CIP Then and Now: A Brief Survey of Measuring and Exploiting Deviations from Covered Interest Parity

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1. Introduction

I am very happy to be here in Basel and delighted to help set the stage for this symposium on covered interest parity (CIP). There is ample evidence that economists are poor at making long-term predictions. This symposium offers us another example. If ten years ago you had asked me (or many of us in this room) whether there would be an international conference on the state of knowledge on CIP, it would have seemed like a feeble joke. For most of the post-Bretton Woods period until 2007, CIP was one of the most reliable and relied upon parity conditions in international finance. But here we are today in a room full of international financial experts trying to better understand:

- What happened to CIP? Are the deviations small, large, and in excess of transaction costs? Is money being left on the table and why doesn't someone step forward to pick it up? Or are some investors and/or issuers already nibbling?
- What's behind the larger disparity in CIP? Is it greater transaction costs, regulatory costs, counterparty risk, execution risk, lack of risk appetite, lack of arbitrage funds, regulatory restrictions, or some other force?
- And what does it mean for pricing of forwards, the pricing of short-term funds on a covered basis, the pricing of longer term funds, for returns on covered investments, and for market efficiency in general? Could government policies help to remedy any <u>measured</u> departure from efficiency?

The last statement is particularly important. Are the CIP deviations we see today only "measured deviations" bounded within a neutral band that captures all the costs and risks of arbitrage? Or are they true, executable profit opportunities waiting to be, or actually

¹ To remain brief, this survey is necessarily selective. See Levich (2001, 2013) for additional references.

being exploited by smaller, more nimble hedge funds and financial managers? Hopefully, the symposium will bring greater clarity on these questions.

To help us get started, the organizers asked me to look back over history to remind ourselves of the theorizing, empirical methods and evidence that led us to assign CIP such a central role, and to eventually take CIP for granted as a truism. Perhaps looking back will give us some clues on how to go forward or maybe just offer us some comfort knowing that we've been here before. The arc of my talk begins by examining why CIP is such an important and useful relationship, and then steps back to consider how covered interest arbitrage was framed through the 20th century. I'll speak briefly about the sea change in CIP we have witnessed over the last 10 years, and close with some conjectures about the implications of wider disparities from CIP.

2. What Makes CIP Important and So Useful?

For starters, CIP informs a currency dealer regarding the equilibrium price to set on a forward contract given the prevailing spot rate and money market interest rates. A forward contract is a perfect example of "just-in-time" production. A client calls for a forward quote. The dealer has none "in stock" but can confidently offer a price quote with the knowledge that he can construct or build the forward position almost immediately using the standard CIP formula.

$$F = S \frac{(1+i)}{(1+i^*)}$$
(1)

where i and i* represent zero-coupon interest rates on domestic and foreign currency respectively that match the maturity of the forward contract. So CIP tells us the recipe or

the "list of ingredients" that go into a forward contract.² In that sense, CIP looks like "ketchup economics," but it is nevertheless a critical relationship that the currency market relies on millions of times daily for pricing billions of dollars in transactions.

CIP also informs us about hedging a forward position. Having just bought or sold a forward contract, the dealer can quickly square his book by creating offsetting positions in spot and FX swap contracts. Elsewhere, far from the trading room, when CIP holds, corporations and financial institutions looking to hedge realize that the expected cost of using a forward market hedge or a money market hedge are identical.³

Third, the typical derivation of CIP and equation (1) informs us that a forward currency contract is a synthetic instrument that can be replicated using a spot contract combined with borrowing and lending in the two currencies (an FX swap). But a simple rearrangement of terms shows that the other legs of the transaction could also be replicated giving us synthetic investment or borrowing positions in either the home or foreign currencies.

$$(1+i) = \frac{F}{S} (1+i^*)$$
(2)

$$(1+i^*) = \frac{S}{F} (1+i)$$
(3)

Equation (2) demonstrates that borrowing (or investing) in the domestic currency asset (at rate *i*) is equivalent to borrowing (or investing) in a foreign currency asset (at rate i*)

² Dealers might not face the same interest rates, and so different dealers might generate different forward quotes but need to match the most competitive quotes to attract business. The "Japan premium" that emerged in August 1995 and continued for several years provides an example. Japanese banks borrowing in the Eurodollar and Euroyen paid a premium relative to interbank rates paid by U.S. and European banks and thus would have developed different, less competitive forward rates. See Peek and Rosengren (2001).

³ Corporations which weigh the costs of a forward market hedge or a money market hedge and pick the more favorable of the two are essentially engaged in one-way arbitrage. These transactions reduce observed deviations from CIP and limit opportunities for profitable, round-trip, risk-free arbitrage.

combined with an FX swap. And likewise equation (3) demonstrates that borrowing (or investing) in a foreign currency asset (at rate *i**) is equivalent to borrowing (or investing) in the domestic currency asset (at rate *i*) combined with an FX swap. Together, equations (2) and (3) help clarify that in equilibrium, markets should reach parity (i.e. interest rate parity, IRP) between interest rates in all currencies when the currency risk is hedged.

Moreover, equations (2) and (3) suggest that if borrowing in one market, say USD, is impeded then agents can compensate by borrowing in GBP and simultaneously entering into offsetting spot and forward currency contracts. Or if investing in GBP seems subject to unusual costs or risks, agents can create a synthetic GBP position by investing in a USD security and simultaneously entering into offsetting spot and forward currency contracts. Creating synthetic positions is straightforward, but as discussed later on, they can create considerable value when financial markets are constrained or under stress. Precisely at these times, investors may willingly choose a synthetic ($i \text{ or } i^*$) that yields less, or borrowers may choose a synthetic that costs more in order to overcome a market dislocation that prevents them from dealing in their direct choice ($i \text{ or } i^*$).

Figure 1 shows a schematic representation of equations (1-3) in a so-called "box diagram" made popular in many international economics and finance textbooks.⁴ Currencies are arranged by row on the left-hand-side and time to maturity is spread across the columns. Exchange rates (a spot rate at t_0 and forward rates at all other maturities) link currencies and zero-coupon interest rates span time intervals from t_0 to any future point t_i . The typical one-period model using one-period forward rates and interest rates can easily be generalized to two periods, three periods and so on using

⁴ Kindleberger and Lindert (1978, p. 240) refer to it as the "lake" diagram.

zero coupon rates for the longer maturity contracts. Assuming CIP holds over any interval [0, T] it is easy to show that CIP also holds over any subinterval $[t_1, t_2]$. Koh and Levich (1994) rely on this principle to demonstrate that highly liquid USD interest rate futures contracts could be combined with currency futures contracts to create synthetic foreign currency interest rate futures contracts.

Likewise, the basic box diagram in Figure 1 can be extended across currencies linking the USD to spot rates, forward rates and interest rates on the CHF, EUR, JPY and so on. Assuming CIP holds between the USD and all other currencies, CIP also holds between all non-USD currency pairs. In the limit, the basic box diagram generalizes into a checkerboard of linkages among the term structure of interest rates and the term structure of forward exchange rates for all currencies bound together by risk-free arbitrage.

In a stylized setting where transaction costs and barriers to capital movement are both nil, it is easy to picture this checkerboard as an efficient conduit for capital across currencies and maturities. The implications for an investment manager or corporate treasurer are immediate: assets and liabilities on the balance sheet in one currency could be easily transformed into another currency using forward currency contracts. Similarly, cash flows in one currency could be easily transformed as well. The implications for macroeconomic policy are also clear: monetary policy in one currency (e.g. USD) is immediately transmitted via exchange markets to affect exchange rates and/or interest rates in other currencies while preserving CIP.

The stylized checkerboard in Figure 1 suggests a grid of established and welltravelled links capable of moving capital quickly between currencies and across maturities

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in a structured manner driven by CIP. In their study of international capital mobility, Frankel and MacArthur (1988) concluded that "the covered interest differential is a better measure of capital mobility – in the sense of financial market integration across national boundaries – better not only than savings-investment correlations, but also than real interest differentials."⁵ CIP remains the benchmark for detecting departures from perfect capital mobility. And it is built into our open economy macro models when we substitute the forward currency premium for the interest differential (or vice versa) to solve out the model.

3. What Does History Tell Us about CIP? A Highlight Reel

Arbitrage is a primitive concept in economics and it plays a critical role in financial economics. References to arbitrage and its impact on prices can be found in the works of early political economists such as Ricardo (1811), Cournot (1838) and Walras (1870).⁶ It was John Maynard Keynes, however, writing in the *Tract on Monetary Reform* (1923) who popularized the expression interest rate parity. Keynes described (in words) the mathematical notion of parity between the forward premium and interest differential and also offered a list of reasons why parity might be violated, as it often was in many markets during Keynes' life.

a. How large were deviations from CIP and why were they persistent?

⁵ Frankel and MacArthur (1988, p. 1111).

⁶ For example, in Walras (1874, Lesson 34, para. 314) "Whenever this state of general equilibrium is disturbed, it will be restored by arbitrage operations in bills of exchange exactly like arbitrage operations in commodities. ... Bills of exchange are *par excellence* the most suitable commodities for arbitrage operations."

While the mathematics of IRP are straightforward, it has long been recognized that there are many explanations why the forward premium and interest differential would not satisfy a simple mathematical relationship. Keynes (1923) provided several cautionary reasons why arbitrage might be insufficient to produce IRP. He emphasized that arbitragers can be subject to credit risks if counterparty were to default on a forward contract or on an investment position in one currency (that is used to offset a short position in another currency). When the legs of an arbitrage are conducted in different countries, another risk is opened through possible capital controls and sovereign risks. As Keynes (1923, pp. 126-7) put it, arbitragers might weigh the "small turns" they could earn out of interest differentials against the possibility of large losses through a credit event, and find that these "may deter conservative banks from doing the business on a substantial scale at any reasonable rate at all." In much the same vein, Keynes suggested that these risks could curtail the amount of funds committed to arbitrage. As he expressed it, "the floating capital normally available, and ready to move from centre to centre for the purpose of taking advantage of moderate arbitrage profits between spot and forward exchange, is by no means unlimited in amount, and is not always adequate to the market's requirements."7

During Keynes' lifetime and up until the development of offshore capital markets, deviations from CIP were frequent, and typically attributed to these usual suspects. In the first foreign exchange market monograph prepared by the Federal Reserve Bank of New York, Holmes (1959) adopted Keynes' assertion that deviations from CIP would need to reach 0.50% per annum to make it worthwhile for arbitragers to move funds from one

⁷ Keynes (1923, pp. 128-9).

market to another. Figure 2 shows the classic CIP diagram (which today we would rotate clockwise 90° to put the forward premium on the vertical axis and the interest differential on the horizontal axis) with a diagonal parity line dividing the graph into regions of risk-free covered arbitrage inflows and outflows. Of special interest is a third region shown by two dashed lines drawn parallel to the interest parity line. Within this region, which Frenkel (1973) referred to as a "neutral band," the costs and risks of arbitrage transactions outweigh the observed or measured CIP deviations. And so those data points might remain undisturbed by any round-trip arbitrage flows.

Holmes reaffirmed that during the Bretton-Woods period, arbitrage flows could be limited by exchange controls in place, but flows could also be deterred by possible future controls, sovereign risks, bank credit risk, as well as the limited stock of bank capital available.⁸ Holmes (1959, pp. 51-2) discussed several examples including the Suez Canal crisis of October 1956 and the Sterling Exchange Crisis of August 1957 (reproduced in Figure 3) that opened up sizeable CIP deviations of 2-3 percent or more favoring flows to the USD and out of GBP. These deviations calculated using U.S. and U.K. Treasury Bill rates lasted for several weeks or more, to be eventually trimmed when domestic policy responded to the imbalance or the crisis subsided. In the 1956 Suez Canal crisis, Holmes explains that British exchange controls inhibited the movement of arbitrage flows. But in the 1957 Sterling crisis, the Bank of England raised interest rates by 2 percentage points (clearly visible in the chart) to drastically reduce the incentive for arbitrage outflows, although not completely back to parity.

⁸ Dooley and Isard (1980) also highlight the distinction between known capital controls in place and the risk of future capital controls. The authors conclude that during the 1970-73 period of controls in Germany, as much as 1-2% per annum of observed deviations from CIP could be attributed to the risk of future controls.

Throughout the 1960s, fresh estimates of the size of the neutral band needed to induce arbitrage were proposed. Holmes and Schott (1965) suggested that only 0.25% per annum was required to induce arbitrage, or half as much as in Holmes' (1959) previous monograph. Based on data for U.S., U.K. and Canadian treasury bills, Branson (1969) derived an estimate of 0.18%. As a well-informed financial journalist, author and historian of currency markets, Einzig (1961) offered 0.06% as his estimate of the minimum incentive needed to induce covered arbitrage.

Other authors pursued an "elasticities approach" to formalize Keynes' observations about the limits of arbitrage and reconcile observed deviations from CIP.⁹ Tsiang (1959) cited "limits to arbitrage" as the most important shortcoming of the interest parity theory: that "even when there is no official restriction on short-term capital movements, the theory is only applicable as long as 'arbitrage funds do not run out.'"¹⁰ Tsiang's detailed reasoning is provided in Appendix 1. The essence of his argument is that banks will become increasingly reluctant to transfer their spot liquid resources from their home to foreign centers, or vice versa.

This follows from the fact that, for their regular business operations, banks and other financial institutions (or any firms with overseas operations) must have command over certain amounts of spot liquid funds in every major overseas financial center; mere forward claims would not serve the purpose. That is to say, spot liquid assets yield some intangible returns of convenience or liquidity in addition to their interest yields.¹¹

The upshot is a revision to the basic interest parity formula shown in equation (4).

$$\frac{F-S}{S} = (i_j + \rho_j) - (i_j^* + \rho_j^*)$$
(4)

⁹ The elasticities approach focused on whether the supply of arbitrage funds is infinitely elastic at any incentive (ϵ) greater than zero or if there is some finite elasticity. Frenkel (1973) estimated the elasticities needed to bound all CIP deviations based on treasury bills and concluded that they were too low to be taken seriously given the highly competitive structure of the foreign exchange market.

¹⁰ Tsiang (1959, pp. 80-81) with the quote attributed to Spraos (1959, p. 88)

¹¹ Tsiang (1959, p. 81)

In Tsiang's formulation, interest rates i_j and i_j^* are particular to the individual arbitrager j and each interest rate is augmented by a subjective marginal convenience or liquidity yield (ρ_j and ρ_j^*) that is specific to the individual arbitrager, *j*. Tsiang's formulation portrays CIP in a fundamentally different light. With ρ varying across currencies, among arbitragers, and over time, measuring CIP deviations becomes a much more tricky exercise.

b. Different data, different methodologies and different results

With the development of offshore financial markets (known at the time as Eurocurrency markets) attention shifted away from the elasticities approach and relied on different data and different methodologies, leading not surprisingly to different results. Aliber (1973) reasoned that arbitrage between Treasury Bills exposed the arbitrageur to differential political risks and risks of capital controls. If one considered arbitrage between offshore instruments (e.g. USD and GBP deposits issued by the same Zurich bank) then political risks would be identical and not separately impede arbitrage. Based on weekly data for the January 1968 – June 1970 period, Aliber showed that CIP deviations were far smaller, and more tightly distributed around zero, using offshore instruments compared to Treasury Bills.¹² Furthermore deviations in the offshore market were symmetrical about zero, whereas deviations using Treasury Bills were skewed right and occasionally very large (ranging from 2% to over 8%). This led Aliber to conclude that CIP using Treasury Bills captured a non-random element which he labeled political risk.

¹² Aliber (1970) reported that 81% of the deviations were within 0.5% using offshore instruments, while only 28% were within that interval using Treasury Bills.

In a pair of papers, Frenkel and Levich (1975, 1977) proposed a new technique for measuring the efficiency of international capital market in eliminating arbitrage profit opportunities. Rather than make an interpretation based on a regression of the forward premium against an interest differential, or calculation of the mean deviation, FL argued that each data point should be treated as a separate event and a new opportunity for the market to engage in arbitrage and establish parity.¹³ Thus how well CIP worked could be summarized by the percentage of data points captured within a "neutral band" given by an independent estimate of transaction costs. Using estimates of foreign exchange transaction costs (based on triangular currency arbitrage) and money market transaction costs into account, there were few, if any, deviations from CIP remaining in 1962-67, a tranquil pegged rate period. In that sense, CIP held exceedingly well among currency pairs in the offshore market.

In a follow-up paper, FL (1977) extended their sample to include 1968-69, a more turbulent pegged rate period, and 1973-75, a managed floating rate period immediately after the demise of Bretton Woods. Once again considering arbitrage between the USD and GBP (as well as the CAD), FL concluded that transactions costs had risen during both the turbulent peg and managed floating periods, but CIP still held in the sense that in offshore markets, very few observations indicated the availability of an arbitrage profit after taking transaction costs in account.

¹³ As Taylor (1989) put it, "What is at issue is not whether CIP holds on average or whether profitable opportunities are statistically significant, but whether covered arbitrage is *ever* profitable." (Emphasis in the original)

Other authors focused more on the quality and type of data used in empirical studies of IRP. Clinton (1988) noted that interbank dealers typically trade in FX swaps (representing a simultaneous purchase and sale of foreign exchange) that benefit from a single small bid-ask spread rather than deal separately in spot and forward contracts which each carry their own spread. With this modification, Clinton showed that the width of the neutral bank in IRP was smaller than in previous studies. Despite this, Clinton's empirical evidence still supported the conclusion that markets were efficiently eliminating nearly all arbitrage opportunities.¹⁴

Taylor (1987) offered the first empirical study using high-frequency data that was carefully time-synchronized. Taylor's data covered three days (November 11, 12, and 13) in 1985 taking observations every 10 minutes from 9:00 am until 4:50 pm for a total of 144 data points per day. All variables in the CIP calculation were recorded to have a tolerance of one minute with each other. Taylor's metric was similar to the Frenkel-Levich (1975, 1977) studies, that is simply counting the number of profit opportunities available through arbitrage for different currency pairs (US dollar-German mark, and US dollar-UK sterling) and different maturities (1, 3, 6, and 12 months). With four maturities, six borrowing-lending currency combinations, and 144 data points the complete sample totaled 3,456 observations. Taylor confirmed that the foreign exchange market was highly efficient in the sense that there were virtually no opportunities for round-trip arbitrage, and only few and scattered possibilities for one-way arbitrage.

¹⁴ McCormick (1979) also raised the possibility that published, printed data sources available in the 1970s might not be adequately time-synchronized and could overstate interbank trading costs. Even so, McCormick (1979, p. 416) concluded that using higher quality Reuters exchange market data led to the same result that virtually all discrepancies from CIP in the offshore market could be explained by transaction costs.

Quite different than high-frequency data at 10 minute intervals, Popper (1993) investigated long-term, cross-currency swap-covered interest parity on about 350 Eurobonds over a 2.5 year period from 1985-1988. Relying on weekly data for 5-year and 7-year bonds in five major non-USD currencies, Popper found that deviations from long-term interest parity were in some cases slightly greater than the deviations measured among short-term assets, the differences were small. In a related study, Fletcher and Taylor (1996) also examined 5-, 7-, and 10-year securities for deviations from long-term covered interest parity. They reported "significant deviations" even after adjusting for transaction costs.¹⁵

It is important to point out that even small differences on large long-term bond can be extremely valuable for the issuer.¹⁶ McBrady and Schill (2007, 2010) conclude that bond issues appear timed to take advantage of deviations from long-term CIP even when the yield difference is as small as 4-14 basis points. The authors conjecture that "that opportunistic issuance by corporations may be a primary mechanism for driving covered interest yields toward parity."¹⁷ Let's consider this "opportunistic behavior" notion a bit further.

¹⁵ This is consistent with results in Taylor (1989) using hand-collected, time synchronized data for the USD-GBP pair during five periods of unusual market turbulence such as the 1967 devaluation, the 1972 floatation of sterling and several others trough 1987. The frequency, size and persistence of profitable arbitrage opportunities tended to be a positive function of the length of maturity considered out to 12 months. Taylor conjectured that because banks operate within credit limits, this would create a preference for shorter maturities leaving dealers freer to take advantage of other profit opportunities as they arise, rather than have funds tied up in over longer periods for a small gain.

¹⁶ For example, on a \$500 million 20-year bond issue, saving 5 basis points saves the issuer close to \$3.4 million in the present value of debt servicing costs assuming a 4% discount rate.

¹⁷ Liao (2016) revisits the question of currency choice and location for issuing long-term bonds with a large sample of bonds covering 2004-2016. His results suggest that differences in credit risk pricing, limits to arbitrage and CIP deviations combine to influence the pattern of debt issuance.

c. A very useful insight: one-way arbitrage

The stylized description of covered interest arbitrage envisions round-trip arbitrage.¹⁸ That is, starting with \$1 cash (in Figure 1) and making four transactions, either clockwise or counter clockwise with the intent of finishing with more than \$1 after transaction costs. The size of the neutral band depends on transaction costs which will be smaller when the arbitrageur begins with cash (there is no need to borrow funds) or when he combines the spot and forward transactions into a single FX swap.

Deardorff (1979) hypothesized that "round trip" arbitrage was really an overly demanding measure. In practice, a manager holding USD today but needing GBP in one period had two choices. The manager could (1) enter into a forward purchase of GBP today and retain his USD earning interest until delivery date on the forward, or (2) buy GBP on the spot market today and invest the proceeds at the market interest rate for one period. Deardorff argued that even the smallest discrepancy would induce the manager to pick the lowest purchase price, and help restore parity. Deardorff showed that the interest rate parity box in Figure 1 held many similar comparisons, which he dubbed "one-way arbitrage." Deardorff claimed that the incentives to engage in one-way arbitrage were so prevalent, that these would take hold first, result in far smaller deviations from IRP, and in all likelihood preclude the possibility of round-trip arbitrage based on market prices

In some sense, one-way arbitrage is simply comparison shopping. Any deviation from CIP within the neutral band is too small to allow round-trip arbitrage. But any deviation offers opportunities for bargain hunters. An investor (or issuer) planning a 3-

¹⁸ Du, Tepper, and Verdelhan (2017) present an unusual example of profitable round-trip arbitrage across bonds issued in different currency by the same obligor (KfW) which holds credit risk constant.

month USD investment (or loan) at rate *i* can gauge whether the synthetic $\frac{F}{s}$ (1 + *i*^{*}) offers an advantage. Notice that the formula is agnostic about *i*^{*} which could represent CHF, GBP, or JPY, and so on. And of course other currencies like the AUD or EUR could play the role of the domestic currency and conduct the same comparison shopping exercise. Note however that one-way arbitrage depends on a true underlying cash flow, or investment or funding demand at some future date. In other words, our comparison shopper was already intending transfer funds from one currency to another for a real business purpose, or to invest (or borrow) USD for a 3-month period; he/she was simply looking for the best currency to generate those desired cash flows. Thus, there may be considerable "life" within the neutral band, and presumably more life the wider is the neutral band, a point we will return to later.

4. CIP in the Global Financial Crisis and its aftermath

From the mid-1970s up until the onset of the Global Financial Crisis, CIP for Eurocurrency deposits was widely accepted. Indeed, the presumption was that currency dealers implicitly used equation (1) thus insuring that CIP held with great precision. In his updated monograph for the Federal Reserve Bank of New York, Kubarych (1978) offered these observations:

Often, the foreign exchange and Eurocurrency deposit traders sit side by side and work in tandem. So, if any divergence of forward rates from interest parity tends to develop, both sets of traders react. They instantly adjust forward quotations, Eurocurrency quotations, or both. Most often the relationship [CIP] is restored before any profitable arbitrage can be made.¹⁹

¹⁹ Kubarych (1978), p. 45.

Twenty year later, Cross (1998) updated the FRBNY's monograph but reached the same conclusion about the validity of CIP in the offshore, Eurocurrency markets.

The forward rate in the *market* can deviate from this theoretical, or implied, equilibrium rate derived from the interest rate differential to the extent that there are significant costs, restrictions, or market inefficiencies that prevent arbitrage from taking place in a timely manner. ... However, today's large and deregulated foreign exchange markets and Eurocurrency deposit markets for the dollar and other heavily traded currencies are generally free of major impediments. ... it was the development of the offshore *Eurocurrency deposit markets* ... in the 1950s and '60s that facilitated and refined the process of interest rate arbitrage in practice and brought it to its present high degree of efficiency.²⁰

In an effort to put a finer point on the term "high degree of efficiency," Akram et al. (2008, 2009) assembled a sample of over 45 million tick-by-tick observations on three exchange rates, and four maturities over a 7-month period (February – September 2004). At this level of microscopic analysis, the authors observed deviations from CIP that were short lived (from 30 seconds to 4 minutes in some cases) but economically significant. These profit opportunities were quickly dissipated, more so when market activity was high and less so when volatility increased. Overall, the results were consistent with a highly efficient market, while leaving open a small window for algorithmic traders to search out very small profits in the dispersed currency market landscape.

Figure 4 shows indicative CIP deviations based on the 3-month maturity for the EUR-USD pair from January 2000 until April 2017. The period through July 2007 appears tranquil with essentially all deviations bounded within 25 basis points of parity and upwards of 95% of all deviations bounded within 10 basis points of parity. The pattern of deviations over last ten years has been remarkably different.

The graph and the message change in the summer of 2007 when two hedge funds operated by Bear Stearns suspended redemptions and BNP-Paribas announced that they

²⁰ Cross (1998), p. 37.

were unable to value three hedge funds. More events followed into 2008 as Northern Rock, one of the top mortgage banks in the United Kingdom, was nationalized and Bearn Stearns collapsed and was sold to JP Morgan Chase. In the initial phase of this pre-Lehman crisis period, deviations from CIP jumped to roughly 40 basis points, then recovered, and after the Bear Stearns collapse returned to the 40–50 basis point range through the summer of 2008.

Once Lehman Brothers failed on September 15, 2008, deviations from CIP in the most active currency pair in the most active financial market in the world spiked to over 200 basis points and for the most part remained above 100 basis points for the next three months. CIP deviations subsided to the 25–50 basis point range by spring 2009, and continued in that range for another two years. However, deviations again surged in August 2011 exceeding 100 basis points throughout November and December 2011 and then retreated to the 50 basis point range in spring 2012.

By January 2013, CIP deviations in this pair had dipped below 25 basis points and even below 10 basis points by the start of 2014. But by mid-2015 until the present, CIP deviations have been firmly in the 25-50 basis point range and occasionally greater.

Several authors have studied what factors led to the sharp increase in CIP deviations at the start of the crisis, and the rapid decline in CIP deviations in the spring of 2009. According to Baba and Packer (2009) and corroborated by Coffey et al. (2009), the combination of funding shortages in the US financial markets as well as a heightened sense of counterparty risk even among large banks active in the FX market led to a deterioration in liquidity and observed deviations from CIP in the USD–EUR pair.²¹ Both

²¹ Griffoli and Ranaldo (2011) analyze CIP deviations using high-frequency data on five currency pairs including the EUR–CHF, a nondollar pair. The authors conclude that most CIP deviations can be

of these studies find that prior to the Lehman Brothers bankruptcy, capital constraints and liquidity risk proxies explain much of the observed deviations from CIP. After the Lehman collapse, Coffey et al. (2009) find that counterparty risk and credit risk proxies become significant variables explaining CIP deviations. Genberg et al. (2009) analyze CIP deviations for the USD–EUR and five other currency pairs. Their results suggest that CIP deviations were smaller for Hong Kong, Japan, and Singapore (vs. the USD) consistent with lower implied bank default risks in those countries.

Consistent with the notion of heightened counterparty risk among banks, Levich (2012) showed that trading volume in exchange traded currency futures contracts grew sharply in the post-Lehman period taking market share away from interbank forward contracts. The inference is that agents preferred traded currency futures settled through a regulated central clearinghouse instead of interbank forward contracts exposed to bank-specific counterparty risks. The general pattern of bank CDS rates over the period (Figure 5) supports this interpretation.

During the crisis period, banks outside the United States had particular difficulty accessing USD facilities. To meet their various USD funding obligations, these banks turned to the synthetic approach suggested by equation (2). By borrowing in the their home currencies (EUR, GBP, or others), perhaps through access to the home central bank, and then executing an FX swap, banks could synthetically create a USD position, but only at a premium to a direct position in USD.²²

explained by funding liquidity constraints in USD, and only a small part due to the risk of default by the forward counterparty. Hence, based on this dataset, the possibility of risk was not a major factor in limiting arbitrage and opening up CIP deviations.

²² Baba and Packer (2009) note that the situation is analytically similar to that of Japanese banks in the 1990s that faced a 'Japan Premium' (i.e., higher borrowing costs in the offshore USD market) because of the declining credit quality of Japanese bank loan portfolios. Japanese banks could attempt to circumvent

The synthetic approach helps to understand one policy response to this aspect of the global financial crisis. In December 2007, the US Federal Reserve along with the European Central Bank and the Swiss National Bank established substantial official swap facilities, which were expanded in 2008 to another dozen central banks.²³ With these official swaps, the supply of USD offshore increased and non-US banks could access USD through their home central bank rather than through their traditional US commercial bank counterparties (who were subject to lending constraints or heightened default risk). Coffey et al. (2009) show that the successive rounds of official swap facility lines opened in the spring 2009 played a significant role in bringing down CIP deviations, and in that sense, helping to restore greater international capital mobility.²⁴ In a related study by Baba and Shim (2010), the authors show that the Bank of Korea's use of US Federal Reserve swap lines had a significant impact on reducing dislocations in the Korean won/US dollar market, while using the Bank's own foreign reserve had no significant impact.

Despite these policy initiatives, Figure 4 suggests that deviations from CIP are experiencing a new normal, with deviations in the range of 25–50 basis points for the EUR–USD pair rather than in the range of 10–25 basis points which had been observed a decade previously.

5. Where do Matters Stand? Life in the Neutral Zone

a. How we rely on CIP

the premium by borrowing in JPY and entering into an FX swap to synthetically create a USD position. For more on the Japan Premium, see Peek and Rosengren (2001).

²³ See Fleming and Klagge (2010) for a detailed review of the Fed's swap line program and its impact.
²⁴ Ivashina, et al. (2015) develop evidence that in the European sovereign crisis, and especially in the second half of 2011 after the official central bank swap lines had wound down, that European banks shifted the currency composition of their lending tilting toward more euro lending and less dollar lending despite the apparent increased riskiness in Europe due to the debt crisis.

McBrady et al. (2010) expressed it very well: "Interest rate parity is a bedrock assumption of international finance." We rely on CIP for knowing the term structure of equilibrium forward rates. We draw on CIP to understand the relationship between spot and forward speculative currency returns, and the relationship between covered costs (and returns) in two or more currencies. We rely on CIP in open economy macro models that assume perfect capital mobility and the equality of interest differentials and forward premia. In essence, deviations from covered interest parity provide their own barometer of conditions in the foreign exchange market and how close we are to perfect capital mobility.

For decades, financial economists have rested comfortably with the notion that the combination of massive market turnover, minimal transaction costs, scant concern for counterparty risk and the absence of costly banking regulations and barriers to capital movement would essentially guarantee CIP, for sure among G-10 currencies and to a close approximation for many others. For the last 10 years, CIP has been the exception rather than the rule.

b. Why it matters whether the band is 0.05% or 0.50%

In the current environment, while turnover is still abundant and transaction costs are small by conventional standards, bank counterparty risk as measured by CDS rates can be large and variable, meaning it cannot be ignored. Bank regulations, specifically the leverage ratio provisions in Basel III can restrict the ability of banks to employ their balance sheet in low-margin activities such as interest arbitrage. Recent reforms in US money market mutual funds effectively increase the share of secured funding relative to unsecured which lessens the pool of arbitrage funds.

The upshot of this is that deviations from CIP measured in the conventional way appear to be larger. And as foretold by Tsiang (1959), CIP deviations may depend significantly who is doing the arbitrage, their own convenience yield and the instruments used in the calculation. Still, researchers may find that CIP "holds" in the sense that once known costs and risks are taken into account, a large percentage of observations are captured within the wider neutral band.

What difference could it make whether the band is 0.05% or 0.50% as long as CIP holds? With a narrower band, the linkage among currency and money markets is necessarily tighter. Changes in one price or rate are more likely to be transmitted quickly and more predictably into other prices guided by CIP. With a wider band, the connectedness of markets and transmission of shocks that we associate with international capital mobility are likely slowed. Agents lose some of the flexibility to recreate synthetic positions in their base currency at little extra cost or risk. The risk of future capital controls or regulatory changes acts as a brake on arbitrage funding, observationally equivalent actual capital controls.

On the other hand, the wider band creates larger incentives for corporate treasurers to venture beyond their normal borrowing habitat and likewise for asset managers to invest abroad with forwards for a yield pickup. Evidence that this is happening is in plain view. Bloomberg page FXFA (Figure 6) displays the higher return or lower borrowing cost by executing a synthetic contract rather than lending or borrowing directly in the target currency. Some currency management firms have advised their clients to consider synthetic (swapped) transactions to affect a yield pickup that is economically significant.²⁵

With round-trip arbitrage curtailed, the burden of adjustment falls on one-way arbitrage. Whether one-way cash flows are sufficient to restore CIP to its historical tolerance is an empirical question. But so far, the answer appears to be no. In the meantime, researchers should be careful in the implications they draw from empirical studies. In the current environment, CIP may hold in the technical sense that a large fraction of observations lay within the wider neutral band. But that need not imply the same degree of international capital mobility as with the narrow band associated with the pre-crisis period. And the wider band may afford tempting opportunities for borrowers and investors within the neutral band.

²⁵ See Record Currency Management, "Monthly Factsheet," August 2016. In their words, "An unusual opportunity has emerged for US investors owing to the breakdown of the no-arbitrage condition called covered interest rate parity."

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Figure 1

A Generalized Covered Interest Parity Box Diagram



 \leftarrow Time to Maturity: interest rates \rightarrow





Source: Holmes (1959, p. 45)

Figure 3

Examples of CIP Deviations in the 1950s



Source: Holmes (1959, p. 51-2)





Note: Daily data on EUR/USD spot rates, 3-month forward rates, and 3-month USD LIBOR and EUR EURIBOR are from Bloomberg. Deviations from covered interest parity in basis points per annum calculated as $[(F/S) \times (1+i(EUR)/400) - (1+i(USD)/400)] \times 40,000$.





5-Year CDS Rates: Monthly Average of 10 International Banks January 2005 - April 2017

Note: The banks in the sample are BNP Paribas, Deutsche Bank, UBS, Barclays, Royal Bank of Scotland, HSBC Bank, Credit Suisse, Citibank, Goldman Sachs, and JP Morgan Chase. Daily data on CDS rates are from Bloomberg.

Figure 6

Bloomberg screen: FXFA Screen shot from May 1, 2017

| 1) Ac | tions 🝷 | 2) Settin | gs 🗝 3) | Refresh | 1 | | | F | X-Intere | est Rate Ar | rbitrage |
|------------------------|------------|--------------|---------------|---------------------------|---------------|------------|------------|-------------------|--------------|----------------|----------|
| Same (| Currency | 0 Multi-Curr | ency | | | | | | | | |
| Currencies 🔻 USD 🛶 EUR | | | | via Pricing Date 05/01/17 | | | | | Auto Refresh | | |
| Spot Sou | Irce BGN | | - | | | | | | | Direct Input | |
| Fwd Source BGN | | | - | 31) RFQ 32) CNF | | | | | | Show Outrights | |
| Imply 👢 | JSD Yiel 🔹 | | | | FX | Swap to I | JSD Depo | | | | |
| | | 7) FX | Swap | 8) USD \ | 'ield (d) | 9) EUR \ | (ield (d) | USD Implie | d Yield | Sprea | id |
| Term | Date | Bid | Ask | Bid | Ask | Bid | Ask | Bid | Ask | Bid | Ask |
| ON | 05/02/17 | 0.916922 | 0.917042 | 1.1723 | 1.1723 | -0.2490 | -0.2490 | 2.7312 | 3.0253 | 1.5589 | 1.8530 |
| TN | 05/03/17 | 0.916846 | 0.916959 | 1.1723 | 1.1723 | -0.2490 | -0.2490 | 1.5612 | 2.0675 | 0.3889 | 0.8952 |
| SP | 05/03/17 | 0.9168 | 0.9169 | | | | | | | | |
| SN | 05/04/17 | 0.916750 | 0.916854 | 1.1706 | 1.1706 | -0.0651 | -0.0651 | 1.7568 | 1.8905 | 0.5862 | 0.7199 |
| 1W | 05/10/17 | 0.916482 | 0.916606 | 1.1707 | 1.1707 | -0.0651 | -0.0651 | 1.5844 | 1.7193 | 0.4137 | 0.5486 |
| 1M | 06/05/17 | 0.915355 | 0.915480 | 1.1712 | 1.1712 | -0.0651 | -0.0651 | 1.6269 | 1.6569 | 0.4557 | 0.4857 |
| 2M | 07/03/17 | 0.913932 | 0.914073 | 1.1717 | 1.1717 | -0.1486 | -0.1486 | 1.6762 | 1.7029 | 0.5045 | 0.5312 |
| ЗM | 08/03/17 | 0.912498 | 0.912623 | 1.1723 | 1.1723 | -0.3697 | -0.3697 | 1.4624 | 1.4734 | 0.2901 | 0.3011 |
| 4M | 09/05/17 | 0.910945 | 0.911094 | 1.2318 | 1.2318 | -0.2007 | -0.2007 | 1.6334 | 1.6491 | 0.4016 | 0.4173 |
| 5M | 10/03/17 | 0.909472 | 0.909627 | 1.2627 | 1.2627 | -0.2091 | -0.2091 | 1.6705 | 1.6851 | 0.4078 | 0.4224 |
| 6M | 11/03/17 | 0.907934 | 0.908107 | 1.2866 | 1.2866 | -0.2490 | -0.2490 | 1.6430 | 1.6591 | 0.3564 | 0.3725 |
| | | | FX Swap | | USD Yield (d) | | eld (d) | USD Implied Yield | | Spread | |
| Term | Date | Bid | Ask | Bid | Ask | Bid | Ask | Bid | Ask | Bid | Ask |
| _ | mm/dd/y | | | | | | | | | | |
| | mm/dd/y | | | | | | | | | | |
| | | | | | | | | | | | |
| | | | | | | | | | | | |
| | | | | | | | | | | | |
| 41) Legend (d) Delaye | | | | ed Cash | Rates | Repr | esents Ho | lidav 🔹 Sr | oot bid/as | k replaced b | ov mid. |
| | Australia | 61 2 9777 86 | 00 Brazil 551 | 2395 9000 | Furope 44 | 20 7330 75 | 00 Germany | 49 69 9204 1210 | Hong Kong 8 | 52 2977 6000 | |

Appendix 1

Modifying the standard interest rate parity formula for arbitrager specific convenience yields.

"This proviso to the interest parity theory is often made, e.g. by Spraos, in a way that implies that the theory holds up to the point where arbitrage funds are about to run out, but ceases to hold beyond that point. In reality, the availability of arbitrage funds does not stop abruptly at any given point. What is more likely is that arbitragers (chiefly banks with overseas operations) will generally, after a certain point, become increasingly reluctant to transfer their spot liquid sources from the domestic center to any particular foreign center. say London, if the arbitrage operations they are induced to perform are persistently in the form of spot purchases against forward sales of, e.g. sterling. Similarly, after a certain point, they will become increasingly reluctant to transfer their spot liquid resources from their foreign centers of operations back to their home market through persistent arbitrage operations in the opposite direction. This follows from the fact that, for their regular business operations, banks and other financial institutions (or any firms with overseas operations) must have command over certain amounts of spot liquid funds in every major overseas financial center; mere forward claims would not serve the purpose. That is to say, spot liquid assets yield some intangible returns of convenience or liquidity in addition to their interest yields. Banks (and other financial institutions) would normally be expected to distribute their command over spot liquid assets in various financial centers in such a way that the marginal yields of interest *cum* liquidity (convenience) net of exchange risks of liquid assets would be approximately equal between different financial centers. As a bank, say in New York is induced to arbitrage on the forward exchange market in the direction of spot buying of sterling against forward sale of sterling of an equal amount, its spot liquid assets in New York are reduced and those in London increased by that amount, though with the insurance amount of sterling can be transferred back into dollars at a fixed rate on a future date. As a result, the marginal yield of convenience of its funds in New York would be increased, while that of its funds in London would be decreased. To induce it to make further arbitrage operations in the same direction, i.e., to purchase more spot sterling against forward sales, the margin of profit represented by the gap between interest parity and the current forward premium (or discount) would have to increase. Thus the equilibrium condition for each arbitrager (this condition has to be stated for each arbitrager, for convenience yields of liquid assets in various centers are different for different arbitragers) should be revised to

$$\frac{FR - SR}{SR} = (I^a + \rho_i^a) - (I^b + \rho_i^b)$$
(5)

where ρ_i^a is the subjective marginal convenience (or liquidity) yield to the individual arbitrager, *i*, of his net short-term liquid assets in New York, and ρ_i^b that of his net short-term liquid assets in London, respectively."

Source: Tsiang (1959, pp. 81-2).