Limits to arbitrage during the crisis: funding liquidity constraints and covered interest parity

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Abstract

Arbitrage normally ensures that covered interest parity holds. But after the Lehman bankruptcy, this central condition in finance broke down. By replicating two major arbitrage strategies using high frequency prices from novel datasets, this paper shows that arbitrage profits were large, persisted for months, involved borrowing dollars, arose independently of whether or not loans were secured, and waned as dollar liquidity was provided by central banks. Empirical analysis suggests that hoarding of funding liquidity in dollars and limited capital to pledge for funding kept traders from arbitraging away excess profits. Contract risk further amplified these profits.

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Arbitrage is the glue of financial markets. It links securities through pricing relationships, and allows for the smooth and efficient functioning of markets. But under sufficient pressure, arbitrage can break down. That this glue can, and does, snap underscores the fragility of the financial system and potentially calls for policy action. A proper understanding of when and why arbitrage breaks down is therefore fundamental.

Arbitrage needs capital to operate properly and may be disrupted by lack of it. That is the main suggestion of a vibrant literature currently emerging under the heading of slow moving capital, captured with eloquence in Duffie (2010). But earlier writings already suggest these frictions are of first order importance. That is the case in Shleifer and Vishny (1997) and notably Keynes who remarked, as early as 1923, that "speculation [in the foreign exchange market may be] exceptionally active and all one way. It must be remembered that the floating capital normally available. . . for the purpose of taking advantage of moderate arbitrage. . . is by no means unlimited in amount" and thus excess profits, when they arise, persist until "fresh capital [is drawn] into the arbitrage business" (Keynes, 1923, pp. 129-130).

This paper revisits the above insights and contributes to the literature on slow moving capital in two ways: by providing a concrete example for large and persistent deviations from arbitrage, and by testing empirically the relevance of specific factors brought up in the literature to explain enduring arbitrage opportunities.

This paper's first goal is thus to measure deviations from arbitrage. The focus is on arbitrage between national money markets – borrowing in one currency and lending in another, while hedging foreign exchange risk – usually ensuring that the covered interest parity (CIP) condition holds. This condition is essential to price foreign exchange forwards and short term money market or cash interest rates.

Measuring deviations from arbitrage entails specifying the arbitrage strategy as a trader would actually implement it. In many ways, actual strategies are rather different from the textbook CIP condition and the way in which most papers model CIP arbitrage. Specifically, arbitrage can be undertaken by borrowing and lending funds on secured terms, as would a hedge fund, or on unsecured terms, by rolling over short term positions, as would a bank's proprietary trading desk (prop desk). We call the first secured and the second unsecured arbitrage. The distinction draws on that made in Brunnermeier and Pedersen (2009).

After replicating these strategies, we obtain four main results relative to CIP deviations. First, deviations were insignificant, as expected in theory, until August 2007 when the first signs of the financial crisis arose. Deviations later jumped to 400 basis points when Lehman collapsed, remaining high for nearly three months thereafter. Second, deviations were currency specific, involving the dollar. Third, deviations were directional, involving borrowing dollars. Fourth, deviations were independent of the arbitrage strategy. Both secured and unsecured strategies – actually quite different in practice – yield very similar results.

A new dataset allows us to obtain these results with precision. Data replicate very accurately the profits a trader could have realized by engaging in either secured or unsecured arbitrage. Data reflect traded prices selected from several daily snaps synchronous across securities, covering several years and currency pairs, and including transaction costs. Specifically, data for secured arbitrage include interbank repo rates in different currencies used, to our knowledge, for the first time in this literature.

This paper's second goal is to investigate why arbitrage broke down and explain the above findings. Did specific transactions necessary for CIP arbitrage become overly risky, as in a classical risk premium or asset pricing story? Or was there too little funding liquidity available to carry out arbitrage in sufficient volume, as suggested by the slow moving capital literature? To answer these questions, we identify specific underlying causes of either risk or funding liquidity constraints. We then attribute a measurable variable to each cause and test the significance of each variable in explaining CIP deviations.

This paper's empirical section finds that funding liquidity constraints predominantly explain deviations from arbitrage. The most primary cause of insufficient liquidity seems to have been lenders hoarding dollar liquidity from arbitrageurs to cover their own funding needs, as theorized in Duffie (2010) and Brunnermeier and Pedersen (2009). This specific channel helps explain why secured and unsecured arbitrage yield very similar profits and why profits are currency specific and directional (i.e. they involved borrowing dollars). In addition, it seems that arbitrageurs were limited in their use of capital to pledge for funding, thereby further explaining why positive arbitrage profits were left on the table. This is as hypothesized and modeled in Gromb and Vayanos (2010). The imperative to shrink balance sheets during the crisis seems to have played a lesser role. Yet, further reinforcing the role of liquidity, this paper finds that CIP deviations waned when the US

Federal Reserve along with other central banks extended dollar liquidity to markets through FX swap lines. Finally, to the extent that risk also played a role, it seems to have been through contract risk, or the risk of default of an arbitrageur's forward counterparty.

In the largely theoretical literature on slow moving capital and market freezes, some papers stand out as providing concrete evidence on deviations from arbitrage. These are Mitchell, Pedersen, and Pulvino (2007) focusing on the convertible bond market, and, during the recent financial crisis, Mitchell and Pulvino (2011) and Garleanu and Pedersen (2011), both addressing the CDS and bond yield spread. More generally, Brunnermeier (2009) and Pedersen (2009) illustrate the role of insufficient liquidity in aggravating of the financial crisis.

Other papers have centered specifically on deviations from CIP arbitrage. The first is Frenkel and Levich (1975, 1977), followed more recently by papers focusing on the financial crisis such as Baba, Packer, and Nagano (2008), Baba and Packer (2009b, 2009a), as well as Coffey, Hrung, Nguyen, and Sarkar (2009), Genberg, Hui, Wong, and Chung (2009) and Jones (2009).

We differentiate ourselves from this literature in four main ways. First, we define and consider two arbitrage strategies, one based on secured loans and the other on rolling over short term unsecured loans. We avoid the textbook case of engaging in unsecured loans of one or three month terms for which markets were dislocated during the crisis. This adds realism to the study of CIP deviations and stacks the cards against finding significant deviations. Moreover, it allows us to exclude loan counterparty risk from explanations of CIP deviations and test new hypotheses, such as limited capital to pledge in exchange for secured arbitrage funding. Second, we avoid measuring CIP deviations with Libor rates, which can be misrepresentative, ill-timed and tainted by a risk premium.[1] The first two issues imply that papers using Libor rates cannot convincingly reject the hypothesis that CIP deviations were just an artifact of mismeasurement, and that the CIP condition based on traded prices actually did hold. Third, we conclude that funding liquidity was more important than risk considerations in driving a profitable wedge in CIP arbitrage as opposed to many of the above papers. These papers' focus on risk is likely to be affected by the risk premium in the Libor rates used to measure CIP deviations. Coffey, Hrung, Nguyen, and Sarkar (2009) do find that strains on dollar liquidity may have arisen from non-US banks. Our paper goes further, though, in specifically testing various drivers of liquidity constraints and risk. As mentioned above, we are able to conclude, for instance, that the hoarding of dollar liquidity was an important cause of insufficient funding available to arbitrageurs. This granularity of results may prove useful, we hope, to policy makers.

Other papers on CIP arbitrage also exist, some of which use very fine data, but pre-date the financial crisis. The four that stand out are Taylor (1989), Rhee and Chang (1992), Akram, Rime, and Sarno (2008) and Fong, Valente, and Fung (2010). These papers all use high frequency data, synchronous

[1] Libor rates can be mis-representative of actual trading rates as they are indicative and only denote borrowing rates (i.e. ask and not bid quotes), void of transaction costs. McAndrews (2009) emphasizes potential distortions in Libor rates during the crisis, underscored recently by actual legal inquiries into banks' Libor reporting practices. Second, while the Libor survey is undertaken at 11 am London time, it is unclear if reported rates represent borrowing costs at any specific time snap. In addition, the survey is undertaken when US and Asian markets are closed. Together, these factors limit the extent to which price data can be synchronized to replicate actual trading profits. Finally, Libor rates do not reflect the possibility of engaging in arbitrage on secured terms.

among the various markets under study, and inclusive of bid-ask spreads as a measure of transaction costs. They focus exclusively, though, on unsecured arbitrage strategies. These papers find that deviations from CIP arbitrage, if any, reach a few basis points during merely seconds, over different currency pairs indistinguishably.

In the remainder of this paper we first outline the structure of CIP arbitrage and specify the payoffs and strategies used for secured and unsecured arbitrage. We then summarize our data and illustrate the size and duration of the break-down of CIP arbitrage. Finally, we try to explain this phenomenon by regressing CIP profits on specific measures of either risk or liquidity factors, each drawn from theory and tied to specific papers in the literature.

1 The structure of CIP arbitrage

The mechanics of CIP arbitrage, as outlined in textbooks and often replicated in papers, are not detailed enough to properly measure CIP deviations. In practice, traders use two major arbitrage strategies. Each is presented below along with its respective payoff function.

1.1 Textbook CIP arbitrage

CIP arbitrage entails borrowing in one currency and lending in another to take advantage of cross country interest rate differentials while avoiding exchange rate risk. The trade is usually described as borrowing in currency k at an interest cost $r_{k,t}$, exchanging the sum to currency j using the spot forex market, lending the proceeds in currency j at rate $r_{j,t}$, and exchanging the principal and accrued interest back to currency k at maturity to reimburse the original loan with interest. The last transaction is undertaken using a forex forward contract thereby eliminating exchange rate risk. To introduce some terminology, in the above example we would say the trader is short in currency k and long in currency j.

Profits from CIP arbitrage are often expressed as,

$$z_{1,t} = \frac{F_{t \cdots T}}{S_t}(1 + r_{j,t}) - (1 + r_{k,t}) \tag{1}$$

where the spot exchange rate S_t is expressed as the price in currency k of one unit of currency j. The same is true of the forward exchange rate, $F_{t \cdots T}$, where the subscript captures the time the contract is written and its maturity.

Because all variables are known at time t, as emphasized by the shared subscripts, textbooks normally suggest CIP arbitrage is riskless and should yield zero profits. When re-arranged with $z_{1,t} = 0$, the above equation is often referred to as the "CIP no-arbitrage condition", or the "CIP condition" for short.

1.2 CIP arbitrage in practice, two types of traders

Replicating actual arbitrage profits brings up several questions. Relative to the above characterization of CIP arbitrage, what instruments are used to borrow and lend? What transactions are undertaken? Are there hidden costs? Over what term should CIP arbitrage hold? Are there any risks involved?[2]

There are typically two ways to implement CIP arbitrage. Each is loosely

[2]Technically, arbitrage does not involve any risk, but simply ensures the prices of two identical goods or securities be equal, as pointed out by Schleifer (2000). Thus, to the extent that CIP arbitrage does involve some risk, as discussed later, it should not be called pure arbitrage. We none-the-less continue to use the term in line with the relevant literature.

representative of a kind of trader, either a hedge fund or a bank's proprietary (prop) desk. The distinction is the same as that in Brunnermeier and Pedersen (2009). Each trader typically operates on different funding markets using different strategies. Hedge funds tend to borrow and lend on secured terms, while banks tend to tap the unsecured interbank market. Thus, each strategy involves different interest rates and maturities, has different risk and liquidity implications, and potentially different payoffs.

1.3 Payoffs from secured CIP arbitrage

Secured arbitrage is the most straightforward to implement. The trader (a hedge fund) pledges capital to obtain a secured loan in currency k from and external lender (Lender L, as illustrated in Figure 1). The hedge fund then exchanges this cash to currency j on the spot market and extends a loan to Borrower B (again referring to Figure 1) against collateral. In market jargon, the hedge fund carries out a "repo" transaction with Lender L and a "reverse repo" with Borrower B, thus paying and receiving respective interbank "repo" rates.[3] These trades are of the term over which the trader wishes to carry out arbitrage. At maturity, the hedge fund reimburses Lender L after exchanging proceeds back to currency k using its pre-established forward contract. Finally, on every transaction, the hedge fund pays a non-negligible cost.

The resulting payoff is given by,

$$z_{2,t} = \frac{F^B_{t\cdots T}}{S^A_t}(1 + r^{R,B}_{j,t\cdots T}) - (1 + r^{R,A}_{k,t\cdots T}) \tag{2}$$

where r^R are repo rates in currency j or k, set in time t up to maturity

[3]The term "repo" refers to selling a security as collateral against cash and repurchasing back the security at maturity.

T, thus of term $(T-t)$. Also, the B and A superscripts denote bid and ask quotes to incorporate transaction costs related to arbitrage. We follow standard convention in assuming the trader pays the ask quotes on what she acquires and the bid quotes on what she sells.[4]

1.4 Payoffs from unsecured CIP arbitrage

Unsecured CIP arbitrage is slightly more complex. Because this strategy uses unsecured loans, traders will usually avoid long-term loans in order to minimize counterparty default risk. Thus, in order to implement arbitrage over a desired period, traders roll over short term – typically overnight – money market positions. In doing so, traders also benefit from the usually very liquid overnight market for funds. This strategy therefore stacks the cards against finding CIP deviations, as risk is minimized while liquidity is maximized.

The expected (ex-ante) payoff from such a strategy is given by,

$$z_{3,t} = \frac{F^B_{t\cdots T}}{S^A_t}(1 + r^{C,B}_{j,t\cdots T}) - (1 + r^{C,A}_{k,t\cdots T}) \tag{3}$$

where $r^C_{t\cdots T}$ are the cumulative interest rates given by rolling over overnight loans from t to T. More explicitly, these are given by,

$$\begin{aligned} 1 + r^{C,A}_{k,t\cdots T} &= \mathbb{E}_t\left[\prod_{s=t}^{T-1}(1 + r^A_{k,s\cdots s+1})\right] \\ 1 + r^{C,B}_{j,t\cdots T} &= \mathbb{E}_t\left[\prod_{s=t}^{T-1}(1 + r^B_{j,s\cdots s+1})\right] \end{aligned} \tag{4}$$

where r in the square bracket captures overnight lending rates.

[4]When a trader buys currency j while selling currency k in the spot market, she pays the *ask* price for the jk exchange rate, where, by convention, the exchange rate is the price of the currency cited first in units of that cited second (such as for EURUSD, where the exchange rate is the price in dollars of one euro).

An immediate drawback from the unsecured arbitrage strategy as described here is interest rate risk. At time t, $r^C_{t...T}$ merely reflects the expectation of the overnight interest rates' future path. In practice, of course, actual rates may vary substantially from this path. Thus, traders typically complement an unsecured arbitrage strategy by hedging interest rate risk with overnight index swaps (OIS contracts, for short).

An OIS is an instrument allowing traders to swap a floating income stream (where floating means time varying and unknown ex-ante) with a fixed rate established ex-ante. The floating leg of an OIS is indexed on an interbank overnight unsecured rate, such as the Federal Funds rate in the US, EONIA in the euroarea, or SONIA in the UK. A long position in an OIS contract allows one to receive this floating income stream against a fixed payment agreed up-front. Just the opposite is true for a short position in an OIS contract. Importantly, though, an OIS contract involves no exchange of notional upon initiation, but just the settlement at maturity of the net difference between the accrued interest on the floating leg and the fixed rate. Engaging in an OIS contract therefore adds very little risk to any trading strategy.

An OIS contract is therefore a convenient and popular instrument to hedge interest rate risk on a cash position, such as in CIP arbitrage. To illustrate, take the arbitrageur's short cash position in currency k, requiring her to make floating overnight interest payments. By taking, in addition, a long position in an OIS contract denominated in currency k, the trader will receive the same floating overnight interest payments. Indeed, the floating leg of the OIS contract and her cash position will be indexed on the same interbank, unsecured, overnight money market rates. Thus, these two floating income streams will cancel out, leaving the trader to pay only the fixed OIS rate known ex-ante, at time t. The same goes for the trader's long money market position in currency j, to be combined with a short OIS position denominated in that currency.

To summarize, the trader rolls over overnight cash or money market positions, short in currency k and long in currency j until maturity T. In addition, at time t, she hedges interest rate risk by engaging in a long OIS position in currency k and a short position in currency j. As a result, the trader's expected payoff from CIP arbitrage is given by,

$$\begin{aligned} z_{4,t} &= \frac{F^B_{t\cdots T}}{S^A_t}\left[(1+r^{C,B}_{j,t\cdots T}) - (1+r^{C}_{j,t\cdots T}) + (1+r^{O,B}_{j,t\cdots T})\right] + \\ &\quad \left[(1+r^{C}_{k,t\cdots T}) - (1+r^{C,A}_{k,t\cdots T}) - (1+r^{O,A}_{k,t\cdots T})\right] \end{aligned} \tag{5}$$

where, in the first square bracket, the first term is the floating income from lending cash in currency j, the last term is the fixed ex-ante OIS rate and the middle term captures the floating payment liabilities of the OIS contract, given by,

$$1 + r^{C}_{j,t\cdots T} = \mathbb{E}_t\left[\prod_{s=t}^{T-1}(1 + r_{j,s\cdots s+1})\right] \tag{6}$$

where the absence of bid or ask quotes on the right hand side captures the fact that the flexible leg of the OIS is technically indexed on an effective rate.

2 Measuring excess profits from CIP arbitrage

The crux of this section is its third part, showing evidence of substantial and persistent deviations from CIP arbitrage. To get to these results, though, we first review data sources.

2.1 Data for secured CIP arbitrage

Secured CIP arbitrage involves borrowing and lending on the interbank repo market against collateral. It therefore requires interbank repo rates which are notoriously difficult to obtain. Data on USD interbank repo rates were acquired from ICAP whose BrokerTec trading platform accounts for over half the interbank repo market in USD. Data for comparable rates in EUR and CHF come from Eurex AG, whose platform is the dominant trading venue for interbank repos in EUR and CHF.[5]

All repo rates represent actually traded prices and include bid-ask spreads for the EUR and CHF. While the data cover several daily snaps, we focus on the 1:45 pm snap (London time), corresponding to market opening in the US, thus ensuring maximum liquidity. For the same reason, we only extract repo rates for one week terms, discarding longer terms.

In all cases, we use repo rates from General Collateral (GC) repos.[6] This ensures maximum liquidity and minimal risk, and makes data more closely comparable across currency markets. Note that while the risk profile of a GC collateral pool may have varied over time, along with its repo rate, it should not have affected the CIP condition. The arbitrage condition, after all, should hold given any interest rate differential, irrespective of the source of fluctuations.

Finally, synchronous spot foreign exchange data, along with bid and ask quotes, come from ICAP's Electronic Brokering Services (EBS) and forward

[5]Data for both EUR and CHF were graciously shared with us on the basis of the close working relationship between Eurex AG and the Swiss National Bank.

[6]GC repos require a standard basket of collateral set by the national central bank usually composed of a wide array of highly rated government bonds. GC repo rates, as opposed to rates on special repos, do not vary with the need to hold any specific security.

rates from Tullet Prebon (TP), a leading intermediary in wholesale financial markets which facilitates the trading activities of its large client base, including financial institutions, brokers, market makers and hedge funds.[7] All data go from March 2006 to April 2009.

2.2 Data for unsecured CIP arbitrage

Moving from theory to data, we make one simplification. Equation (5) requires data on OIS rates in two currency markets as well as half spreads on future overnight money market rates. But these spreads are not known to the trader at time t, nor are they available to us. More importantly, these spreads are likely to be very small, especially compared to the size of deviations from CIP. For estimation purposes and in the spirit of replicating traders' expected arbitrage profits, we therefore ignore this half spread, thereby allowing us to simplify equation (5) to,

$$z'_{4,t} = \frac{F^B_{t \cdots T}}{S^A_t}(1 + r^{O,B}_{j,t \cdots T}) - (1 + r^{O,A}_{k,t \cdots T}) \tag{7}$$

OIS, spot and forward data span the same 2006-2009 time period and are perfectly synchronous across the forex and money markets considered, coming from four daily snaps at 9 am, 11 am, 4 pm and 11 pm, London time. The first snap captures the trading hours of European and Asian markets, the third of European and US, the fourth of US and Asian markets and the second coincides with the Libor fixing.

Data cover a wider set of currencies than those considered for secured

[7] Whereas spot rates are perfectly synchronous with the repo rates, taken at 1:45 pm London time, we use forward rates with time snaps at both 11 am and 4 pm London time as data collection was optimized for exact synchronization first and foremost among the richer dataset used in unsecured arbitrage. But results for secured arbitrage are not sensitive to the use of either forward market snap.

arbitrage. Currencies covered are EURUSD, USDCHF, USDJPY, GBPUSD, as well as EURCHF, the last serving as a control not involving the dollar. In each case, data cover relevant OIS and forward contracts of one week as well as 1, 3, 6, 8, 12 and 24 month maturities.[8]

The OIS and forward data from Tullet Prebon are technically indicative, although very close to binding bid and ask prices. This is because TP clients emitting quotes most often use the TP platform for actual trading. Indeed, there are few alternative platforms to trade these instruments.

Figure 2 shows the bid-ask spreads related to unsecured CIP arbitrage. Average spreads in the forex market, both spot and forward, became more volatile after the start of the crisis in August 2007, and increased substantially after the Lehman bankruptcy. Only in April 2009 were spreads back to pre-crisis levels. Average OIS spreads followed forex spreads in a stunning jump in September 2008, but remained elevated at end of sample.

2.3 Actual CIP profits

In the case of secured arbitrage, CIP arbitrage profits – as measured by $z_{2,t}$ – are generally negligible or negative, as expected, up to the first signs of the crisis, in August 2007. Profits then increase somewhat, suggesting growing tensions in arbitrage, although levels remain relatively small. The spike coinciding with the Lehman bankruptcy is instead a very clear indication of a break-down of arbitrage.

At their peak, profits reach nearly 400 bps on an annualized basis – a

[8]Forward rates are expressed in "pips" to be divided by 10^4 and added to the spot rate. Note also that OIS rates are annualized and thus needed to be adjusted by a multiplier in order to be consistent with their maturity. The multiplier is $\mu = T/360$ where T is maturity in days, except for sterling and yen for which the denominator is 365.

very substantial amount. Moreover, they remain high for about two months. These dynamics are visible in Figure 3 which plots CIP profits for EURUSD and USDCHF trades. In both cases, trades represent short dollar positions in the spot market. We thus refer to these as long EURUSD and short USDCHF trades.

As a comparison, Akram, Rime, and Sarno (2008) study CIP profits from tick-by-tick data in 2004 over various currency pairs. They find that annualized mean returns from CIP arbitrage, when they occur, range from 2 to 15 pips and last between 2 to 16 seconds.

Two other results emerge. First, the reverse of these trades, involving long dollar positions on the spot market, yield negative returns, as shown in Figure 4. And second, CIP profits over EURCHF yields negative returns independently of the direction of the trade, as plotted in Figure 5.

These results suggest that the very unusual arbitrage profits derived from CIP trades are (i) currency specific (involving the dollar) and (ii) directional (involving short dollar spot positions). Both these take-aways will inspire our explanations for the break-down of arbitrage.

These stylized facts are strongly corroborated by results for unsecured arbitrage profits – as measured by $z'_{4,t}$. Indeed, the extent and duration of CIP profits from secured and unsecured strategies over one week terms are nearly the same for EURUSD and USDCHF, as plotted in Figures 6 and 7.

Data for unsecured arbitrage allow us to explore the robustness of results along two further dimensions: more currency pairs and longer terms of arbitrage. Results are very similar to those described above. Figure 8 plots CIP profits for short dollar trades against the euro, yen, sterling and Swiss franc, over a one month term. As above, CIP profits increase in August 2007 and spike at the time of the Lehman bankruptcy, reaching nearly 400 bps annualized. Returns remain persistent to year end. The second spike, not visible in either secured or unsecured arbitrage over one week, most likely comes from end-of-year market perturbations often dubbed "window dressing effects" referring to flight from risky and illiquid assets; this is the only noticeable difference from extending the term of arbitrage. As before, CIP returns are negative when spot positions are long in dollars, as shown in Figure 9. And finally, returns on EURCHF unsecured arbitrage over a one month term remain negative throughout the sample, irrespective of which currency is used for financing, as illustrated in Figure 10.

To summarize, all measures show that CIP profits appear to be dollar specific and directional, as well as persistent and closely tied to the Lehman event. Profits seem to be insensitive to the arbitrage strategy.

3 Explaining excess profits from CIP arbitrage

Measured profits from CIP arbitrage, or CIP deviations, essentially have three possible explanations. First, prices of the securities used are non-representative. Thus, CIP deviations are just an artifact of mismeasurement and the actual CIP condition continues to hold in practice. We discard this explanation on the basis that our dataset represents traded prices. Second, CIP arbitrage entails some risks and these increased substantially during the crisis. In other words, the CIP condition as in $z_{1,t}$, $z_{4,t}$ or $z'_{4,t}$ should actually include a risk premium term. Third, CIP arbitrage rests on ample funding liquidity. This instead became unavailable or rationed during the crisis.

We test the validity of these last two explanations by digging deeper. We first identify three specific causes of each explanation. We then link a measurable variable to each cause and subsequently test if these variables help explain CIP profits in a regression.

3.1 Risk factors

We isolate three possible sources of risk specific to the arbitrage trade. The first, contract risk, involves default of the trader's FX forward counterparty during the term of arbitrage. Both Duffie and Huang (1996) and Melvin and Taylor (2009) emphasize this risk. Clearly, contract risk is common to both secured and unsecured arbitrage.

Contract risk involves the early termination of arbitrage and thus exposes the trader to exchange rate risk by having to close her positions using a reverse spot transaction (or renew her forward contract). We thus capture exchange rate risk with one month forex option implied volatility.

Second, the trader is exposed to rollover risk, but only when engaging in unsecured arbitrage. Indeed, her unsecured trading strategy involves rolling over overnight money market positions. At any point, though, Lender L (referring back to Figure 1) may stop rolling over the trader's debt, or the trader may do the same to Borrower B. Acharya, Gale, and Yorulmazer (2011), among others, suggest that rollover risk may lead to market freezes when investor sentiment turns negative.[9]

[9]Other papers emphasize sentiment shocks, as Shleifer and Vishny (1997) which brings up the prospects of self fulfilling prophecies. The availability of information also plays a central role, as in Hombert and Thesmar (2009) and Morris and Shin (2010), where imperfect knowledge of aggregate losses is paramount.

Rollover risk entails foregone profits from having to close arbitrage positions early. These losses depend on the maturity structure of current and expected short term interest rate differentials (losses increase when this differential rises in time, since profits are made on the differential). We therefore capture rollover risk with the one week to one month OIS spread in currency j relative to that in currency k. This "interest rate differential" corresponds to potentially lost profits from closing positions after one week instead of the planned one month (unsecured CIP profits are taken over one month terms in our regressions).

Third, the trader engaged in unsecured arbitrage faces counterparty default risk, as recently emphasized in Taylor and Williams (2009). Specifically, the risk is that Borrow B default. Of course, this risk is typically small for overnight loans, but exists none-the-less and is potentially dissuasive of lending at times of extreme crisis.

We capture counterparty default risk with the CDS index of US financial institutions (results are unchanged with CDS of European banks). And finally, as a control variable, we add a more general measure of risk which could affect any of the above three factors, in the form of the VIX index for equities, such as in Brunnermeier, Nagel, and Pedersen (2009). These variables and their correspondence to specific sources of risk are summarized in Table I.

3.2 Liquidity factors

We identify three potential causes of funding liquidity constraints. The first is prudential in nature, involving Lender L hoarding liquidity away from the arbitrage trader, thereby giving up lucrative lending revenue, to address its own funding strains. Again, this phenomenon affects both secured and unsecured arbitrage. McGuire and von Peter (2009) clearly document the importance of this channel during the financial crisis. By 2008, banks had accumulated substantial dollar assets, funded mostly on a very short term basis on unsecured terms. On net, McGuire and von Peter (2009) estimate that Canadian, Dutch, German, Swiss, UK and Japanese banks required an aggregate of USD 1.2 trillion (net) in USD to fund their assets. When funding markets dried up and when the assets in question became illiquid, banks faced a severe funding strain in dollars. The situation was exacerbated by signaling dynamics: banks did not want to be caught by their peers scrambling for liquidity and knew that posting sufficient liquidity was essential to maintaining their credit rating. As a result, banks sacrificed lending profits to rebuild their liquidity pools, mostly in dollars. These dynamics emphasizing the vicious circle between market and funding liquidity, as well as cross market contagion, are modeled more explicitly in Brunnermeier and Pedersen (2009), Adrian and Shin (2008a) and Gromb and Vayanos (2009), and eloquently discussed in Brunnermeier (2009) and Pedersen (2009).

We measure the extent of prudential liquidity hoarding in dollars with cash deposits at Federal Reserve Banks in excess of reserve balances. These represented safe liquidity pools in dollars for banks, held at significant opportunity costs. This variable as well as subsequent liquidity variables are summarized in Table I.

The second possible cause of funding liquidity constraint comes from Lender L's pressure to deleverage, or reduce her balance sheet size, and thus cut funding, albeit lucrative, to the arbitrage trader. This is common to both secured and unsecured arbitrage strategies and reflects the notion in Duffie (2010) of intermediaries' "balance sheet capacity." The impressive extent to which financial institutions deleveraged during the recent crisis is documented and discussed in Adrian and Shin (2008b) and McCauley and McGuire (2009), among others. Garleanu and Pedersen (2011) also focus on deleveraging and suggest a model in which assets with lower margin requirements – with less impact on the balance sheet – can trade at lower prices.[10] We capture the impetus to deleverage using the measure of balance sheet size of financial intermediaries developed in Adrian and Shin (2008a).[11]

The third cause of liquidity constraint builds on the theory of limited capital and is specific to secured arbitrage. According to this theory, reviewed with particular clarity in Gromb and Vayanos (2010),[12] capital to pledge in exchange for cash funding can be insufficient in times of crisis. Indeed, borrowing on secured terms requires capital to cover margins or haircuts. Following the Lehman bankruptcy, many hedge funds faced increasing redemptions and incurred heavy losses on their portfolios. In a time when

[10] Other papers also emphasize feedback from balance sheets to asset prices, as Acharya and Viswanathan (2011) and Benmelech and Bergman (2009). Other papers emphasize related frictions also leading to capital constraints and market freezes, such as the structure of financial institutions, as in Diamond and Rajan (2005), He and Krishnamurthy (2008b) and Duffie (2009), the structure of markets, as in Acharya and Pedersen (2005), Allen and Gale (2003), Allen, Carletti, and Gale (2009) and Lagos, Rocheteau, and Weill (2009), or adverse selection or investor sentiment as in Malliaris and Yan (2010), Mancini Griffoli (2009), Heider, Hoerova, and Holthausen (2009), and Bolton, Santos, and Scheinkman (2008). Finally, Cornett, McNutt, Strahan, and Tehranian (2010) suggests that during the crisis the pressure to deleverage was exacerbated by having to honor prior commitments to credit lines, mostly in USD; the paper documents the sharp drop in new loans emanating especially from banks needing to deleverage.

[11] We thank the authors for kindly sharing their data with us.

[12] But also at the heart of models in Acharya, Shin, and Yorulmazer (2009), Brunnermeier and Pedersen (2009), Kondor (2009), He and Krishnamurthy (2008b,a), Liu and Longstaff (2004), Gromb and Vayanos (2002), Rinne and Suominen (2009) and Shleifer and Vishny (1997)

raising equity was nearly impossible, available capital became scarce. As a result, hedge funds were curtailed in their ability to engage in lucrative arbitrage trades.

The literature is less clear as to which variables best track constraints on available capital to pledge for funding. We draw inspiration from Coffey, Hrung, Nguyen, and Sarkar (2009) as well as Gorton and Metrick (2009) in using the spread between Agency MBS and GC repo rates. The idea is that as capital becomes scarce, lenders are in a position to extract higher rents from borrowers in the form of higher repo rates. This is all the more true on riskier collateral, such as MBS.

While liquidity was drying up, policy was working to facilitate borrowing conditions. We therefore add two policy measures which represent a more exogenous source of liquidity fluctuations.[13] The first of these is USD swap lines extended by the Fed to other central banks (BOE, BOJ, BOC, ECB and SNB), and the second is the Fed's "Reserve Bank Credits". Reserve bank credits include securities held outright, but more importantly repos, term auction credits, other loans, as well as credit extended through the commercial paper funding facility and the money market investor funding facility.[14] While these measures had the goal of improving funding liquidity issues generally, FX swaps were more precisely targeted at solving the shortage of dollar funding abroad.

To these, we add two control variables in the form of more general liquidity measures which could be related to any of the factors above. The first are

[13] Papers studying the policy responses to liquidity constraints are Cecchetti and Disyatat (2009), Drehmann and Nikolaou (2009) and Sarkar (2009).

[14] Weekly data is available on the Federal Reserve Bank of New York's website www.federalreserve.gov/releases/h41/

TED spreads (the difference in three month T-bill and Libor rates in USD), as in Brunnermeier (2009) and Brunnermeier, Nagel, and Pedersen (2009), implying that liquid capital is withdrawn from markets when it flies to high quality government bonds. The second are one month Libor-OIS spreads. We orthogonalize these variables relative to their risk components by always including the earlier mentioned risk variables in the regression. This is as in Taylor and Williams (2009).

A final two variables are considered, intended to capture market liquidity more generally, as opposed to funding liquidity measures. We do this following Brunnermeier and Pedersen (2009) who emphasize the link between market and funding liquidity. We capture market liquidity with the first principal component across currencies (or currency pairs) of bid-ask spreads in the one month OIS and forex market. This is as in Korajczyk and Sadka (2008) and yields two latent liquidity variables.[15]

3.3 Specification and methodology

Based on the above arguments and variables, we estimate the following regression,

$$\Delta z_t = \alpha + \gamma \Delta z_{t-1} + \beta_1' \Delta \Sigma_t + \beta_2' \Delta \Psi_t + \beta_3' \ \Delta \Theta_t + \epsilon_t \tag{8}$$

where Σ_t is a matrix of variables capturing "risk", Ψ_t is a matrix of "funding liquidity" variables and Θ_t is a matrix including the "market liquidity" vari-

[15] The FX latent liquidity variable is defined as the first principle component (FPC) of the bid-ask spreads of the exchange rates (both spot and forward rates) against the USD. The FPC accounts for more than 80% of the overall liquidity and the loadings are extremely similar across exchange rates. We also tried using a straight average and found, as expected, very similar results. The OIS latent liquidity variable is defined as the FPC that accounts for 60% of the total volatility and the loadings are very similar across currencies (i.e. between 0.42 and 0.54), except for the JPY which has a loading of -0.14. The exclusion of the latter leaves the results essentially unchanged.

ables. Note that all variables are taken in first differences, as it is primarily the impact of the tightening of funding liquidity on the growth of excess CIP profits that interests us. Estimation is carried out for both the EURUSD time series and a panel including EURUSD, USDJPY, GBPUSD, and USD-CHF, all over a one month term for unsecured arbitrage. Shorter and longer terms are explored in the robustness tests. For secured arbitrage, results are shown only for EURUSD over a one week term. Time series regressions are estimated using OLS with Newey-West standard errors, and panel regressions using Seemingly Unrelated Regression with fixed effects, exchange rate specific constants and autoregressive coefficients.

The identification strategy entails testing the significance of each funding liquidity variable separately, while controlling for risk as well as market liquidity factors. The only funding liquidity variable included in all regressions due to its exogeneity is FX swaps. This method entails running seven regressions for unsecured arbitrage and eight for secured arbitrage. Other variants are instead explored in the robustness tests. Finally, identification of coefficients does not rely on the Lehman bankruptcy event alone. As discussed in some more details in the robustness tests, the sign and significance of coefficients does not change if these are estimated in the crisis sample between August 2007 and just before the Lehman bankruptcy.

3.4 Estimation results

Liquidity hoarding, as measured by central bank deposits, is positive and significant across both the unsecured arbitrage panel and time series regressions (Tables III and II) and the secured arbitrage regressions (Table IV). This is as expected. Indeed, this channel promised to be particularly helpful to explain CIP profits. First, the channel is common to both secured and unsecured arbitrage and can thus help explain these strategies' very similar profits. And second, liquidity hoarding can help explain why CIP profits were currency specific and directional; as described earlier, banks hoarded mostly dollars to cover funding of their large dollar books.

Balance sheet deleveraging, as measured by the Adrian and Shin measure of balance sheet size, is not significant across the board. It does gain significance and appears with the expected negative sign when all variables are taken in levels (included in robustness tests). In addition, the balance sheet measure may be tainted by banks having to absorb formerly off-balance sheet vehicles or other pre-committed credit lines, while wanting to deleverage on other fronts none-the-less. Yet, the lack of clear significance could also come from the fact that it is harder for deleveraging to explain why CIP profits would necessarily involve borrowing dollars and not arbitrage over all currency pairs equally. Of course, stories can always be told of banks attempting to rebalance their currency exposure while shrinking their balance sheets, thereby reducing assets (or loans to arbitrageurs) in dollars.

The third funding liquidity variable of interest, Agency MBS to GC repo spreads, tied to the limited capital hypothesis, is also significant in the relevant secured arbitrage regressions (Table IV). While it is not immediately straightforward to tie this explanation to the fact that CIP profits mostly involved borrowing dollars, limited capital may have served to amplify or extend CIP profits over time. Yet, it is not unlikely that hedge funds lacked mostly dollar assets to pledge as collateral for funding, as these - especially MBS - were hit hardest during the crisis.

Further highlighting the importance of funding liquidity constraints in dollars during the crisis, the policy variables – USD FX swaps and Federal Reserve bank credits – appear as negatively and significantly related to CIP profits in all regressions (Tables III, II and IV). This suggests that as policy injected greater dollar funding liquidity, excess CIP profits decreased. Note that both variables are taken with a one week lag, to allow for the transmission of policy. This is when significance is highest, although coefficients remain significant when policy variables are included with a two week lag, or contemporaneously.

Finally, other funding liquidity variables – TED and Libor-OIS spreads – as well as market liquidity variables are also mostly significant and have the expected positive sign. The only exception is the negative sign on forex transaction costs which indeed mechanically erode arbitrage profits, and the lower significance of market liquidity variables in the EURUSD time series regressions, probably coming from the greater liquidity of the EURUSD spot forex market.

Of the risk variables, the only one with some significance is forex implied volatility, tracking contract risk. The variable is always positive and significant in the EURUSD time series regressions (Table II), although the picture is somewhat less clear in the more representative panel case (Table III) or the secured arbitrage case (Table IV). The other risk variables – banks' CDS, interest rate differential and the VIX – are almost never or never significant. These results are also expected. Contract risk is the only source of risk common to both secured and unsecured arbitrage, and thus the only variable able to explain these two strategies' very similar profits. Contract risk alone, though, cannot explain why CIP profits were dollar specific and directional. Other explanations, related to funding liquidity constraints, are therefore also necessary. But contract risk can help explain the persistence of arbitrage opportunities.

To summarize, then, the above results suggest that CIP deviations can be explained mostly by funding liquidity constraints in dollars, due in great part to liquidity hoarding in dollars and limited capital to pledge in exchange for funding. The imperative to shrink balance sheets may have been less central. The policy response to provide dollar funding liquidity through FX Swaps was thus effective and, indeed, can significantly explain the reduction in CIP profits. Finally, contract risk, relative to the forward contract, was probably responsible to amplify and extend CIP profits.

3.5 Additional robustness tests

Results from additional robustness tests are described verbally for the sake of brevity. None-the-less, any specific result is available upon request.

- Time of day does not seem to affect CIP profits. Results are unchanged when using a 4 pm snap relative to the baseline 11 am snap for unsecured arbitrage (all times are London time).

- Considering unsecured arbitrage over a six month or a one week term, instead of one month, does not affect results.

- Results over sub-samples support our main findings: liquidity variables are insignificant prior to August 2007, become significant between August 2007 and just before the Lehman bankruptcy, and grow substantially thereafter. Risk related variables instead remain mostly insignificant throughout each period.

- Results are robust to different regression specifications. Results are nearly unchanged when considering all variables in levels instead of first differences (except for the significance of the balance sheet variable as discussed earlier) and when including each variable separately, while still controlling for a constant and an autoregressive term. An encompassing regression that includes all variables together delivers consistent results, except that TED spreads lose significance most probably due to their collinearity with Libor-OIS spreads. Finally, accounting for ARCH effects leaves all findings essentially unchanged.

4 Conclusion

This paper provides empirical evidence for the theory of slow moving capital and limits to arbitrage, and adds to recent studies on the effects of the financial crisis. This paper focused on measuring precisely, and explaining, deviations from covered interest parity (CIP) arbitrage. The paper described how such arbitrage strategies are actually implemented in practice, using either secured or unsecured money market transactions. Especially after the Lehman bankruptcy, excess profits from CIP arbitrage were substantial and persistent, involved borrowing dollars and did not depend on whether borrowing was secured. These results were found with data which closely match those a trader would have used to undertake arbitrage. Data are intra-daily, synchronized across markets and inclusive of transaction costs. Results implied that it was especially the lack of dollar funding liquidity –

due mostly to liquidity hoarding and limited capital – that hindered arbitrage and thus failed to balance the CIP condition. Policy to provide dollar funding liquidity was an effective tool to normalize tensions across national money markets.

Looking ahead, these results suggest that policy aimed at avoiding future crises, or at least at containing their effects on the proper functioning of markets, should also take into consideration the role of funding liquidity. More precise recommendations along these lines, building on this paper's results, have already been raised in Kashyap, Berner, and Goodhart (2011) and in the IMF's Global Financial Stability Report (2011) in which CIP deviations are suggested as a measure of systemic risk to be included in Basle III.

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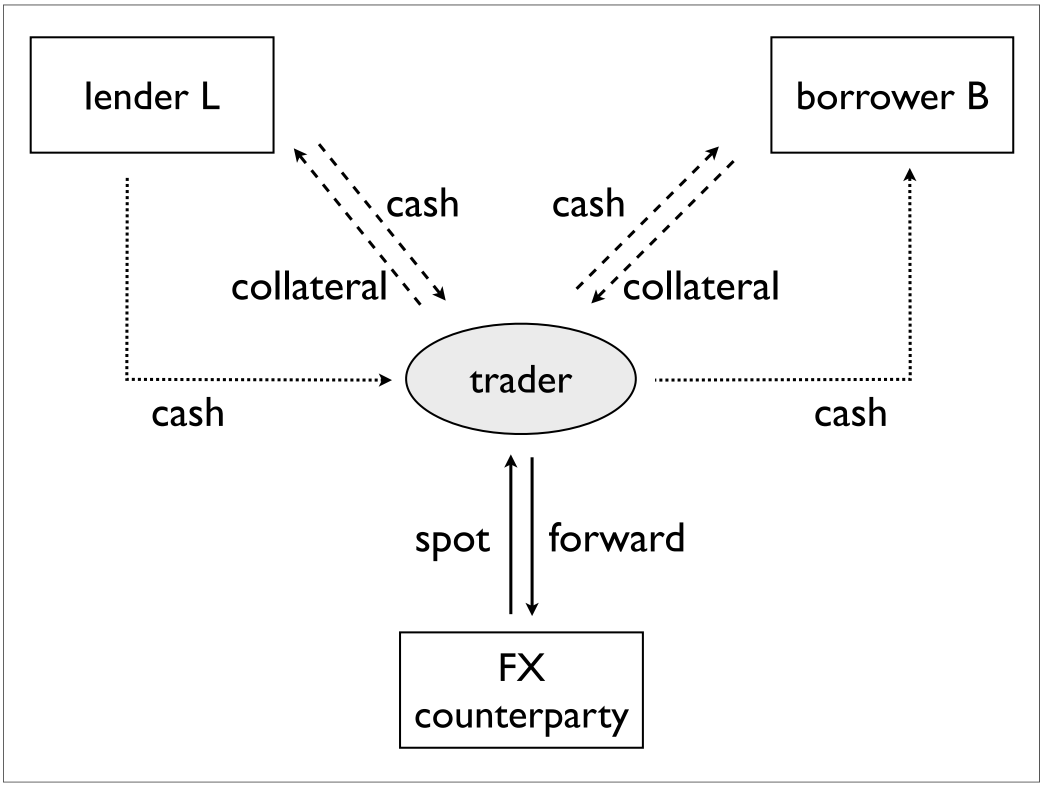

Figure 1: *An illustration of CIP arbitrage: the trader can be thought of as either a hedge fund or the prop desk of a large financial institution. Typically, the former borrows and lends on secured terms by exchanging cash against collateral (hashed lines), and the latter does so on unsecured terms (dotted lines). Both are money market transactions. The trader also engages in two forex transactions with appropriate counterparties, one spot and one forward. In all, CIP arbitrage involves four transactions.*

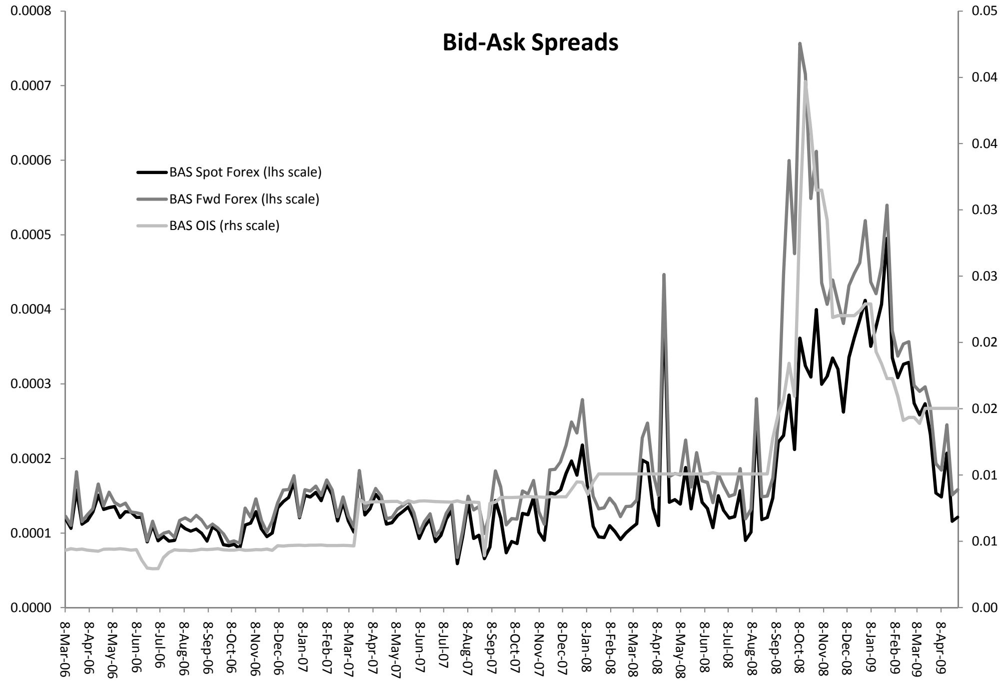

Figure 2: *Average bid–ask spreads across currency pairs in the forex spot and forward markets, as well as OIS market. Bid–ask spreads are calculated as $(Ask - Bid)/C$ where C is the average midquote.*

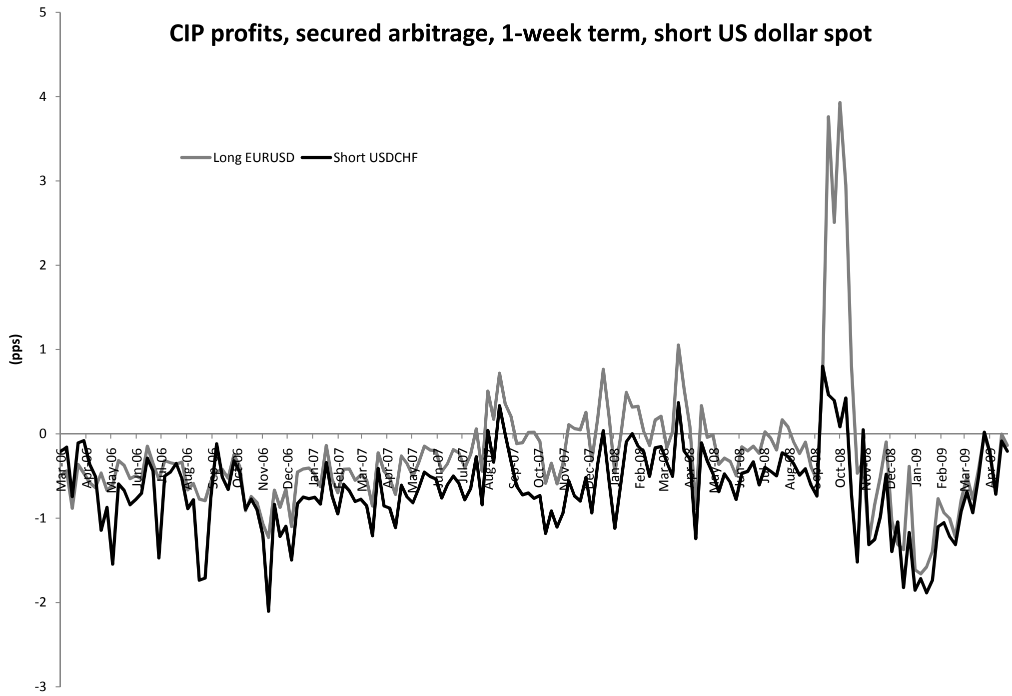

Figure 3: *Excess profits are large and persistent from secured CIP arbitrage on trades involving a short USD spot position, over a 1 week term.*

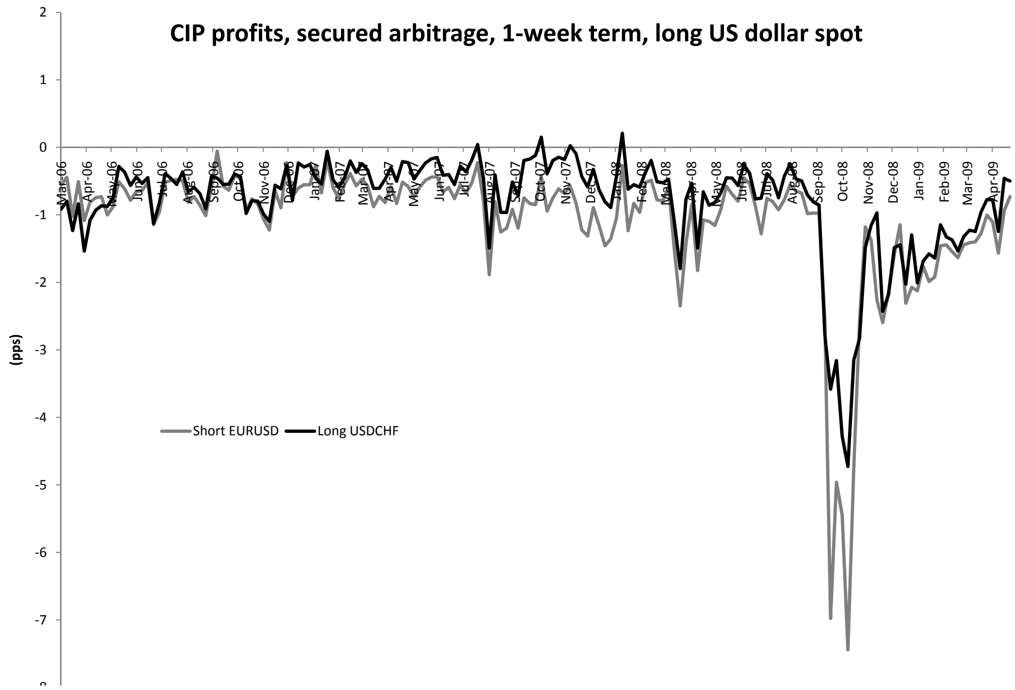

Figure 4: *Excess profits are negative from secured CIP arbitrage on trades involving a long USD spot position, over a 1 week term.*

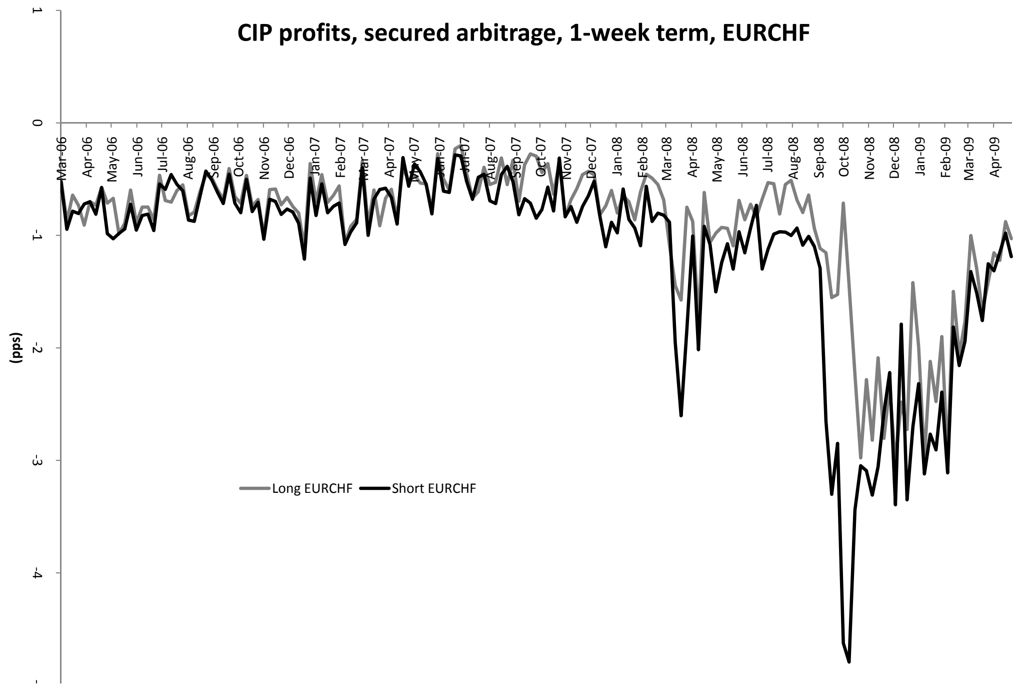

Figure 5: *Excess profits are negative from secured CIP arbitrage over a 1 week term on trades in EURCHF, irrespective of the currency used for financing.*

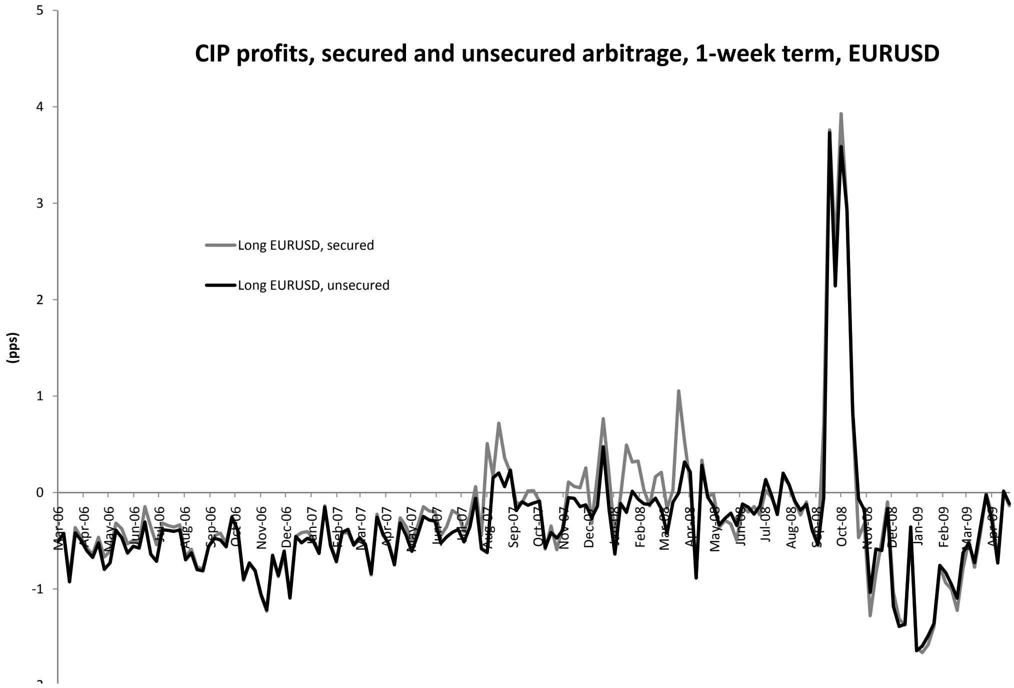

Figure 6: *Excess profits are exactly the same on secured and unsecured CIP arbitrage over a 1 week term on trades involving a short USD spot position.*

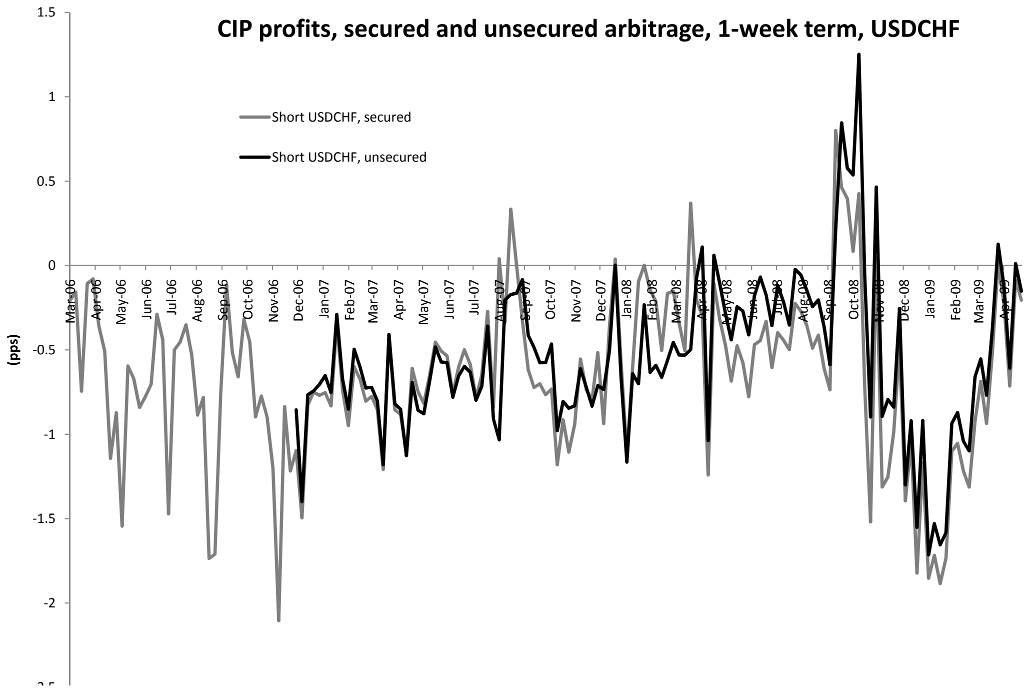

Figure 7: *Excess profits are nearly the same on secured and unsecured CIP arbitrage over a 1 week term on trades involving a short USD spot position.*

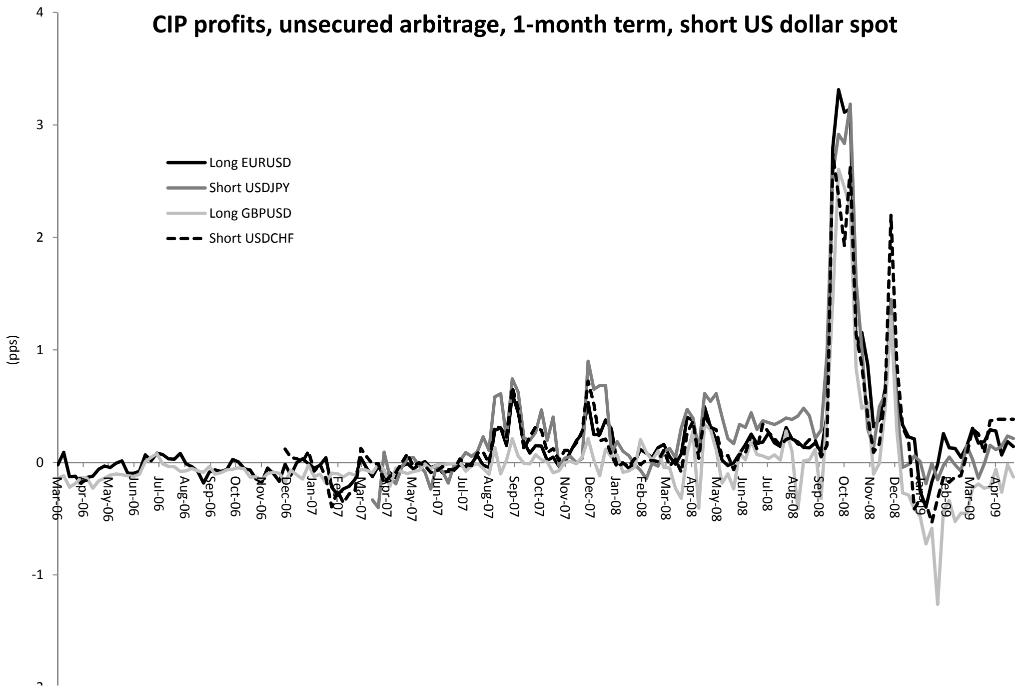

Figure 8: *Excess profits are large and persistent from unsecured CIP arbitrage on trades involving a short USD spot position, over a 1 month term.*

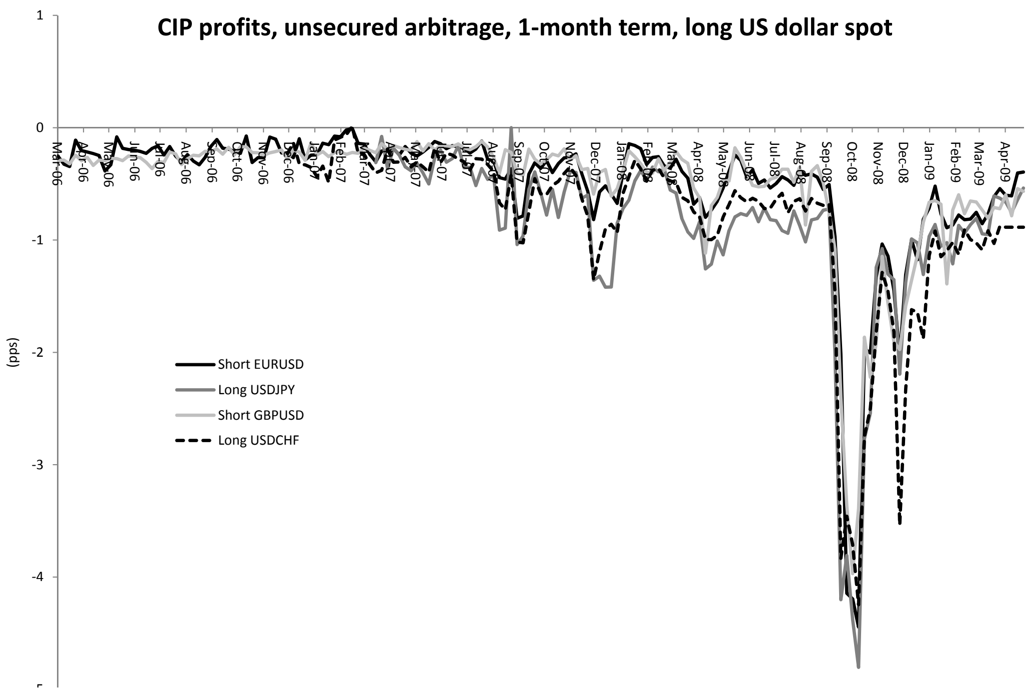

Figure 9: *Excess profits are negative from unsecured CIP arbitrage on trades involving a long USD spot position, over a 1 month term.*

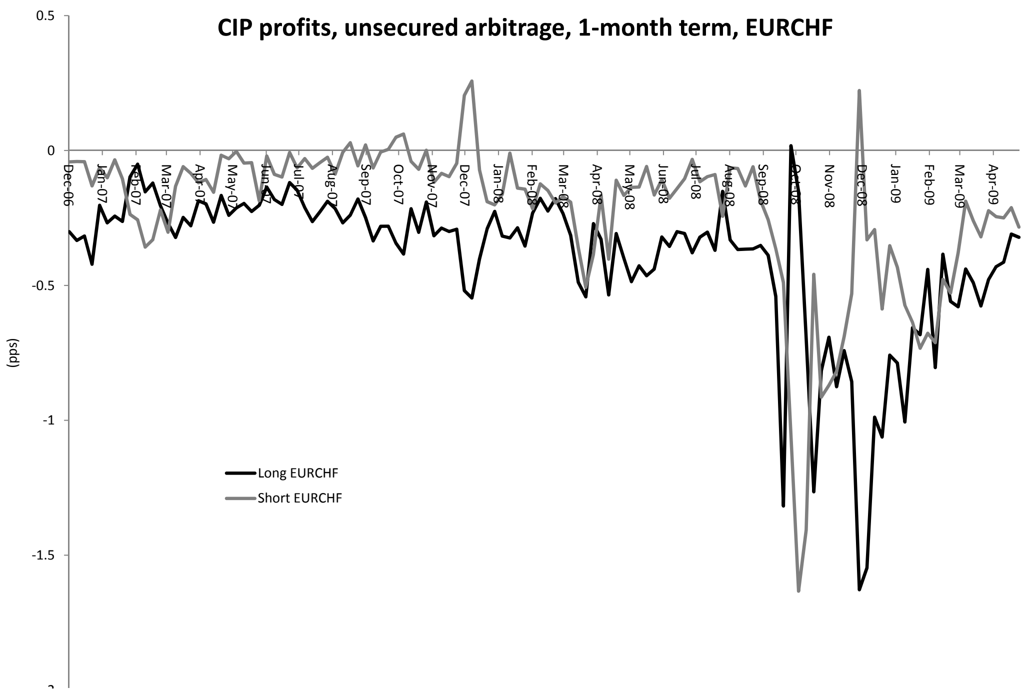

Figure 10: *Excess profits are negative from secured CIP arbitrage over a 1 month term on trades in EURCHF, irrespective of the currency used for financing.*

	Factor	Unsecured arbitrage proxy	Secured arbitrage proxy
Risks			
	Contract	Implied volatility (IV)	Implied volatility (IV)
	Rollover	Interest differential	NA
	Counterparty default	CDS	NA
	General/ controls	VIX, CDS	VIX, CDS
Funding liquidity			
	Prudential liquidity hoarding	Fed deposits	Fed deposits
	Deleveraging	Balance sheet	Balance sheet
	Limited capital	NA	MBS-GC repo spreads
	Policy measures	CB swaps, Reserve credits	CB swaps, Reserve credits
	General/ controls	TED, Libor-OIS	TED, Libor-OIS
Market liquidity			
	Transaction costs	OIS & FX BAS spreads	OIS & FX BAS spreads

Table I: *Summary of various explanatory factors for excess profits from CIP arbitrage, categorized according to risk, funding liquidity and market liquidity. Each factor is intended to be captured by a corresponding "proxy" or variable. Since some factors are not relevant to both unsecured and secured arbitrage strategies, some proxies are market as not applicable (NA).*

Time series, long EURUSD unsecured CIP arbitrage (1M)

	Specification						
	1	2	3	4	5	6	7
Market Liquidity							
FX liquidity	-0.021	**-0.039**	**-0.039**	-0.032	-0.026	-0.040	**-0.041**
	-0.906	-1.671	-1.747	-1.331	-1.153	-1.573	-2.171
OIS liquidity	**0.302**	**0.321**	**0.374**	0.089	0.129	**0.330**	**0.237**
	2.661	2.741	3.150	0.740	1.139	2.666	2.924
Funding Liquidity							
CB swap		**-6.704**		**-4.618**	**-4.721**	**-6.743**	**-7.537**
		-4.498		-3.303	-3.468	-4.120	-8.198
Reserve credits			**-4.289**				
			-3.300				
TED Spread				**0.655**			
				4.032			
Libor-OIS					**0.765**		
					4.426		
Balance sheet						1.433	
						0.661	
Fed deposits							**1.009**
							10.649
Risks							
IV		**1.697**	**1.581**	**0.967**	**1.397**	**1.853**	**1.074**
		3.104	2.920	1.796	2.763	3.050	2.802
Interest Diff.		-0.246	-0.293	-0.205	-0.154	-0.291	-0.124
		-1.219	-1.415	-1.102	-0.840	-1.317	-0.939
CDS		-0.305	-0.270	-0.477	-0.243	-0.335	0.118
		-0.808	-0.704	-1.329	-0.695	-0.776	0.475
VIX		0.446	0.257	0.179	0.075	0.358	-0.191
		0.968	0.564	0.393	0.166	0.701	-0.565
Adj. R2	0.040	0.237	0.185	0.345	0.380	0.223	0.637

Table II: *Time series results for long EURUSD spot positions. For each variable, estimated coefficients appear above corresponding t-statistics. Numbers in bold represent significance at least at the 10% level. AR(1) coefficients are always significant, while the constant is never so; neither are shown to simplify the table.*

Panel, short USD unsecured CIP arbitrage (1M)

	Specification						
	1	2	3	4	5	6	7
Market Liquidity							
FX liquidity	**-0.073**	**-0.077**	**-0.083**	**-0.075**	**-0.072**	**-0.079**	**-0.065**
	-3.838	-4.014	-4.281	-4.195	-4.455	-3.792	-4.029
OIS liquidity	**0.349**	**0.350**	**0.387**	0.134	**0.161**	**0.354**	**0.271**
	3.949	4.050	4.270	1.606	2.216	3.955	4.037
Funding Liquidity							
CB swap		**-5.741**		**-3.494**	**-3.854**	**-5.945**	**-7.184**
		-5.648		-3.759	-4.658	-5.456	-9.676
Reserve credits			**-2.417**				
			-3.133				
TED Spread				**0.739**			
				6.985			
Libor-OIS					**0.850**		
					8.505		
Balance sheet						0.171	
						0.119	
Fed deposits							**0.898**
							11.641
Risks							
IV		**0.856**	0.587	0.194	**0.671**	**0.929**	**0.832**
		2.112	1.406	0.529	2.073	2.081	2.658
Interest Diff.		-0.091	-0.072	**-0.172**	**-0.157**	-0.103	**-0.149**
		-0.951	-0.712	-2.002	-1.851	-1.002	-1.908
CDS		0.155	0.383	-0.214	0.053	0.221	0.044
		0.575	1.354	-0.898	0.245	0.720	0.214
VIX		0.576	0.346	0.182	0.003	0.522	-0.042
		1.634	0.952	0.564	0.009	1.365	-0.149
Adj. R2							
EURUSD	-0.045	0.124	0.012	0.281	0.298	0.101	0.614
USDJPY	0.006	0.246	0.098	0.446	0.514	0.253	0.436
GBPUSD	0.127	0.171	0.128	0.295	0.381	0.142	0.402
USDCHF	-0.061	0.133	-0.033	0.306	0.404	0.115	0.528

Table III: *Panel results for USD group exchange rates, involving short USD spot positions. For each variable, estimated coefficients appear above corresponding t-statistics. Numbers in bold represent significance at least at the 10% level. AR(1) coefficients are always significant, while the constant is never so; neither are shown to simplify the table.*

Time series, long EURUSD secured CIP arbitrage (1W)

	Model							
	1	2	3	4	5	6	7	8
Market Liquidity								
FX liquidity	-0.062	-0.065	-0.067	**-0.080**	**-0.068**	-0.053	**-0.086**	**-0.092**
	-1.539	-1.626	-1.609	-2.072	-1.714	-1.222	-2.639	-2.433
OIS liquidity	**0.746**	**0.776**	**0.854**	**0.491**	**0.658**	**0.765**	**0.738**	**0.483**
	4.166	4.568	4.536	2.899	3.857	4.369	5.673	2.976
Funding Liquidity								
CB swap		**-10.413**		**-8.128**	**-9.371**	**-9.860**	**-12.529**	**-7.637**
		-5.448		-4.440	-4.949	-4.846	-8.586	-4.352
Reserve credits			**-4.374**					
			-2.968					
TED Spread				**0.819**				
				4.055				
Libor-OIS					**0.529**			
					2.348			
Balance sheet						2.713		
						1.060		
Fed deposits							**1.109**	
							7.643	
Repo spread								**0.612**
								2.685
Risks								
IV		**1.521**	0.803	1.013	**1.515**	**1.611**	**1.379**	0.887
		1.983	0.977	1.419	2.043	1.909	2.372	1.291
CDS		0.099	0.264	-0.003	0.166	0.239	0.284	-0.114
		0.205	0.494	-0.007	0.357	0.438	0.778	-0.191
VIX		0.379	0.011	-0.167	-0.022	0.087	-0.300	-0.138
		0.579	0.015	-0.268	-0.033	0.123	-0.581	-0.325
Adj. R2	0.159	0.267	0.156	0.357	0.298	0.260	0.528	0.396

Table IV: *Time series results for long EURUSD spot positions. For each variable, estimated coefficients appear above corresponding t-statistics. Numbers in bold represent significance at least at the 10% level. AR(1) coefficients are always significant, while the constant is never so; neither are shown to simplify the table.*