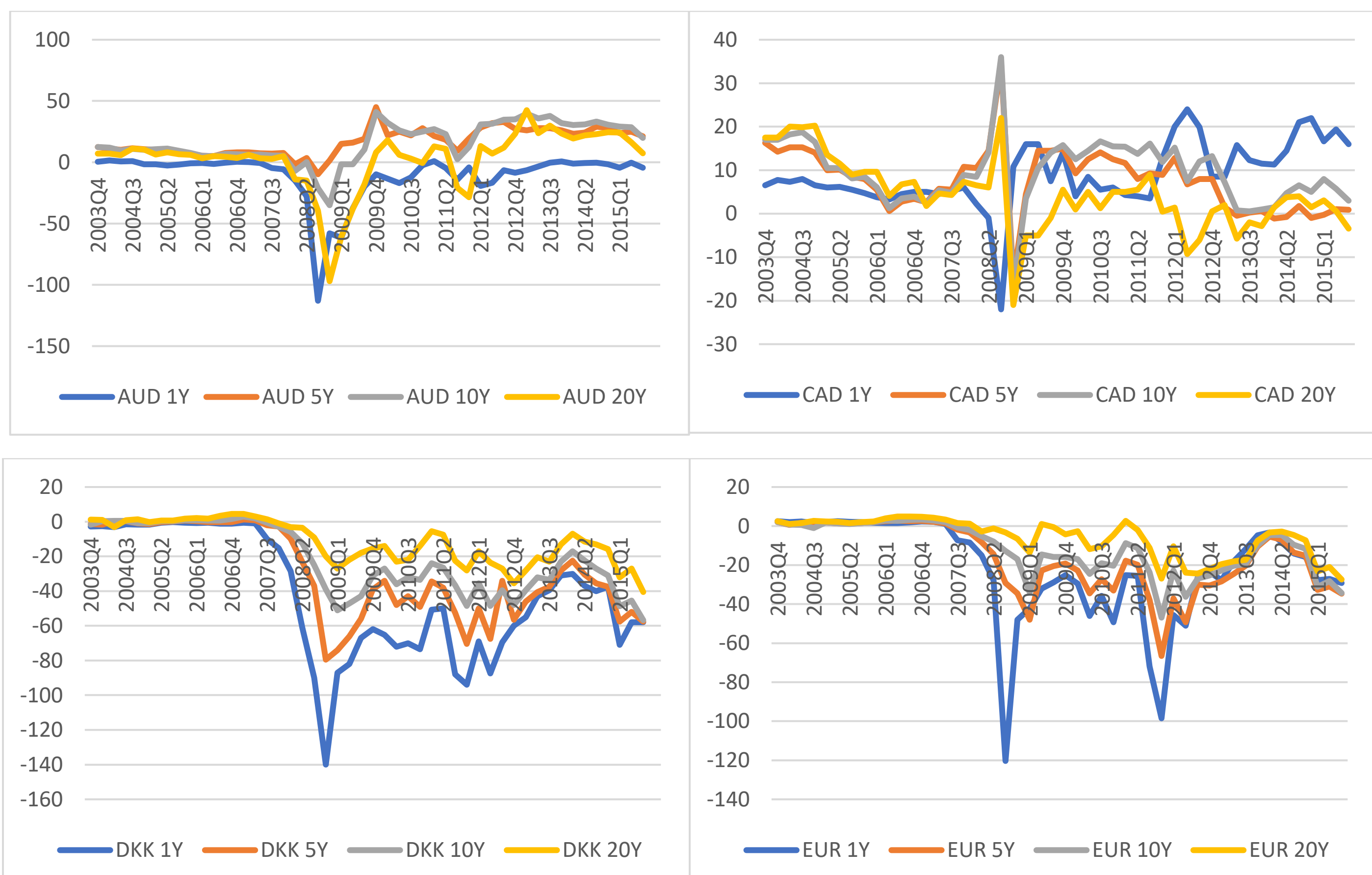
Thus, under this framework, we would expect currency depreciations to widen the cross-currency basis swap spread, an increase in relative money supply and a rise relative output to tighten and widen the cross-currency basis swap spreads respectively. These are the hypotheses that are tested empirically for the different currencies in the subsequent section.

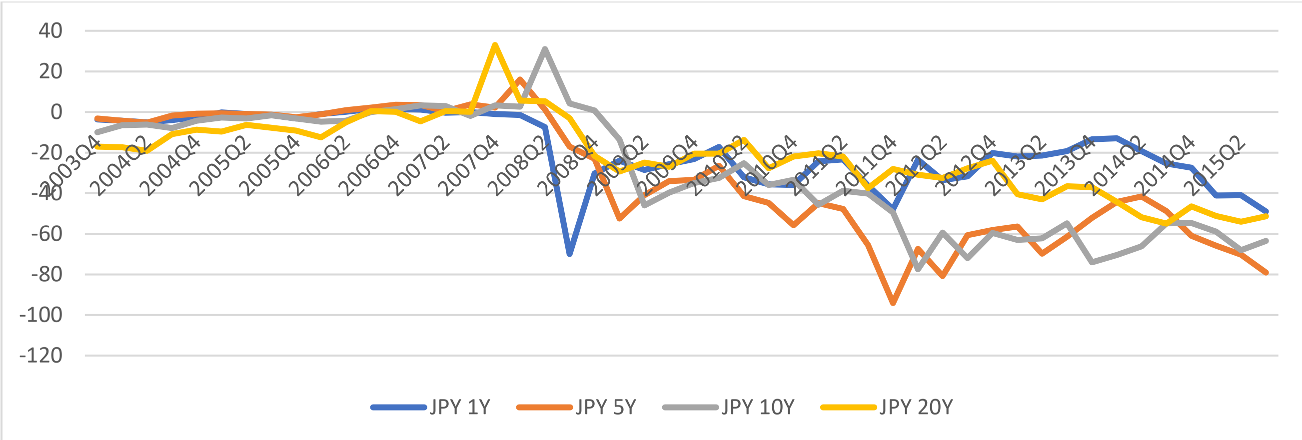
3. Data and Empirical Strategy

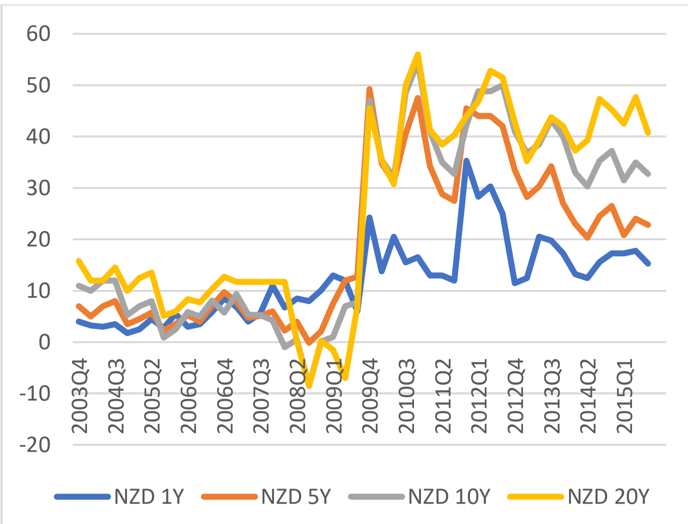
a. Data

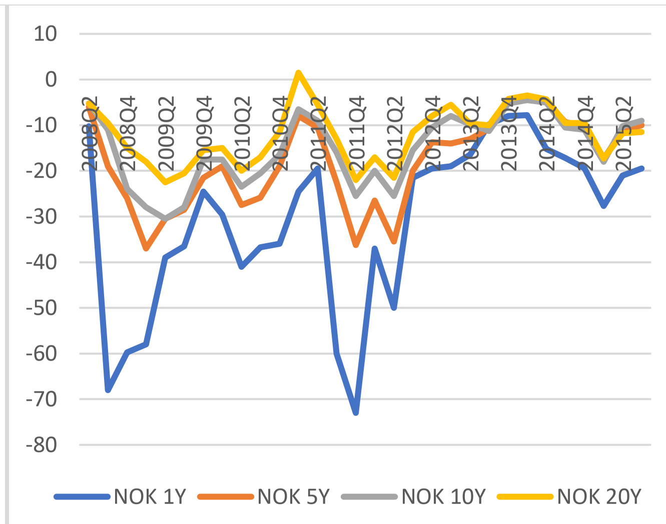
This section describes the data samples used in the empirical analysis, specifically the measures of CIP deviations at 1-, 5-, 10- and 20-year maturity, money supply, real output and nominal exchange rate. The data samples for the analysis are based on quarterly observations spanning 2008 to 2015 for 11 countries with liquid currencies. These are the G10 countries' currencies plus the Singapore dollar. Data samples are selected based on availability and are obtained from two major sources – Bloomberg and International Financial Statistics (IFS) of the International Monetary Fund. The real output and money supply data are from IFS while cross-currency swaps data come from Bloomberg. The cross-currency basis swap spreads measure the extent of CIP deviations and they enter our analysis in basis point levels. Real output enters our analysis as relative real output; the numeriare country is the US and the relative real output series, which is the ratio of country *i* real output to US real output enters the empirical analysis as the ratio of the foreign country real output to US real output, in logs. Money supply in our analysis is represented as broad money supply of each country *i* relative to US broad money supply, with the fraction expressed in logs, in line with the literature. The nominal exchange rate is also expressed in logs.

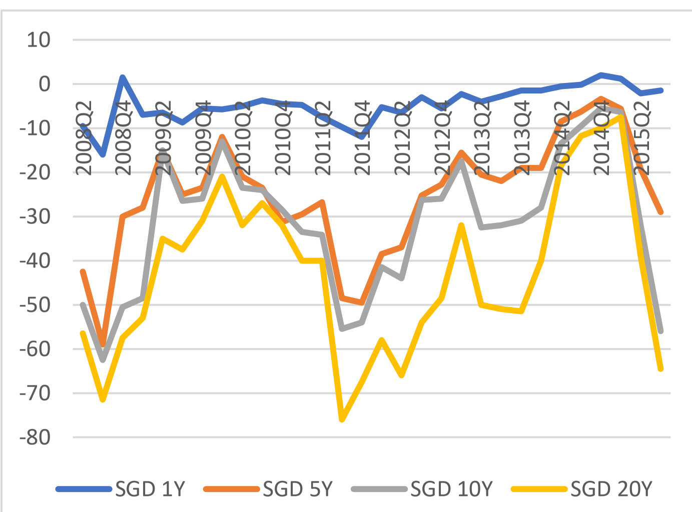
Fig.1: Evolution of Cross-Currency Basis Swap Spreads (CIP Deviations)

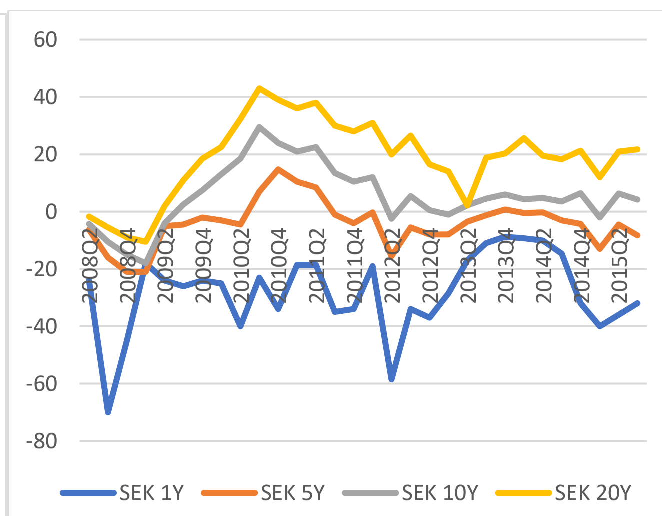


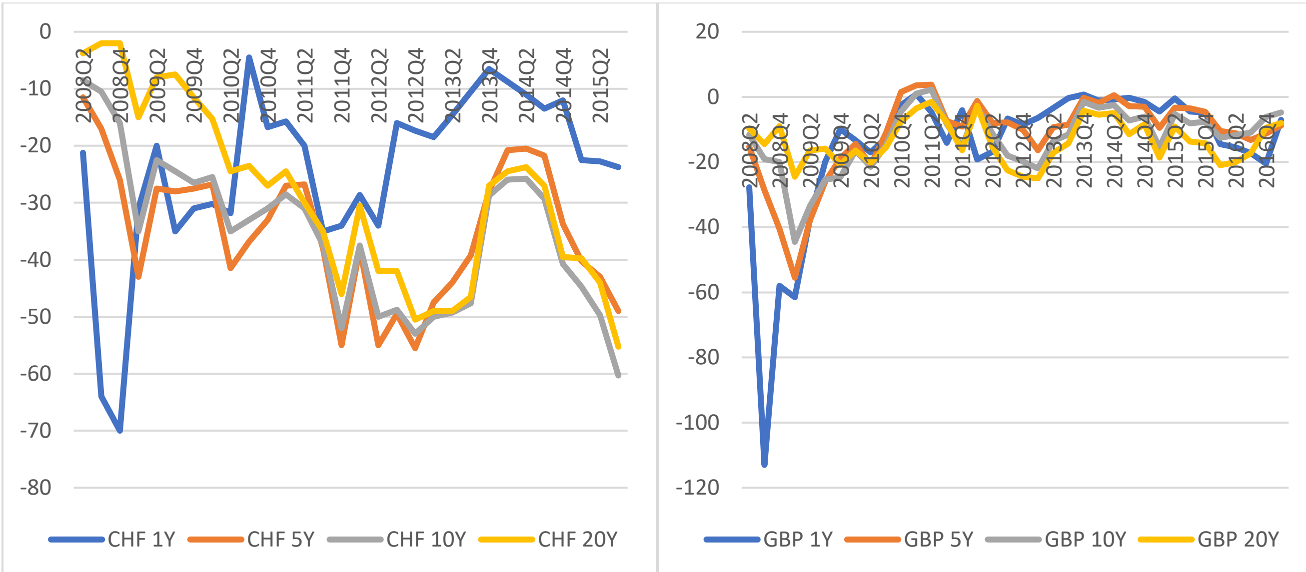

JPY 1Y
JPY 5Y
JPY 10Y
JPY 20Y


NZD 1Y
NZD 5Y
NZD 10Y
NZD 20Y


NOK 1Y
NOK 5Y
NOK 10Y
NOK 20Y


SGD 1Y
SGD 5Y
SGD 10Y
SGD 20Y


SEK 1Y
SEK 5Y
SEK 10Y
SEK 20Y



3.2 Empirical Analysis

In this section, we present the empirical procedure employed in the paper. We examine the empirical relation between the relative money supplies and the cross-currency basis swap spreads associated with the currencies represented in our analysis. After reporting some summary statistics of CIP deviations and monetary fundamentals, we examine the non-stationarity of the variables in levels and establish the existence of cointegration between monetary fundamentals and cross-currency basis swap spreads. We then show that a consistent positive long run relationship exists between the relative money supply and CIP deviations across all maturities considered – being 1Y, 5Y, 10Y and 20Y maturities. Next, we present evidence which enables us to argue that the long run relationship between the cross-currency basis and the real economy, represented as relative real output, as well as the dollar spot exchange rate is mixed and inconsistent. We perform a robustness check by including VIX and VOL as control variables among the regressions. Our results continue to support a strong and positive long-run relationship between the cross-currency basis and the relative money supply. We also check whether the long-run relationship between the cross-currency basis and the monetary fundamentals is similar for European currencies versus non-European countries. To achieve this, we generate two long panels – one containing monetary fundamentals and cross-currencies basis swaps associated with European currencies and another for non-European currencies. After estimating the long-run relation for these two panels, we show that the relative money supply is positively linked to the cross-currency basis swap for the European currencies while for the non-European currencies, we find that relative real output bears a positive long run relationship with the cross-currency basis.

3.3 Summary Statistics

Our empirical analysis is based on the following 11 liquid currencies which are: Australian, Canadian and New Zealand dollar, Japanese yen, Swiss franc, Danish krone, euro, British pound, Norwegian krone, and Swedish krona. The cross-currency basis is Libor-based defined as the difference between the direct US Libor and the dollar interest rate implied by swapping foreign currency into dollars. Data on cross-currency basis swaps of the 11 currencies vis-à-vis the US dollar, and nominal exchange rate are obtained from Bloomberg while data on relative money supply and relative real output come from the International Monetary Fund. Our sample frequency is quarterly and our sample period ranges from Q2 2008 to Q3 2015 chosen based on data availability. The quarterly frequency is used because this is the earliest time that data on economic variables such as real output are released. Table 1 below provides some descriptive statistics of the cross-currency basis swap spreads at different maturities.

Table 1: Mean and standard deviations of the cross-currency basis

	$\mathbf{1}Yx$		$\mathbf{5}Yx$		$\mathbf{10}Yx$		$\mathbf{20}Yx$	
Currency	Mean	Std	Mean	Std	Mean	Std	Mean	Std
AUD	-15.62	23.81	21.93	10.17	21.47	17.87	1.75	29.54
CAD	11.04	8.75	6.89	8.52	9.48	8.64	0.76	6.94
DKK	-64.61	22.71	-46.58	14.70	-35.33	10.72	-19.53	8.83
EUR	-34.68	24.96	-27.26	12.85	-19.89	9.92	-10.90	9.05
JPY	-28.79	12.33	-51.29	19.71	-45.31	24.74	-31.31	14.43
NZD	16.51	6.59	27.43	13.30	31.96	16.65	34.22	18.79
NOK	-30.85	18.02	-18.07	9.67	-15.11	7.66	-12.12	6.14
SGD	-4.60	3.98	-25.22	12.96	-31.56	15.37	-42.66	18.12
SEK	-28.23	13.76	-4.08	8.00	5.52	10.71	18.74	13.76
CHF	-24.02	14.48	-35.04	11.64	-35.28	12.93	-28.86	15.49
GBP	-15.62	23.81	-12.06	13.67	-13.51	10.27	-13.25	6.75

Note: Mean and standard deviation of basis swap spreads (in basis points)

Except for NZD, CAD and AUD, the mean cross-currency basis is negative for most of the currencies in our sample. For the negative basis, the average 1Y basis ranges from -64.61 for Danish krone to 4.60 is positive for Singapore dollar. For the 5Y basis, the range is from -51.29 for Japanese yen to -4.08 for Swedish krone while for the 10Y and 20Y basis, the range is from -41.31 for Japanese yen to -13.51 for British pound and -42.66 for Singapore dollar to -10.90 for Eurozone euro respectively.

3.4 Relative money supply and the cross-currency basis

We focus on the long-run relation between cross-currency basis swap spreads and the monetary fundamentals in a panel framework. We first study the nonstationarity of the variables, then we test for existence of some long-run cointegration using both Pedroni method and Kunsder which corrects for any presence of cross-sectional dependence and thus improves the power of the cointegration test. We show that a cointegrated relation exists among the components of the vector $[x_{it}, (m^*_{it} - m_t), (y^*_{it} - y_t), s_{it}]$. After establishing that variables are cointegrated, we estimate the coefficients of the associated variables using different estimators; the panel dynamic ordinary least squares (PDOLS) and panel fully modified ordinary least squares (PFMOLS) are most appropriate for estimating cointegrated panels. By estimating the cointegration equation, we are able to uncover the long-run relation among these variables.

Based on equation (1.8a), we estimate the following regression equation for the long relation between monetary fundamentals and cross-currency basis swap spreads[2]

$$x_{it} = \alpha_i + \beta_1 s_{it} + \beta_2 (m^*_{it} - m_t) + \beta_3 (y^*_{it} - y_t) + \varepsilon_{it} \quad (1.8)$$

where x_{it} is the cross-currency basis swap spreads at different maturities: 1-, 5-, 10- and 20- year maturity, s_{it} is the bilateral nominal exchange rate, $(m^*_{it} - m_{it})$ and $(y^*_{it} - y_t)$ are the relative money supply and relative real output of country i relative to the US, and ε_{it} is the error term. Before estimating, the above long-run relation, we first present the panel nonstationarity and cointegration results.

A. Panel unit root test

For the panel of 11 currencies presented, we need to examine the nonstationarity of each variable and this involves investigating the integration properties of the cross-currency basis, x_{it}, at all of the maturities as well as the relative money supply, $(m^*_{it} - m_{it})$, relative real output, $(y^*_{it} - y_t)$, and nominal exchange rate, s_{it}, respectively. If variables are integrated of the first order, then we proceed and investigate the cointegrating relationships which could exist among them. The integration property is a necessary condition for long-run relationships and must be established before cointegration tests are performed. In this section, we report results for two different panel-based unit root tests which are Levin, Lin, and Chu - LLC (2002) and Im, Pesaran and

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[2] We exclude the forward rate from the regression specification as we are more interested in realized values of macroeconomic variables, not market's projections based on contractual agreements, although it would be interesting to examine how forward rate contracts influence the basis. Shinada (2005) show that the effect of forward exchange rate is relatively small and does not have much influence on the basis.

Shin - IPS (2003). Combining LLC (2002) and IPS (2003) provides a sound premise on which to draw conclusions nature of integration of each variable. Results obtained using both panel unit root tests of Levin, Lin and Chu (2002) and Im, Pesaran and Shin (2003) for each set of panels are reported below

Table 2: LLC and IPS panel unit root tests

Variable	LLC (2002)	IPS (2003)	
$1Y\ x$	-6.91***	-7.73***	I(0)
$5Y\ x$	0.62	-1.62*	I(1)
$10Y\ x$	-0.51	-1.81*	1(1)
$20Y\ x$	0.05	-2.24**	I(1)
m	1.16	0.64	I(1)
y	-0.46	0.11	I(1)
s	-1.21	0.58	I(1)

Note: *, ** and *** indicate significant at 10%, 5% and 1% level respectively

To objectively determine the order of integration of the variables - that is whether variables are I(0) or I(1) - we adopt the following criteria: If both LLC and IPS tests reject the null hypothesis of nonstationarity at the 5% level of statistical significance or better, then we would conclude that the variable is I(0), otherwise it is I(1). Table 2 shows that both tests reject the null hypothesis of nonstationarity at the 1% level for the 1-year maturity basis, which makes it I(0). For the rest variables, in general, either one or none of the tests rejects the null of nonstationarity at conventional levels of significance. Therefore, we conclude that these variables are I(1); they have a unit root and their first difference is I(0). In the subsequent analysis, we drop the 1-year basis since we have established an overwhelming evidence of stationarity and the procedure we adopt for cointegration analysis requires that variables be unit root integrated as a precondition for cointegration, a condition which the 1-year basis fails to meet.

B. Cointegration Test

We examine whether the cross-currency basis swap spreads are cointegrated with the monetary fundamentals. If they are, then some long-run relationship exists between these swap spreads and the monetary fundamentals. To determine test for the existence of cointegration, we employ both Pedroni method and Westerlund panel cointegration tests. Both methods test the null hypothesis of no cointegration against the alternative hypothesis of cointegration in panels with multiple regressors and have the advantage of incorporating the effect of possible heterogeneity. More importantly, Westerlund panel cointegration test corrects for the presence of cross-sectional dependence and thus improves the power of the cointegration test. Table 3 reports our panel cointegration test results.

Table 3: Pedroni and Westerlund panel cointegration tests

	Pedroni Panel Cointegration Test	Westerlund Panel Cointegration Test
$[5Y\ x, m, y, s]$	-3.44***	-1.40*
$[10Y\ x, m, y, s]$	-3.21***	-1.62**
$[20Y\ x, m, y, s]$	-4.09***	-1.75**

Note: *, ** and *** indicate significant at 10%, 5% and 1% level respectively

We see from the results that there is an overwhelming evidence of cointegration. For both tests, the test statistics allow us to reject the null hypothesis of no cointegration in favor of the alternative of cointegration mostly at the 5 percent level or better. For the Pedroni test, most of the rejections occur at the 1 percent level while for the Westerlund test, which corrects for possible cross-section dependence, the rejections mostly occur at the 5% level. Overall, there is a substantial evidence of cointegration among cross-currency basis swap spreads, relative money supply, relative real output and nominal exchange rate at most maturities. This leads to the conclusion that, based on the panel framework, movements in cross-currency basis swaps for the 11 currencies are cointegrated with monetary fundamentals, so that there exists some long-run relationship between cross-currency basis swaps and monetary fundamentals. As such, our model could be appropriate to explain long-run movements in CIP deviations. Having established the existence of cointegration relationships, we next present panel estimates of the cointegrating coefficients.

C. Empirical estimation

The panel test results from the preceding section establish the existence of cointegrating relationships between cross-currency basis swap spreads and monetary fundamentals. This ensures we can estimate the coefficients of the cointegrating vectors without the risk of obtaining spurious long-run association that is often the case when levels relationships are estimated when variables are not cointegrated. The evidence that variables are cointegrated implies there exists an equilibrium relationship which keeps the variables in proportion to one another in the long run. This is noteworthy because estimating coefficients of vectors that are not necessarily cointegrated, or that are integrated of different orders, using an inappropriate estimation technique, might generate weak results or even weaken the reliability of results.

In this section, we employ different estimation methods to estimate the coefficients. The estimated coefficients will be compared across the different estimators for robustness and, most importantly, compared with the theoretical predictions of the monetary model to check for the empirical strength of our results. However, much emphasis will be placed on the estimators that are most suitable for estimating cointegrating relations. These estimators are PDOLS and PFMOLS. As a preliminary exercise, we first perform a pooled ordinary least squares (POLS) and bias-adjusted least squares (LSDV) estimation. POLS is a super consistent estimator of the coefficients of cointegrated variables, but its standard errors are biased and unsuitable for inferences in the presence of serial correlation and endogeneity. Thus, our main estimation of the cointegrating vector is based on the PDOLS and PFMOLS techniques. These methods are most suitable for cointegrated variables within the framework of panel data and have several advantages. First, they overcome issues associated with endogeneity and serial correlation. Second, they produce estimates that are asymptotically efficient and have appropriate covariance matrices for inferences. Third, they uncover long run relationships when variables are cointegrated as they provide optimal estimates of cointegrating regressions. The results of these estimators are shown below –

Table 4: Empirical results: long run effects of relatively money supply, relative real output and exchange rate on cross-currency basis swap spreads

	Pooled OLS				Bias-adjusted LSDV			PDOLS				PFMOLS			
	m	y	s	R^2	m	y	s	m	y	s	R^2	m	y	s	R^2
5Y x	1.44***	-0.58	-27.01***	0.19	0.58**	-0.83	14.91	1.41**	-12.71	69.43*	0.90	1.28***	15.69	49.93*	0.81
	(4.32)	(-1.28)	(-13.17)		(2.08)	(-0.09)	(1.13)	(2.09)	(-0.49)	(1.85)		(2.63)	(0.84)	(1.83)	
10Y x	1.50***	-1.01**	-22.54***	0.14	0.74***	6.82	5.75	1.39**	11.37	6.52	0.91	1.42***	64.89***	21.29	0.80
	(4.36)	(-2.15)	(-10.60)		(2.72)	(0.71)	(0.44)	(2.10)	(0.45)	(0.17)		(2.73)	(3.24)	(0.73)	
20Y x	0.78**	-0.31***	-12.41***	-0.01	0.68**	9.26	6.91	1.02	40.25	-101.92**	0.86	1.06*	78.95***	-42.48	0.71
	(2.21)	(-18.19)	(-5.78)		(2.33)	(0.91)	(0.47)	(1.38)	(1.44)	(-2.47)		(1.73)	(3.34)	(-1.23)	

Note: Number of observations is 330 (11 currencies × 30 quarters). Estimation by PDOLS uses 1 lead and 1 lag; *, ** and *** indicate significant at 10%, 5% and 1% level respectively

We now examine the relationship between the monetary fundamentals and the cross-currency basis. The results of the panel regressions based on the specification in equation (1.10a) are presented in table 1 above for the cross-currency basis swap spreads at the different 5Y, 10Y and 20Y maturities. The first column reports regressions estimated using the POLS, second column uses LSDV, while the third and fourth columns display results estimated using the PDOLS and PFMOLS respectively. In the PDOLS, all regressions are PDOLS (-1,1) specifications. At almost all maturities of the dependent variable, the most consistent result is the relationship between the cross-currency basis swap spreads and relative money supply.

The result shows that the cross-currency basis swaps are positively related with relative money supply across all maturities and estimators. This relationship is especially significant for the 5Y maturity across all the estimators utilized. Among our preferred estimators - PDOLS and PFMOLS - the instance when this positive relation is not significant is at the 20Y maturity for PDOLS. Even in this instance, the estimated coefficients are still positive.

The coefficient estimate on relative money supply is positive and significant across most estimators, suggesting that a rise in relative money supply is associated with a tighter, less negative, cross-currency basis, and, hence, smaller CIP deviations. Regarding the magnitude of the positive impact, the coefficient estimate on relative money supply for our preferred long-run estimators implies that a one unit rise in relative money supply is linked with a 1.28 – 1.42 unit increase in or tightening of the cross-currency basis. The positive relation suggests that an increase in broad money supply in country *i* relative to the US does not widen the cross-currency basis swap spreads. Instead, it is associated with a tightening of the cross-currency basis swap spreads at most of the maturities.

The insight from this result deserves a further explanation. A possible explanation for this rather unexpected outcome is as follows – when money supply increases in a country, this encourages either consumption spending or saving for investment. If much of the increase in money supply find its way into domestic consumption or domestic investment, then it is reasonable to opine that the rise in money supply would have very little effect on the corresponding country's swap market. If, however, agents in that country do not increase domestic consumption or domestic investment but instead decide to invest a significant fraction of that increase in money supply in a dollar denominated asset, perhaps due to a search for higher returns or safe heaven assets, then they would approach the swap market as their demand for dollar hedging activities increases. This can potentially widen the cross-currency basis swap spreads when a significant amount of the increase in money supply goes into this transaction. Also, an increase in money supply in country i can give rise to the issuance of reverse Yankee bonds in that currency and in that country. If this issuance increases and agents in that country purchase the issued reverse Yankee bond, then the cross-currency basis swap spread can widen as the proceeds raising from issuing the reverse Yankee bond can be asset swapped into the US dollar, widening the basis swap spreads associated with that currency. Given that for the country under study, an increase in relative money supply does not widen the basis swap spreads, in fact tightens it, it is safe to say that in the period under study and for most of the countries under study, much of the increase in money supply is absorbed via domestic consumption or saving for investment, limiting the currency that finds its way to the swap market to be asset swapped and hence preventing the widening of the cross-currency basis. Overall, for the different estimators utilised, the estimated coefficients for relative money supply is positive, and in most instances significant. This feature is robust to the different estimation techniques employed and is the strongest at the 5Y and 10Y maturities.

Turning to relative real output, we note that no particularly strong consensus can be drawn as results are largely mixed, inconsistent and or insignificant. Look at our preferred long run estimators – PDOLS and PFMOLS. For the 5Y, 10Y and 20Y maturities, the long-run relation is mixed and/or not significant. When the long-run relation is estimated with the FMOLS at the 10Y and 20Y maturities, we find some significance. However, since our conclusion on the long-run relation is based on the combined outcome of all estimators, especially both PDOLS and FMOLS, we take the seemingly positive and significant relationship from FMOLS with a grain of salt, as the relation is completely different in direction when compared to estimates from pooled OLS. Thus, the result appears mixed and this allows us to conclude that the evidence of a significant and consistent long run relation between relative real output and the cross-currency basis is rather weak for the full sample.

Moving now to the spot exchange rate, the spot exchange rate shows the same phenomenon of a mixed long-run impact on cross-currency basis swap spreads. In some instances, it shows a negative long run relation while in others, it shows a positive or insignificant long run relation with the cross-currency basis and this is true across all the 4 maturities considered. The mixed and insignificant effect of bilateral exchange rate on CIP deviations suggests that in the long run currency hedging demand due to idiosyncratic fluctuations in currency against the dollar may either not significantly drive cross-currency basis or drives cross-currency basis differently across currencies.

Overall, two major stylized features of the data emerge clearly from these regressions: First, there is a positive and mostly significant long-run relation between the relative money supply and CIP deviations for the full sample, providing some support that it is possible for an increase in relative money supply to not widen the cross-currency basis swaps associated with the currencies; it fact, it can tighten it, although our estimated coefficients suggest that the tightening may only be marginal. Second, the long run impact of spot exchange and relative real output on the cross-currency basis for the whole sample is either mixed or insignificant. This insignificance between bilateral spot exchange rate and CIP deviations is isometric to the findings of Avdjiev et.al (2018). Summarily, the postulate of our simple theoretical model – that an increase in relative money supply can in fact tighten the basis, has some empirical support in the *full sample* only in the case of relative money supply. For the other variables, the evidence is largely mixed.

D. Robustness Checks

As a robustness check of our results for the full sample, we control for other potential drivers of the cross-currency basis and we include as regressors the CBOE implied volatility of S&P 500 index options (*VIX*) and the implied volatility of FX options (*VOL*), in line with Avdjie et al. (2018) who posits that VIX tracks the level in global risk sentiment while VOL the risk-neutral volatility of FX movements. This gives rise to a new benchmark regression specification -

$$x_{it} = \alpha_i + \beta_1 s_{it} + \beta_2(m_{it}^* - m_t) + \beta_3(y_{it}^* - y_t\ ) + \beta_4 VIX_t + \beta_5 VOL_t + \varepsilon_{it} \tag{1.9}$$

The results of estimating the above regression specification is shown below.

Table 5: Controlling for other potential drivers of the basis

	Pooled OLS						Bias-adjusted LSDV				
	m	y	s	VIX	VOL	R^2	m	y	s	VIX	VOL
5Y Basis	1.10***	-4.29***	-15.2***	-0.11	-1.62***	0.29	0.54*	19.9*	35.96***	-0.41***	-0.02
	(3.49)	(-6.19)	(-5.88)	-0.42	(-2.70)		(1.85)	(1.86)	(2.62)	(-3.47)	(-0.05)
10Y Basis	1.22***	-4.19***	-12.4***	-0.05	-1.47**	0.22	0.69**	22.77**	19.85	-0.34***	0.10
	(3.64)	(-5.71)	(-4.52)	-0.2	(-2.30)		(2.36)	(2.05)	(1.38)	(-2.89)	(0.29)
20Y Basis	0.42	-3.88***	-0.39	-0.17	-1.53	0.19	0.60**	33.12***	19.98	-0.38***	0.15
	(1.29)	(-5.35)	(-0.14)	-0.63	(-2.43)		(2.10)	(3.18)	(1.43)	(-3.39)	(0.44)

	PDOLS						PFMOLS					
	m	y	s	VIX	VOL	R^2	m	y	s	VIX	VOL	R^2
5Y Basis	1.42*	27.85	99.05**	-0.56	0.07	0.94	1.19***	39.18**	81.7***	-0.32*	-0.65	0.84
	(1.92)	(0.87)	(2.09)	(-0.72)	(0.03)		(2.68)	(2.22)	(3.20)	(-1.76)	(-1.28)	
10Y Basis	1.37**	11.85	-6.66	-1.02	1.72	0.95	1.33***	85.08***	46.22*	-0.39*	-0.23	0.81
	(2.00)	(0.40)	(-0.15)	(-1.35)	(0.93)		(2.71)	(4.67)	(1.63)	(-1.94)	(-0.41)	
20Y Basis	1.16	24.24	-88.22*	-1.62*	3.53	0.92	0.96*	101.76***	-15.01	-14.98	-0.01	0.74
	(1.42)	(0.68)	(-1.67)	(-1.79)	(1.59)		(1.65)	(4.37)	(-0.44)	(-0.44)	(-0.02)	

Note: Number of observations is 330 (11 currencies × 30 quarters). Estimation by PDOLS uses 1 lead and 1 lag; *, ** and *** indicate significant at 10%, 5% and 1% level respectively

The positive effect of the relative money supply remains mostly significant. Also, spot exchange rate and relative real output both individually provide either insignificant or mixed results, suggesting continuing to reiterate our previous funding that their effects for the full sample are mixed.

In terms of control variables, the level of VIX impacts the CIP deviations negatively and mostly enter significantly in our regression specification. The implied volatility of FX options is sometimes negatively related with the cross-currency basis, but at other times the relationship is either positive or insignificant.

4. Panel Splits – European versus non-European currencies

The panel data regressions in the previous section impose an implicit assumption of cross-country homogeneity in our modelling of the drivers of the cross-currency basis swap spreads. In this section, we ask whether the finding obtained so far fully characterizes the bases represented in our analysis. In other words, with regard the long-run impact of the variables on the cross-currency basis swap spreads, we ask if European currencies are the same or different from non-European currencies. In answering these questions, we run panel regressions for country subpanels, where the sample is split into two panels – panel A comprising European currencies and panel B made up of non-European currencies. To conserve space, we report results from the FMOLS and PDOLS which are the most suitable for cointegrated variables. The results are shown below.

The results show some interesting outcome. First, in panel A, there is a strong consensus that relative money supply and the cross-currency basis are positively linked in the long run, as previously obtained in the prior section. Interestingly, for panel B, it is the relative real output that bears a consistently positive and significant relationship with the cross-currency basis. Thus, the response to cross-currency basis to movements in monetary fundamentals is different for European vs non-European currency. As a robustness test, we include the control variables into the panel regression for each of the two panels and we re-estimate the panel regressions. Our results continue to support the finding that relative money supply is positively linked to the cross-currency basis swap for European currencies while it is the relative real output that positively links with the cross-currency basis swap for the non-European currencies.

Table 6: Panel splits – European versus non-European currencies

	Europe								Non-Europe							
	PDOLS				PFMOLS				PDOLS				PFMOLS			
	m	y	s	R^2	m	y	s	R^2	m	y	s	R^2	m	y	s	R^2
5Y Basis	1.28**	-77.8**	34.21	0.67	1.17***	-58.72**	41.9	0.63	43.96**	75.16**	67.52*	0.90	11.86	77.93***	37.82	0.86
	(1.99)	(-2.29)	(0.45)		(2.62)	(-2.31)	(1.02)		(2.12)	(2.06)	(1.68)		(0.73)	(3.19)	(1.14)	
10Y Basis	1.28***	-44.20	11.42	0.84	1.29***	-8.92	32.85	0.68	63.61***	94.13**	2.79	0.89	35.66*	114.98***	7.53	0.82
	(2.45)	(-1.59)	(0.19)		(3.23)	(-0.39)	(0.89)		(2.67)	(2.26)	(0.06)		(1.81)	(3.87)	(0.18)	
20Y Basis	1.05*	25.49	32.15	0.76	1.07***	56.75**	48.01	0.71	38.03	104.65**	-147.47***	0.81	27.77	87.44**	-84.3	0.70
	(1.92)	(0.88)	(0.49)		(2.55)	(2.36)	(1.23)		(1.29)	(1.99)	(-2.55)		(1.07)	(2.24)	(-1.61)	

Note: Number of observations is 330 (11 currencies × 30 quarters). Estimation by PDOLS uses 1 lead and 1 lag; *, ** and *** indicate significant at 10%, 5% and 1% level respectively

For the non-European currencies, the positive link between relative money supply and cross-currency basis turns negative or insignificant while the relative real output, whose effect on the cross-currency basis is either mixed or insignificant for the European currencies, turns mostly significant and positive for the non-European currencies in panel B. This, in our view, can work according to the following mechanisms – when the real output of these countries accelerates, this would attract a policy response from their central banks in order to rein in possible inflation. Thus, yields increase in line with the increase in interest rate and credit spreads tighten. The rise in yields means that it has become more expensive for domestic entities to issue domestically, and perhaps relatively cheaper to access the Yankee bond market because of/given the relatively lower interest rates in the US (on the back of a relatively slower expansion in US real output). Thus, these foreign entities issue Yankee bonds in the US. American investors would be eager to purchase the Yankee bond as a way of gaining access/entry into these countries/markets that have been growing persistently. These dollars raised by these foreign entities from the issuance of Yankee bonds in the US is then asset swapped into their respective currencies, tightening their cross-currency basis swap spreads and hence reducing the CIP deviations.

On the other hand, the positive long-run relation between relative money supply and CIP deviations for European currencies seems to suggest that a rise in money supply in Europe does not induce the issuance of reverse Yankee bonds by US entities to be asset-swapped into the US dollars and widen the cross-currency basis swap spreads associated with these countries. A possible explanation is that the broad money supply in the US in the period makes it cost effective enough and adequate for US entities to raise dollars domestically without the need to approach the reverse Yankee bond market and the swap market.

5. Error-correction Models and Convergence to the Long Run

To gain insight into how the long-run equilibrium is restored between the cross-currency basis swap spreads and the macroeconomic fundamentals, we estimate successively the following multivariate error-correction models:

$$\Delta x_{it} = \gamma_0 + \sum_{k=1}^{p} \gamma_{1k}\, \Delta x_{it-k} + \sum_{k=1}^{p} \gamma_{2k}\, \Delta m_{it-k} + \sum_{k=1}^{p} \gamma_{3k}\, \Delta y_{it-k} + \sum_{k=1}^{p} \gamma_{4k}\, \Delta s_{it-k} + \omega_{\Delta x,z} z_{it-1} + \varepsilon_{1it} \quad (2.0)$$

$$\Delta m_{it} = \pi_0 + \sum_{k=1}^{p} \pi_{1k}\, \Delta x_{it-k} + \sum_{k=1}^{p} \pi_{2k}\, \Delta m_{it-k} + \sum_{k=1}^{p} \pi_{3k}\, \Delta y_{it-k} + \sum_{k=1}^{p} \pi_{4k}\, \Delta s_{it-k} + \omega_{\Delta m,z} z_{it-1} + \varepsilon_{2it} \quad (2.1)$$

$$\Delta y_{it} = \tau_0 + \sum_{k=1}^{p} \tau_{1k}\, \Delta x_{it-k} + \sum_{k=1}^{p} \tau_{2k}\, \Delta m_{it-k} + \sum_{k=1}^{p} \tau_{3k}\, \Delta y_{it-k} + \sum_{k=1}^{p} \tau_{4k}\, \Delta s_{it-k} + \omega_{\Delta y,z} z_{it-1} + \varepsilon_{3it} \quad (2.2)$$

$$\Delta s_{it} = \varphi_0 + \sum_{k=1}^{p} \varphi_{1k}\, \Delta x_{it-k} + \sum_{k=1}^{p} \varphi_{2k}\, \Delta m_{it-k} + \sum_{k=1}^{p} \varphi_{3k}\, \Delta y_{it-k} + \sum_{k=1}^{p} \varphi_{4k}\, \Delta s_{it-k} + \omega_{\Delta s,z} z_{it-1} + \varepsilon_{4it} \quad (2.3)$$

where z_{it-1} is the one-period lagged residual associated with the cointegrating vector $[x, m, y, s]$, and $m_{it} = (m^*_{it} - m_{it})$ and $y_{it} = (y^*_{it} - y_t)$ for notational convenience. Since the variables are cointegrated, the residual is, by implication, stationary. So, equations 2.0 through 2.3 are a set of multivariate regressions with stationary variables.

Meanwhile, it is important to note that equations 2.0 –2.3 are constructed in line with the Granger representation theorem, which requires that the residual from the cointegration equation can forecast changes in at least one of the four variables $[x, m, y, s]$. Accordingly, the coefficient of the lagged residua is expected to be significant and negative in at least one of the four equations.

Given that the variables are cointegrated, any deviation from the established long-run path (level) must adjust to ensure that the long-run relation is restored. For instance, at any given time, if the cross-currency basis swap spread is tighter (higher) than its long-run level implied by the macroeconomic fundamentals - so that the residual becomes positive - then either the cross-currency basis swap spread itself must fall (widen) or the other regressors, to which it is cointegrated, must undergo some adjustment, or both of these must happen, in order to ensure that the cross-currency basis swap spread is restored to its established long-run equilibrium level. Thus, investigating the error-correction mechanism provides insight into which variables endogenously adjust to ensure convergence to the long-run level and the speed at which this convergence occurs.

Table 7 below present the estimates of the error-correction coefficients that govern the adjustment to the long-run equilibrium. The estimates provide the dynamic impact of the error-correction term on changes in the variables that make up the cointegrated vector.

Table 7: Error-correction Model Coefficient Estimates

	$5Y\ x$	m	y	s
A. Full Sample				
ECM	-0.060***	0.010***	-0.010	-0.020
	(-2.840)	(3.230)	(-0.640)	(-0.590)
R^2	0.030	0.030	0.001	0.001
No of Obs.	330	330	330	330
B. Europe				
ECM	-0.140***	-0.030***	-0.001	0.004
	(-4.670)	(-3.540)	(-1.330)	(1.040)
R^2	0.100	0.070	0.010	0.010
No of Obs.	180	180	180	180
C. Non-Europe				
ECM	-0.100**	-0.001	0.000	0.000
	(-2.180)	(-0.240)	(-0.160)	(-0.500)
R^2	0.190	0.020	0.010	0.020
No of Obs.	150	150	150	150

	$10Y\ x$	m	y	s
A. Full Sample				
ECM	-0.083***	0.010**	-0.010	-0.002
	(-3.630)	(2.410)	(-0.820)	(-1.110)
R^2	0.040	0.020	0.002	0.002
No of Obs.	330	330	330	330
B. Europe				
ECM	-0.110***	-0.030***	-0.001	0.000
	(-3.960)	(-3.920)	(-1.230)	(1.190)
R^2	0.080	0.080	0.010	0.010
No of Obs.	180	180	180	180
C. Non-Europe				
ECM	-0.120***	-0.001	-0.001	-0.010
	(-3.010)	(-0.470)	(-0.440)	-0.770
R^2	0.060	0.003	0.002	0.004
No of Obs.	150	150	150	150

	$20Y\ x$	m	y	s
A. Full Sample				
ECM	-0.110***	0.010	0.000	0.000
	(-4.150)	(1.340)	(0.210)	(0.010)
R^2	0.100	0.100	0.020	0.030
No of Obs.	330	330	330	330
B. Europe				
ECM	-0.070***	-0.030***	-0.003	0.000
	(-3.170)	(-4.120)	(-0.540)	(0.980)
R^2	0.050	0.090	0.010	0.070
No of Obs.	180	180	180	180
C. Non-Europe				
ECM	-0.100***	-0.003	0.000	0.000
	(-2.450)	(-0.130)	(-0.010)	(-0.420)
R^2	0.040	0.001	0.000	0.001
No of Obs.	150	150	150	150

Note: $5Y\ x, 10Y\ x,\ 20Yx$ denote the cross-currency basis swaps at the 5, 10 and 20-year maturity. ECM is the speed of adjustment coefficient representing the estimated coefficient on the one-period lagged residual from the estimated cointegration equation linking the cointegrating vector $[\ x, m, y, s]$ normalized on *x*, the cross-currency basis, at the different maturities. Dependent variable is in first differences. Each regression also includes lag of the dependent variable, plus the contemporaneous first differences of the other regressors. t-statistics are in parentheses. ***, **, * denote significance at the 1%, 5%, and 10% levels, respectively.

Table 7 shows that for the full sample, as well as the split samples – European and non-European currencies – it is the cross-currency basis swap spreads that mostly adjust to restore long-run equilibrium across all maturities, following a short run deviation. The estimated error-correction coefficients across the three maturities suggest that 6%, 8% and 11% of the disequilibria emanating from changes in the cross-currency basis swap spreads associated with the 5-year, 10-year and 20-year maturity are corrected within one quarter for the full sample. For the European sample, 14%, 11% and 7% of the cross-currency basis swap spreads disequilibria are corrected in one quarter while for the non-European sample, it is 10%, 12% and 10% for the 5-year, 10-year and 20-year maturity respectively.

Turning now to the half-life, which is the time it takes for one-half of the deviations emanating from the cross-currency basis swap spreads to dissipate or decay, we see that for the full sample, the speed of adjustment coefficients imply a half-life for cross-currency swap spreads misalignments of 11-12 quarters, 8-9 quarters and 6-7 quarters for the 5-year, 10-year and 20-year maturities respectively. This seems to suggest that, for the full sample, the time it takes for the deviations from the basis to dissipate decreases as the maturity of the basis increases. For the European sample, the half-life corresponding to the 5-year, 10-year and 20-year maturity are 4-5 quarters, 6-7 quarters and 9-10 quarters respectively. Thus, it appears that for European currencies, the time it takes for deviations emanating from the basis to dissipate increases as the maturity of the basis increases. Finally, for the non-European sample, the half-life for the dissipation of the deviations from the basis at the 5-year and 20-year maturity are similar, at 6-7 quarters, while it is slightly lower for the 10-year maturity, at 5-7 quarters. This provides some evidence that the pattern of adjustment to equilibrium for non-European cross-currency basis swap spreads is likely different from their European counterparts. As such, the mechanism by which disequilibrium emanating from the basis is restored for European currencies is not the same with non-European currencies.

With respect to the other variables, the error correction (ECM) variable has no explanatory power for the dynamics of the relative real output and nominal exchange rate for the full and split panels and across all maturities. It plays a minor role in the adjustment of relative money supply for the European sample across all maturities and has a positive and significant sign across the 5- and 10-year maturity for the full sample.

Overall, the error correction analysis suggests that the exchange rate and relative real output are the most weakly exogenous variables across all samples and maturities followed by the relative money supply. As a way of context, this implies that when deviations from the long-run equilibrium level of the cross-currency basis occur, it is predominantly the basis itself that adjusts to restore long-run equilibrium across all samples and maturities. For European currencies, the relative money supply also adjusts similarly across maturities. The different adjustment mechanisms at work for European countries compared to their non-European counterparts possibly reflect the varying heterogeneity in the composition of the basis associated with the two groups of currencies. While the cross-currency basis swap spreads associated with major European currencies mostly exhibit negative CIP deviations, for non-

European currencies, the CIP deviations are largely mixed, with currencies like JPY exhibiting a negative basis across maturities while other such as CAD, AUD and NZD have been predominantly positive.

6. Conclusion

In this paper, we investigate the long run relationship between monetary fundamentals and CIP deviations using panel data econometrics. For the full sample of currencies, we show that the most consistent long-run link is the positive relation between relative money supply and cross-currency basis swap spreads. We also show that the evidence of a long-run relationship between spot exchange rate and CIP deviations and between relative real output and CIP deviations is mixed for the full sample of currencies. Our results are generally robust to different estimators, control variables and consideration of possible endogeneity of the regressors.

Taking a step further, we examine whether the positive link between relative money supply and CIP deviations for the full sample is generally true for European versus non-European currencies. To do this, we construct two panels – panel A and panel B, where panel A comprises European currencies and panel B contains non-European currencies. The outcome is interesting. We find that while the positive relation between relative money supply and cross-currency basis swaps is largely preserved for European currencies, it loses its significance and/or reverses sign for non-European currencies. An especially interesting finding is that for non-European currencies, it is the relative real output that consistently links positively with the cross-currency basis swap spreads. This finding is revealing for several reasons, notable of which is that the long run effect of monetary fundamentals on cross-currency basis swaps is not always the same across currencies, and thus should attract different policy responses.

We also estimate error-correction models associated with the cointegrating vector of the cross-currency basis swap spreads and the macroeconomic fundamentals with a view to gaining insights into the adjustment process through which the long-run relation is reestablished following a system-wide shock or deviation. We find that the adjustment process varies between European and non-European currencies and is mostly driven by adjustments in the cross-currency basis across all maturities. In order words, the cross-currency basis bears the most brunt of adjustment following a shock which causes deviations from equilibrium.

On balance, the generally consistent stylized facts obtained from the empirical findings are that – 1) in the long run, an increase in relative money supply is associated with a tighter cross-currency basis swap spreads for European currencies; 2) in the long run, a rise in relative real output is generally associated with a tighter cross-currency basis swap for non-European currencies; 3) evidence of a long run relation between CIP deviations, relative real output and spot exchange rate is mixed for European currencies; 4) evidence of long run links between CIP deviations and relative money supply/spot exchange rate is mixed for non-European currencies, and 5) the mechanism governing the adjustment to equilibrium is different for European versus non-European currencies. In general, when there is a move away from equilibrium, it is the cross-currency basis swap spreads that adjust to ensure the system returns to equilibrium, across all maturities and samples.

With respect to policy, on the one hand, the existence of a positive long-run relation between relative real output and CIP deviations for the non-European currencies suggests that a persistent increase in the relative output of these countries, whether through faster growth in real output or slowdown in US real output, will eventually tighten their cross-currency basis, lowering the CIP deviations. On the other hand, the positive long-run relation between relative money supply and CIP deviations for European currencies implies that in the long run, US entities do not necessarily accelerate the issuance of reverse Yankee bonds just because money supply has increased in European countries, an outcome which will not necessarily widen the cross-currency basis but may in fact tighten it.

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