

CENTRAL BANK DOLLAR SWAP LINES AND OVERSEAS DOLLAR FUNDING COSTS

1. INTRODUCTION

In the decade prior to the financial crisis, the dollar-denominated assets of foreign banks, especially institutions in Europe, increased dramatically. But with the onset of the crisis in 2007, these banks saw their access to dollar funding come under tremendous stress—with potentially dire consequences for financial markets and real activity associated with banking.

The progression of market stresses led the Federal Reserve in December 2007 to establish central bank (CB) dollar swaps: reciprocal currency arrangements with several foreign central banks that were designed to ameliorate dollar funding stresses overseas. These arrangements expanded as the crisis continued throughout 2008 and they remained in place through the end of 2009, becoming an important part of global policy cooperation.

In this article, we provide an overview of the CB dollar swap facilities, discuss the changes in breadth and volume as funding conditions (both in the market and through the facilities) evolved, and assess the economic research documenting the efficacy of the swaps. We conclude that the CB dollar swap facilities are an important tool for dealing with or minimizing systemic liquidity disruptions, as demonstrated in the reintroduction of the swaps in May 2010.

We begin in Section 2 by describing the dollar funding needs of foreign banks and examining the private cost of dollars before, during, and after the crisis. Two measures are used to

show the increased cost of dollar funds in private markets during the crisis. The first is the spread between the London interbank offered rate (Libor) and the overnight index swap (OIS) rate. The second measure is the foreign exchange (FX) swap implied basis spread, which reflects the cost of funding dollar positions by borrowing foreign currency and converting it into dollars through an FX swap.

Additional evidence of disruptions to dollar markets is drawn from the intraday federal funds market. We compare the average price of federal funds during morning hours with the average price during afternoon trading. The differential in cost was normally close to zero in the precrisis period through August 2007 and thereafter evolved to reflect a substantial premium paid for federal funds acquired in morning trading. This “morning premium” persisted through December 2008, reaching elevated levels following the bankruptcy of Lehman Brothers. Among the explanations is the view that this spread can be interpreted partially as a “European premium” that evolved over the course of the crisis as a result of dollar demand by European banks lacking a natural dollar deposit base for meeting dollar funding needs.

In Section 3, we provide a history of the CB dollar swap facilities. After starting in 2007, the Federal Reserve’s program for providing dollars to foreign markets evolved extensively with respect to both the number of countries with swap agreements and the amount of dollars made available abroad. The tenor of funds made available through the dollar auctions also evolved over time, increasing from up to one month

initially to up to three months six months later, ultimately returning to primarily shorter tenors.

At the program's peak, longer term swaps dominated the total amount outstanding. Net dollars outstanding through the CB dollar swaps peaked at nearly \$600 billion toward the end of 2008, as banks hoarded liquidity over year-end, although some of this demand for dollars began to unwind following year-end. Amounts outstanding at the dollar swap facilities declined to less than \$100 billion by June 2009, to less than \$35 billion outstanding by October 2009, and to less than \$1 billion by the time the program expired on February 1, 2010.¹

In Section 4, we show the differential costs of accessing dollars at the official liquidity facilities, with the effective “all-in” cost of dollars at the various central banks deriving from the specific facility designs and collateral policies. We show that, while funds obtained through the dollar swap facilities were competitively priced in the early stages of the crisis, the dollars acquired through overseas dollar swap facilities eventually cost more than those from the Federal Reserve's Term Auction Facility (TAF) or, as money market functioning improved, from the private market for most borrowers.

Funds obtained through dollar swap facilities were typically priced close to 100 basis points higher than the dollars that banks, including some foreign institutions in the United States, obtained at the TAF. Indeed, with funds at the TAF priced below indicative market rates for many banks, and with the minimum bid rate at the TAF the same as the rate of interest on excess reserves, participation in the TAF remained broad through much of 2009. In contrast, the dollar auctions of other central banks had dollars priced above the market rates that were available to many banks. Overall, taking into account the consequences of the auction structures and collateral considerations, we observe that the continued participation of some banks in the CB dollar swap auctions through the first half of 2009 reflected persistent pockets of supply shortages in the dollar markets. Credit tiering among banking counterparties continued, as did some self-selection of less creditworthy banks that continued to seek liquidity from the central banks auctioning dollars.

Section 5 presents evidence of the dollar swap facilities' effects on liquidity conditions in financial markets in the United States and abroad. First, we share anecdotal accounts from market participants—including dealers, brokers, and bank treasurers—who argue that the CB dollar swaps contributed to improved market conditions. Second, we argue that, despite the overall improvement, credit tiering remained

¹ This expiration date refers not to the maturity but to the last day for initiation of a swap. The Bank of Japan had a balance of \$100 million in twenty-nine-day funds, initiated on January 14, 2010, that matured on February 12, 2010. We do not explore here the reintroduction of the CB dollar swaps in May 2010.

for banks seeking access to liquidity. One piece of evidence comes from the Euro Interbank Offered Rate (Euribor) panel, where the FX swaps' implied basis spreads on dollars were quite different across banks with different strength ratings. By comparing the interest cost of euros for stronger, more moderate, and lower rated financial institutions in Europe, we conclude that the degree of credit tiering peaked in November 2008 and remained elevated well into the third quarter of 2009.

Third, we discuss the key findings, as well as the limitations, of a range of relevant econometric studies of the CB auctions' effects during the crisis. The main methodology is a type of event study that tracks the consequences for financial variables of announcements about liquidity facilities, whether these pertain to amounts to be offered, scope of access, or actual auction dates. Based on the effects on financial market spreads, the studies conclude that the TAF and the CB dollar swaps played important roles in reducing the cost of funds, especially when dollar liquidity conditions were under the most stress. While the results are compelling, we note the difficulty in using such studies as conclusive metrics of market effects.

We conclude in Section 6 with more forward-looking comments on the importance of currency swap facilities as part of a central bank's toolbox for managing and resolving crises.

2. PRESSURES IN DOLLAR FUNDING MARKETS

In this section, we provide an overview of the initial pressures in dollar funding markets and the evolution of these pressures over time. We consider some measures of the cost of funds across markets and tenors, showing how the measures evolved over the period covered by the CB dollar swaps.

2.1 Demand for Dollars

To provide perspective on the pressures banks faced in the crisis period, we begin with the issue of how many U.S. dollars foreign banks needed and how these dollar needs were satisfied prior to the crisis. In brief, the high level of dollar-denominated assets that European banks were exposed to, both on and off balance sheet, and the banks' heavy reliance on short-term, wholesale markets to fund these assets exacerbated the significant strains in funding markets during 2008 and into 2009.

The foreign currency exposures of European banks had grown significantly over the decade preceding the crisis. Dollar

exposures accounted for half of the growth in the banks' foreign exposures over the 2000-07 period (McGuire and von Peter 2009a). The on-balance-sheet dollar exposures of euro area, United Kingdom, and Swiss banks were estimated to exceed \$8 trillion in 2008, of which \$1.1 trillion to \$1.3 trillion was funded through short-term sources. The growth in dollar exposures can be attributed to a number of factors. Among them are differences in the bank regulatory framework that allowed European banks to invest in many of the highly rated, dollar-denominated structured finance products that proliferated at the time.² In addition, the continuing globalization of capital markets increasingly provided investment opportunities in nondomestic currencies for banks and investors globally.

Prior to the crisis, dollar exposures were funded from a range of sources, detailed in a series of articles published by the Bank for International Settlements. As shown by McGuire and von Peter (2009a, b), key sources of funds were money market funds (\$600 billion to \$1 trillion), the monetary authorities (\$500 billion), and the foreign exchange swap market (\$700 billion). Banks also turned to interbank borrowing, flows from U.S.-based affiliates, and other sources.³ Off-balance-sheet exposures to other contingent lines of credit and wholesale-funded conduits likely intensified the demand for dollars among European financial institutions. European banks (and other non-U.S. banks) lack a dollar-denominated retail deposit base and had grown increasingly reliant on wholesale funding sources to meet these expanding U.S. dollar liquidity needs.

Nearly all of these funding sources came under extreme stress in fall 2008 as escalating credit and liquidity concerns evolved into a much broader systemic issue after the failure of Lehman Brothers. In particular, the offshore wholesale market for dollars—that is, the Eurodollar market—and the FX swap market experienced particularly heightened strains. These strains were evident in the commonly cited spread between Libor and the OIS and the spread between the FX swap implied dollar funding cost and Libor, both of which reached historically wide levels in September 2008. The short-term nature of many of these funding sources and the accompanying “rollover” risk increased the potential for stressed banks to engage in widespread sales of dollar-denominated assets and contributed to a vicious cycle of downward pressures on asset prices.

² For example, many international bank regulators focused on capital as a percentage of risk-weighted assets, while U.S. and a few other international regulators included capital as a percentage of unweighted assets as well. As such, banks domiciled in regulatory regimes with a focus on risk-weighted assets were able to accumulate significant amounts of highly rated securities.

³ Baba, McCauley, and Ramaswamy (2009) and McGuire and Von Peter (2009a, b) discuss exposures to U.S. dollar funding. Cetorelli and Goldberg (2008, 2010) address the international transmission of shocks that can occur when managing global bank liquidity through internal capital markets.

2.2 Foreign Exchange Swap Basis

One metric used to measure funding stress in foreign exchange markets is the *foreign exchange swap basis*. To arrive at this metric, analysts take an implied measure of dollar funding from a foreign exchange swap using the uncovered interest rate parity formula and compare it with Libor. A foreign exchange swap is a contract combining an FX spot and forward transaction and whose price, according to the uncovered interest rate parity, is derived from the differential between interest rates in the domestic currency and the foreign currency.

For example, consider the cost of borrowing euros in unsecured markets and converting them to dollars and then comparing that with borrowing dollars directly in the unsecured markets. This cost is defined as:

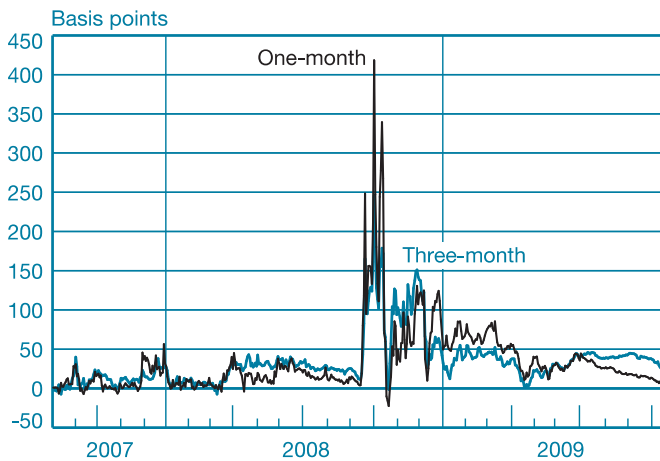
$$Basis_t^{eur, \$} \equiv \frac{F_{t,t+s}}{S_t} (1 + r_t^{eurLibor}) - (1 + r_t^{\$Libor}),$$

where S_t is the foreign currency spot rate at time t , $F_{t,t+s}$ is the foreign currency forward rate contracted at time t for delivery at time $t+s$, and $r_t^{eurLibor}$ ($r_t^{\$Libor}$) is the uncollateralized euro (dollar) interest rate from time t to time $t+s$.

Normally, arbitrage would drive the basis to zero given that firms would choose the more attractive dollar funding option of either borrowing at dollar Libor or borrowing euros and swapping them into dollars. For example, if the FX basis is greater than zero, arbitragers could borrow dollars unsecured at a relatively low interest rate and then lend the dollars through an FX swap at a relatively higher implied interest rate. Yet, with the dollar shortage during the crisis, arbitragers were unable to borrow sufficient dollars in the unsecured market to take advantage of this opportunity. Consequently, because of the dollar shortage, non-U.S. banks faced market-based dollar funding costs that were higher than the dollar Libor rates would suggest.

As noted by Baba, McCauley, and Ramaswamy (2009) and Coffey, Hrung, and Sarkar (2009), there was a substantial deviation from this pricing during the crisis period: The cost of borrowing euros at the euro Libor and swapping the euros for dollars was higher than borrowing dollars at the dollar Libor. The history of the FX basis for one- and three-month funds shows that the premium paid for dollars in the FX swap market rose relative to normal levels in August 2007 but then soared to extremes of more than 400 basis points in October 2008 (Chart 1). The dislocations were broad-based across funding tenors and were also evident in other FX swap currency pairs, such as the dollar/yen.

CHART 1
Euro-U.S. Dollar Implied Swap Basis Spread



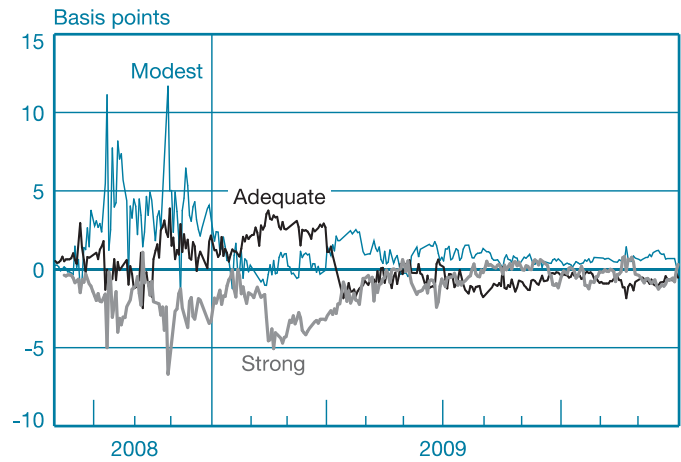
Sources: Reuters; Federal Reserve Bank of New York staff calculations.

2.3 Tiering in Costs of Dollar Funds

Since the FX swap basis is an average implied premium paid for dollar funds in the FX swap market relative to Libor, it does not fully capture the fact that different market participants likely have varying degrees of access to the unsecured markets—both in the amounts and in the rates at which counterparties would be willing to lend. For example, if a given bank can borrow euros at Euribor (a daily reference rate for the euro interbank market) but can borrow dollars only at Libor + 20 basis points in the unsecured markets, then the FX basis for that bank would be the implied U.S. dollar funding cost compared with (Libor + 20) rather than Libor, resulting in a smaller FX basis. This similarly applies to a bank's access to the unsecured euro cash markets used in calculating the implied U.S. dollar funding cost.

Our discussion of the FX basis emphasizes that the first part of the transaction reflects the cost of euros, in terms of interest rates by which companies in the euro area acquire liquidity before converting it into dollars through swap markets. However, the aggregate measure for $r_t^{eurLibor}$ is an average across a range of institutions bidding for euros in private markets. A closer look at the underlying data reveals that, as the crisis intensified, a pattern of deep and persistent implied credit tiering emerged within Euribor quotes. While broader market conditions may appear to have returned to close to normal conditions in mid-2009 when measured by indicators such as Libor-OIS spreads, these more detailed data, combined with anecdotal evidence, show that credit tiering was still very much in operation even after the CB dollar swaps were in effect and in the uncapped format. Credit tiering within the euro

CHART 2
Average Borrowing Rate Relative to Euribor Reference Rate, by Bank Category One-Month Tenor



Sources: Euribor; Bloomberg; Moody's (bank financial strength ratings).

Note: Panel banks' historical data are available starting September 2008.

borrowing market would likely extend to the cost of European banks acquiring dollars through private swap transactions.

Some evidence on this point comes from panel data related to the Euribor, whose rate is determined by a panel consisting of forty-three major banks, nearly all of them European. (By comparison, Libor's panel consists of only sixteen banks.) Each bank submits the interest rate it believes one prime bank is quoting to another prime bank in the euro market for tenors ranging from one week to one year.⁴ The Euribor is calculated by averaging the middle 70 percent of the panel banks' reported borrowing rates. Historical data are available for the panel banks' contribution to Euribor beginning in September 2008.⁵

To check for credit tiering in the euro lending market, we classify each of the forty-three banks at each date based on its bank financial strength rating (BFSR). A bank's BFSR, which is reported by Moody's and ranges from A to E, is meant to reflect the bank's intrinsic soundness.⁶ Each bank was classified as stronger (B- or higher), adequate (C or C+), or modest (C- or lower). Using a range of tenors, we examine each bank category's average borrowing rate relative to the Euribor

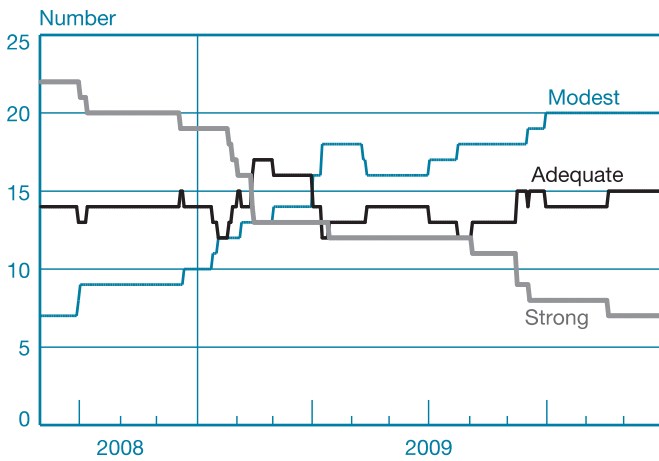
⁴ Tenors include one week, two weeks, three weeks, and periods ranging from one month to twelve months.

⁵ Historical data are available at http://www.euribor.org/html/content/euribor_data.html.

⁶ The rankings take five factors into consideration: franchise value, risk positions, regulatory environment, operational environment, and financial fundamentals. See http://www.moody.com/cust/content/Content.aspx?source=StaticContent/Free%20Pages/Products%20and%20Services/Static%20Projects/GBRM/pdf/Global_Bank_Rating_Methodology-Brochure.pdf.

CHART 3

Number of Banks in Each Category of Euribor Panel



Sources: euribor.org; Bloomberg; Moody’s (bank financial strength ratings).
 Note: Panel banks’ historical data are available starting September 2008.

reference rate. Our results are presented in Chart 2, which shows each bank category’s average borrowing rate relative to the Euribor reference rate using the one-month tenor. The construction is based on each bank’s BFSR on each date (banks move between categories when a rating change warrants it). The number of banks in each category is shown in Chart 3.

Chart 2 shows that stronger banks, on average, were able to borrow euros on more favorable terms than were the more modest or adequate banks during the crisis period. Credit tiering was especially pronounced during late 2008 and early 2009, peaking in late November 2008. Although the chart reflects only one-month tenor spreads, the borrowing rate spread between the categories is similar for all maturities. The shorter tenors, such as one week, displayed smaller spreads, which we interpret as less credit tiering.

2.4 The Federal Funds Market

Another, albeit less standard, indicator of dollar market pressures comes from the intraday market for federal funds. To explore this intraday market, we use data on the hourly effective federal funds rate (HEFFR), which is the overnight rate at which depository institutions lend dollars to one another at each hour.⁷ Using hourly data over each of the days spanning August 2002 through October 2009, we explore whether there

⁷ The HEFFR is a proprietary calculation of ICAP (an inter-dealer money broker) and is not publicly available, so we describe the difference between morning and afternoon effective rates without presenting these data.

is a differential cost of dollar funding during periods when European markets were open and dollar demands were most acute, compared with after the European markets closed. Owing to time zone differences, European institutions participate in dollar funding markets before 1 p.m. Eastern Standard Time. If there is a European premium to obtaining dollars, one would expect dollar funding costs to be higher in the morning (earlier than 1 p.m.), when European institutions are participating, than in the afternoon (1 p.m. and later).

When markets are functioning normally, the difference between the morning HEFFR average and the afternoon HEFFR average should be small. The effective federal funds rate should not change drastically in the same direction during the day. Indeed, this is the pattern seen in daily data over the six-year interval from 2002 through July 2007. The difference between the morning average and afternoon average hovered around zero basis points. By contrast, we observe that after the crisis began, the difference between the morning average and the afternoon average became greater and was commonly positive. The morning premium in the HEFFR was most striking in the period between late September and early October 2008, after Lehman’s collapse. This premium peaked in October and then abated in 2009.

One explanation for this pattern is that the morning premium actually reflected a “European premium,” which arose from a structural shortage of dollars. Of course, other factors could have played a significant role in the deviations between morning and afternoon federal funds rates during the crisis. Most notable was the tendency for U.S. banks to build a precautionary buffer of funding in the morning and then lend those funds to the market in the afternoon as banks became more certain of their actual funding needs.

3. EVOLUTION OF CB DOLLAR SWAP FACILITIES

As pressures in the U.S. dollar funding markets built in late 2007 and continued through 2008, non-U.S. banks began to report difficulty accessing dollars through the FX swap and other short-term interbank funding markets. The Federal Reserve and foreign central banks held expanded discussions on ways to address the disruptions in dollar funding markets and the more broad-based dysfunction occurring in money markets. The idea of using a CB swap facility to address money market dysfunction and achieve broader financial stability contrasted with the goals of most prior CB swap agreements, which had been used primarily as tools of foreign exchange policy.

TABLE 1

Timeline of Dollar Swap Announcements

| Date | Event | New Participants | Total Authorization (Billions of Dollars) | Terms Extended | Expiration Extended |
|--------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------|----------------------------------------------|-------------------|------------------------|
| 2007 | | | | | |
| December 12 | Federal Reserve establishes six-month dollar swap agreements with ECB (\$20 billion) and SNB (\$4 billion); auction tenors are twenty-eight days. | | 24 | | |
| 2008 | | | | | |
| March 11 | Lines are expanded with ECB (to \$30 billion) and SNB (to \$6 billion). | | 36 | | |
| May 2 | Lines are expanded with ECB (to \$50 billion) and SNB (to \$12 billion); agreement is extended to January 30, 2009. | | 62 | | x |
| July 30 | Line is expanded with ECB (to \$55 billion); ECB and SNB add eighty-four-day auctions. | | 67 | x | |
| September 18 | Lines are expanded with ECB and SNB (to \$110 billion and \$27 billion, respectively). Facilities are established with BoJ, BoE, and BoC (in amounts of \$60 billion, \$40 billion, and \$10 billion, respectively). | x | 247 | | |
| September 24 | Dollar swap is established with RBA (\$10 billion), Danmarks Nationalbank (\$5 billion), Sveriges Riksbank (\$10 billion), and Norges Bank (\$5 billion). | x | 277 | | |
| September 26 | Lines are expanded with ECB and SNB (to \$120 billion and \$30 billion, respectively). | | 290 | | x |
| September 29 | Lines are expanded with ECB (to \$240 billion), SNB (to \$60 billion), BoC (to \$30 billion), BoE (to \$80 billion), BoJ (to \$120 billion), Danmarks Nationalbank (to \$15 billion), Norges Bank (to \$15 billion), RBA (to \$30 billion), and Sveriges Riksbank (to \$30 billion). Agreements are extended until April 30, 2009. | | 620 | | |
| October 13 | Dollar swaps are expanded with ECB, SNB, and BoE to accommodate quantity demanded; BoJ considers doing the same. | | No prespecified limit | | |
| October 14 | Dollar swap is expanded with BoJ to accommodate quantity demanded. | | No prespecified limit | | |
| October 28 | Swap line is extended to RBNZ (\$15 billion). | x | No prespecified limit | | |
| October 29 | Lines are extended to Brazil, Mexico, Korea, and Singapore (up to \$30 billion each); lines are authorized until April 30, 2009. | x | No prespecified limit | | |
| 2009 | | | | | |
| February 3 | Swap agreements are extended until October 30, 2009. | | No prespecified limit | | x |
| April 6 | Federal Reserve announces arrangement with BoE, ECB, BoJ, and SNB to provide foreign currency liquidity to U.S. institutions. | | No prespecified limit | | |
| June 25 | Swap agreements are extended until February 1, 2010. | | No prespecified limit | | x |
| 2010 | | | | | |
| February 1 | Swap agreements expire. | | | | |

Source: Board of Governors of the Federal Reserve System.

Notes: The four central banks with no prespecified limit as of October 2008 offered dollar liquidity at a fixed price, which, along with collateral constraints, served to limit demand. ECB is European Central Bank, SNB is Swiss National Bank, BoJ is Bank of Japan, BoE is Bank of England, BoC is Bank of Canada, RBA is Reserve Bank of Australia, RBNZ is Reserve Bank of New Zealand.

3.1 Main Developments in CB Swaps

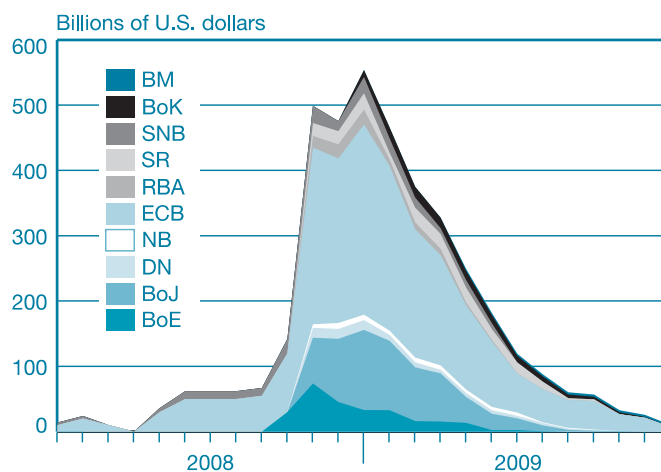
In December 2007, the Federal Reserve established temporary reciprocal currency arrangements with the European Central Bank (ECB) and the Swiss National Bank that allowed for the two institutions to draw up to \$20 billion and \$4 billion, respectively. The initial auctions were fully subscribed. Despite an easing of pressures in early 2008, funding pressures and use of the swap lines again escalated in March 2008 as Bear Stearns neared its acquisition by JPMorgan.

Table 1 describes the sequence of events in the Federal Reserve's swap facilities with foreign central banks. Expansion of the dollars made available through the swap facilities proceeded in stages, first through increases in the size of the lines and then through extensions, through July 2008, of the tenors for auctions held by the European Central Bank and the Swiss National Bank.

Ultimately, fourteen foreign central banks entered into swap arrangements with the Federal Reserve. From an initial aggregate of \$24 billion in December 2007, the amount authorized grew to nearly \$620 billion following the bankruptcy of Lehman Brothers. The quantity was soon "uncapped" for several central bank swap counterparties on October 13, 2008, as markets experienced extreme pressures. The dramatic move to uncapped, full-allotment auction formats was made by the European Central Bank, the Swiss National Bank, the Bank of Japan, and the Bank of England. Under the full-allotment auction format, the Federal Reserve made dollars available to these four central banks in quantities not subject to prespecified limits. The foreign central banks, in turn, made dollar loans to financial institutions within their jurisdictions and took on the related collateral and counterparty risks, although the Federal Reserve engaged in swap transactions only with the foreign central banks. The swap lines were a coordinated effort among central banks to address elevated pressures in global short-term U.S. dollar funding markets and to maintain overall market stability.

Chart 4 shows the contributions of various central banks to the overall size of swaps outstanding by the Federal Reserve. Clearly, the European Central Bank, the Bank of Japan, and the Bank of England consistently made up the majority of draw-downs on the reciprocal currency arrangements. According to monthly balances published by the Federal Reserve, peak CB dollar swap balances reached \$291 billion for the European Central Bank (December 2008), \$122 billion for the Bank of Japan (December 2008), and \$74 billion for the Bank of England (October 2008). Overall use of the swap lines climbed rapidly in October 2008, peaked in December 2008, and declined dramatically through the first half of 2009.

CHART 4
Central Bank Dollar Swap Amounts Outstanding



Source: Board of Governors of the Federal Reserve System, "Credit and Liquidity Programs and the Balance Sheet."

Note: BM is Banco de México, BoK is Bank of Korea, SNB is Swiss National Bank, SR is Sveriges Riksbank, RBA is Reserve Bank of Australia, ECB is European Central Bank, NB is Norges Bank, DN is Danmarks Nationalbank, BoJ is Bank of Japan, BoE is Bank of England.

While the CB dollar swaps with foreign central banks differed primarily in size, the auctions conducted by the foreign central banks differed in the formats used for distributing the U.S. dollars. Each central bank worked closely with the Federal Reserve to structure auctions used for distributing the dollars to domestic institutions. Structuring these auctions took into account a variety of factors, including the central banks' in-depth knowledge of their own domestic funding markets and financial institutions as well as their operating guidelines with respect to accessing their liquidity facilities and establishing acceptable collateral.

Box 1 broadly defines the various possible choices for the auction structures. For example, auctions can be competitive or noncompetitive. Within the competitive auction classifications, pricing can be either at a single common price or at multiple prices, depending on the structure of bids. Though the noncompetitive, fixed-rate auctions are fully allotted, the use of a higher spread to OIS and potential constraints on banks' availability of collateral may limit the demand for dollars.

Table 2 presents details on the dollar auctions conducted by foreign central banks. On the quantity side, as we observed, four central banks after October 2008 did not have prespecified limits on the amounts that could be drawn, while ten other countries were authorized to access up to \$15 billion or \$30 billion from the Federal Reserve. With the move to uncapped quantities in

Auction Types

In general, auctions can have either competitive or noncompetitive formats. Pricing conventions can be described as 1) single price, 2) multiple price, or 3) fixed-rate, full-allotment.

| Format | Pricing | Description |
|----------------|----------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Competitive | Single-price | Bids are accepted from the highest interest rate bid on down, until the total auction size is allotted. All allocations are made at the lowest accepted bid rate. |
| | Multiple-price | Bids are accepted from the highest interest rate bid on down, until the total auction size is allotted. All allocations are made at the respective bid rates of “winning” bidders. |
| Noncompetitive | Fixed-rate, full-allotment | The interest rate is fixed, and all bids received are satisfied subject to collateral requirements. |

October 2008, the European Central Bank, the Bank of Japan, the Swiss National Bank, and the Bank of England had fixed-rate, full-allotment auctions, in which they provided dollars to their constituent depository institutions at a fixed interest rate of approximately 100 basis points over OIS. This cost of funds implied that overseas extensions of dollars were priced at a premium relative to the expected stance of U.S. monetary policy over the intervals that dollar swaps were extended. The Bank of England, the European Central Bank, and the Swiss National Bank coordinated their auctions such that they used the same tender rate and held their auctions simultaneously. Danmarks Nationalbank and Sveriges Riksbank had single-price, competitive auctions. The remaining central banks that drew on the CB dollar swaps with the Federal Reserve established multiple-price competitive auctions. Other central banks

auctioned dollars competitively, with minimum bid rates ranging from OIS + 50 basis points to Libor + 50 basis points. Four of the fourteen facilities—with Canada, New Zealand, Brazil, and Singapore—were never drawn on.

On April 6, 2009, the Federal Open Market Committee of the Federal Reserve announced that it had established foreign currency swap facilities with the European Central Bank, the Bank of Japan, the Swiss National Bank, and the Bank of England. These facilities were designed to enable the Fed to provide foreign currency liquidity to U.S. institutions should the need arise. This facility essentially mirrored the existing U.S. dollar liquidity facility and was never drawn on by the Federal Reserve. It expired concurrently with the dollar swaps on February 1, 2010.

TABLE 2

Details on Dollar Auctions by Central Banks, October 2008 through February 1, 2010

| Central Bank | Line Size (Billions of Dollars) | As-of Date (2008) | Range of Tenors Offered since Inception | Minimum Bid Rate | Notes | Current Auction Format |
|---------------------------------|------------------------------------|----------------------|---------------------------------------------|----------------------|------------------------------------------------------------------------------------------------------------------|--------------------------------------------|
| European Central Bank | Full allotment | October 13 | Overnight, one-week, one-month, three-month | USD OIS + 100 bp | Prior to introduction of fixed-rate, full-allotment on October 13, auction used minimum bid of OIS, same as TAF. | Noncompetitive, fixed-rate, full-allotment |
| Swiss National Bank | Full allotment | October 13 | Overnight, one-week, one-month, three-month | USD OIS + 100 bp | Prior to introduction of fixed rate, full allotment on October 13, auction used minimum bid of OIS, same as TAF. | Noncompetitive, fixed-rate, full-allotment |
| Bank of England | Full allotment | October 13 | Overnight, one-week, one-month, three-month | USD OIS + 100 bp | Prior to introduction of fixed rate, full allotment on October 13, auction used minimum bid of OIS, same as TAF. | Noncompetitive, fixed-rate, full-allotment |
| Reserve Bank of Australia | \$30 | September 29 | One-month, three-month | USD Libor | In mid-April 2009, minimum bid rate was changed from OIS + 50 bp. | Competitive, multiple-price |
| Reserve Bank of New Zealand | \$15 | October 28 | Not drawn | | | |
| Bank of Japan | Full allotment | September 29 | One-month, three-month | USD OIS + 100 bp | Prior to introduction of fixed-rate, full-allotment on October 13, auction used minimum bid of OIS, same as TAF. | Noncompetitive, fixed-rate, full-allotment |
| Bank of Canada | \$30 | September 29 | Not drawn | | | |
| Danmarks Nationalbank | \$15 | September 29 | One-month, three-month | Libor + 50 bp | On February 10, 2009, minimum bid rate was changed from OIS + 50 bp. | Competitive, single-price |
| Sveriges Riksbank | \$30 | September 29 | Three-month | USD OIS + 50 bp | | Competitive, single-price |
| Norges Bank | \$15 | September 29 | One-month, three-month | TAF stop-out + 50 bp | | Competitive, multiple-price |
| Bank of Korea | \$30 | October 29 | Three-month | USD OIS + 50 bp | | Competitive, multiple-price |
| Banco do Brasil | \$30 | October 29 | Not drawn | | | |
| Banco de México | \$30 | October 29 | Three-month | USD OIS + 50 bp | | Competitive, multiple-price |
| Monetary Authority of Singapore | \$30 | October 29 | Not drawn | | | |

Source: Board of Governors of the Federal Reserve System.

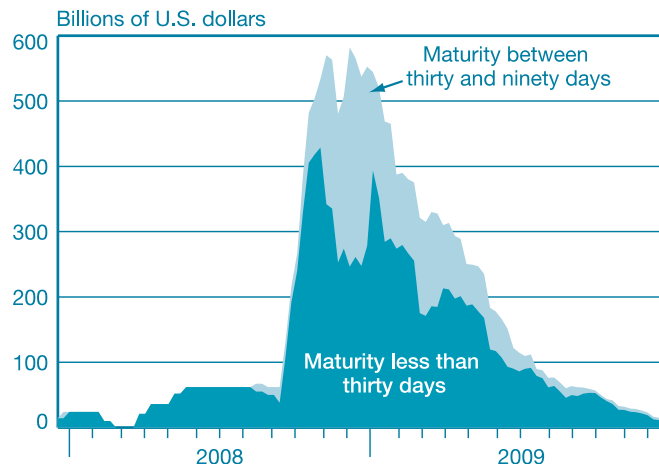
Notes: Collateral eligibility for these auctions matches criteria for domestic open market operations. As of June 25, 2009, all central bank dollar swaps were extended through February 1, 2010. Overnight funds auctions were eliminated as of November 7, 2008. Minimum bid rates are calculated from the most recent auction announcements and results. Libor is the London interbank offered rate; OIS is the overnight index swap rate; TAF is the Federal Reserve's Term Auction Facility; bp is basis points.

3.2 Evolution of Outstanding Balances and Tenors

In addition to changes in the terms and quantities, the composition of loan tenors extended through the CB dollar swaps evolved considerably over time (Chart 5). Clearly, the largest and most dramatic run-ups in use of the dollar swaps occurred at the end of October 2008, as the size and scope of the facilities broadened rapidly amid escalating market tensions and the approaching year-end. Most of this expanded borrowing took place through three-month operations, the longest on offer, as liquidity available in the market quickly contracted to encompass only the shortest tenors. Most of the demand came from the fixed-rate, full-allotment operations, which constituted around 85 percent of outstanding swaps by December 31, 2008.

In part, the evolution of tenors shown in Chart 5 resulted from the changing offerings of maturities made available by the various central banks. The initial auctions by the European Central Bank and the Swiss National Bank, held between December 2007 and July 2008, provided only twenty-eight-day funds. On July 30, 2008, the scope was expanded to cover three-month (eighty-four-day) funding, adding a broader array of tenors, including one-week and overnight, introduced in October. The large, discrete jumps in outstanding dollar balances coincided with the first two full-allotment eighty-four-day dollar auctions on November 6, 2008, and December 4, 2008; together, these auctions accounted for an additional \$129 billion and \$114 billion, respectively. Financial institutions accumulated liquidity in advance of the 2008 year-end, but after this “risk event” participating banks partially unwound their outstanding balances as their precautionary dollar needs

CHART 5
Central Bank Dollar Swap Amounts Outstanding, by Loan Term



Source: U.S. Treasury Department, “U.S. International Reserve Position.”
Note: Data are weekly.

declined. Net outstanding balances likewise declined when these two operations matured on January 29, 2009, and February 26, 2009, respectively.

Table 3 shows how the demand for dollars unwound over the course of the auctions, presenting each central bank’s net outstanding position with the CB dollar swap balance at year-end 2008 and at the end of second-quarter 2009. In total, the CB dollar swaps outstanding declined nearly \$440 billion between December 31, 2008, and June 30, 2009. The decline in position by the European Central Bank (to \$231.45 billion) accounted for more than half of this total drop, followed by

TABLE 3
Net Outstanding Positions by Foreign Central Bank

| | Billions of Dollars | | | Percent | |
|---------------------------|---------------------|---------------|---------|---------|------------------------------|
| | December 31, 2008 | June 30, 2009 | Change | Change | Contribution to Total Change |
| European Central Bank | 291.35 | 59.90 | -231.45 | -79 | 53 |
| Swiss National Bank | 25.18 | 0.37 | -24.81 | -99 | 6 |
| Bank of England | 33.08 | 2.50 | -30.58 | -92 | 7 |
| Bank of Japan | 122.72 | 17.92 | -104.79 | -85 | 24 |
| Reserve Bank of Australia | 22.83 | 0.24 | -22.59 | -99 | 5 |
| Sveriges Riksbank | 25.00 | 11.50 | -13.50 | -54 | 3 |
| Norges Bank | 8.23 | 5.00 | -3.23 | -39 | 1 |
| Danmarks Nationalbank | 15.00 | 3.93 | -11.07 | -74 | 3 |
| Bank of Korea | 10.35 | 10.00 | -0.35 | -3 | 0 |
| Banco de México | 0.00 | 3.22 | 3.22 | — | -1 |

Source: Federal Reserve Bank of New York, “Treasury and Federal Reserve Foreign Exchange Operations” quarterly reports.

reduced balances for the Bank of Japan (\$104.79 billion) and the Bank of England (\$30.58 billion). Banco de México actually had increases in swap amounts outstanding, but primarily because of the timing of its first auction in early 2009.

4. CB DOLLAR SWAP FACILITIES AND THE TAF

The dollar swaps with foreign central banks were only one of the many dollar liquidity facilities established during the financial crisis. Indeed, the auctions associated with the initial CB dollar swaps announced on December 12, 2007, were coordinated with the TAF auctions in the United States, which periodically provided term funding to eligible depository institutions in sound condition.⁸

4.1 Comparison and Relationship to the TAF

The TAF uses a competitive, single-price auction, which accepts bids at the highest interest rate on through to successively lower rates. When necessary, bids at the lowest accepted interest rate are prorated. All participants whose bids have been accepted are awarded funds at the same interest rate, which is the lowest interest rate at which bids were accepted, regardless of the rates at which participants bid for funds. Known as the “TAF stop-out rate,” this is also the fixed rate at which the European Central Bank and the Swiss National Bank allotted funds at their CB dollar swap operations prior to the fixed-rate, full-allotment structure.

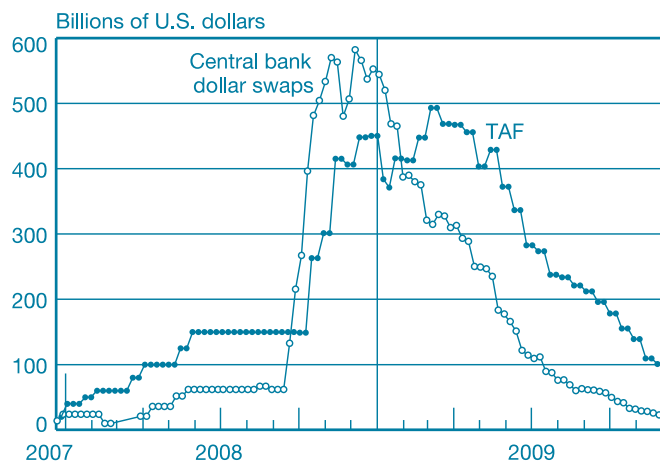
The structure and functioning of the reciprocal currency arrangements are intertwined with the TAF in the sense that they would facilitate the extension of term dollar liquidity—but this time to banks in overseas jurisdictions. As we observed, the schedules for the twenty-eight-day and eighty-four-day dollar auctions conducted by the European Central Bank, the Bank of England, the Swiss National Bank, and the Bank of Japan largely coincided with the similar-tenor TAF operations.

Box 2 shows the basic schedule for a representative twenty-eight- or eighty-four-day TAF auction and swap between the European Central Bank and the Federal Reserve. A typical sequence of events has the Federal Reserve conducting its TAF auction first, but not communicating the results until the European Central Bank, the Swiss National Bank, the Bank of England, and the Bank of Japan have held their operations for the same tenor.

⁸ An overview of the TAF is provided in Armantier, Krieger, and McAndrews (2008).

CHART 6

TAF and Central Bank Dollar Swaps Net Outstanding



Sources: Federal Reserve Statistical Release H.4.1, “Factors Affecting Reserve Balances”; U.S. Treasury Department, “U.S. International Reserve Position.”

Note: TAF is the Federal Reserve’s Term Auction Facility.

While these schedules were closely related, the CB swaps were not an exact international replica of the TAF format. Unlike the fixed-rate, full-allotment structure of several of the foreign central banks’ dollar auctions held since October 2008, at the TAF auction a predetermined fixed supply of dollar funds was offered at each preannounced date.⁹ In practice, each TAF auction held since the auction sizes were increased to \$150 billion on October 6, 2008, was undersubscribed. Thus, the cost of dollars at these auctions fell to the minimum bid rate.¹⁰

It is interesting to compare the outstanding balances at dollar swap facilities with the pattern of demand observed at the TAF. Outstanding TAF balances expanded through the fall of 2008, but declined little thereafter (Chart 6). Indeed, despite a reduced rollover of positions in January and February 2009, some of the TAF participants increased their net outstanding balances in March and April 2009. With TAF funds priced more attractively relative to market rates (a point expanded on below), a different set of incentives was presented to financial institutions choosing among alternative official and private funding sources.

⁹ For details on the TAF auction process, see <http://www.federalreserve.gov/monetarypolicy/taffaqa.htm>.

¹⁰ The minimum bid rate was the OIS until the Federal Reserve cut rates to a range of 0 to 25 basis points in December 2008. Thereafter, the minimum bid rate became the interest rate paid on excess reserves.

A Representative Twenty-Eight-Day or Eighty-Four-Day U.S. Dollar Auction by the Federal Reserve and the European Central Bank

Monday

| | |
|------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 10 a.m. | The Federal Reserve releases the minimum bid rate. |
| 11 a.m. | TAF operation “opens” for bidding. |
| 12:30 p.m. | TAF operation “closes” bidding. |
| 5:00 p.m. | The Federal Reserve Bank of New York sends the European Central Bank, the Bank of Japan, the Bank of England, and the Swiss National Bank the OIS rate to use in conducting their full-allotment tenders. |

Tuesday

| | |
|------------|---------------------------------------------------------------|
| 3:45 a.m. | Bidding at the European Central Bank closes. |
| 5:00 a.m. | The European Central Bank releases the results of operations. |
| 10:00 a.m. | The Federal Reserve releases TAF results. |

Notes: Times are Eastern Standard. TAF is the Federal Reserve’s Term Auction Facility; OIS is the overnight index swap rate.

4.2 Direct Costs of Funds across TAF and CB Dollar Swaps

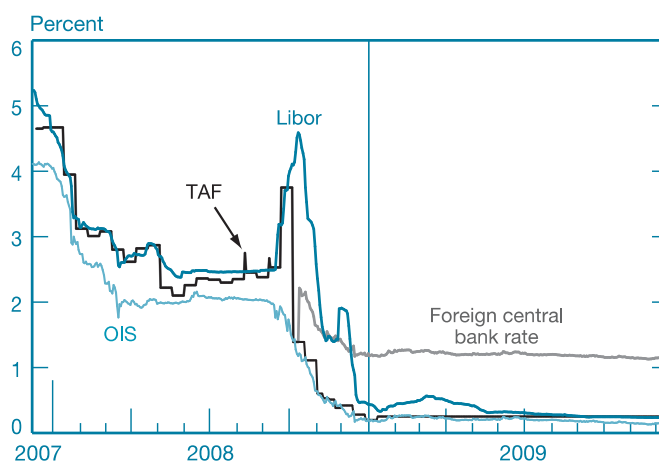
In fall 2007, costs in the short-term funding markets—as reflected, for example, in Libor rates—were historically high relative to the expected path of policy rates as measured by the OIS. When the TAF was introduced in December 2007, dollar liquidity was made available to firms within the United States—including those foreign banking organizations with access to Federal Reserve liquidity facilities—and to some financial institutions abroad that could also access dollars through the European Central Bank or the Swiss National Bank. Various studies of the effectiveness of the TAF (discussed further in Section 5) have pointed to the subsequent and ongoing “normalizing” of the Libor rate as evidence that the TAF and swap facilities were effective in restoring liquidity and confidence in short-term funding markets.¹¹ However, both the one-month Libor and the TAF stop-out rates still increased significantly relative to the expected path of policy rates after Lehman’s failure in September 2008 (Chart 7).

The cost of collateralized funds provided through the TAF and the CB dollar swap facilities, which initially allotted dollars at the TAF stop-out rate, tracked Libor closely until September 2008. However, the cost of dollars at these two facilities diverged after Lehman’s collapse as the auction types and pricing diverged. The TAF rates stopped out substantially below Libor, instead closely following OIS rates, as the available TAF funds were increased shortly after Lehman’s bankruptcy.

On October 13, 2008, four foreign central banks introduced the fixed-rate, full-allotment format for their dollar auctions. The evolution of these four central banks’ auction prices is shown in Chart 7 as the foreign central bank rate. The change

¹¹ See, for example, McAndrews, Sarkar, and Wang (2008).

CHART 7
TAF Stop-Out Rate, One-Month OIS,
and One-Month Libor

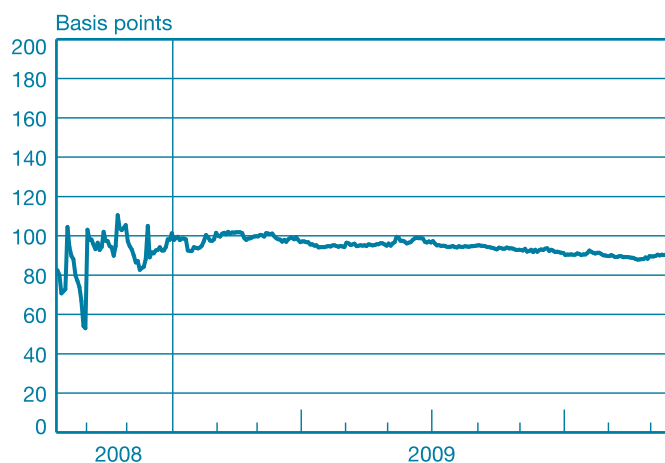


Sources: Bloomberg (OIS, Libor); Board of Governors of the Federal Reserve System (TAF).

Note: TAF is the Federal Reserve’s Term Auction Facility, OIS is the overnight index swap rate, Libor is the London interbank offered rate.

in pricing for these four central banks, to a fixed rate of approximately 100 basis points over OIS, and the decline in TAF stop-out rates made the cost of dollars from these foreign central bank swap facilities available at a higher rate relative to funds at the TAF (Chart 8). In part, the pricing of the fixed-rate, full-allotment CB swap programs ensured that the facility was available to meet dollar funding demands without hindering the eventual recovery of liquidity in the private Eurodollar or foreign exchange swap markets. This structure also reinforced the existence of the CB dollar swaps as backstop liquidity facilities.

CHART 8
Central Bank Dollar Swap Less TAF Stop-Out Rate



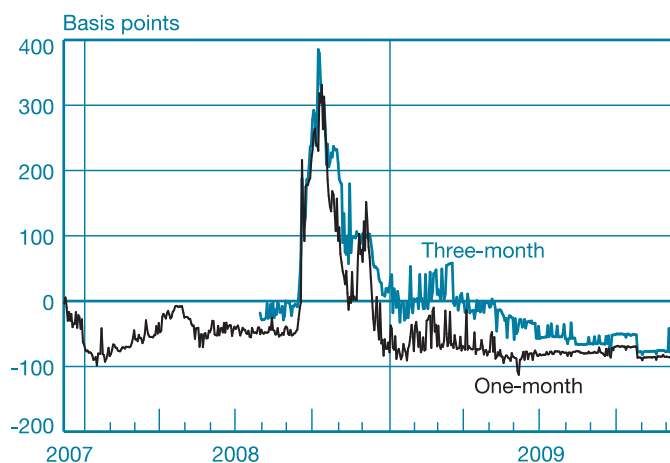
Sources: Bloomberg (OIS); Board of Governors of the Federal Reserve System (TAF).

Notes: TAF is the Federal Reserve’s Term Auction Facility, OIS is the overnight index swap rate. Prior to October 13, 2008, the European Central Bank, the Bank of England, the Swiss National Bank, and the Bank of Japan used the TAF stop-out rate and allocated funds to bidders on a prorated basis. After October 13, these banks switched to fixed-rate, full-allotment operations at OIS + 100 basis points.

For some overseas depository institutions, the swap facilities, despite carrying a penalty rate relative to the TAF, remained attractive as long as the cost of funds remained advantageous compared with dollars obtainable in the market. That is, the swap facilities remained attractive to a financial institution as long as its cost of borrowing in the market was more than 100 basis points over OIS. Chart 9 shows the spreads between one- and three-month Eurodollars relative to the fixed rate of approximately OIS + 100 basis points. Negative values indicate when the average cost of private-market dollar funds was less expensive than the funds available through the central bank auction facility.

As we noted, dollars obtained through the TAF and the CB swap dollars were priced comparably to private-market funds as measured by Libor prior to September 2008. Thereafter, the swap funds were considerably less expensive than private-market funds during the height of the crisis as the spread between Libor and OIS widened dramatically. However, by this measure, through first-quarter 2009, only three-month funds remained available more cheaply than private-market funds from central bank sources (though they were still more expensive than through the TAF). CB dollar swaps would still be attractive to those depository institutions that had limited or no access to dollars near the Libor fixings. By contrast, the availability of competitively priced TAF funds continued to keep demand for dollars directly from the Federal Reserve higher and steadier. Private-market costs of dollars as measured by Libor were higher than TAF costs.

CHART 9
Eurodollar Rates Less Dollar Swap Fixed Rate of OIS



Source: Bloomberg (U.S. dollar offshore deposit rate, OIS).

Notes: OIS is the overnight index swap rate. The three-month operation was introduced July 30, 2008.

4.3 Indirect Costs Associated with Collateral Requirements¹²

Availability of eligible collateral and the “haircuts” on different types of collateral influenced the effective cost of funds and dollar demand at the respective dollar facilities. For example, there were additional haircuts for foreign exchange risks when banks pledged non-dollar-denominated collateral at a foreign central bank, adding to the cost of borrowing dollars. These collateral requirements in the United States and abroad could have impinged on the choice of where to access dollars—for example, from foreign central banks or the TAF. Access to the TAF, however, would be permitted only if a foreign-owned bank had an eligible affiliate in the United States.¹³

The availability of eligible collateral can be a constraint on foreign participation in the TAF. In order to participate in the TAF, a credit institution could pledge assets located in the United States, or assets located in an International Central Securities Depository (ICSD), such as Euroclear Bank (Belgium) and Clearstream Banking Luxembourg.

However, a number of factors limit the availability of eligible collateral located in the United States as well as in

¹² The authors thank Sergio Grittini of the European Central Bank for insightful contributions to this section.

¹³ As noted by the Bank for International Settlements (2008), several central banks during the crisis widened, either temporarily or permanently, the range of eligible collateral—and, in some cases, counterparties—in order to facilitate an effective distribution of central bank funds. The BIS Committee on Payment and Settlement Systems also explores the arrangements through which alternative central banks accept foreign collateral (Bank for International Settlements 2006).

Europe, possibly constraining foreign participation in the TAF. Some foreign banks' portfolios of Federal Reserve-eligible assets located in the United States were relatively small. Moreover, prudent liquidity management practices for some banks require that part of those assets be left unencumbered to enable access to the discount window on short notice and to enhance the bank's rating.

In addition, the Federal Reserve applies stringent eligibility criteria that limit the pool of assets located in the ICSDs. Specifically, the eligible assets included foreign government debt, German Jumbo Pfandbriefe, international agency debt, foreign government agency debt, municipal bonds, and corporate bonds. Asset-backed securities and bank loans were not eligible as collateral for the TAF when they were located in Europe, but were eligible when they were located in the United States.

Furthermore, non-dollar-denominated instruments must have a market price from a recognized pricing source and a AAA rating; the exception is government debt, for which the rating threshold is lower (Standard and Poor's BBB- and Moody's Baa3). Finally, as with assets located in the United States, not all eligible assets located in Europe could be used to participate in the TAF, given the need to leave a portion unencumbered or available for other purposes (for example, for participating in the Eurosystem's euro-providing operations).¹⁴

In addition, a U.S.-based entity of a foreign banking group participating in the TAF could be different from the entity that owns the assets deposited in the ICSDs (for example, European Union-based). Meeting collateral requirements of the TAF would require one entity to transfer the ownership title on the assets to the other entity through an intragroup transaction (for example, a repo or a bond lending operation). Moreover, considering the potentially small amount of eligible and usable assets located in the two ICSDs, some foreign banks reportedly decided not to invest resources to address these legal and organizational issues and thus were unable to use the eligible assets deposited in the ICSDs.

Haircuts also affect the relative attractiveness of facilities. Different haircuts apply to collateral accepted by the Federal Reserve and the European Central Bank. For comparison purposes, we focus on the subset of assets eligible in both operations. Assets located in the United States were not eligible to be pledged at the operations carried out by the European Central Bank, because the latter requires that the assets be deposited or registered (issued) in the European Economic Area¹⁵ and held and settled in the euro area. In contrast, most

¹⁴ Foreign-owned but globally oriented banks reported that legal and operational issues could hinder the use of eligible assets deposited with the ICSDs. In particular, the one-off legal preparatory work that is needed to pledge these assets in the TAF could have initially delayed foreign banks' participation in the facility.

of the assets in the ICSDs that are eligible to be used as collateral in the TAF are also eligible for the European Central Bank dollar facility.

The lendable value for these assets differs according to the central bank to which they are pledged. In particular, the lendable value for a given amount of euro-denominated assets located in an ICSD was typically *higher* in the twenty-eight-day TAF than in any European Central Bank dollar auction. This was mainly because, compared with the Federal Reserve, the European Central Bank applied significantly higher additional initial margins to account for foreign exchange rate risk as part of its risk management framework. Specifically, the European Central Bank's additional haircuts were 10, 12, 17, and 20 percent for dollar operations with durations of one, seven, twenty-eight, and eighty-four days, respectively, whereas the Federal Reserve's additional FX haircuts ranged from 2 percent to 5 percent, according to the residual maturity of the debt instruments.¹⁶ As a result, there were two margins for haircuts: margins based on the security type and an additional margin if the collateral was denominated in foreign currency.

The relationship between lendable values in the TAF and the ECB dollar facility changed when eighty-four-day funds were considered. In fact, a bank would be able to borrow more against euro-denominated assets located in an ICSD in the eighty-four-day ECB dollar auctions than in the TAF. This can occur because, on July 30, 2008, the Federal Reserve introduced an additional collateral requirement for advances of more than twenty-eight days. Under this requirement, the total amount of term primary credit and TAF credit with original or remaining term to maturity exceeding twenty-eight days could not exceed 75 percent of the lendable value of an individual depository institution's available collateral.¹⁷

All else equal, the differences in the haircut regimes reinforced the relative attractiveness of the twenty-eight-day TAF compared with the ECB dollar auctions while lowering the relative attractiveness of the eighty-four-day TAF compared with the ECB dollar auctions. The haircut differences across

¹⁵ The European Economic Area includes the twenty-seven member states of the European Union and Iceland, Liechtenstein, and Norway.

¹⁶ For example, the lendable value for euro-denominated foreign government debt located in an ICSD at a twenty-eight-day TAF was between 85 percent and 92 percent of the asset's market value, depending on the residual maturity of the debt instrument. The lendable value of the same instrument at the ECB dollar auction was instead between 76 percent and 83 percent of the asset's market value, depending on the structure of the debt instrument (fixed or zero-coupon) and its residual maturity. The lendable value of euro-denominated German Jumbo Pfandbriefe (another relevant asset class) at a twenty-eight-day TAF was between 85 percent and 92 percent of the asset's market value, depending on the residual maturity, while the corresponding values at the ECB dollar auction were between 73 percent and 82 percent.

¹⁷ For example, this additional collateral requirement lowered the lendable value for euro-denominated foreign government debt and German Jumbo Pfandbriefe located in an ICSD at an eighty-four-day TAF to between 64 percent and 69 percent of the asset's market value, depending on the residual maturity of the debt instrument.

Collateral and Haircuts at Dollar Auctions by the Federal Reserve and the European Central Bank

- Define h^{FRS} and h^{ECB} as the haircuts on comparable collateral, as applied by the Federal Reserve and the European Central Bank (ECB).
- Define r^{TAF} and r^{ECB} as the cost of funds at the Federal Reserve's Term Auction Facility (TAF) and the ECB's dollar swap facility.
- Define r^m as the market rate on uncollateralized funds. For a bank with \$1 of eligible collateral, the cost of borrowing \$1 is—
 at the TAF: $(1 - h^{FRS}) * r^{TAF} + h^{FRS} * r^m$;
 at the ECB dollar swap facility: $(1 - h^{ECB}) * r^{ECB} + h^{ECB} * r^m$.

The total cost of \$1 borrowed at the TAF is below the cost at the European Central Bank provided that

$$(1 - h^{FRS}) * r^{TAF} + h^{FRS} * r^m < (1 - h^{ECB}) * r^{ECB} + h^{ECB} * r^m.$$

Example: Assume $h^{FRS} = 0.36$, $h^{ECB} = 0.24$. The inequality that must be satisfied for the TAF to be less costly than the ECB funds becomes $r^m < 6.33r^{ECB} - 5.33r^{TAF}$.

On May 11, 2009, with $r^{ECB} = \text{OIS} + 100 = 1.197$ and $r^{TAF} = 0.25$, $r^m < 6.3$ percent.

assets can be viewed in terms of a supplemental interest rate differential favoring the TAF. If the lendable value for an asset was 64 percent at the TAF and 76 percent at the ECB dollar auction (as it is for foreign government bonds in eighty-four-day operations), in May 2009 a bank would have found it profitable to borrow at the ECB dollar auction at OIS + 100 basis points instead of at the TAF at 0.25 percent only if its private-market funding costs were more than 6.3 percentage points (Box 3). The facilities complement each other, with collateral a necessary but not necessarily exclusive determinant of the location of facilities used for supplementing liquidity.

5. EFFECTS OF CB SWAPS ON DOLLAR FUNDING MARKETS

The implementation and expansion of the swap lines between the Federal Reserve and the various foreign central banks significantly ameliorated the cost of dollars shown in the Libor-OIS spread and the FX basis spread, even if these costs remained elevated by historical measures.¹⁸ In this section, we consider evidence from our discussions with market participants, from data on the cost of funds to different market segments, and from formal econometric studies.

¹⁸ The Federal Reserve established other facilities in addition to the TAF to address the freezing of money markets, including the Commercial Paper Funding Facility and the Asset-Backed Commercial Paper Money Market Mutual Fund Liquidity Facility. Meanwhile, the U.S. Department of the Treasury implemented the Temporary Guarantee Program for Money Market Funds and the Temporary Liquidity Guarantee Program. Similar efforts were undertaken globally by fiscal and monetary authorities.

5.1 Discussions with Market Participants

Liquidity conditions in the FX swap market improved considerably following the height of market stresses in late 2008. At that point, the FX basis spread narrowed from its widest level. By late spring 2009, bid-ask spreads for both euro/dollar and dollar/yen FX forwards had converged toward more typical levels, although trade sizes remained a fraction of the typical precrisis trade size.

Dealers, brokers, and bank treasurers attributed these improvements to several factors. First, the demand for dollar funding diminished as foreign banks continued to write down many of their dollar-denominated credit-related assets, reducing the value of assets that needed funding. Second, the biggest suppliers of dollars in FX swaps (mostly large U.S. banks) began to grow more comfortable with their access to dollars, which increased their willingness to supply foreign banks with dollars in exchange for foreign currency. Third, global financial institutions became more conservative in their liquidity management practices—partly in anticipation of tighter regulation, which may have reduced their reliance on short-term cross-currency funding. These observations were consistent with anecdotal reports that the overall volume of activity in the FX swap market remained well below precrisis levels. Despite the significant improvement, liquidity conditions in the FX swap market remained notably impaired by historical measures through spring 2009.

Similarly, conditions in the Eurodollar market showed nascent signs of improvement beginning at the end of December 2008 after increases in the authorized sizes of the Federal Reserve's TAF and the CB swap lines. These

improvements continued until a renewed sense of concern in the financial sector emerged early in 2009. However, spillovers to the dollar funding markets were more limited given the existence of a strong backstop provided by the CB dollar swaps. After early March 2009, the process of “normalization” continued almost uninterrupted. The entire Libor curve shifted lower and flattened, as the three-month Libor-OIS spread narrowed to levels prevailing before the Lehman bankruptcy. Market participants also reported increasing activity in tenors beyond one month, a sign of significant improvement from late 2008.

Expectations of future market conditions also improved. The expected three-month Libor-OIS spread (as reflected in the spread between forward rate agreements and forward OIS rates) narrowed significantly, the rates implied in the 2009 and 2010 Eurodollar futures contracts declined significantly, and the implied rates for three-month Libor fixings fell below 1 percent for all contracts through June 2010.

5.2 Econometric Analyses

In this section, we interpret the econometric evidence exploring the role of the TAF and the CB swaps in bringing down the cost of funds, especially when dollar liquidity conditions were at their most stressed. Formal econometric testing has identified some of the effects of the TAF and the CB dollar swaps on market liquidity. In general, these studies begin with high-frequency data (generally daily) on financial market indicators—for example, Libor-OIS spreads or FX basis swaps—and consider the effects of announcements and actual auction events. “Effectiveness” is generally interpreted as a statistically significant and persistent decline in the cost of funds. Another area of research considers the relationship between the CB swaps and the impact on conditions in the last four markets—Brazil, Mexico, Korea, and Singapore—to be added to dollar swaps with the Federal Reserve.

Initial studies of the liquidity facilities’ consequences focused primarily on the TAF, and the CB dollar swaps were treated as a related arm of the liquidity facilities. Mishkin (2008) originally argued that the TAF “may have had significant beneficial effects on financial markets,” but this claim was met with skepticism by Taylor and Williams (2009), who focused on the effects of the facilities introduced in the first phase of the crisis, specifically the period from August 9, 2007, through March 20, 2008. Taylor and Williams concluded that the TAF auctions (seven in their sample) had no effect in reducing the three-month Libor-OIS spread.¹⁹

In a comprehensive study of the early response to the crisis, McAndrews, Sarkar, and Wang (2008) use more of an event-study methodology, as in Taylor and Williams (2009). They

explore a broader events panel that includes TAF as well as CB swap announcement dates and auction dates. Also using the three-month Libor-over-OIS spread, with the dependent variable being *changes* and not the (potentially nonstationary) level of the spread, McAndrews, Sarkar, and Wang find that TAF announcements as well as actual TAF operations significantly reduced spreads. Noteworthy for our discussion of the central bank swap facilities is that these researchers distinguish between domestic TAF and international (swap facility) announcements in econometric exercises. The announcements along the international dimension of the liquidity facilities are the dominant drivers of the overall announcement effects, both quantitatively and in terms of statistical significance.²⁰

Baba and Packer (2009) and Aizenman and Pasricha (2009) also focus directly on the dollar swap facilities. Baba and Packer provide extensive details on the U.S. dollar auctions by the European Central Bank, the Swiss National Bank, and the Bank of England in the period between September 2007 and October 2008. In addition to examining Libor-OIS spreads, they examine daily data for three FX swap pairs over the periods from August 2007 through September 2008 and from September 2008 through January 2009. The econometric analysis focuses on whether the CB swaps affected counterparty-specific risks and had a common-effects component across all three FX swap bases.

As in McAndrews, Sarkar, and Wang (2008), Baba and Packer distinguish between announcement effects and the actual auctions’ effects. The effects of the actual auctions are mixed and contingent on the maturities of funds supplied at the auctions. Announcements about the auctions are permitted to differ, by time period, in their effects on financial variables.

¹⁹ Further, Taylor and Williams (2009) use the *level* of (not the *changes* in) the Libor-OIS spread as the dependent variable in regressions, biasing the results against finding a TAF effect. The period examined covers only the early stages of the TAF (announced December 12, 2007) and dollar swaps with the European Central Bank and the Swiss National Bank (see Table 1). The variable of interest in the econometric work is the spread between the three-month Libor and the Fed’s overnight federal funds rate target. Other authors, such as Wu (2008) and McAndrews, Sarkar, and Wang (2008), take issue with the identification strategy of Taylor and Williams, noting, for example, that the study omits the effects on spreads of facility announcements, considers only the actual auction events, and was performed on the level of the spreads—not the changes in spreads. In Wu (2008), the econometric strategy is to examine separately the TAF’s effects on relieving financial institutions’ liquidity concerns and on reducing the counterparty risk premiums, and then to quantify the overall effects on strains in the interbank money market. Wu’s econometric specification assumes that the Libor-OIS spread would be permanently moved by the introduction of the TAF (with a dummy variable introduced equal to 1 for days since December 12, 2007, the first TAF announcement date), concluding that the TAF significantly reduced the Libor-OIS spread.

²⁰ Meyer and Sack (2008) and Deutsche Bank (2009) likewise find that TAF announcements and auctions reduce the Libor-OIS spread for a number of different specifications of the credit risk and VIX (Chicago Board Options Exchange Volatility Index) measures, although without the distinctions between domestic and international facility announcements.

The CB dollar auction variables reduce both the level and volatility of all the spreads in the period after Lehman's failure, but mainly serve to reduce volatility in the period prior to the bankruptcy.

The analysis by Aizenman and Pasricha (2009) reaches more mixed conclusions about the effects of the announcements of the Federal Reserve's swap arrangements with the central banks of Brazil, Korea, Mexico, and Singapore. The authors treat these countries as being in a special emerging-markets group that had swap arrangements with the United States. They find that the credit default swap (CDS) spreads of these countries fell at the time the CB swap facilities were announced, but so did the CDS spreads of other emerging-market countries. Indeed, the spreads of most emerging markets had started to decline even before the CB swap arrangements were announced. Exchange rates responded significantly for the currencies of the countries with these arrangements, on average appreciating when nonswap countries' currencies depreciated, though these effects were subsequently reversed.

The general tenor of these few empirical studies of CB dollar swaps supports a role for the dollar swap facilities in influencing financial markets. This role was achieved through some combination of announcement effects and the actual operations' effects. However, it is important to point out that definitive statements about the consequences of any specific CB dollar swap operation, announcement, or facility remain difficult to quantify. The measured effects may have been short term and not measurably persistent.

This type of result and critique is common to empirical studies that examine the effects of news on high-frequency data. Thus, tests of long-term consequences are notoriously difficult to conduct in light of the highly volatile conditions and the many changes in facilities and operations over the life of the swap facilities. Indeed, Baba and Packer (2009) acknowledge similar difficulties in evaluation, noting that "these measures were widely welcomed by market participants and credited with alleviating funding pressures in term funding markets. However, the increase in the dollar swap lines to unlimited amounts occurred shortly after the adoption of many other measures by the authorities to stabilize the financial system by reducing counterparty credit and liquidity risks . . . with the combination of the [range of] measures . . . likely important in alleviating funding pressures on non-U.S. banks in particular."

Benchmarks for what might have occurred in the absence of the facility are speculative by definition. Overall, though, the balance of market perceptions and the carefully implemented empirical studies suggest that the central bank reciprocal swap arrangements were a highly welcome and useful response to the dollar funding shortages in international markets.

6. CONCLUSION

This paper has reviewed the evolution of the reciprocal currency arrangements, or dollar swap facilities, that the Federal Reserve established with various foreign central banks in 2007 and 2008 and exited in February 2010. In brief, the performance of the CB swap facilities is intertwined with the pricing and functioning of TAF auctions, which were another means of providing dollar liquidity to banks. Both the TAF and the dollar swap facilities have been effective in reducing dollar funding costs to domestic and foreign firms and have been viewed as successful backstop facilities for depository institutions.

It is worth noting that while we have focused exclusively on the Federal Reserve dollar swaps with foreign central banks, this type of facility has been implemented by other networks of European and Asian monetary authorities, including the ASEAN group's Chiang Mai initiative.²¹ The global network of swap facilities targeted widespread dysfunction across markets, as central banks extended loans against the collateral provided by their constituent financial institutions.

Empirical studies have pointed to the particular role played by the international facilities in influencing financial markets. The large expansion of the Federal Reserve's balance sheet that was associated with the CB dollar swaps in fourth-quarter 2008 occurred as global banks demanded term funding to cover potential year-end shortages. These positions unwound significantly in first-quarter 2009 as outstanding balances matured and were not rolled over, and they continued to decline during 2009. Availability of dollars to foreign banks was associated with credit tiering across these institutions that persisted, even if less severely, well into 2009.

In crisis periods, broad market dysfunction is often accompanied by significant credit tiering across financial firms. Such tiering can persist for some time after the need for broad liquidity provision has receded. As a crisis abates, a key challenge for policymakers is to identify when the use of liquidity support becomes concentrated among "adversely selected" institutions that might continue to rely on the liquidity facilities. The use of penalty rates in pricing these liquidity operations can assist in making such judgments because penalty rates create economic incentives for participants to exit these programs as the cost of market-based sources of funds returns to more normal levels.

Overall, we conclude that currency swap facilities, beyond their more traditional use in foreign exchange policy, have been an important part of the central bank toolbox for managing and resolving financial crises.

²¹ Details are provided in McGuire and von Peter (2009b, Figure 7).

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