The dynamics of limits to arbitrage: Evidence from international cross-sectional data*

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ABSTRACT

The Law of One Price suggests a simple arbitrage relationship that links prices of Treasury bonds when issued by the same issuer in different currency denominations. This relationship was widely violated during the 2007-2008 Financial Crisis. In this paper, we use international cross-sectional data on this phenomenon to learn about the relative importance of different models of limits to arbitrage. A key source of information is a unique dataset that provides details on the cost of borrowing and the inventory of lendable bonds at brokers-dealers. We focus on four main explanations of limits to arbitrage: (i) Liquidity risk, (ii) Short-selling constraints, (iii) Leverage constraints and funding costs, (iv) Institutional frictions in the context of a large macro demand and wealth shock. We find that bond specific liquidity costs and short-selling constraints have only a limited ability to explain the observed elevated basis. Instead, we find stronger evidence of an interaction between leverage constraints and funding costs in the presence of a large macro shock reducing the supply of risk capital. In addition, we find that the geographical distribution and concentration of bank holdings of these bonds help to explain cross-sectional differences in the Basis. Finally, we quantify the extent to which monetary policy interventions helped to reduce these frictions.

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It is good for a scientific enterprise, as well as for a society, to have well established laws. Physics has excellent laws, such as the law of gravity. What does economics have? The first law of economics is clearly the law of supply and demand, and a fine law it is. We would nominate as the second law "the law of one price", hereafter simply the Law. Lamont and Thaler (2003a)

THIS PAPER EMPIRICALLY INVESTIGATES the dynamic properties of violations of the law of one price (LOP) in sovereign bond markets occurring around periods of market distress. We study the extent to which limits to arbitrage are time-varying, how they are related to specific market frictions and risk factors, and how they have changed before, during and after the 2007-2008 Crisis. An important component of this study is a unique dataset that provides very detailed coverage on sovereign bond lending at the security specific level. It includes detailed information on the total amount lent out, the total available lending supply, loan transactions, loan fees (cost of borrowing), and active loan utilizations of both Euro- and USD-denominated sovereign Eurobonds, provided by the major prime brokers, custodians, and the lending desks of large firms that actually lend/borrow these securities. We use this detailed information to help distinguish between alternative models of limits to arbitrage.

Several nations and multinational corporations issue debt denominated in more than one foreign currency. Brazil, for instance, issues a considerable amount of both USD- and Euro-denominated bonds with similar time-to-maturities. When the expected recovery rates in different foreign currencies are the same (as is the case for the bonds that we include in the study), yield spreads across two foreign currencies must satisfy a simple LOP restriction. The price of a USD-denominated Brazilian bond should be equal to its Euro-denominated equivalent (with same maturity) once the foreign exchange rate risk is swapped/hedged in the USD-Euro FX swap market.[1]

During the Crisis, however, several institutional investors reported the existence of an anomaly in these markets.[2] Was the law of one price genuinely impaired in the markets after carefully accounting for transaction costs and other frictions? Indeed, while we find no evidence of a violation before 2007, during the 2007-2008 Crisis a significant anomaly emerges that did not merely last a few days but rather that persisted for almost a year. In December 2008, for instance, Brazil's Euro-denominated credit yield spread on 10-year Eurobonds was nearly 25% higher than the credit yield spread on the same maturity bond

[1]Notice that we are comparing two bonds that are *both* denominated in a *foreign* currency to the issuer, as opposed to two bonds being one in domestic and the other in foreign currency. In the latter case, the potential for selective default on domestic bonds may give rise to different credit risks.

[2]HSBC, Deutsche Bank and Thames River Capital discuss in their investor reports relative value opportunities in USD and Euro spreads in emerging markets. BlueBay, a large European high-yield institutional investor discusses this phenomenon in its investor letter, and highlights investment opportunities by shorting USD-denominated bonds, and longing the similar Euro-denominated bonds (see Wigglesworth, Financial Times, retrieved from http://www.ft.com (October 4, 2011)).

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denominated in USD; this difference was only 4% in November 2005. By mid-October 2008, the LOP deviation between 2010 Brazilian USD bond and its Euro equivalent, reached 407 bps after hedging out the exchange rate, and accounting for the transaction costs. Around the same period, this deviation was 209 bps for 2015 Brazilian bonds, 136 bps for 2020 Mexican bonds, 169 bps for 2014 Turkish bonds, and 201 bps for 2019 Turkish bonds. The anomaly persisted for over three months. These are large values indeed, given the liquid nature of these securities.

This phenomenon raises a series of fundamental financial economics questions related to the type of limitations that may prevent price convergence. Four main sources of frictions have been suggested in the extant literature: (a) liquidity factors, (b) short selling constraints, (c) funding costs affecting the debt capacity of arbitrageurs (leverage constraints), and (d) institutional frictions in the context of a large macro demand and wealth shock affecting the demand for risk arbitrage.[3] To study these channels, we build an international dataset that provides cross-sectional information on sovereign bonds across different geographical areas and maturities.

There is extensive literature studying market anomalies. Some of the most significant anomalies include the U.S. TIPS-Treasury Bond puzzle (Fleckenstein, Longstaff, and Lustig (2010)), the CIRP puzzle (Griffoli and Ranaldo (2011)), and the CDS-bond basis (Garleanu and Pedersen (2011), Bai and Collin-Dufresne (2011)) and the Siamese-Twin stocks puzzle (Rosenthal and Young (1990)). A differentiating feature of our dataset is that it provides both cross-sectional and time-series information to study the properties of the law of one price across different markets. Moreover, while the CDS-bond basis refers to a spread between two somewhat different assets, with substantially different liquidity and counterparty risks (a feature that is notoriously difficult to measure precisely), sovereign bond pairs are more homogeneous. In addition, sovereign bond markets are substantially more liquid compared to twin stocks. Finally, bonds have a finite terminal resolution of uncertainty, so that the cash flows of the two legs of the trade must converge in finite time (either at maturity or at default).

We select the three most important emerging sovereign bond markets (by notional amount outstanding) with issues denominated in both USD and in Euro (i.e. Turkey, Brazil, and Mexico). These countries have four important features: (a) they have large and liquid Eurobond markets, in which search and trading costs were small before the crisis, (b) they were "remote" to the epicenter of the crisis as all these countries have been upgraded by all three credit rating agencies between 2007 and 2011, (c) their bond prices satisfied the law

[3] Within the limits to arbitrage literature, important contributions to understanding market liquidity risk include (Mitchell, Pedersen, and Pulvino (2007), Amihud and Mendelson (1986), Duffie, Garleanu, and Pedersen (2007)); Short-selling constraints and associated borrowing costs at the level of each individual security have been studied by (Harrison and Kreps (1978), Diamond and Verrecchia (1987), Scheinkman and Xiong (2003), Tuckman and Vila (1992)); Leverage constraints and the effect of different funding markets have been studied by (Gromb and Vayanos (2002), Bernanke and Gertler (1989), Fostel and Geanakoplos (2008), Gabaix, Krishnamurthy, and Vigneron (2007), Garleanu and Pedersen (2007), Brunnermeier and Pedersen (2009), Garleanu and Pedersen (2011)); The role of balance sheet and wealth shocks on the availability of risk capital are discussed in (Shleifer and Vishny (1997), Gromb and Vayanos (2010)).

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of one price prior to the crisis, and (d) they provide multiple pairs of tradable assets across different continents. We proceed in the following steps. First, we use pairs of bonds from the same issuers with near identical maturities, and denominated in different currencies. We swap the cash flows of one bond into the other currency to hedge the FX risk, and to construct a measure for the $Basis_{\text{bond}}$, which proxies the extent of deviation from the LOP. This measure is net of both transaction and hedging costs. Then, we investigate whether $Basis_{\text{bond}}$ is state-dependent, and what drove its dynamics during the different phases of the 2007-2008 market turmoil. We use the behavior of the $Basis_{\text{bond}}$ to study the relative importance of the four main classes of frictions that have been proposed by different models of limits to arbitrage in the context of our international cross-sectional dataset. Third, we use our dataset to study the extent to which monetary policy interventions have affected the $Basis_{\text{bond}}$ of seemingly unrelated sovereign bond markets. We frame this last part of the analysis in the context of an event study, and quantify the impact of the U.S. government's liquidity interventions, lending facilities, stress tests, and asset purchase programs on the dynamics of $Basis_{\text{bond}}$.

We find a number of novel empirical results. First, $Basis_{\text{bond}}$ for all emerging markets is state-dependent. Under normal conditions (i.e. Pre-Crisis), it is not significantly different from zero. However, for an extended period of time during the Credit Crisis, $Basis_{\text{bond}}$ becomes large, persistent, and volatile.

Second, the time-variation in bond-specific bid-ask spreads (a proxy of liquidity), and the bond-specific inventory of lendable securities (a proxy of bond availability to short-sellers) help to explain the dynamics of $Basis_{\text{bond}}$, which tends to increase with higher bid-ask spreads, and decrease with higher loan availability. This is consistent with recent findings on equity markets about the impact of the short-selling bans on price efficiency. However, at most 2% of the total variation in the $Basis_{\text{bond}}$ can be explained by bid-ask spreads and the inventory of lendable securities. We find that bond-specific Loan Fees (capturing cost of borrowing) are insignificant. This joint result suggests that it is unlikely that liquidity risks and short-selling constraints played a key role in helping to explain this phenomenon. On the other hand, we find that funding costs in both the secured and unsecured markets are statistically and economically significant after controlling for global macro-level shocks. This empirical finding supports the explanation based on the interaction between capital constraints and macroeconomic shocks.

Our third finding is related to the geographical characteristics of the funding markets. We find a significant cross-sectional dispersion in $Basis_{\text{bond}}$: On average, Brazil and Mexico pay higher risk premia in Euro compared to USD, while the opposite holds true for Turkey. We show that this pattern is linked to the nature of their respective funding markets. We obtain data on bank holdings and all branches (and subsidiaries) on a worldwide consolidated basis, disaggregated by country exposure. We find that, to a great extent, European (U.S.) banks had substantially larger concentration of Turkish (Mexican and Brazilian) bonds. This implies that the presence of frictions limiting the ability of banks to fund assets using outside capital (foreign denominated unsecured commercial paper) versus inside capital (insured domestic deposits) has the potential to increase the shadow cost of carrying foreign denominated assets, thus generating a cross-sectional dispersion in the Basis. Based on a "diff-in-diff" analysis, our empirical evidence support this conjecture.

Fourth, we find evidence that global economic factors (based on U.S. economic variables) are highly significant in explaining the $Basis_{\text{bond}}$ of assets on local markets. This is consistent with the idea that the (marginal) arbitrageur is exposed to sources of risks that go above and beyond the risk factors affecting the local market (the issuing country in our study). See Gromb and Vayanos (2010) for a model in which global arbitrageurs, who are present across different markets, are affected by common wealth shocks. When arbitrageurs find it difficult to absorb these shocks by accessing debt markets, this friction becomes a source of contagion across seemingly unrelated assets.

Our fifth finding is related to how monetary policy interventions by the U.S. Treasury and the Fed affected the $Basis_{\text{bond}}$ in emerging markets. FOMC has extended global dollar swap lines to Brazil and Mexico, but not to Turkey. This fact allows us to use Turkey as a control group, and to identify the cross-sectional impact of the dollar swap lines on $Basis_{\text{bond}}$. We find that, indeed, the cross-sectional dispersion between the Turkish Basis vs. the Brazilian/Mexican Basis tends to widen further when these swap extensions are authorized. Following the announcement of swap extensions on October 29, 2008, the $Basis_{\text{bond}}$ of Brazil and Mexico begin to diminish almost immediately, whereas the $Basis_{\text{bond}}$ of Turkey continues to rise. We also find that, after the Fed publishes the stress test results on financial institutions, and directly addresses market uncertainty via public signaling, $Basis_{\text{bond}}$ levels begin to decrease across all markets. This has important policy and welfare implications that deserve further study.

Finally, we find evidence against the market practice of using USD yield spreads as the de-facto input for pricing the same credit risk denominated in different currencies. While this appears to be a popular approach in the industry, we find that investors require different risk premia on USD- and Euro-denominated bonds, despite the fact that they are issued by the same sovereign.[4]

The remainder of the paper is organized as follows. Section 1 frames the contribution of the paper in terms of the existing literature. Section 2 provides the framework of the LOP relationship for sovereign bonds issued across two foreign currencies by the same issuer. Section 3 describes the data selection. Section 4 explains the calculation of our LOP proxy, and outlines the size of dislocation. Section 5 discusses the determinants of $Basis_{\text{bond}}$ through liquidity, funding and macro-shock channels. Section 6 explains the geographical differences in the sign of $Basis_{\text{bond}}$. Section 7 investigates the effects of different policy interventions on $Basis_{\text{bond}}$. Section 8 concludes.

[4]Thus, the assumption of currency independence may lead to seriously mispriced credit products. Credit pricing models should take into account the funding risks specific to each corresponding currency.

I. Related Literature

This paper is related to three streams of the asset pricing literature. The first stream studies the economic reasons for observed deviations from the law of one price. Shleifer and Vishny (1997) argue that a widening in the mispricing of an asset may lead arbitrageurs to unwind their positions, which may further amplify the initial mispricing. Such forced unwinding can be due to a suboptimal design of the capital structure of the arbitrageur. As he loses money on his positions, his investors ask earlier reimbursement. If the arbitrageur cannot compensate the demand shock of his investors (for instance by increasing his leverage), then deviations from the LOP can be persistent. The first part of this stream of limits to arbitrage literature studies different forms of frictions that may cause this persistence: (a) liquidity costs; (b) short-selling constraints; (c) leverage constraints; (d) other institutional frictions and macro shocks.[5]

The second stream of the literature investigates market anomalies that appear to be unrelated to economic fundamentals. Within this literature several empirical studies focus on violations of the LOP. These include the Siamese-Twin stocks puzzle by Rosenthal and Young (1990), the closed-end discount puzzle by Klibanoff, Lamont, and Wizman (1998), the Palm-3Com spin-off puzzle by Lamont and Thaler (2003b), the put-call parity deviations by Ofek, Richardson, and Whitelaw (2004), the U.S. TIPS-Nominal Bonds puzzle by Fleckenstein, Longstaff, and Lustig (2010), and the CIRP violation puzzle by Griffoli and Ranaldo (2011).[6] Our study is more directly related to the latter two. An important point of differentiation with respect to several of these studies is both the structure of our data and the type of questions we ask. Our empirical analysis is based on data from a large and liquid market (Euro- and USD-denominated emerging market bonds), where searching/shorting costs are tiny and symmetrical across currency denominations, and the two assets converge in value at maturity. The potential violations were, on the other hand, systematic and persistent during the crisis. Our $Basis_{\text{bond}}$ proxy is obtained in a fairly simple framework where replication is static. Moreover, the nature of our dataset allows us to address a different question than the previous literature: what are the cross-sectional and geographical differences in the $Basis_{\text{bond}}$, and how are they correlated with the respective funding markets?

A third stream of the literature investigates the role of institutional and credit frictions in the international provision of liquidity. Ivashina, Scharfstein, and Stein (2012) argues that during the credit crisis shocks to U.S. money-market funds caused a sharp reduction

[5] On the role of market liquidity risk, see Mitchell, Pedersen, and Pulvino (2007), Amihud and Mendelson (1986), and Duffie, Garleanu, and Pedersen (2007). On short-selling constraints, see Tuckman and Vila (1992). On leverage constraints, see Gromb and Vayanos (2002). On the role of collateral value, see Bernanke and Gertler (1989) and Fostel and Geanakoplos (2008). On limited risk capital, see Gabaix, Krishnamurthy, and Vigneron (2007) and Garleanu and Pedersen (2007). On margin requirements, see Brunnermeier and Pedersen (2009) and Garleanu and Pedersen (2011). On banking frictions, see Allen and Gale (2004) and Acharya and Viswanathan (2011).

[6] Refer to Gromb and Vayanos (2010) for an excellent treatment of the main literature on market anomalies.

to the funding provided to European banks. This might have created a wedge between the cost of dollar and euro funding. They provide a model in which a European bank would cut dollar lending more than euro lending in response to a shock to their credit quality. This literature focuses on how systemic liquidity shocks that originate from one market are transmitted to local lending channels of other markets (Tong and Wei (2011); Schnabl (2012)); and how global banks contribute to the amplification of the international transmission of local liquidity shocks (Cetorelli and Goldberg (2012); Giannetti and Laeven (2012)).

Finally, our work is related to the literature on credit risk pricing. This stream has developed in two directions. The first deals with the decomposition of yield spreads in a *single*-currency setting (Elton, Gruber, Agrawal, and Mann (2001); Collin-Dufresne, Goldstein, and Martin (2001); Longstaff, Neis, and Mithal (2005)). These studies show that yield spread levels and dynamics are difficult to reconcile with traditional structural credit risk models with additive preferences when calibrated to historical default and recovery rates. Collin-Dufresne, Goldstein, and Martin (2001) argue the existence of a systematic factor that is not identifiable from traditional risk factors. The second direction deals with yield spreads of a single issuer in a *multi*-currency setting. Examples include studies on currency dependence in credit factor risk models (Kercheval, Goldberg, and Breger (2003)), the impact of the correlation between default variables and exchange rates (Jankowitsch and Pichler (2005)), and the impact of sudden devaluations (Ehlers and Schonbucher (2006)).[7] Our results support the importance of accounting for the heterogeneity of funding markets in credit risk pricing.

II. The No Arbitrage Restriction

We consider two Eurobonds issued by *the same* sovereign countries in two *foreign* currencies. The only difference between these two bonds is their currency denomination (USD and Euro, respectively). The domestic currency of the issuing country is neither USD nor Euro. We use the law of one price to define a variable called $Basis_{\text{bond}}$, defined as the deviation from a no-arbitrage relationship that should prevail in a frictionless economy.

According to the covered interest rate parity, the following condition must hold for a riskless investment between period t and T:

$$(1 + R^a(t,T)) = \frac{X(t)}{F(t,T)}(1 + R^b(t,T)), \tag{1}$$

[7]These questions are important among practitioners since it is common market practice among investment banks, data suppliers (i.e. Reuters and Bloomberg) and rating agency companies (i.e. Moody's and Standard Poors) to employ USD as an input to price the credit risk of products that make reference to the same issuer, even across different currency denominations. The implicit assumption is that the FX market is liquid and deep enough to make the USD a perfect substitute for other currencies, and that yield spreads (across two currencies) are functions only of the underlying risk-free rates and the default credibility of the issuer.

where $R^i(t,T)$ is the underlying risk-free rate in the two corresponding currencies $i = (a,b)$ - being USD and Euro, respectively - and $X(t)$ and $F(t,T)$ are the EUR/USD (Euro per USD) spot and forward exchange rates, respectively. An investor can borrow one dollar today, owing $[1 + R^a(t,T)]$ at time T, convert it to $X(t)$ Euros, invest in a Euro deposit, and thus receive $X(t)[1+R^b(t,T)]$ Euros at maturity. If the forward exchange rate is $F(t,T)$, the dollar value at time t of this investment is $X(t)[1 + R^b(t,T)]/F(t,T)$, which therefore needs to equate $[1 + R^a(t,T)]$ unless an arbitrage opportunity exists. One can extend the previous argument to sovereign defaultable bonds. Consider that Brazil, for instance, issues two pure discount bonds with maturity T in two different foreign currencies (i.e. USD and Euro). Let δ^i and $S^i(t,T)$ be the recovery rates and credit yield spreads, respectively, in currency i. Then, the following condition must also hold in a frictionless market:

$$\delta^a \times (1 + \underbrace{R^a(t,T) + S^a(t,T)}_{Y^a(t,T)}) = \frac{X(t)}{F(t,T)}(1 + \underbrace{R^b(t,T) + S^b(t,T)}_{Y^b(t,T)}) \times \delta^b. \tag{2}$$

The same argument of the CIRP applies.[8] Both bonds are foreign to the issuer, and the recovery rates are the same, as discussed in the next subsection, (i.e. $\delta^a = \delta^b$). Then,

$$\frac{X(t)}{F(t,T)}(1 + Y^b(t,T)) - (1 + Y^a(t,T)) = 0. \tag{3}$$

Based on this relationship, we can thus define a time-t measure of the sovereign covered bond basis which is equal to the deviation from the zero bound. This can be decomposed into two main parts: a component which is related to the functioning of the international FX market, and a second component that is linked to differences in funding channels for bond markets, and other institutional frictions. This is discussed in more detail in the following sections.

A. *Sovereign Default and the Paris Club*

Defaults of sovereign bonds denominated in foreign currencies are often governed by the debt treatment clauses of the Paris Club, an organization of creditors that coordinates the payment process of the debtor countries. The main objective is to ensure the sustainability of equal conditions for all investors, both in terms of bond maturity and recovery rates. This is also based on the "comparability of treatment" clause, which states that "all external creditors must be subject to a balanced treatment for the outstanding debts of the debtor countries". The clause aims to avoid cases of selective default, and to ensure, in case of restructuring, equal exposure of all creditors independent of their currency denomination. This explains the common practice of assuming that recovery rates of bonds of the same

[8] One can borrow one dollar of an issuer's USD-denominated bond, exchange it to X_t Euros, buy X_t Euros of the same issuer's Euro-denominated bond, and enter a forward contract to convert $X_t(1 + R^e(t,T) + S^e(t,T))$ Euros to USD dollars at $F(t,T)$.

country are equal across different (foreign) currency denominations.[9]

Sometimes things are complicated by the issuance of bonds under different jurisdictions. Since 2003, many EM sovereigns including Brazil, Mexico and Turkey have adopted the use of collective action clauses (majority restructuring provisions and majority enforcement) in sovereign bond contracts. Starting in June 2003, collective action clauses were also agreed by the EU in their "foreign jurisdiction" bonds. Bonds included in our analysis are governed by the same jurisdiction (i.e. New York State Law) and are regulated by very similar collective clause action rules (75% threshold).[10] Thus, the 1/1/2015 maturity bond issued by Brazil and denominated in USD should have the same credit risk of the 1/1/2015 maturity bond issued by Brazil but denominated in Euro.[11]

III. Data Description

We use a unique dataset that provides information at the daily and bond-specific level on the inventory of lendable bonds available at broker dealers as well as their borrowing costs.

Bond Yield Data. We obtain daily bid-ask prices and yields for July 2005 to April 2010 on Euro- and USD-denominated bonds in maturities up to 30 years for the three largest emerging market (i.e. EM) sovereign issuers: Turkey, Brazil and Mexico. These countries have issued a large cross-section of bonds across both currencies in the ten years prior to the Crisis, and their domestic currencies are neither USD nor Euro (to exclude the possibility of strategic default). All bonds have fixed coupon rates, and are neither callable, puttable, structured or convertible. Brady Bonds are excluded. We exclude domestic bonds and/or bonds governed by domestic jurisdictions.[12] Bid-ask prices and yields are retrieved as the end-of-day (17:00) weighted average of the quotes submitted by a minimum of five brokers and dealers (Bloomberg BGN).[13] This procedure does not pick the lowest (highest)

[9] This, obviously, does not apply to recovery rates of domestic bonds, which are subject to domestic rules that may differ from those of applied to Eurobonds.

[10] As stated in their term-sheets, "Under these provisions, the Republic may amend certain key terms of the notes, including the maturity date, interest rate and other payment terms, with the consent of the holders of not less than 75% of the aggregate principal amount of the outstanding notes of the series, voting as a single class."

[11] Ukraine's default provides a useful example of how equal conditions apply across currency denominations. Following its independence, Ukraine sustained its development by issuing large amounts of foreign denominated debt. In February 2000, however, its Finance Ministry declared that Ukraine would have failed to meet its coupon repayment for a specific Eurobond issue denominated in DM (i.e. the 16% DM bonds). In January, Ukraine also defaulted on the coupon payment for the 16.75% USD Eurobonds. After several rounds, a restructuring plan was coordinated to give bondholders the option of choosing between two 7-year coupon amortization bonds (with average terms of 4.5 years) denominated either in USD or Euro in exchange for the old debt. The terms of the restructuring were symmetric for both Euro and USD bond holders. A detailed calculation leads to estimates for the USD and Euro haircuts that differ only by a decimal of a percent (see Sturzenegger and Zettelmeyer (2005) for details), consistent with the "comparability of treatment" clause.

[12] After these filters, as of July 2005, Turkey has 10 Euro- and 22 USD-denominated outstanding bonds. Brazil has 6 Euro- and 22 USD-denominated bonds and Mexico has 5 Euro- and 10 USD-denominated bonds. Note that the number of bonds denominated in Euro is usually smaller than in USD.

[13] See also Fleckenstein, Longstaff, and Lustig (2010) and Bao, Pan, and Wang (2011) for other examples using BGN prices.

price offer, but assigns a weight to each contributor based on specific factors, such as the updating frequency.[14] In addition, we collect data on U.S. and Euro riskless swap rates, and EUR/USD spot and forward exchange rates using matching end-of-day Bloomberg data. Data for the determinants of Basis (discussed in Section 5) are also retrieved from Bloomberg, unless otherwise noted.

Security Borrowing and Lending Market Data. The core of the dataset includes detailed bond-specific information on the available inventory for lending, loan transaction numbers, and loan fees (cost of borrowing) of both Euro- and USD-denominated bonds across the three EM countries. The daily data is obtained from Data Explorers and provides the most extensive coverage on sovereign bond security lending and borrowing currently available.[15] It includes the major prime brokers, custodians, and the lending desks of large firms that actually lend/borrow these securities. It captures bond-specific loan trading information from over 100 participants and covers approximately 85% of the OTC securities lending market. All double-counted fields are eliminated. "Loan Fee" denotes the bond-specific current transaction lending fees. "Inventory" denotes the bond-specific quantity of actively lendable inventory, filtered out from the inactive loans.[16] "Transaction" denotes the number of transactions being carried out for a specific bond at a given day.

IV. Calculating the Dislocation in Sovereign Bond Markets

To calculate the $Basis_{\text{bond}}$ in sovereign Eurobond markets we follow the same procedure used by Fleckenstein, Longstaff, and Lustig (2010) to compute the TIPS pricing anomaly. We first select pairs of bonds from the same issuer with nearly matching maturities. Then, at each time t we enter into a series of forward contracts to swap the EUR coupon flows at each coupon date and the face value at the maturity date into USD. This creates a synthetic USD bond. We then calculate the yield-to-maturity of this synthetic USD bond and call it Y^{a^*}.[17] In the absence of frictions, Y^a (the yield of the original USD denominated bond) should be equal to Y^{a^*} in light of equation (3). We define $Basis_{\text{bond}} = Y^{a^*}$ - Y^a.

Example. To provide a specific example, let's take the USD- and Euro-denominated foreign bonds of Brazil. The USD bond matures on March 7, 2015. On October 31, 2008, the quoted yield-to-maturity of Brazilian USD bond is $Y^a = 7.54\%$, and the quoted yield-to-maturity

[14] This allows for the minimization on the impact of measurement error from a specific broker dealer, and makes prices more reflective of market conditions. For particular currency pairs, BGN prices are adjusted to trading hours where contributions are good.

[15] Data Explorers, which is announced to be acquired by Markit on April 2012, covers $12 trillion of securities over 20,000 institutional funds.

[16] The total inventory can either be active or inactive. This is due to the fact that there is sometimes a difference between the total amount that could be lent out and the actual amount that was offered. Data Explorers state that this happens when "securities are held in too small parcels or have been restricted by the beneficial owner."

[17] Based on the previous notation, $Y^a(t,T) = R^a(t,T) + S^a(t,T)$. Empirically, we use the market convention for the day-counts of USD-denominated bonds (30/360) and EUR-denominated bonds (ACT/ACT), and adjust for the accrued interests.

for its Euro counterpart is $Y^b = 9.46\%$. With approximately 6.3 years until maturity, the investor shorts 100 dollars of USD-denominated bond, swaps the proceeds to 78.59 Euros in the spot FX market, and purchases 78.59 Euros of the Euro-denominated bond, which pays seven coupons (7.375% of the face value) during the remainder of its lifetime. The calculated face value of the Euro-denominated bond is 82.01 Euros, and thus the corresponding coupon payments are 6.05 Euros. Using market forward rates F_u for each coupon date (every 3rd of February from 2009 to 2015), all Euro cash-flows are converted into USD cash-flows. Since there are seven cash-flow periods, we execute seven forward contracts. This creates a synthetic USD bond consisting of only USD coupon flows, equal to \$7.69 on February 3, 2009, \$7.69 on February 3, 2010, \$7.70 on February 3, 2011, \$7.75 on February 3, 2011, \$7.81 on February 3, 2013, \$7.85 on February 3, 2014 and \$7.85 on February 3, 2015. Finally, the forward-converted face value is \$106.38. The yield-to-maturity of the synthetic bond Y^{a^*}, calculated based on these USD flows, is 9.68%, after accounting for the bid-ask spreads in the execution of FX contracts. Hence, in terms of bps, $Basis_{\text{bond}} = Y^{a^*}$ - Y^a = 968 bps - 754 bps = 214 bps. Clearly, the synthetic USD bond, constructed from the EUR-denominated bond, generates a substantially higher yield than its original USD counterpart. In addition to FX costs, at each time t and for every bond pair, we also account for the transaction costs based on the bid-ask spreads involved in the trading of these bonds on the cash market. For this specific example, the total bond bid-ask spread is approximately 12 bps at this date. The $Basis_{\text{bond}}$ is therefore approximately 202 bps, net of transaction costs. In some cases, bonds do not have identical maturity dates. We only include bond pairs with a maturity mismatch of less than or equal to 70 days (see also Fleckenstein, Longstaff, and Lustig (2010)). This is the case for the 2010 Brazilian bonds, which have a maturity mismatch of 70 days, the 2015 Brazilian bonds (32 days), the 2014 Turkish bonds (26 days), the 2019 Turkish bonds (22 days), and the 2020 Mexican (49 days).

A. The Size of the Basis

Time Series Properties. We divide the July 2005 - April 2010 period into three main sub-samples (and two further sub-samples for the Crisis period). The "Pre-Crisis" period starts on July 1, 2005 and ends on August 8, 2007; the "Crisis" period starts on August 9, 2007 and ends on March 31, 2009; the "Post-Crisis" period begins with April 1, 2009 and ends on April 30, 2010.[18] Longstaff (2010) argues that Lehman's collapse changed the nature of the crisis: While previously the major concern had been the lack of market liquidity, after Lehman's collapse the crisis became more affected by solvency risk.[19] Accordingly,

[18] As an explanation of the Federal Reserve's response to the crisis, Bernanke (2009) also argues that during the first stage of the crisis, the Federal Reserve provided liquidity to solvent institutions with minimal credit risk. However, during the second stage of the crisis, the Federal Reserve accepted credit risk exposure by providing capital to some impaired borrowers and to the market in order to directly address counterparty credit risk.

[19] We follow (Taylor and Williams 2009) and Longstaff (2010) and assume that the beginning of the "Liquidity Crisis" coincides with BNP Paribas's suspension of redemptions from their 2 billion USD asset-backed funds; while we assume the "Credit Crisis" began one week before the Federal Housing Finance Agency's decision to place Fannie

we divide the crisis period further into two additional subsamples: the "Liquidity Crisis" (August 9, 2007 - August 29, 2008) and the "Credit Crisis" (September 1, 2008 - March 31, 2009).[20]

We test the null hypothesis that there is no significant difference in mean deviations across two or more of the subsamples. We use the absolute value of $Basis_{\text{bond}}$ net of transaction costs. We strongly reject the null hypothesis, and conclude that $Basis_{\text{bond}}$ is state-dependent. During the Pre-Crisis period, the averages (standard deviations) of $Basis_{\text{bond}}$ are 5 bps (14 bps), -5 bps (7 bps) and 18 bps (11 bps) for Brazil 2015, Turkey 2014, and Mexico 2020 bonds, respectively. They are not statistically different from zero.

During the Credit Crisis, however, transaction-cost adjusted averages (standard deviations) are 51 bps (48 bps) for Brazil 2015, 32 bps (32 bps) for Mexico 2020, and 53 bps (30 bps) for Turkey 2014 bonds (see Table 1).

[Table 1, *about here*]

Examples of Dislocation. To provide specific examples of the price disruption during Credit Crisis, $Basis_{\text{bond}}$ for the 2015 Brazilian bonds, on October 8, 2008, was 104 bps after accounting for transaction costs. Two days later, on October 10, 2008, the anomaly was even larger for the 2010 Brazilian bonds, with a net $Basis_{\text{bond}}$ equal to 407 bps. While $Basis_{\text{bond}}$ fluctuated between 163 bps and 209 bps for the 2015 Brazilian bonds between 23 October and 31 October, it varied between 250 bps and 345 bps for the 2010 Brazilian bonds that same week. Similarly, $Basis_{\text{bond}}$ for the Mexican 2020 bonds reached 136 bps at the end of October. Once again, on October 23, 2008, the net absolute $Basis_{\text{bond}}$ is equal 98 bps for the 2014 Turkish pair, and 170 bps for the 2019 Turkish bonds. Figure 1 shows the evolution of $Basis_{\text{bond}}$ (shown in blue lines) for the 2015 Brazilian, the 2020 Mexican and the 2014 Turkish bonds. The evolution of the total bid-ask spreads are shown in red lines.

Mae and Freddie Mac in government conservatorship on September 7^{th}, and two weeks before the collapse of Lehman Brothers on September 15^{th}.

[20]While our definition of sub-sample periods is motivated by a naturally chosen important economic event (the Fannie Mae and Lehman bankruptcies, which occurred on September 6th and 15th, respectively), we run Chow Breakpoint Tests to identify the timing of the potential structural breaks. Our tests indeed reveal the existence of these turning points.

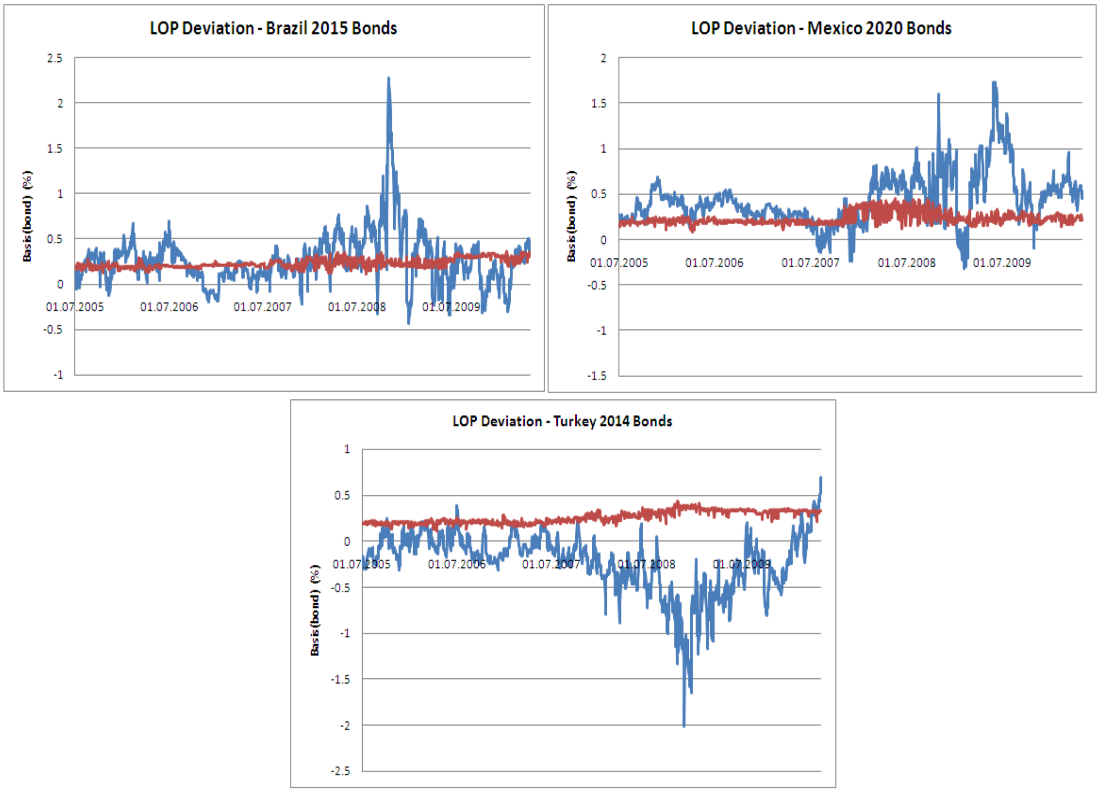


Figure 1. *Basis(bond) Dynamics:* The plots show the evolution of $Basis_{\mathrm{bond}}$ (shown in blue, in percentages) for the 2014 Turkish, the 2015 Brazilian and the 2020 Mexican bonds. The Basis is positive when the USD-denominated bond is trading rich. Total bid-ask spreads are summarized by the red lines.

The anomaly persisted over three months. A second round of disruption seems to have developed in mid-November. From November 10 to November 14, 2008, for instance, $Basis_{\mathrm{bond}}$ fluctuated persistently between 115 bps and 151 bps for the 2015 Brazilian bond pair. On November 20, 2008, the net absolute value of $Basis_{\mathrm{bond}}$ widened to 169 bps for the 2014 Turkish bonds, and 201 bps for the 2019 Turkish bonds. Fluctuations continued between November and January. This was particularly true for the 2019 Turkish bonds, for which the net absolute value of the deviation ranged between 155 bps and 195 bps. After the Crisis period, the average $Basis_{\mathrm{bond}}$ tends to diminish for the majority of bonds with the clear exception of Mexico. Although we observe that the Mexican $Basis_{\mathrm{bond}}$ begins to dwindle beginning in the last quarter of 2009, the finding suggests that the disruption in Mexico lasted longer, reaching its peak of 155 bps on May 28, 2009.

We note that the magnitude of $Basis_{\mathrm{bond}}$ exceeds the CDS-bond basis for U.S. corporate bonds of similar credit ratings. This is interesting for two reasons. Trading the CDS-bond basis is riskier, as CDS contracts are different from the referenced bonds due to several features: (a) the counterparty risk embedded in CDS contracts, and (b) the regulatory uncertainty about the definition of a CDS default event. Thus one might expect a larger basis in the CDS market. Second, the $Basis_{\mathrm{bond}}$ that we use in the present study refers to claims on cash flows of countries that were seemingly unexposed to the subprime crisis.

Cross Section and International Differences. Figure 1 reveals a second interesting feature: the sign of $Basis_{\text{bond}}$ is country-specific. The Turkish $Basis_{\text{bond}}$ is, on average, negative, whereas for Mexico and Brazil it is, on average, positive. In all three sample periods, Turkey usually pays a higher yield in USD, whereas Brazil and Mexico pay a higher yield in Euro. Therefore, the arbitrageur should long the USD denominated Turkish bond and short its Euro denominated equivalent; he should do the opposite trade for Mexican and Brazilian bonds. This cross-sectional difference provides an opportunity to learn about the nature of the frictions that were responsible for these dynamics. So which type of international market frictions are consistent with both the time-series and cross-sectional evidence? We address this question in the following sections.

V. Determinants of the Basis

A. Liquidity Frictions

An elevated Basis could be evidence of liquidity frictions and risks. Traders may be reluctant to take positions, concerned about the potential future market impact of their trades.[21] Starting in early 2007, a reduction of liquidity increased bid-ask spreads in several financial markets, leading commentators to refer to this period as a liquidity crisis. We investigate the link between the Basis and the reduced liquidity in the cash bond and FX markets.

First, we compare the dynamics of bid-ask spreads of both the cash bonds and the forward contracts required to build a long-short position with their corresponding $Basis_{\text{bond}}$. Indeed, in the Liquidity Crisis, total bid-ask spreads increased on average, 1.4x, with respect to the Pre-Crisis period. Bond bid-ask spreads, on average, account for 67% of the total transaction costs in the Pre-Crisis period, and 64% in the Liquidity Crisis period. From the Pre-Crisis to the Credit Crisis period, total bid-ask spreads increased more than 1.8x: this is due to a 1.7x increase in bond bid-ask spreads and a 2x increase in FX bid-ask spreads. While transaction costs certainly increased, we find, however, that the increase in $Basis_{\text{bond}}$ far outstrips total transaction costs during the Credit Crisis (see Figure 1). $Basis_{\text{bond}}$ reaches levels that in some periods exceed total bid-ask spreads by 5x for Turkey 2014, 11x for Turkey 2019, 6x for Brazil 2010, 9x for Brazil 2015, and 5x for Mexico 2020 bonds.[22]

In an important study that investigates the role of market liquidity on covered-interest rate violations, Griffoli and Ranaldo (2011) find that the first principal component of bid-ask spreads across different currency pairs explains no-arbitrage violations in FX markets

[21] Amihud and Mendelson (1986), as well as a vast literature that followed, argue that bond-specific market liquidity is a significant factor in the pricing of corporate bonds. Longstaff, Neis, and Mithal (2005) point out the fact that a large portion of corporate spreads is due to default risk, but the time-varying nature of the non-default component is strongly related to bond-specific illiquidity.

[22] Note that the credit ratings of these countries have been upgraded by Fitch from 2007 to 2010: Brazilian treasuries from BB to BBB, Mexican treasuries from BB+ to BBB, and Turkish treasuries from BB- to BB+. This is consistent with the relatively small observed variations in bid-ask spreads for these bonds.

during this period. This result is interesting, since it suggests the existence of a latent liquidity variable that helps to explain the dynamics of arbitrage profits. We replicate this variable by using both spot and forwards, which we call FX-Liq.[23] At the same time, we follow Fontaine and Garcia (2009), and construct also a proxy of latent liquidity in bond markets from the on-the-run minus general collateral repo spreads in U.S. Treasuries data. We call this variable FG-Liq. Then, we regress the changes in the absolute gross value of $Basis_{\text{bond}}$ on changes in bond-specific total bid-ask costs, as well as FX-Liq and FG-Liq. Table 2 details the regression specifications, and summarizes the results. During the Credit Crisis, FX-Liq, FG-Liq and total bid-ask spreads are found to be insignificant. The explanatory power is limited, never exceeding an R-squared of 2%. These findings suggests that liquidity risk plays a limited role in explaining the observed phenomenon.

[Table 2, *about here*]

B. Short-Selling Constraints and Security Lending Frictions

To implement a convergence trade, a trader needs to borrow a security from a broker dealer. If this security is not available, and/or the cost of borrowing is high, the trader can effectively face a short-selling constraint. Indeed, important literature has emerged that studies the implications of short-selling constraints (Harrison and Kreps (1978), Diamond and Verrecchia (1987), Scheinkman and Xiong (2003), Tuckman and Vila (1992)). To investigate this channel, we use bond-specific data on: (i) total lendable value adjusted to include the active availability for lending (Inventory); (ii) loan fees for the new trades (Loan Fees); iii) number of transactions being carried out in a given day (Transaction). The first captures the tightening in the loan supply and short-selling constraints, the second captures the cost of borrowing in the repo market, and the third captures the equilibrium quantity of transactions in the repo market.[24] We categorize them under "Short-Selling Frictions".

Controlling for country-fixed effects, we run panel regressions for the changes in the net absolute $Basis_{\text{bond}}$ of the bond pairs included in the analysis on the changes in bond-specific Inventory, Loan Fees and Transaction. We find that Inventory helps to explain the $Basis_{\text{bond}}$ during Credit Crisis, with an expected coefficient sign: an increase in Inventory reduces the $Basis_{\text{bond}}$ (see Table 2). Loan Fees increase by about 2.5x between the Liquidity and the Credit Crisis. Nevertheless, this channel has limited statistical explanatory power. The model explains only about 2% of the total variation. If borrowing constraints had been binding, Loan Fees would have been statistically significant: as traders demand more securities to short, the cost of shorting should increase. During this period, however, Loan Fees are only weakly correlated with $Basis_{\text{bond}}$. The lower amount of transactions in the security

[23] Instead of using the bid ask spreads of different currency pairs, we use the bid ask spreads of different maturities of USD/EUR in the forex market.

[24] Inventory series are standardized prior to estimations.

loan market seems, therefore, to be more likely due to a negative demand shock. Broker dealers reduce their inventory of lendable assets without increasing the cost of borrowing.

To learn more about this link, we study in detail the dynamics of these variables. We find that during the Liquidity Crisis, there were 3,719, 2,030 and 3,294 million USD worth of total active lendable Eurobonds in Brazil, Mexico, and Turkey, respectively. Between September 2008 and April 2009, however, there were 3,441, 1,251 and 2,670 million USD worth of total active lendable Eurobonds in Brazil, Mexico and Turkey, respectively (see Figure 2). This suggests that the total inventory decreased in value by approximately 7% for Brazil, 38% for Mexico and 19% for Turkey. Similarly, the number of transactions decreased by more than 53% for Brazil, 36% for Mexico and 72% for Turkey. After April 2009, the total active lendable Eurobonds start to grow in value by 8% in Brazil and 3% in Turkey, whereas they continue to drop by 43% for Mexico.

If liquidity costs and short-selling constraints do not really explain the majority of $Basis_{\text{bond}}$ variation, then what does? A third source of frictions that has been investigated by the limits of arbitrage literature is related to leverage constraints, which we explore in the next section.

C. Funding Costs and Leverage Constraints in Debt Markets

Consider a wealth shock that negatively affects the balance sheet of an arbitrageur. If this arbitrageur has access to external capital, the wealth shock would be inconsequential, since it would be absorbed by additional borrowing. If access to external capital is limited, however, the wealth shock may force the arbitrageur to reduce his risky arbitrage positions. This could induce an amplification of the initial shock giving rise to a deviation from the LOP. A third important stream of the LOP literature studies the role of limited capital. Gromb and Vayanos (2002), Gromb and Vayanos (2010) study a model in which arbitrageurs must collateralize their positions in each asset to implement an arbitrage. Arbitrageurs can enforce LOP if their wealth is large relative to the demand shock and the margin requirement. In this case, demand shocks cannot affect relative price changes. Brunnermeier and Pedersen (2009), and Gromb and Vayanos (2010) extend this analysis to multiple assets. With multiple assets, they show that leverage constraints can generate contagion of shocks to seemingly unrelated assets. Shocks to one asset are transmitted to otherwise unrelated assets through changes in the arbitrageur balance sheet. This argument is related to our analysis: if trading desks operate simultaneously on multiple sovereign bond markets, then it may explain how wealth shocks can internationally propagate frictions across these assets.

Two types of traders are usually involved in arbitrage opportunities: proprietary trading desks of investment banks and hedge funds. Although they chase similar arbitrage opportunities, they usually operate under different funding markets. While hedge funds borrow and lend against collateral on secured terms ("Secured funding"),[25] the prop desks of investment banks participate in unsecured money market operations ("Unsecured funding").[26] We categorize these variables under "Funding Risks ".

We find Unsecured to be significant with a 95% confidence interval. The slope coefficient is positive, as expected: an increase in unsecured funding costs increases $Basis_{\text{bond}}$ (see Table 2). The R-squared is 8%. This result highlights the role of the unsecured channel for leverage constraints and the dynamics of the Basis. This is consistent with statements made by central bankers, both before and during the crisis, that focused on the importance of the unsecured interbank funding market. Greenspan (December 18, 2008) argues that the LIBOR/OIS differential captures a key characteristics of interbank lending and of the functioning of capital markets; he consistently referred to this indicator to measure the policy effectiveness of the Fed interventions: "Lehman default [...] drove LIBOR/OIS up markedly. It reached a riveting 364 basis points on October 10th. The passage by Congress of the 700 billion dollar Troubled Assets Relief Programme (TARP) on October 3rd eased, but did not erase, the post-Lehman surge in LIBOR/OIS. The spread apparently stalled in mid-November and remains worryingly high." A statement that convinced the Federal Reserve to intervene in the swap market in order to address the unusually wide LIBOR/OIS spreads in the initial stage of the crisis. When we control for short-selling constraints, we find that the funding channel retains significance and plays a dominant role in $Basis_{\text{bond}}$ dynamics.

D. The Macro Environment and the Supply of Risk Capital

Financial frictions are certainly not exogenous, as they emerge in specific states of the economy. In this section, we investigate the robustness of the previous results after controlling for shocks to macro fundamentals, discount rates, and default risks. We organize the control variables, for notational convenience, under: (i) "Global Cash-Flow Factors", (ii) "Local Risk Factors", (iii) "Global Discount Rate Factors", and (iv) "Global Uncertainty Factors". Details and discussions of the constituents of each category are given in Appendix A. Table 3 details the regression specifications and summarizes the results.

[Table 3, *about here*]

We find evidence that $Basis_{\text{bond}}$ is indeed affected by factors that are global in nature and that operate in seemingly unrelated markets (see also Longstaff, Pan, and Pedersen (2010)). During the Liquidity Crisis, the most significant variables are within the "Global

[25] We compute the average spreads between two- to ten-year Agency MBS and the US Treasury rates as an empirical proxy (see Coffey, Hrung, and Sarkar (2009)). Since both rates refer to a collateralized loan, this spread captures the difference in value between high-quality vs. low-quality collateral securities. See also Gabaix, Krishnamurthy, and Vigneron (2007) for a discussion of the role of MBS as a funding markets.

[26] We compute the spread between 3-month LIBOR and U.S. Overnight Index Swap (OIS) rates as an empirical proxy. A rise in the differential implies that financial institutions become less willing to lend to each other.

Liquidity Factors" group. In particular, the global FX liquidity factor, suggested by Griffoli and Ranaldo (2011), and the Perceived Tail Event Risk (VIX) are positively significant. The R-squared is 11%. No other factors linked to economic activity are significant.

During the Credit Crisis, however, a different picture emerged. Variables within the "Global Discount Rate Factors" and "Global Cash-Flow Factors" became statistically significant. A valuation proxy based on the average discount of a portfolio of EM closed-end funds (i.e."Closed End") is highly significant with a negative coefficient sign (absolute $Basis_{\text{bond}}$ increases when the Closed End decreases). Moreover, the significance of "Global Cash-Flow Factors" reveals that the $Basis_{\text{bond}}$ is sensitive to the aggregate level of economic activity (the lower the level of macro-economic activity, the higher the absolute $Basis_{\text{bond}}$). This suggests that during this period the $Basis$ is not simply the outcome of a security-specific phenomenon but is in fact correlated with systematic factors. Shocks to fundamentals appear correlated to the tightness of leverage constraints and the demand for risk capital that helped to explain deviations from the LOP.[27] The result is consistent with the argument discussed in De Long, Shleifer, Summers, and Waldmann (1990) and Garleanu and Pedersen (2011). We control for credit and local risks using a EM credit default swap index ("Local Risks"). We find that EM-CDSI is statistically significant with the expected coefficient sign: a decrease in the CDS index (i.e. an increase in EM default risk) increases $Basis_{\text{bond}}$. The explanatory power of the model is considerably higher with an R-squared of 45%.

Even after controlling for these global macro-economic factors, we find that both the "Unsecured" and "Secured" funding channels are significant with t-statistics of 2.63 and 2.95, respectively, which are even larger than on Table 2. They have the expected positive coefficient sign. We conclude that this result is robust, and it highlights the role of both funding channels, possibly due to the role played by both hedge funds and investment banks.[28] The impact of Inventory under "Short-Selling Frictions" is also maintained.

During the Post-Crisis period, on the other hand, none of the global factors are significant (not reported). The only significant explanatory variables are bond-specific, such as Inventory, with the expected negative sign. The R-squared drops to 12%.

VI. The Geography of the Basis

One of the most intriguing findings is that $Basis_{\text{bond}}$ is country-specific. As mentioned earlier, $Basis_{\text{bond}}$ of Turkey is negative on average, whereas for Mexico and Brazil it is, on average, positive (see Figure 1). This implies that an arbitrageur in Turkey should have gone long on the USD bond and short on the Euro bond, whereas he should have made the opposite trade in Mexico and Brazil. This result is of interest to us, since it provides

[27] See also Bernanke and Gertler (1989) for earlier related work.

[28] Secured funding is significant at a (t-1) lag.

clues as to the type of frictions that are at the source of these dynamics. For instance, it is clear that frictions that are specific to the FX market cannot explain this cross-sectional difference.

Ivashina, Scharfstein, and Stein (2012) suggest an interesting hypothesis. Suppose that a large part of Turkey's lending activity is carried out by European banks. These banks can fund their Euro-lending activity by raising cash from their domestic retail base with (insured) Euro-denominated deposits. On the other hand, since foreign banks cannot raise dollars using this channel,[29] the large portion of the funding of USD lending activity takes place either by issuing (unsecured) USD-denominated commercial paper, or by synthetically swapping part of their Euro deposits into dollars. If the credit risk of the bank is small, the costs of direct and synthetic dollar funding are approximately the same. Suppose, however, that the credit risk perception of this bank deteriorates. The cost of funding dollar assets through commercial paper would increase as U.S. money-market funds would reduce, coeteris paribus, their exposure to the European bank. This is not sufficient, however, to explain a cross-sectional dispersion in the $Basis_{\text{bond}}$: in the absence of other frictions, the bank could simply raise capital in Euro, taking advantage of the insurance subsidy, and swap it using FX forwards. In the presence of limited capacity in forward markets, however, the bank may have a relative advantage to lend in Euro. Depending on the initial geographical distribution of funding to these countries, these frictions could generate a cross-sectional dispersion in the $Basis_{\text{bond}}$.

Frequent reports in 2007-2008 suggest that European financial institutions were finding it difficult to secure dollar fundings to support conduits for which they had committed backup (dollar) liquidity (see Baba (2009)).[30] The general increase in counterparty risk and the capital repatriation of U.S. financial institutions reduced the supply of dollars in the interbank market, giving rise to a potentially significant friction. Indeed, the Fed-ECB currency swap facilities was in part motivated by the need to partially relax this constraint.

A. Bank Holdings Exposure to Sovereign Bonds

The first step to study this hypothesis is to analyze the geographical characteristic of the funding markets for these sovereign bonds. Countries that rely more on the funding of European (American) banks are also those for which the cost of dollar (Euro) financing increased the most during the Credit Crisis.

We obtain detailed data on the geographical distribution of bank holdings for these sovereign bonds. The dataset is from the BIS and covers all contractual lendings by the head office, and all its branches (and subsidiaries) on a worldwide consolidated basis but

[29] Only the capitalized U.S. subsidiary of a European headquartered bank can issue FDIC-insured deposit in the U.S.

[30] See, among others, "Central bank actions calms investors nerves", Financial Times, August 13, 2007; "Fed-ECB currency swap politically tricky", Reuters, August 13, 2007.

disaggregated by country exposure. The classification is based on "ultimate risk".[31] For the purpose of this paper, we strip out all other forms of lending to focus exclusively on sovereign bond exposure. As Table 4 shows, the geographical properties of economic funding is strongly asymmetric. Most Turkish bonds have indeed been funded in Europe, so that, during the Credit Crisis (Quarter 4, 2008), 80% of the claims were held in Europe, and 11% were held in the United States. On the other hand, most of the Mexican and Brazilian bonds have been funded in the United States, so that, during the Credit Crisis (Quarter 4, 2008), only 9% of the claims were held in Europe, and more than 80% were held in the United States. The data, which is available to us quarterly but reported annually for reasons of space, shows that this pattern is stable over time.

[Table 4, *about here*]

This supports our conjecture. However, the argument suggested above also requires that the relative cost of funding through outside capital (unsecured commercial paper) versus inside capital (insured deposits) increases. Indeed, we find that starting as early as January 2007, American banks started to face substantially higher costs of financing assets via Euro-denominated commercial paper. The differential went from 1.50% to more than 3.00% in Summer/Fall 2008. At the same time, while for European banks the cost of funding by means of USD-denominated commercial paper reached the lowest value around April 2008, this differential jumped from -1.50% to 0.50% in Fall 2008. The dynamics depend both on events related to the evolution of the commercial paper and on deposit markets (see Ivashina, Scharfstein, and Stein (2012)).

Figure 3 summarizes the dynamics of (a) USD CP Rate minus EUR Deposit Rate, (b) EUR CP Rate minus USD Deposit Rate, (c) Total Bank Deposit Distribution of Turkey (in USD and EUR), (d) Differential of Bank Deposit Rates in Turkey (USD minus EUR).[32] To investigate the null hypothesis of the existence of a bank funding friction channel operating at the local level, we run two different panel regressions controlling for country fixed effects:

$$\Delta\left|Basis(bond)_{TR,t}\right| = \nu_j + \eta_1\left[\Delta(USD\ CP - EUR\ Depo)_t\right]' + \epsilon_{j,t}. \tag{4}$$

$$\Delta\left|Basis(bond)_{BR,MX,t}\right| = \nu_j + \eta_1\left[\Delta(EUR\ CP - USD\ Depo)_{t-2}\right]' + \epsilon_{j,t}. \tag{5}$$

We find that the difference of [USD CP - EUR Depo] rates is statistically significant, helping to explain the absolute net *Basis* of Turkey (see Table 5). It has the expected positive coefficient sign, suggesting that an increase in [USD CP - EUR Depo] rates increases the

[31] The consolidation is either based on the country of "immediate borrower" or on the "ultimate risk". The latter is defined as the country where the guarantor of the claim is located, or in other words, where the domestic bank head office is located. The exposures of the foreign branches and subsidiaries are included. We proceed according to the "ultimate risk" classification, so that a purchase by the Morgan Stanley London branch of Turkish bonds, for instance, contributes to the exposure of its U.S. head office.

[32] Commercial Paper Rates (USD and Euro) are retrieved from Bloomberg. USD Deposit Rates are retrieved from FRED Economic Data: Economic Research Federal Reserve Bank of St. Louis. EUR Deposit Rates are retrieved from European Central Bank Data.

absolute *Basis* of Turkey. The findings also show that the difference of the two-week lagged [EUR CP - USD Depo] rates is significant for the absolute net *Basis* of Brazil and Mexico. It has the expected positive coefficient sign, suggesting that an increase in [EUR CP - USD Depo] rates increases the absolute *Basis* of Brazil and Mexico.

[Table 5, *about here*]

To further investigate this cross-sectional evidence, we decide to use one country (Turkey) as a control group, and run "in-diff" analysis by computing the ratio between the net absolute Mexico (and Brazil) $Basis_{\text{bond}}$ over net absolute Turkish $Basis_{\text{bond}}$. Then, we run a regression of this ratio on the changes in the relative cost of funding. The objective is to understand whether the relative behavior of the *Basis* was indeed affected by changes in the relative cost of funding of USD- versus Euro-denominated assets by banks, in the United States versus Europe. The maintained assumption is that most Turkish sovereign bonds were funded by European-based banks while Brazilian and Mexican bonds by U.S.-based banks (as shown on Table 4)

$$\frac{|Basis(bond)_{MX,t}|}{|Basis(bond)_{TR,t}|} = \nu_j + \eta_1 \left[\frac{(EUR\ CP - USD\ Depo)_t}{(USDCP\ \ - EUR\ Depo)_t}\right]' + \epsilon_{j,t}. \tag{6}$$

$$\frac{|Basis(bond)_{BR,t}|}{|Basis(bond)_{TR,t}|} = \nu_j + \eta_1 \left[\frac{(EUR\ CP - USD\ Depo)_t}{(USDCP\ \ - EUR\ Depo)_t}\right]' + \epsilon_{j,t}. \tag{7}$$

We find that the coefficient for Mexico is positive and strongly significant, with a t-statistics of 4.89. This implies that a relative increase in the cost of unsecured Euro funding of US banks contributes to a widening on the Mexico Basis *relative* to the Turkey Basis. We find that the slope coefficient for the ratio of Brazil over Turkey is not significant (see Table 5).

We decide to investigate even more directly the behavior of the interest rates for deposits denominated in different currencies. Evidence consistent with this null hypothesis should show tightness in the dollar deposit market in Turkey and in the Euro deposit market in Mexico and Brazil. Indeed, after Lehman's collapse, we find that the 3-month USD deposit rates in Turkey increased well above the Euro rates, from -20 bps to 80 bps. Moreover, the total dollar bank deposit volume in Turkey fell from 60 billion USD in mid-2008 to 48 billion in November 2008, whereas the Euro bank deposit rose from 25 billion to about 30 billion Euros in the same period, consistent with a substantial deleverage in USD, and a substantial increase in Euro deposits.

This evidence supports the hypothesis about the emergence of country-specific capital imbalances that made the cost of funding via inside capital (insured deposits) substantially cheaper than outside unsecured financing on a foreign market.

B. Capital Imbalance and the Dynamics of Broker-Dealer Inventory

Is the evidence in previous sections consistent with capital hoarding at the country-specific level? This phenomenon, perhaps triggered by a precautionary motive in anticipation of future expected losses from security write-downs, might have played a role in the geography of funding capital. To investigate this hypothesis in greater detail, we study the evolution of both currency reserves at the central bank level and the composition of the lendable inventory of bonds at the broker's dealer level. Two sets of results emerge.

First, when we study the central bank foreign currency reserve distributions (see Table 4), the proportion of USD (Euro) reserve assets to total foreign assets in Turkey, in 2008, is 51% (46%). The situation is different for Brazil, which has the U.S. as a major trade partner. In Brazil, the weight of USD reserve assets rose from 55% in 2004 to 89% in 2008, whereas the weight of the Euro assets, during the same period, fell from 35% to 9%.[33]

Second, we use the bond specific data collected from Data Explorers. When we measure the evolution of the lendable stock of securities in the two currency denominations for each country, we find that during the Crisis the lendable inventory of bonds dropped in all currency denominations. This suggests that economic agents were afraid to lend their bonds during the crisis period, perhaps similarly to the money-market funds increasing their repo haircuts. At the same time, we find that the total inventory of USD-denominated bonds in Brazil dropped much more rapidly than the total inventory of its Euro-denominated bonds. The differential between the total quantity of USD minus Euro lendable assets, as of the week of Lehman's collapse, dropped by 231 million (from 3.1 billion to an approximate 2.8 billion). Similarly, in Mexico, the differential dropped by 450 million (from 1.2 billion to 701 million). In both cases USD-denominated bonds became scarcer to borrow as owners made them less available. The opposite is true for Turkey, where the differential instead increased by about 71 million during the same period. The imbalance is consistent with observable cross-sectional differences in loan fees. In December 2008, the average loan fee for a 100 USD investment in a Mexican 2020 USD bond was about 0.15 USD, which is approximately 2.5 times higher than its Euro fee equivalent. Similarly, in same month, the average loan fee for a 100 USD investment of a Brazilian 2010 USD bond was about 0.91 USD, which is again approximately 2.5 times higher than its Euro fee equivalent. On the other hand, in the same month, the average loan fee for a 100 USD investment of a Turkish 2014 USD bond was about 0.15 USD, which is approximately 4.5 times lower than its Euro fee equivalent.

This evidence suggests the existence of a form of segmentation with asset prices reflecting country-specific institutional characteristics (see Vayanos and Vila (2009); Gromb and Vayanos (2010)).

[33] No data is available for Mexico's central bank foreign reserve distribution.

C. Price Discovery

If institutional frictions create asymmetries in the relative cost of funding for different sovereign bonds, this asymmetry would be visible in terms of the relative difference in the information content of each bond. We use a price discovery analysis to learn about the potential effects of the geographical frictions discussed above on the cross-sectional differences in information content.

There are two traditional ways to conduct a price discovery analysis. The first one is based on the information share (IS) measure, as suggested by Hasbrouck (1995). The second one is based on the component share (CS) measure, as suggested by Gonzalo and Granger (1995).[34] Following Blanco, Brennan, and Marsh (2005), we calculate the IS measures to find the contribution of USD credit yield spreads (i.e. S_t^a) to their Euro equivalents (i.e. S_t^b). We calculate $S^i(t,T) = Y^i(t,T) - R^i(t,T)$ for currency i=[a, b] for the bond pairs used in our analysis. Let $S_t = [S_t^a, S_t^b]$ be the vector of bond credit yield spreads in a=USD and b=EUR markets. The two bond spreads must satisfy a long-run arbitrage restriction, namely $[S_t^a - k_t \times S_t^b] = 0$, with $k_t = X(t)/F(t,T)$. Let us define $z_t \equiv [S_t^a - k_1 \times S_t^b]$. It is natural to specify and estimate the system S_t in a Vector Error Correction form (i.e. VECM) as follows:[35]

$$\Delta S_t = A z_t + \Phi(L)\Delta S_{t-1} + u_t \tag{8}$$

with $A = [A_1, A_2]'$.[36] Instead of estimating the cointegration parameter k_1, we use directly the restrictions implied by the LOP and set it equal to the average of $X(t)/F(t,T)$. We are interested in exploring two properties of this dynamic system: (a) the existence of an asymmetric structure in the vector A, and (b) the Hasbrouck information-share coefficient.

In the presence of frictions, if the Euro credit spread contributes more to the price discovery, then A_1 should be statistically significant and negative. On the other hand, if the USD credit spread contributes more to the price discovery, then A_2 should be statistically significant and positive. If both coefficients are significant, then both currencies are jointly important in the price discovery process.

Hasbrouck (1995) measure of "information share" is based on the Stock and Watson (1988) decomposition. It assumes that the price volatility reflects new information. Let σ_1 and σ_2 be the volatility of the estimated residuals u_1 and u_2, and let σ_{12} be the covariance. The market that contributes the most to the variance of the innovations to the common factor is presumed to be the one that contributes the most to price discovery. When $\sigma_{12} = 0$, Hasbrouck's measure is defined uniquely; when the $\sigma_{12} \neq 0$, this measure provides

[34] Both measures rely on the estimation of a vector error-correction models (VECM) of market prices; but IS assumes that price volatility reflects new information, and allows for the correlation among multiple markets via the variance and covariance of price innovations.

[35] We use Johansen cointegration test, and find that the USD and Euro credit yield spreads are highly cointegrated during the sample period.

[36] We determine the lags (L) by using Akaike Information Criteria.

two bounds, H_l and H_u, expressed as follows:

$$H_l = \frac{A_2^2\left(\sigma_1^2 - \frac{\sigma_{12}^2}{\sigma_2^2}\right)}{A_2^2\sigma_1^2 - 2A_1A_2\sigma_{12} + A_1^2\sigma_2^2}, \qquad H_u = \frac{\left(A_2\sigma_1 - A_1\frac{\sigma_{12}}{\sigma_1}\right)^2}{A_2^2\sigma_1^2 - 2A_1A_2\sigma_{12} + A_1^2\sigma_2^2} \tag{9}$$

In the latter case, Baillie, Booth, Tse, and Zabotina (2002) suggest using the average of H_l and H_u, namely H_m. Based on Eq. (9), H_m estimates how much S^a contributes to the price discovery process. If $H_m > 50\%$, then S^a is the main contributor. Therefore, $1 - H_m$ shows how much S^b contributes to the price discovery process. Table 6 summarizes the results, indicating a clear pattern. For Brazil and Mexico, A_2 is positive and statistically significant, showing that S^a contributes more to the price discovery process. On average, H_m is 73% for Brazil, and 84% for Mexico. The exact opposite is true for Turkey. We find that A_1 is negative and statistically significant, showing that S^b contributes more to the price discovery process. On average, H_m is 30%, so that the contribution of S^b is 1- $H_m =$ 70%.

[Table 6, *about here*]

These results show geographical differences in the information content of sovereign bonds. This is consistent with earlier empirical findings showing that American banks are the main lenders to Mexico and Brazil, and European banks are the main lenders to Turkey. As market dislocation increases, the relative cost of outside capital (commercial paper) with respect to inside capital (insured deposit), the two different funding channels create a cross-sectional dispersion in the price discovery process.

D. Decomposing the Basis

What is the link between the *Basis* at the level of the individual issuing countries and the $CIRP$ violation in the global FX market? While it is difficult to identify the fundamental source of priced risk, a way to gain additional understanding is by decomposing the total value of the Basis into two components. The first component is common across all bonds, and it is related to violations of the covered interest rate parity condition, which only depends on the international FX market (i.e. $Basis_{\text{cirp}}$). The second component is related to the specific characteristics of the funding channels and other institutional frictions operating at the issuing country level (i.e. $Basis_{\text{spread}}$). In a frictionless market with no arbitrage, both components must be equal to zero. We can rearrange Eq. (2) as follows:

$$\underbrace{\left[\frac{X(t)}{F(t,T)}(1 + R^b(t,T)) - (1 + R^a(t,T))\right]}_{\text{CIRP Component}} + \underbrace{\left[\frac{X(t)}{F(t,T)}S^b(t,T) - S^a(t,T)\right]}_{\text{Bond Spread Component}} = 0. \tag{10}$$

First, we follow the procedure described in details in Baba (2009), and compute the size of the CIRP violation (i.e. $Basis_{\text{cirp}}$) in the FX market using cross-currency basis swaps data.[37] Then, we obtain $Basis_{\text{spread}}$ from the difference of $Basis_{\text{bond}}$ minus $Basis_{\text{cirp}}$. We find that for Mexico and Brazil $Basis_{\text{spread}}$ and $Basis_{\text{cirp}}$ have the same sign. On average, 22% (78%) of the total Basis of 2015 Brazilian bonds is attributed to the common $Basis_{\text{cirp}}$ component ($Basis_{\text{spread}}$). Similarly, 10% (90%) of the total Basis of 2020 Mexican bonds is attributed to $Basis_{\text{cirp}}$ component ($Basis_{\text{spread}}$).

On the other hand for Turkey $Basis_{\text{spread}}$ and $Basis_{\text{cirp}}$ have opposite signs. This implies that the negativity of the total Turkish Basis is so large (due to high USD credit yield spreads) that even the positivity of the CIRP component is insufficient to pull it back to zero. Specifically, we find that -36% (136%) of the total Basis of 2014 Turkish bonds is attributed to the common $Basis_{\text{cirp}}$ component ($Basis_{\text{spread}}$). In all cases, the country-specific Bond Spread Component is indeed the dominant factor. This suggests that, at the peak of the crisis, significant frictions were operating at a domestic level.

The set of results in this section support the notion of an institutional-based explanation of the type of frictions that were responsible for the cross-sectional properties of the *Basis*.

VII. Monetary Policy Implications on LOP

Can monetary authorities ease some of these frictions? If arbitrageurs are contemporaneously present on multiple asset markets, Gromb and Vayanos (2010) argue that balance sheet shocks can give rise to contagion effects even across seemingly unrelated assets. In this context, it is possible that some of the monetary policies with objective of relieving funding conditions on the U.S. markets, at the time of crisis, might have relaxed some of the constraints eventually affecting $Basis_{\text{bond}}$. We design this last part of the analysis as an event study and quantify the impact of different monetary interventions on the dynamics of $Basis_{\text{bond}}$.

We define two main monetary policy phases: (1) "Funding Relief Policy", divided into (a) Liquidity Risk Interventions, and (b) Credit Risk Interventions; and (2) "Uncertainty Relief Policy", which consists of stress test announcements on major U.S. banks, which were policy moves that aimed to address financial uncertainty via public signaling.

In the first part of the "Funding Relief Policy" phase, namely the Liquidity Risk Interventions, the Federal Reserve became increasingly concerned about market illiquidity. On December 12, 2007, the Federal Reserve introduced a Term Auction Facility (TAF), designed to lend funds directly to depository institutions for a fixed term (28 or 84 days), and to relieve the frictions related to interbank borrowing. Two important restrictions applied: (a) funds were in fixed term, and in limited supply; and (b) foreign banks could bid through their U.S. branches (or agencies) if they maintained reserves with the Federal Reserve Bank, otherwise they needed to borrow in their own jurisdictions. To facilitate the provision of

[37] Baba (2009) argues that for durations longer than one year, traders use cross-currency basis swaps (due to smaller trading costs), which are used to test the CIRP violations. See also Popper (1993) for related work.

USD liquidity to other central banks around the globe, the Federal Open Market Committee (FOMC) authorized currency swap lines with the European Central Bank (ECB) and the Swiss National Bank (SNB) in the amounts of $20 billion and $4 billion, respectively, on December 12, 2007. On September 29, 2008, the FOMC expanded swap lines with the Bank of England, the Bank of Canada, SNB, ECB, Norges Bank, Danmarks Nationalbank, Sveriges Riksbank, the Bank of Japan, and the Reserve Bank of Australia in the amount of $330 billion. One month later, on October 29, 2008, the FOMC established new swap lines to the central banks of emerging markets that are major U.S. partners, such as Banco Central do Brasil, Banco de Mexico, the Monetary Authority of Singapore, and the Bank of Korea in the amount of $30 billion each. Mexico used it in three occasions: 21 April, 16 July, and 14 October 2009, with tenor of 88 days and 3.22 billion each. The Turkish Central Bank, on the other hand, never had access to this arrangement.

In the second part of "Funding Relief Policy" phase, namely the Credit Risk Interventions, the Federal Reserve and U.S. Treasury developed new policies and shifted the nature of their interventions to directly address credit risk concerns. Three unconventional policy interventions followed: (1) The Troubled Asset Relief Program (TARP) by the U.S. Treasury, aimed at compensating for the lost capital of U.S. banks and restarting their lending activities,[38] (2) The Term Asset-Backed Securities Loan Facility (TALF) by the Fed, aimed at increasing credit availability, and supporting economic activity by facilitating renewed issuance of consumer and business ABS at normal interest rate spreads,[39] and (3) The Commercial Paper Funding Facility (CPFF) by the Fed, aimed at relieving short-term funding frictions, and thereby contributing to greater availability of credit for businesses and households.[40] A key difference between the U.S. Treasury and the Fed programs was that while the Treasury's balance sheet interventions mainly addressed secured markets via purchasing large amounts of bank preferred stocks and taking on credit risk exposure (by providing capital), the Fed's interventions tended to affect unsecured markets (i.e. interbank funding markets via new term auction facilities).

The final phase, labeled as the "Uncertainty Relief Policy" phase, is quite different compared to the first one or to any previous historical experience. In 2009, the Federal Reserve Board decided to more directly address market uncertainty and tail risk perception by implementing explicit economic assessments and stress tests on a broad set of banks and financial institutions. On February 25, 2009, the Federal Reserve Board - together with the Federal Deposit Insurance Corporation, the Office of Thrift Supervision and the Office of the Comptroller of the Currency - announced that they will conduct stress tests

[38]The program was signed into law on October 3, 2008, and involved the mass purchasing of troubled assets, such as mortgage-backed securities, from U.S. banks and other financial institutions (initially up to $700 billion). The Capital Purchase Program (CPP) was a part of TARP that involved the purchase of preferred stocks of U.S. banks.

[39]The program was announced on November 25, 2008, and involved the lending of up to $1 trillion to holders of AAA-rated asset-backed securities.

[40]The program was created on October 27, 2008, and allowed the Federal Reserve Bank to finance the purchase of highly rated unsecured and asset-backed commercial paper.

on eligible U.S. banks. An initial set of stress test results was released on May 7, 2009. The goal of this exercise was to reduce uncertainty about the true fundamental value of major financial institutions and to regain the trust of market participants via public signals on the value-at-risk of a series of banks.[41]

Which, if any, of these policy measures have been significant in reducing $Basis_{\text{bond}}$? To address this question thoroughly we run a comprehensive regression event analysis as detailed below. The fact that Turkey did not have access to global swap lines allows us to use Turkey as a control group and to identify the cross-sectional impact of different relief programs with a "diff-in-diff" event study analysis.

We collect an extensive database of a total of 218 policy announcements as well as financial news originating from the U.S., Europe and the rest of the world (i.e. China) from 2007 to early 2010.[42] Table 7 provides the dates and the examples of the policy events at our disposal during the Liquidity, Credit, and Post-Crisis periods. We aggregate and classify the most important policy events into two main groups: (1) "Funding Relief Policy" variables, which we divide into three subsets (a) Policy announcements of the Fed (PAF); (b) Policy announcements of the U.S. Treasury (PAT); (c) USD Swap Lines to developed and emerging markets (SWAP); and (2) the "Uncertainty Relief Policy" variable, which denotes the stress tests announcements on U.S. financial institutions (STRESS). Since some of the effects of these measures are affected by economic news on fundamentals, we also control for "News Control" variables: (a) News on U.S. finance (NEWS-US), (b) News on European finance (NEWS-EU), (c) News on UK finance (NEWS-UK), (d) News on rest of the world finance (NEWS-ROW), (e) Announcements on write-downs and subprime losses for the U.S. financial institutions (WRD), and (f) Announcements on the U.S. housing market (FF). Each explanatory variable is treated as a dummy variable that equals 1 on the days of the announcements. In order to capture the inertia effect of the explanatory variables, we compute forward-looking one-week, two-week and three-week rolling averages of $Basis_{\text{bond}}$.

[Table 7, *about here*]

Table 8 details the regression specifications and summarizes the results. Our findings indeed reveal that SWAP is highly significant on the one-week average of [Turkey $Basis_{\text{bond}}$ - Brazil $Basis_{\text{bond}}$] and the three-week average of [Turkey $Basis_{\text{bond}}$ - Mexico $Basis_{\text{bond}}$]. SWAP has a positive coefficient sign. This implies that the cross-sectional dispersion between Turkish Basis vs. Brazilian/Mexican Basis tends to widen further when the SWAP extensions (excluding Turkey) are authorized. The presence of dollar swap relief to Brazil and Mexico, therefore, possibly helped Brazilian and Mexican $Basis_{\text{bond}}$ to shrink. Figure 4 supports this view. Following the announcement of swap lines on October 29, 2008,

[41] To highlight the positive assessment results, Bernanke pointed out to the Joint Economic Committee: "I've looked at many of the banks and I believe that many of them will be able to meet their capital needs without further government capital." (Reuters News Agency on May 5, 2009).

[42] Similar to Dooley and Hutchison (2009), the crisis time line is based on two data sources: one being the official source (the Federal Reserve Bank of Saint Louis) and the other being a market source (Bloomberg)

$Basis_{\text{bond}}$ of Brazil and Mexico indeed began to diminish almost immediately, whereas $Basis_{\text{bond}}$ of Turkey continued to rise. The cross-currency basis swap market provides additional consistent evidence with this interpretation. Turkish (Tribor vs. USD Libor) 5-year cross-currency swap prices decrease from -50 bps in mid-2008 to a record -250 bps in January 2009.[43] This suggests that Turkey was in short supply of USD funding, and that the costs of synthetic dollar funding increased.

[Table 8, *about here*]

Our results also reveal that stress test announcements helped to reduce the cross-sectional dispersion between the Turkish Basis and the Mexican Basis. Stress tests are found to be statistically significant for the $Basis_{\text{bond}}$ of each country, and to have a negative coefficient sign. This supports the argument that stress tests were indeed helpful in reducing uncertainty and relaxing funding constraints.[44] This finding highlights the importance of the role played in addressing market uncertainty, and the formation of expectations for the dynamics of $Basis_{\text{bond}}$. This result is consistent with the Acharya and Merrouche (2010) argument that "[...] regulatory attempts to thaw the money market stress and reduce variability of inter-bank rates [...] should involve addressing insolvency concerns (for example, early supervision and stress tests, and recapitalization of troubled banks) and not just provisions of emergency liquidity."

VIII. Conclusions

We use cross-sectional information on violations of the LOP in large and liquid emerging markets. We use a detailed dataset on repo market activity (bond specific lendable inventory, loan transaction numbers, and loan fees) by the major prime brokers, custodians, and lending desks of large firms to help identify the role of different frictions. We derive a cross-sectional time-series of LOP deviations for emerging market Eurobonds, which are issued by the same sovereign country in two different foreign currency denominations (i.e. USD and Euro). We generate an empirical proxy called $Basis_{\text{bond}}$, which became large, volatile, and persistent during the Credit Crisis. It started to converge back to initial levels several months after the initial widening. This suggests that arbitrageurs were either facing persistent frictions, or that their funding constraints and required risk-adjusted compensations were so elevated that they could not provide sufficient liquidity to the market. We focus on four main explanations suggested in the literature: (i) Liquidity Frictions, (ii) Short-Selling Constraints and Security Lending Frictions, (iii) Funding Costs and Leverage Constraints

[43] Cross currency basis swap is quoted as 3-month TRIBOR against 3-month USD Libor so that the cross-currency swap price is added to TRIBOR.

[44] One potential view is that the stress tests address the market risk-aversion parameter. The impact of the risk-aversion appears to be eliminated after the stress test announcements. This result implies that a policy tool that addresses a relevant risk factor might also be relevant in healing the Basis.

in Debt Markets, and (iv) Institutional frictions in the context of a large macro demand and wealth shock. We find that both liquidity and short-selling constraints are not the key factors to understanding the cross-sectional and time-series properties of $Basis_{\text{bond}}$. On the other hand, the impact of funding channels, in the context of challenging macro-activity shocks, are statistically and economically significant. This highlights the potential interaction between leverage constraints and funding costs in the presence of a large economic shocks, reducing the demand for risky arbitrage.

One of the most intriguing findings is that $Basis_{\text{bond}}$ is country-specific. The Turkish $Basis_{\text{bond}}$ is, on average, negative, whereas for Mexico and Brazil it is, on average, positive. This is due to the fact that Brazil and Mexico on average pay higher risk premia in Euro compared to USD, while the opposite holds true for Turkey. A detailed dataset on bank consolidated holding exposures on sovereign bonds unveils substantial cross-sectional differences in funding, suggesting geographical concentration in banking exposure. Indeed, we find that during periods in which the difference between the external cost of funding and the insured deposit rate increases, the geographical concencentration is consistent with the observed cross-section of the Basis. The general increase in counterparty risk and the capital repatriation of U.S. financial institutions reduced the supply of dollars (Euros) in the European (American) interbank market. This supports the model discussed in Ivashina, Scharfstein, and Stein (2012).

Finally, we also conducted a comprehensive event study to investigate how the Fed's and the U.S. Treasury's lending facilities, asset purchase programs and stress test announcements affected the LOP relationship, thus providing new insights into the monetary transmission mechanism during the Credit and Liquidity Crises. We note that the FOMC has extended global dollar swap lines to Brazil and Mexico, but not to Turkey. This fact allows us to use Turkey as a control group and to identify the cross-sectional impact of dollar swap facilities on the Basis. We also find that, after the Fed published the stress test results on financial institutions, thus directly addressing market uncertainty via public signaling, $Basis_{\text{bond}}$ levels began to decrease. This evidence is consistent with the interpretation that constraints of arbitrageurs were binding both because of an initial balance sheet shock, and also because of economic uncertainty that stress tests might have helped to reduce. This obviously bears welfare and policy implications that should be researched further.

Appendix A.

In this section we explain the construction of the economic control variables used in the panel regressions: (i) Global Cash-Flow Factors, (ii) Local Risk Factors, (iii) Global Discount Rate Risk Factors, and (iv) the Global Uncertainty Factor. Details and a discussion of each of the explanatory variables follow.

Global Cash-Flow Factors

- Macro-Activity Risk: To proxy for macro cash-flow factors, we follow Ludvigson and Ng (2009), who estimate a set of common factors from a panel of 132 real, nominal, and monetary measures of economic activity.[45] Unlike Ludvigson and Ng, however, we exclude price-based information from the panel in order to interpret this variable as a pure macro-activity factor, and to allow for easier distinction between macro-activity and other risk factors. After removing price based information from the panel, we end up with 99 cross-sectional economic series from which we extract the first principal component.[46] The time series are based on Stock and Watson (2002), and are collected from the Global Insights Basic Economics Database and the Conference Board's Indicators Database. We label the weekly-adjusted factor as LN-Macro.
- Term Premia: a vast literature show that the slope factor of the U.S. yield curve is a forward looking proxy of macroeconomic activity. It has also been argued that arbitrageurs fund their activities rolling short maturity instruments. See Vayanos and Vila (2009) for a model in which the slope of the term structure is informative about the relative cost of arbitrageurs funding risky arbitrage in bonds. We define the U.S. slope as the difference between 10-year Treasury and 3-month Libor yields. We label this factor as TP.

Local Risk Factors

- Local Equity and Credit Factors: To measure the impact of local EM factors, we control for two components: (a) the MSCI Emerging Market stock market and (b) the Markit CDX Emerging Markets Index (capturing the EM default risk). We label the former EM-MSCI, and the latter EM-CDSI.

Global Discount Rate Factors

- Equity Risk Premium Factor: Garleanu and Pedersen (2011) use dividend yields in the context of their heterogeneous risk-aversion model to proxy for states of the world in which "constraints are binding and deviations of the law of one price occur." Dividend yields are found to explain expected excess returns (equity risk premia). Accordingly, we use the weekly S&P500

[45] They show that such a procedure that synthesizes information from macroeconomic activity possesses the ability to strongly predict excess bond returns, explaining 26% of the one-year-ahead variation in returns.

[46] Examples of price variables removed include: the S&P dividend yield, the Federal Funds (FF) rate, the 10-year T-bond, the Baa - FF default spread, and the Dollar-Yen exchange rate.

dividend-price ratio (retrieved from Datastream) to control for hidden priced state variables that may affect market-wide expected excess returns. We label this proxy as DIVY.[47]

- Closed End Fund Discount Risk: A large literature investigates the persistence of the closed-end fund discount as an LOP anomaly under rational or behavioral models. Rational models tend to explain the anomaly with frictions as agency costs, managerial abilities and time variation in the discount factor (Malkiel (1977); Spiegel (1997); Ross (2002); Berk and Stanton (2007)), whereas behavioral models argue that it is due to irrational investment decisions and market sentiments (De Long, Shleifer, Summers, and Waldmann (1990); Lee, Shleifer, and Thaler (1991); Bodurtha, Kim, and Lee (1995); Baker and Wurgler (2007)). We compute the weighted average of closed-end funds discount of the four largest U.S. Emerging Market debt funds (EDD, TEI, ESD and MSD), and label it Closed End.[48] While it is unclear what are the exact sources of the discount, we use it as a proxy of risk aversion in the Emerging Markets.

- Perceived Tail Event Risk: A measure of market perception of tail event risk can be obtained from the VIX index. It summarizes the cost of protection against major market tail event risk (see, among others, Pan and Singleton (2008) for an application in the context of credit markets).[49]

Global Uncertainty Factor

- Subjective Uncertainty: An emerging literature uses dispersion in analyst forecasts as a proxy for ambiguity and uncertainty in financial markets. They find that disagreement in beliefs helps to explain yield spreads. Thus, we incorporate subjective uncertainty using the Buraschi and Whelan (2012) dispersion which is intended to capture U.S. based macroeconomic uncertainty. The disagreement in beliefs proxy is labeled as DiB.

[47]Indeed, DIVY increased substantially during the Crisis Period, reaching its maximum in November 2008, and beginning its decline in the Post-Crisis period following April 1, 2009.

[48]A closed-end fund premium (discount) is how much greater (smaller) the fund's market price compared to its net asset value (NAV). We generate the corresponding premiums (discounts) by dividing market prices to NAVs. This ratio reaches its lowest average and highest volatility during the Credit Crisis.

[49]Further examples include Campbell and Taksler (2003), Landschoot (2008), Cremers, Driessen, and Maenhout (2008).

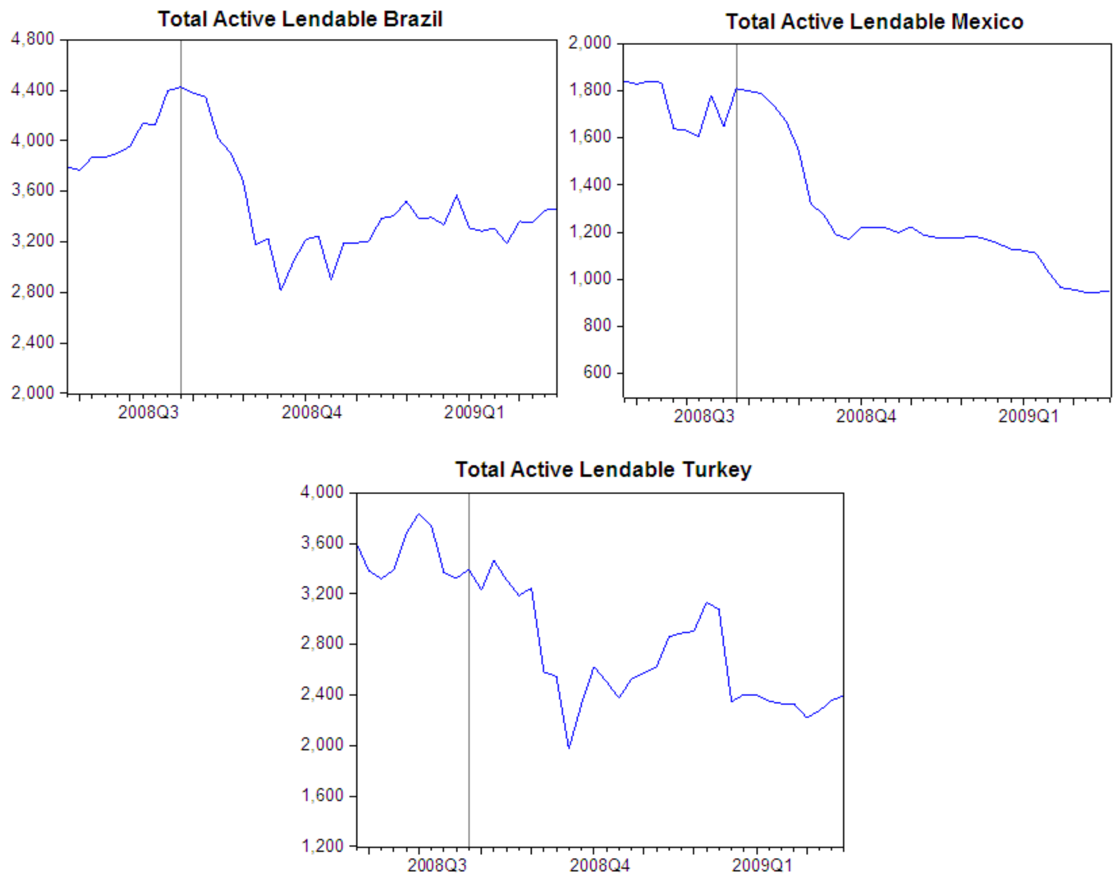


Figure 2. *Total active lendable values:* The three panels above show the Total Active Lendable Value (i.e. the amount available for lending) for the Eurobonds of Brazil, Mexico, and Turkey, respectively, in millions of USD. The sample includes the Credit Crisis period, where the vertical lines denote the start of Credit Crisis in September 2008.

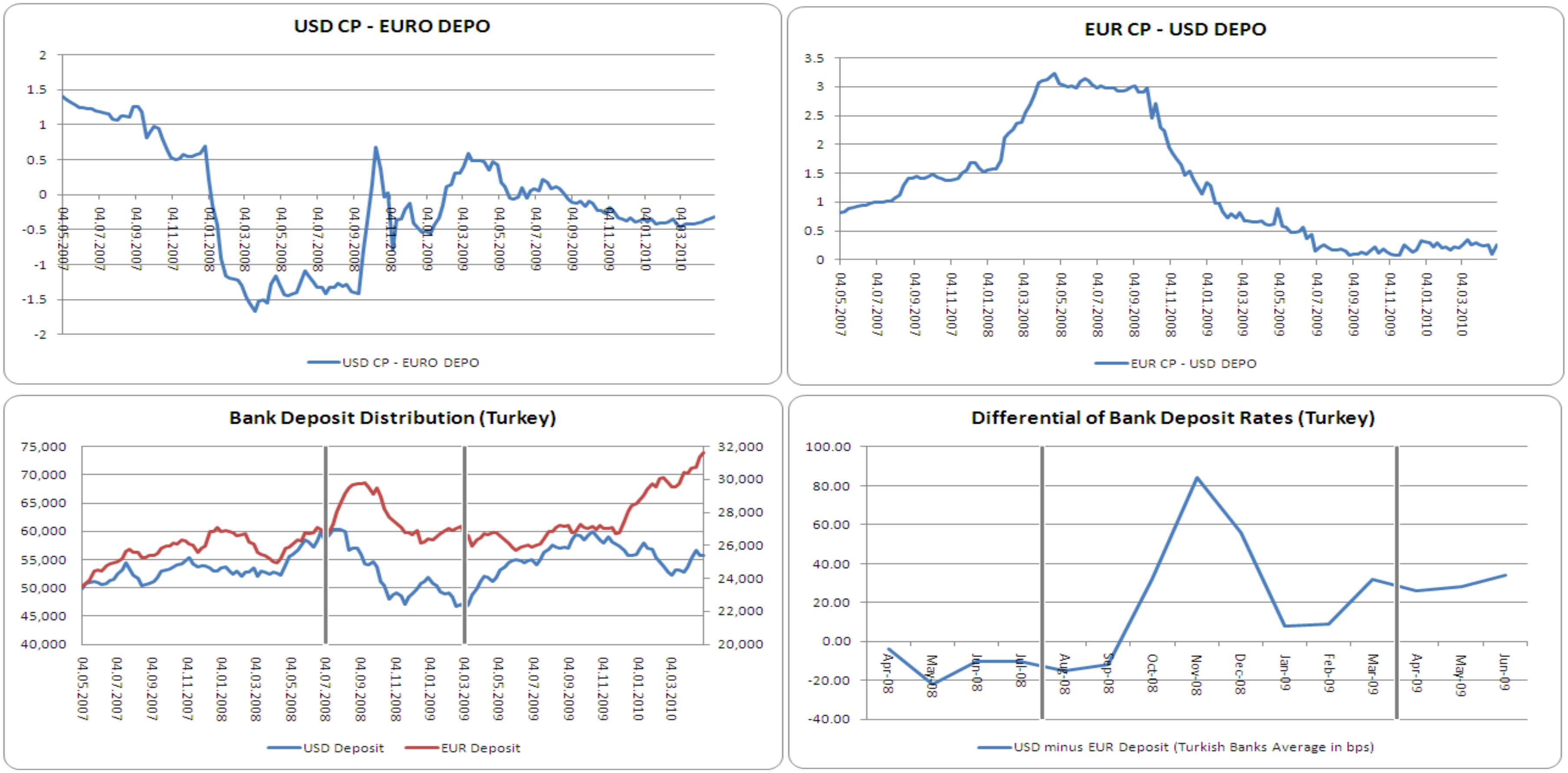


Figure 3. *Geography of Funding:* The top left panel above displays the Unsecured USD Commercial Paper Rate minus the Secured Euro Deposit Rates. The top right panel above displays the Unsecured EUR Commercial Paper Rate minus the Secured USD Deposit Rates. The bottom left panel above displays the total Bank Deposit Distribution (in millions) in USD (left axis) and in Euros (right axis) in Turkey between 2007-2010. The bottom right panel above displays the difference between the 3-month average USD minus Euro deposit rates (bps) of Turkey between 2008-2009. The vertical lines on the graphs denote the period between July 2008 and March 2009.

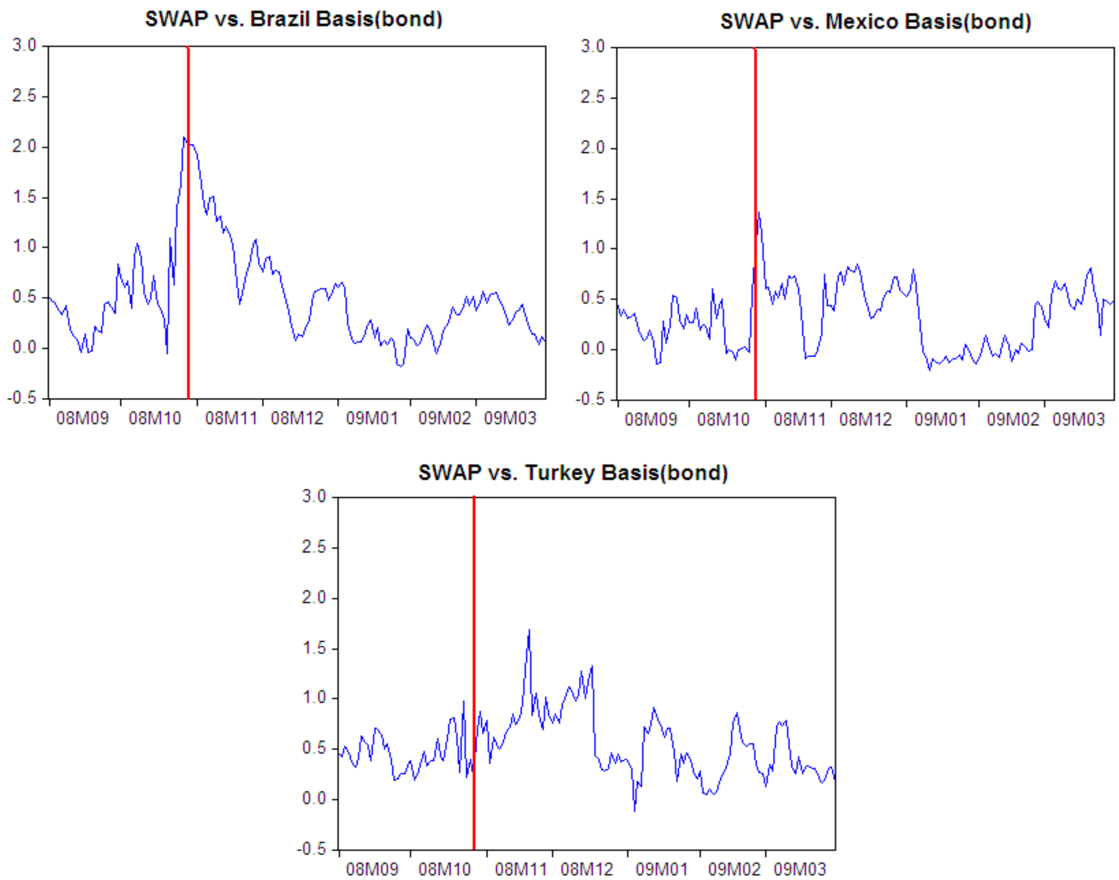


Figure 4. *Impact of emerging market swap line extension:* The figures above display the evolution of the average of the absolute value of the Net $Basis_{\text{bond}}$ of Brazilian, Mexican, and Turkish bonds after the FOMC announced it was going to extend dollar swap lines to Brazil and Mexico (not Turkey) on October 29, 2008 (indicated by the red vertical line).

Table 1

Summary Statistics

Panel A shows the means, maximums and standard deviations of the transaction-cost adjusted absolute values of $Basis_{\text{bond}}$ (in %) for each subsample. For brevity, we provide summary statistics for the following bond pairs: 2015 Brazil, 2020 Mexico and 2014 Turkey. The average total bid-ask spreads are shown in the fourth column. Panel B visualizes the mean of net absolute $Basis_{\text{bond}}$ in the four sub-samples. Panel C reports the p-values of a test of the null hypothesis that the $Basis_{\text{bond}}$ in the Credit Crisis period is equal to the $Basis_{\text{bond}}$ in the Pre-Crisis period.

PANEL A

Brazil

Brazil 2015	Statistics Table			
	Mean	*Max*	*St. Dev*	*Bid-Ask*
Pre-Crisis	0.05	0.53	0.14	0.20
Liquidity Crisis	0.17	0.74	0.19	0.22
Credit Crisis	0.51	2.09	0.48	0.23
Post-Crisis	-0.03	0.34	0.13	0.29

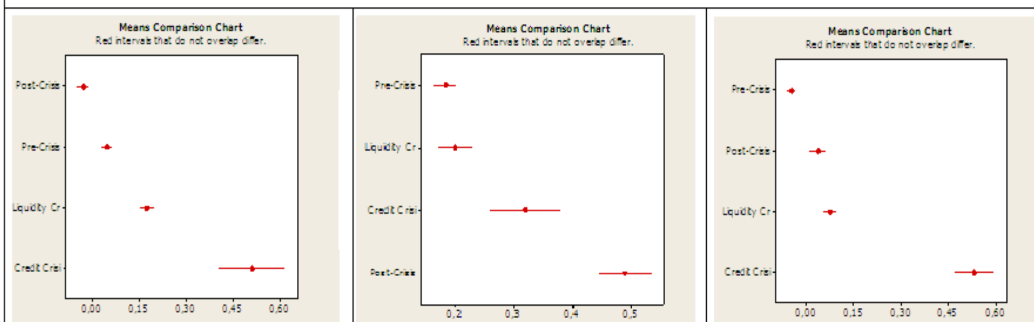
Mexico

Mexico 2020	Statistics Table			
	Mean	*Max*	*St. Dev*	*Bid-Ask*
Pre-Crisis	0.18	0.53	0.11	0.19
Liquidity Crisis	0.20	0.75	0.23	0.27
Credit Crisis	0.32	1.36	0.32	0.23
Post-Crisis	0.49	1.55	0.34	0.23

Turkey

Turkey 2014	Statistics Table			
	Mean	*Max*	*St. Dev*	*Bid-Ask*
Pre-Crisis	-0.05	0.21	0.07	0.20
Liquidity Crisis	0.08	0.66	0.17	0.27
Credit Crisis	0.53	1.69	0.30	0.35
Post-Crisis	0.04	0.57	0.20	0.33

PANEL B



PANEL C

Brazil	Mexico	Turkey
p-value = 0.000	***p-value = 0.000***	***p-value = 0.000***

Ho: Subsamples are drawn from populations with same mean values

Table 2

Panel regressions on liquidity risk, short-selling frictions, and funding risks

Summary fixed-effects panel regressions on net absolute $Basis_{\text{bond}}$ of Brazil 2010, Brazil 2015, Mexico 2020, Turkey 2014, and Turkey 2019 bond pairs. Δ denotes first-difference, $\bar{\Delta}$ denotes percentage difference, and j denotes the specific bond pair. We report the parameter estimates, so that the associated t-statistics are displayed immediately below (based on White's standard errors). Sample is the Credit Crisis period. Results for Liquidity Risks (i.e. BidAsk, FX-Liq, FG-Liq), as in Eq. (A), are shown on Panel A. Results for the Short-Selling Constraints (i.e. Inventory, Transaction, Loan Fees), as in Eq. (B), are shown on Panel B. Results for Funding Risks (i.e. Secured, Unsecured), as in Eq. (C), are shown on Panel C. Intercepts are not reported. (**) shows a 95% confidence interval, and (*) shows a 90% confidence interval.

$$(A) \qquad \Delta\left|Basis(bond)_{j,t}\right| = a_j + B_1\left[\Delta BidAsk_{j,t}\right]' + B_2\left[\Delta FX\ Liq_t\right]' + B_3\left[\Delta FG\ Liq_t\right]' + \epsilon_{j,t}.$$

$$(B) \qquad \Delta\left|Basis(bond)_{j,t}\right| = b_j + \lambda_1\left[\bar{\Delta} Inventory_{j,t}\right]' + \lambda_2\left[\Delta Transaction_{j,t}\right]' + \lambda_3\left[\Delta Loan\ Fees_{j,t}\right]' + \epsilon_{j,t}.$$

$$(C) \qquad \Delta\left|Basis(bond)_{j,t}\right| = c_j + \theta_1\left[\bar{\Delta} Inventory_{j,t}\right]' + \theta_2\left[\Delta Transaction_{j,t}\right]' + \theta_3\left[\Delta Loan\ Fees_{j,t}\right]' + \theta_4\left[\Delta Unsecured_t\right]' + \theta_5\left[\Delta Secured_t\right]' + \epsilon_{j,t}.$$

		Credit Crisis (1 September 2008 - 31 March 2009)		
		Panel A	**Panel B**	**Panel C**
Category	**Variable**	**Coeff./t-stat**	**Coeff./t-stat**	**Coeff./t-stat**
Liquidity Risks	**BidAsk**	1.1278		
		1.0827		
	FX-Liq	0.0187		
		0.9059		
	FG-Liq	-0.4055		
		-0.5256		
Short-Selling Frictions	**Inventory**		-0.0203	-0.0235
			-1.8631*	-2.3524**
	Transaction		0.0036	0.0072
			0.5467	1.0792
	Loan Fees		-0.1704	-0.0462
			-1.4050	-1.2097
Funding Risks	**Unsecured**			0.2836
				1.9904**
	Secured			-0.1487
				-1.2314
	R-Squared	2%	2%	8%

Table 3
Panel regressions on macroeconomic shocks and supply of risk capital
Summary fixed-effects panel regressions on net absolute $Basis_{\text{bond}}$ of Brazil 2010, Brazil 2015, Mexico 2020, Turkey 2014, and Turkey 2019 bond pairs. Δ denotes first-difference, and j denotes the specific bond pair. We report the parameter estimates, so that the associated t-statistics are displayed immediately below (based on White's standard errors). The regression specification is specified below in Eq. (D). Funding Risks are regressed with the weekly lag parameter $v = 0$ for Unsecured Funding, and $v = 1$ for Secured Funding. Samples are the Liquidity and the Credit Crisis periods. Explanatory variables, shown as vectors, are Funding Risks [Unsecured, Secured]; Liquidity Risks [FX-Liq, FG-Liq]; Global Cash-Flow Factors [LN-Macro, TP]; Local Risk Factors [EM-CDSI, EM-MSCI]; Global Discount Rate Factors [DIVY, Closed End, VIX]; Global Uncertainty Factor [DiB]; Short-Selling Frictions [Inventory, Transaction, Loan Fee]. Each of these explanatory variables are detailed in Appendix A. Intercepts are not reported. (**) shows a 95% confidence interval, and (*) shows a 90% confidence interval.

$$(D) \quad \Delta\left|Basis(bond)_{j,t}\right| = \alpha_j + \beta_1 \left[\Delta Funding\ Risks_{t-v}\right]' + \beta_2 \left[\Delta Liquidity\ Risks_t\right]' + \beta_3 \left[\Delta Global\ Cash\ Flow\ Factors_t\right]' + \beta_4 \left[\Delta Local\ Risk\ Factors_t\right]' + \beta_5 \left[\Delta Global\ Discount\ Rate\ Factors_t\right]' + \beta_6 \left[\Delta Global\ Uncertainty\ Factor_t\right]' + \beta_7 \left[\Delta Short\ Selling\ Frictions_{j,t}\right]' + \epsilon_{j,t}.$$

Categories	Coefficients	Liquidity Crisis Period	Credit Crisis Period
		Slope Coef. / t-stat	Slope Coef. / t-stat
Funding Risk	Unsecured	-0.0683	0.3234
		-0.7088	2.6340**
	Secured	0.1486	0.4441
		1.1893	2.9479**
Liquidity Risk	FX-Liq	0.0190	0.0223
		1.9693**	1.2582
	FG-Liq	-0.1911	-2.1956
		-0.4563	-2.7135**
Global Cash-Flow Risk	LN-Macro	-0.0128	-0.4206
		-1.1211	-1.8774*
	TP	-0.1170	0.3466
		-1.7452*	2.8491**
Local Risk	EM-MSCI	0.0000	0.0000
		0.0802	-0.0092
	EM_CDSI	0.0101	-0.0299
		0.7239	-2.7850**
Global Discount Rate Risk	DIVY	0.0392	-0.2284
		0.2016	-0.7427
	Closed End	0.5824	-2.9727
		1.2518	-4.1386**
	VIX	0.0083	-0.0037
		3.0159**	-0.4717
Global Uncertainty	DiB	0.1985	1.4826
		0.4412	1.3218
Short-Selling Frictions	Inventory	0.0024	-0.0236
		0.6111	-2.1261**
	Transaction	0.0004	0.0076
		1.0307	1.0997
	Loan Fee	-0.0046	-0.1793
		-0.0665	-1.4655
	R-squared	11%	45%

Table 4

Banks holding exposure and international reserve distribution

Panel A displays the time evolution of the distribution of European and U.S. banks' on-balance sheet exposure to Brazilian, Mexican, and Turkish aggregate amounts of external sovereign bonds based on "ultimate risk"- covering the sample from 2005 to 2010. Panel B displays the time evolution of the distribution of foreign asset values to total foreign assets in the Central Bank of Brazil (Banco Central do Brazil) and the Central Bank of Turkey (Turk Merkez Bankasi) - covering the sample from 2004 to 2010. The reserve distribution data preceding 2008 is not available for Turkey. The foreign assets include the following currencies: the U.S. dollar (USD), Euro (EUR), and others (e.g. Japanese Yen (JPY), British Pound (BGP), Canadian Dollars (CAD), Australian Dollars (AUD).)

PANEL A: Banks Holding Exposure

Year/Quarter	**Brazil**		**Mexico**		**Turkey**	
	Europe	*U.S.*	*Europe*	*U.S.*	*Europe*	*U.S.*
2005-Q4	8.7%	81.6%	10.0%	85.0%	75.0%	9.0%
2006-Q4	8.5%	84.0%	10.0%	83.0%	81.0%	10.0%
2007-Q4	11.0%	81.0%	10.0%	84.0%	83.0%	11.0%
2008-Q4	9.0%	81.0%	9.0%	85.0%	80.0%	11.0%
2009-Q4	7.6%	85.0%	8.0%	83.0%	79.0%	8.0%
2010-Q4	10.0%	82.0%	5.0%	85.0%	79.0%	9.0%

PANEL B: Central Bank Foreign Reserve Distribution

Year	**Brazil**			**Turkey**		
	EUR	*USD*	*Other*	*EUR*	*USD*	*Other*
2004	35.1%	54.6%	10.3%	-	-	-
2005	21.3%	73.2%	5.5%	-	-	-
2006	10.3%	88.3%	1.4%	-	-	-
2007	9.5%	90.0%	0.5%	-	-	-
2008	9.4%	89.1%	1.5%	46.0%	51.0%	3.0%
2009	7.0%	81.9%	11.1%	44.6%	52.6%	2.8%
2010	4.5%	81.8%	13.7%	46.5%	51.3%	2.2%

Table 5

Regressions on commercial paper rates and deposit rates

Summary regressions on net absolute $Basis_{\text{bond}}$ of Brazil 2010, Brazil 2015, Mexico 2020, Turkey 2014, and Turkey 2019 bond pairs. Δ denotes first-difference, and j denotes the specific bond pair. Turkey is denoted by TR, Brazil by BR, and Mexico by MX. We report the parameter estimates, so that the associated t-statistics are displayed immediately below (based on White's standard errors). Sample is the Credit Crisis. Panel results for [USD CP - EUR Depo] for Turkish $Basis_{\text{bond}}$, as in Eq. (E), are shown on Panel E. Panel results for [EUR CP - USD Depo] for Brazilian and Mexican $Basis_{\text{bond}}$, as in Eq. (F), are shown on Panel F. Results for the ratio of [EUR CP - USD Depo]/[USD CP - EUR Depo] on Mexico vs. Turkey, as in Eq. (G), are shown on Panel G. Results for the ratio of [EUR CP - USD Depo]/[USD CP - EUR Depo] on Brazil vs. Turkey, as in Eq. (H), are shown on Panel H. Intercepts are not reported. (**) shows a 95% confidence interval, and (*) shows a 90% confidence interval.

$$(E) \qquad \Delta \left|Basis(bond)_{TR,t}\right| = \nu_j + \eta_1 \left[\Delta(USD\ CP - EUR\ Depo)_t\right]' + \epsilon_{j,t}.$$

$$(F) \qquad \Delta \left|Basis(bond)_{BR,MX,t}\right| = \nu_j + \eta_1 \left[\Delta(EUR\ CP - USD\ Depo)_{t-2}\right]' + \epsilon_{j,t}.$$

$$(G) \qquad \frac{\left|Basis(bond)_{MX,t}\right|}{\left|Basis(bond)_{TR,t}\right|} = \nu_j + \eta_1 \left[\frac{(EUR\ CP - USD\ Depo)_t}{(USDCP\ - EUR\ Depo)_t}\right]' + \epsilon_{j,t}.$$

$$(H) \qquad \frac{\left|Basis(bond)_{BR,t}\right|}{\left|Basis(bond)_{TR,t}\right|} = \nu_j + \eta_1 \left[\frac{(EUR\ CP - USD\ Depo)_t}{(USDCP\ - EUR\ Depo)_t}\right]' + \epsilon_{j,t}.$$

Coefficients	**Credit-Crisis Period**			
	Panel E **Coef. / t-stat**	**Panel F** **Coef. / t-stat**	**Panel G** **Coef. / t-stat**	**Panel H** **Coef. / t-stat**
USD CP - EUR Depo	*0.28* *1.6965**			
EUR CP - USD Depo		*1.52* *2.0092***		
Ratio CP Depo			*0.01* *4.8928***	*-0.01* *-0.4169*
R-squared	*5%*	*11%*	*7%*	*4%*

Table 6
Price discovery analysis
Summary results of the price discovery regressions between the USD and Euro credit yield spreads of the bond pairs used in our analysis. The tests are based on VECM specification shown below. We let $S_t = [S_t^a, S_t^b]$ be the vector of bond credit yield spreads in a=USD, b=EUR, and $z_t \equiv [S_t^a - k_1 \times S_t^b]$, where k_1 is the average of $X(t)/F(t,T)$. We denote $A = [A_1, A_2]'$, and the corresponding error terms as $u_t = [u_{1t}, u_{2t}]$, so that σ_1, σ_2, σ_{12} are the standard deviations and covariance of u_{1t} and u_{2t}, respectively. The optimal number of lags (L) are determined by AIC. We report the average of A_1 and A_2 coefficients for each region, and the average t-statistics immediately below. H_l and H_u are the Hasbrouck bounds, and H_m is the average of the two. We report the average H_m for each region, capturing the contribution of S^a to the price discovery process. 1-H_m captures the contribution of S^b to the price discovery process. The VECM and the Hasbrouck bounds are specified in order as follows:

$$\Delta S_t = A z_t + \Phi(L)\Delta S_{t-1} + u_t$$

$$H_l = \frac{A_2^2\left(\sigma_1^2 - \frac{\sigma_{12}^2}{\sigma_2^2}\right)}{A_2^2\sigma_1^2 - 2A_1A_2\sigma_{12} + A_1^2\sigma_2^2}, \quad H_u = \frac{\left(A_2\sigma_1 - A_1\frac{\sigma_{12}}{\sigma_1}\right)^2}{A_2^2\sigma_1^2 - 2A_1A_2\sigma_{12} + A_1^2\sigma_2^2}$$

Region	**Coeff.**		**Hasbrouck Measure**
	$A1$	$A2$	H_m
Brazil	0.01	0.22	73%
	0.05	3.44	
Mexico	0.01	0.04	84%
	0.56	2.07	
Turkey	-0.51	-0.20	30%
	-2.49	-1.23	

Table 7
Policy events and announcements summary
This table summarizes the classification and sample characteristics of the policy events and news that occurred during the sample period. The event categories are: (1) "Funding Relief Policy" variables, divided into three subsets (a) Policy announcements of the Fed (PAF), (b) Policy announcements of the US Treasury (PAT), (c) USD Swap Lines to developed and emerging markets (SWAP); (2) "Uncertainty Relief Policy" variable, which consists of the announcements of stress tests on U.S. financial institutions (STRESS); (3) "News Control" variables: (a) News on U.S. finance (NEWS-US) (b) News on European finance (NEWS-EU), (c) News on UK finance (NEWS-UK), (d) News on rest of the world finance (NEWS-ROW), (e) Announcements on write-downs and subprime losses for the U.S. financial institutions (WRD), and (f) Announcements on the U.S. housing market (FF). An example event is reported for each category. Sample is the Liquidity, Credit and Post-Crisis periods. The entries are left undefined (-) for the events that had no occurrence in the given subsample periods.

Category	Event	Definition	Example	Date	Number of Events		
					Liquidity	Credit	Post
Funding Relief Policies	PAF	Policy announcements on the Federal Reserve's balance sheet	the Fed announced the creation of the Commercial Paper Funding Facility (CPFF) to provide liquidity backstop to U.S. issuers of commercial paper	07.10.2008	9	8	4
	PAT	Policy announcements on the US Treasury's balance sheet	U.S. Treasury announces Troubled Asset Relief Program (TARP) to purchase capital in financial institutions under Emergency Economic Stabilization Act of 2008.	14.10.2008	-	27	18
	SWAP	Fed Swap Lines to developed and emerging markets	The FOMC expands a $330 billion of swap lines to nine central banks of developed markets The FOMC expands a $120 billion of swap lines to four central banks of emerging markets	29.09.2008 29.10.2008	4	9	3
Uncertainty Relief Policy	STRESS	Stress Tests on US financial institutions	For U.S. bank holding companies with assets over $100 billion, the Federal Reserve Board announces that it will make stress tests or economic assessments	25.02.2009	0	1	2
News Control	NEWS-US	News on U.S. finance	Bank of America announces that it will purchase Countrywide Financial	11.01.2008	22	5	-
	NEWS-EU	News on European finance	Liquidity funding by ECB, BoE and Swiss	21.01.2008	21	12	-
	NEWS-UK	News on UK finance	Nationalization of Northern Rock	22.02.2008	16	12	-
	NEWS-ROW	News on rest of the world finance	A two-year $586 billion stimulus plan is announced by China	09.11.2008	1	1	-
	FF	Policy announcements on the U.S. housing market	Fannie Mae announces $25.2 billion loss in fourth quarter 2008 Freddie Mac announces $23.9 billion loss in fourth quarter 2008	26.02.2009 11.03.2009	22	5	-
	WRD	Write-down announcements on US financial institutions	$18 Billion Write-down of Citi and Infusion of Merill Lynch	15.01.2008	16	-	-

Table 8
Event analysis regressions
Event analysis regressions on Brazil, Turkey and Mexico are reported below. The dependent variable, as shown below, consists of $QBasis_{bond}$, where Q = [1W, 2W, 3W], capturing one-week, two-week and three-week forward-looking rolling averages of $Basis_{bond}$, respectively. Explanatory variables are the policy and news events, each treated as a dummy variable on the dates of the announcements. The event categories are: (1) "Funding Relief Policy" variables, divided into three subsets (a) Policy announcements by the Fed (PAF), (b) Policy announcements of the US Treasury (PAT), (c) USD Swap Lines to developed and emerging markets (SWAP); (2) the "Uncertainty Relief Policy" variable, which consists of the announcements of stress tests on U.S. financial institutions (STRESS); (3) "News Control" variables: (a) News on U.S. finance (NEWS-US) (b) News on European finance (NEWS-EU), (c) News on UK finance (NEWS-UK), (d) News on rest of the world finance (NEWS-ROW), (e) Announcements on write-downs and subprime losses for the U.S. financial institutions (WRD), and (f) Announcements on the U.S. housing market (FF). Sample is from July 1, 2005 to April 30, 2010. Results for Eq. (I) are shown on Panel I; Results for Eq. (J) are shown on Panel J. We report the parameter estimates, so that the associated t-statistics are displayed immediately below. Intercepts are not reported. (*) shows a 90% confidence interval, and (**) shows a 95% confidence intervals.

$$
\begin{aligned}
(I)\quad \Delta\left[\left|1WBasis(bond)_{TR,t}\right| - \left|1WBasis(bond)_{BR,t}\right|\right] &= \rho + \pi_1 PAF_t + \pi_2 PAT_t + \pi_3 SWAP_t + \pi_4 STRESS_t \\
&+ \pi_5 NEWS_{US,t} + \pi_6 NEWS_{EU,t} + \pi_7 NEWS_{UK,t} \\
&+ \pi_8 NEWS_{ROW,t} + \pi_9 FF_t + \pi_{10} WRD_t \\
&+ \pi_{11}\Delta\left[\left|1WBasis(bond)_{TR,t}\right| - \left|1WBasis(bond)_{BR,t}\right|\right] \\
(J)\quad \Delta\left[\left|3WBasis(bond)_{TR,t}\right| - \left|3WBasis(bond)_{MX,t}\right|\right] &= \rho + \pi_1 PAF_t + \pi_2 PAT_t + \pi_3 SWAP_t + \pi_4 STRESS_t \\
&+ \pi_5 NEWS_{US,t} + \pi_6 NEWS_{EU,t} + \pi_7 NEWS_{UK,t} \\
&+ \pi_8 NEWS_{ROW,t} + \pi_9 FF_t + \pi_{10} WRD_t \\
&+ \pi_{11}\Delta\left[\left|2WBasis(bond)_{TR,t}\right| - \left|2WBasis(bond)_{MX,t}\right|\right]
\end{aligned}
$$

	News	**Turkey-Brazil 1W**	**Turkey-Mexico 3W**
Funding Relief Policy Variables	**PAF**	-0.0128	-0.0099
		-1.1470	-2.6211**
	PAT	0.0051	-0.0011
		0.7290	-0.4577
	SWAP	0.0302	0.0207
		2.3884**	4.7992**
Uncertainty Relief Policy Variable	**STRESS**	0.0165	-0.0308
		0.6161	-3.3747**
News Control Variables	**NEWS-US**	0.0176	0.0030
		1.9384*	0.9810
	NEWS-EU	-0.0110	-0.0099
		-1.3204	-3.479**
	NEWS-UK	-0.0070	-0.0019
		-0.7694	-0.6085
	NEWS-ROW	0.0014	0.0074
		0.0499	0.7967
	FF	-0.0086	-0.0062
		-0.8571	-1.789*
	WRD	0.0082	0.0002
		0.6908	0.0522
	Mean Reversion	0.1269	0.5003
		14.6541**	33.5724**
	R-Squared	15%	50%

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