Online appendix for

Central Bank Swap Lines:

Evidence on the Effects of the Lender of Last Resort

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Appendix A discusses how the swap lines interact with other monetary policies and compares the swap lines with other alternative ways for recipient-country banks to borrow in source-country currency. Appendix B extends the abitrage argument to consider collateral and regulation requirements. Appendices D-F have additional empirical results and robustness results on the regressions discussed in sections 4-6 the main text, respectively. Appendix G describes in detail how we built the variables used throughout the paper.

A The role of the swap lines in the central bank toolkit

This section expands on section 2's discussion of how the swap lines work

A.1 The division of tasks and alternatives

With a swap line, the source central bank provides liquidity in response to a financial crisis, while the recipient central bank judges which banks are eligible for the assistance. This division of tasks and risks arises because this liquidity operation involves the source-country monetary base, but the banks that are borrowing are regulated by the recipient central bank, which should have superior information on their solvency, the quality of their collateral, and the potential for moral hazard in ex ante bank risk-taking.

There are three alternatives to the swap lines that under efficient financial markets would be equivalent: recipient-country banks borrowing directly from the source-country central bank, recipient-country central banks borrowing source-country currency in private markets, and recipient-country banks borrowing from their central banks in recipient-country currency and converting it into source-country currency. Different financial frictions account for their difference and justify why the swap lines were not perfect substitutes with existing arrangements and so had an impact.

First, with respect to borrowing directly from the source-country central bank. In the case of the Fed, most major foreign banks have a U.S. branch or subsidiary, so they could go to the discount window. If information about the financial health of the borrowing bank was public, and there were no constraints in enforcing contracts and seizing collateral, these two programs might be equivalent. However, in the case of the swap line, because the Fed is officially lending to the recipient central bank, there are no mandatory disclosure procedures when it comes to which foreign banks receive the currency. Thus, the stigma that has been associated with the discount window does not apply, since the recipient central bank can keep the anonymity of the borrower for a longer period of time. Even today, the ECB does not make public the identity of the financial institutions that borrowed dollars from it. Moreover, the amounts lent were very large relative to the size of the U.S. branches or subsidiaries of foreign banks.[50] Given the Fed's limited monitoring ability over foreign banks

[50]For example, in 2008Q3 the total assets of foreign banking offices in the US were $1169bn (U.S. Flow of Funds, table L.111), compared to the peak swap line drawing a few weeks later of $586bn.

outside its jurisdiction, the swap lines allow the use of the recipient central bank's monitoring and selection on the financial health of the borrower. Finally, the recipient bank's assets in the source country were often held at the level of the recipient's parent. Hence, the required funding needs were large relative to the branch/subsidiary's balance sheet and would require collateral transfers from the parent, which recipient-country regulators might be uneasy with.[51]

The second alternative would be for the recipient central bank to borrow source-country currency in private markets, and then lend them out to its banks. For example, a similar swap contract to borrow dollars could be written with private lenders as it was with the Fed. However, these private institutions are reluctant to serve as intermediaries in a crisis (Avdjiev et al., 2018). The financial frictions that make financial institutions raise the price charged for hedging exchange-rate fluctuations to private clients likely apply to central banks as well. Two further properties of central bank swap lines are that they automatically increase the quantity of source-country currency in circulation, thus accommodating the increase in demand, and (more speculatively) the recipient central bank may be less likely to default on the source-country central bank than on private financial intermediaries.

A third and final alternative is for recipient-country banks to get their own currency from the recipient central bank, and swap them into source-country currency using a derivatives contract removing the exchange-rate risk. Even at the height of the financial crisis, the foreign exchange market for dollars never closed. The seller of dollars in the spot market will be a U.S. institution that can in turn obtain them from the Fed's domestic lending facilities. Usually this option is available, which perhaps explains why swap lines had little role to play in the decade prior to 2007. But this private operation has a hedging cost: the CIP deviation which our model elaborates on.

A.2 The implications of the swap line for monetary policy

A drawing of the swap line gives rise to a credit to the account of the recipient central bank at the source central bank. When the source-country currency is then lent out to banks and used to make payments, the reserve balances of commercial banks will increase. Because this meets an increase in demand for that currency by the recipient-country banks, in principle it is consistent with the control of inflation. Moreover, the swap-line rate is set as a spread over the short-term interest rate used for inflation control, so when the latter moves, so does the swap-line rate, again with no direct implications for source-country inflation. On the side of the recipient central bank, its new reserve balances never become currency in circulation, being held and returned by the source central bank, and none of its policy rates change, so there is no direct effect on inflation.

[51]In regular times, with smaller shocks, global banks use internal capital markets, as documented by Cetorelli and Goldberg (2012). However, when it comes to emergency borrowing after large shocks, the swap lines are preferred to the discount window. An alternative was the Term Auction Facility (TAF), which ran from December 2007 to March 2010, allowing many foreign banks to get dollars from the Fed directly, albeit a smaller set of banks than the ones that have access to their own-country swap line and subject to a narrower set of accepted collateral. Unlike the swap line, the TAF kept the credit risk and the need for monitoring at the Fed.

As important as what they are, is what the new swap lines are not. First, they are not directly used to finance exchange rate interventions. Central bank swap lines have been used in the past to obtain the foreign currency in order to sustain a peg. Yet, with the current advanced-economics swap lines, the source-country currency is not used right away to buy recipient-country currency and affect its price. Rather, the source-country currency is lent out to banks that could instead have borrowed from the recipient central bank in its currency. The large bulk of dollars lent out by the Fed went to the ECB, the Bank of England, and the Bank of Japan (see figure 1), all of which did not have explicit targets or policies for intervening in the value of their currency vis-a-vis the dollar.

Second, the swap lines are not a response to current account imbalances in the way that IMF loans are. They are a short-term liquidity program that emerged because of the expansion of global banks with large gross positions in the source-country assets, usually funded in source-currency. The swap line borrowing replaces borrowing from private markets, with little effect on net positions, and it is reverted in a short period of time, with no policy conditionality.

Third, the swap lines do not lead the recipient central bank to absorb exchange-rate risk or bad foreign assets from its banks. The recipient central bank has only credit risk, as in any lender of last resort operation, and can apply its standard criteria for eligible collateral. The banks under its jurisdiction have their currency needs met, not their risk nationalized.

Finally, the swap line is not a subsidy from the source central bank to foreigners. It is a liquidity program where, so long as the interest rate charged is the same as that charged in domestic lending facilities, all banks, domestic or foreign, face similar terms. Insofar as the source central bank is charging a spread over the overnight rate, but the recipient central bank bears the credit risk, then the source central bank is actually receiving a transfer from foreigners in risk-adjusted terms.

B Collateral and regulation

Constraints on the banks through collateral requirement or regulatory restrictions loosen the ceiling result, but do not overturn it.

Loans to banks from the central bank through the swap line are secured and a haircut applies to the collateral. Letting ξ^c denote the cash coefficient applied to the collateral offered by the bank, the cost of borrowing from the central bank is $\xi^c i_t^s + (1-\xi^c) i_{a,t}^u$ where $i_{a,t}^u$ is the unsecured financing rate in dollars facing bank a. In terms of bank capital and regulation requirements, deposits at the central bank have a zero risk weight in bank capital adequacy calculations and, in some jurisdictions, do not count towards leverage ratio requirements. However, the interaction of the Basel III leverage ratio requirements that became binding at different dates starting in 2016, the use of FX derivatives, and the evaluation of stress tests, may result in the trade that we describe requiring some bank equity. Imagine that for every $1-\omega$ of debt from the swapline the bank must have ω of equity, which has a bank specific shadow cost $\lambda_{a,t} > i_t$, where a is an index of banks.

Given this, we now obtain a revised proposition:

Proposition 4. *Bank-specific deviations from covered interest parity ($x_{a,t}$) have a ceiling given by the spread between the source swap and interbank rates, plus the difference between the recipient central bank policy and deposit rates, plus the shadow value of collateral, plus the shadow cost of regulation on banks that is triggered by borrowing and lending from their central bank:*

$$x_{a,t} \leq (i_t^s - i_t) + (i_t^{p*} - i_t^{v*}) + (1 - \xi^c)(i_{a,t}^u - i_t^s) + \psi_{a,t}. \tag{A1}$$

Proof: To set up the proof, first consider what happens when: (i) bank a can choose whether to obtain dollars from the swap line or from an "other" source, and their rate-collateral pairs are: (ξ^c, i_t^s) and (ξ^o, i_t^o), respectively; (ii) the unsecured lending rate for bank a is $i_{a,t}^u$; (iii) for every unit of investment in the trade, the bank needs ω of equity, which has shadow cost $\lambda_{a,t}$, and $1 - \omega$ of debt financing, so that ω can be thought of as the total equity held against the central bank issued reserves and the forward contract. In that case, the arbitrage argument in equation (1) becomes instead:

$$(1 - \omega) \min\{\xi^c i_t^s + (1 - \xi^c) i_{a,t}^u, \xi^o i_t^o + (1 - \xi^o) i_{a,t}^u\} + \omega \lambda_{a,t} \geq s_t - f_t + (i_t^{v*} + i_t^* - i_t^{p*}). \tag{A2}$$

Using the definition of the CIP deviation in equation (2) and rearranging gives the generalized version of our ceiling result:

$$x_{a,t} \leq (1 - \omega) \min\{\xi^c i_t^s + (1 - \xi^c) i_{a,t}^u, \xi^o i_t^o + (1 - \xi^o) i_{a,t}^u\} - i_t + (i_t^{p*} - i_t^{v*}) + \omega \lambda_{a,t}. \tag{A3}$$

There is still a ceiling, and an exogenous reduction in i_t^s still weakly reduces the right-hand side.

We argue that the following held during our sample period: (i) the alternative source of funding was borrowing from the recipient-country central bank's recipient-country currency and using the forward market to turn it into synthetic dollars, so $i_t^o = i_t^{p*} + s_t - f_t$, (ii) during this sample period, the policy and OIS rates were almost identical, so $i_t^{p*} = i_t^*$, and (iii) the collateral requirements by recipient-country central banks were identical for their dollar swap line and conventional recipient-currency lending, so $\xi^o = \xi^c$. It then follows that:

$$\min\{\xi i_t^s + (1 - \xi^c) i_{a,t}^u, \xi^o i_t^o + (1 - \xi^o) i_{a,t}^u\} = \xi^c \min\{i_t^s, i_t + x_{a,t}\} + (1 - \xi^c) i_{a,t}^u. \tag{A4}$$

Thus, the bank will not use the swap line, unless $x_t \geq i_t^s - i_t$. Given the reasonable assumptions that: (i) $i_{a,t}^u \geq i_t$, or that unsecured borrowing rates exceed secured borrowing rates, (ii) the interest on reserves puts a floor on the policy rate, $i_t^{p*} \geq i_t^{v*}$, then:

$$i_t^s - i_t \leq \xi^c \min\{i_t^s, i_t + x_{a,t}\} + (1 - \xi^c) i_{a,t}^u - i_t + (i_t^{p*} - i_t^{v*}). \tag{A5}$$

Therefore, we can dispense with the min operator in the ceiling expression.

The ceiling result then becomes:

$$x_{a,t} \leq (i_t^s - i_t) + (i_t^{p*} - i_t^{v*}) + (1 - \xi^c)(i_{a,t}^u - i_t^s) + \psi_{a,t}, \tag{A6}$$

as long as we define: $\psi_{a,t} = \omega(\lambda_{a,t} - i_t^s - (1 - \xi^c)(i_{a,t}^u - i_t^s))$, the shadow value of relaxing the regulatory constraint. Note that in principle $\psi_{a,t} \geq 0$ since bank equity is more costly than the weighted cost of secured and unsecured debt. This completes the proof.

Collateral and regulation considerations add a third possible source of variation to the ceiling on bank quotes, one that is bank-specific. Note that some large investors, notably the safest banks, will have enough safe assets that their unsecured and secured funding rates are the same, so $i_{a,t}^u = i_t^o$. Likewise, for banks in at least some jurisdictions, there are no regulations involved in borrowing and lending from the central bank, so for them $\psi_{a,t} = 0$. Thus, for these banks, the market ceiling will be $x_{a,t} \leq (i_t^s - i_t) + (1/\xi^c)(i_t^{p*} - i_t^{v*})$, which reduces to proposition 1, as expected, when $\xi^c = 1$.

With regards to the identification strategy used in section 4 is still valid in the presence of these considerations. The November 2011 date is well before regulations being discussed and approved that could interfere with the swap line. The considerations on regulation discussed in proposition 4 should not apply. Moreover, the reduction in the swap-line rate comes with potential higher use of the central bank facilities, which tend to have more generous treatment of collateral, thus lowering the shadow value of collateral, so the ceiling would still unambiguously fall in proposition 4.

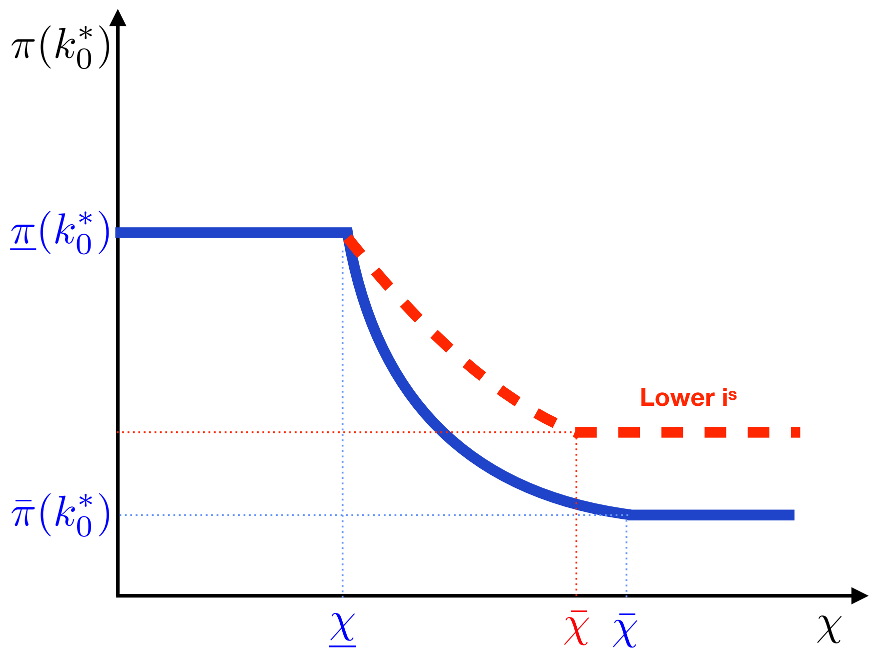
Finally, we can broadly interpret the multipliers as also capturing some "stigma" in the use of the central bank facilities. Arguably, the policy change in 2011 reduced that stigma. Then, the multiplier would have become smaller, and the ceiling tighter, thus again moving in the same direction as the interest rate on the swap line.

C Proof of proposition 3

First, consider what is investment in the second period, k^*, as a function of the financial shock χ. When χ is small, CIP holds, $MC = i$, and so investment is at the first best $\hat{k}^*$ (conditional on $k^a st_0$). As the financial constraint becomes binding, $\chi > \underline{\chi}$, and the exchange-rate intermediaries start operating at an increasing cost. Defining the function $H(.) \equiv \bar{\delta}h(k^* + \chi - \bar{l}) + (1 - \bar{\delta})(i^s - i)$, now in equilibrium $\partial F(.)/\partial k^* = i + H(k^* + \chi, i^s - i)$. The bank takes this cost as given, but it increases with the amount of investment in equilibrium, because the cost of hedging away the exchange rate risk is rising. If the financial shock become more extreme, then banks start turning to the swap line and $MC = i^s$. The size of the shock that triggers this switch is $\bar{\chi}$, defined as the solution to $H(\bar{k}^* + \bar{\chi}, i^s - i) = i^s - i$. At this point, investment is $\bar{k}^*$, which solves $\partial F(.)/\partial k^* = i^s$, independent of the realization of the shock.

Next, consider what profits in the second period are as a function of the financial shock. This

Figure A1: Period 2 profits as a function of the financial shock



is defined as $\pi(k_0) = \max_{k^*} \left\{F(k_0^*, k^*) - ik^* - H(.)\max\{k^* + \chi - \bar{l}, 0\} - (i^s - i)\max\{k^* - \bar{k}^*, 0\}\right\}$ and plotted in figure A1. For small χ, the financial constraint is slack. Profits are high as the marginal cost of borrowing is low. Once the shock exceeds $\underline{\chi}$ the recipient-country banks start using their country's funding and exchange-rate hedging, so the marginal cost rises, and profits fall. If the shock gets high enough, above $\bar{\chi}$ then banks turn to the swap line and profits become again independent of the size of the shocks.

Finally, we can turn to long-term investment k_0. The banks choose it in the first period to maximize $\Pi_0 = \int \pi(k_0, \chi)dG(\chi) - \rho k_0$. The first order condition is:

$$G(\underline{\chi})\underline{\pi}'(k_0^*) + (1 - G(\bar{\chi}))\bar{\pi}'(k_0^*) + \int_{\underline{\chi}}^{\bar{\chi}} \pi'(k_0^*, \chi)dG(\chi) = \rho \tag{A7}$$

where $\underline{\pi}(.)$ and $\bar{\pi}'(.)$ are the profit functions, independent of χ, when the hocks are below $\underline{\chi}$ and above $\bar{\chi}$, respectively.

By the envelope theorem, if there were no shocks, only the first term on the right-hand side would be non-zero, and this would reduce to $\underline{\pi}'(k_0^*) = \partial F(.)/\partial k_0^* = \rho$. The first-best level of capital would be reached. Otherwise, investment is now lower because, as figure A1 shows, for a range of realizations of the shock, the profits are lower. When recipient-country banks decide to invest in the source-country firm, they take into account that next period they may get hit by a large shock, leading to higher costs and lower profits.

Recall that a lower rate charged on the swap line has two effects. First, it lowers the $\bar{\chi}$ as banks switch from market to swap-line borrowing sooner. Second, it lowers the private rates that banks get in the market by improving their outside option relative to the traders. Both contribute to lower the expected costs from having to respond ex post to a financial crisis. Thus, the profits from investing abroad are weakly higher across the realization of the shocks. Because of the complementarity between the two types of capital in production, marginal profits for each unit of first period investment are also now higher. This raises long-run investment and expected profits across financial shocks.

D Additional Results on CIP deviations

This section describes further results and robustness checks on our empirical analysis in section 4. In addition, it presents estimates of the demand curve for dollars by banks at the swap line.

D.1 CIP across currencies

Figure A2 presents the equivalent of figure 3 for other swap line currencies and the DKK. CAD does not experience any ceiling violations. In the case of CHF and JPY, the CIP deviations are also subject to spikes at year end, and at quarter end from 2015 onward for the JPY, but also experience occasional short lived spikes towards during the year. See section 5 for discussion regarding why these spikes are not necessarily problematic. In contrast, consider the DKK: on February 1, 2010 the swap line lapsed, and after that the CIP deviation experienced sustained periods above an hypothetical ceiling in mid 2012 and early 2015.

D.2 Difference-in-differences CIP estimates: pre trends

Figure A3 presents daily data on 1-week Libor CIP deviations vis-a-vis the USD for the 10 currencies in our sample in the three months prior to the announced change in the swap line rate on 30th of November 2011. As the picture shows, the deviations are both volatile through time and heterogeneous across currencies. There is no obvious pre-trend among currencies in either group. Nor do the days in the build up to the announcement appear unusual.

D.3 Difference-in-differences CIP estimates: break down of the changes

Table A1 and A2 decomposes the distribution CIP deviations before and after the swap line rate change, as presented in table 1 into the level and differences for the treatment and control.

Figure A2: CIP deviations and the swap line ceiling: CAD, CHF, JPY and DKK

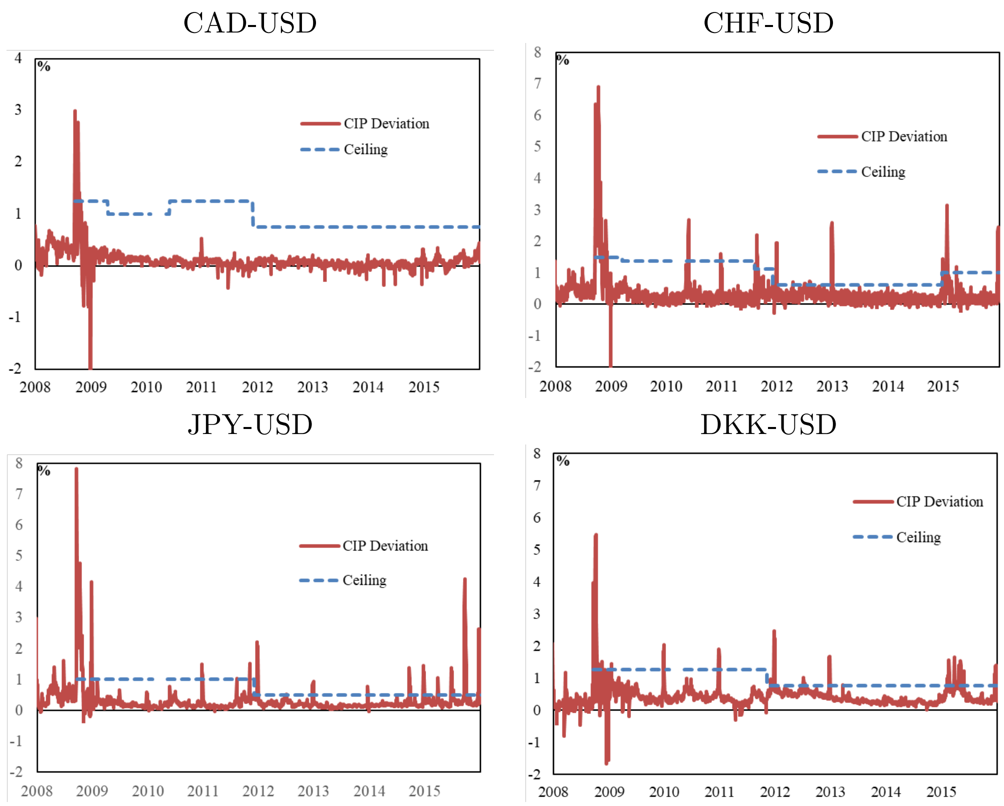


Table A1: Breakdown of the effect of the swap line rate change on CIP deviations: treatment group

	(1) *Baseline: 23/11-29/11 vs 8/12-13/12, Quotes*	(2) *23/11-29/11 vs 1/12-7/12, Quotes*	(3) *Nov vs Jan, Quotes*	(4) *Nov vs Jan, Daily Data*	(5) *23/11-29/11 vs 8/12-13/12, No Euro, Quotes*	(6) *23/11-29/11 vs 8/12-13/12, European Currencies, Quotes*	(7) *23/11-29/11 vs 8/12-13/12, EUR, CHF vs DKK, NOK, Quotes*
Before							
Mean	.2681	.2681	.2860	.2456	.1089	.4489	.5382
Median	.1683	.1683	.0975	.2342	.0627	.4235	.4922
75 %tile	.5072	.5072	.5137	.4105	.2516	.7595	.7692
90 %tile	.8219	.8219	.9135	.4620	.4347	.8433	.8828
After							
Mean	.1381	.2147	.0959	.1524	.0483	.2392	.2796
Median	.0948	.1294	.1175	.1172	.0094	.2630	.3130
75 %tile	.3122	.3753	.1492	.2077	.1196	.3588	.4084
90 %tile	.4220	.7302	.1837	.2790	.2674	.5534	.5710
Difference							
Mean	-.1300	-.0534	-.1901	-.0932	-.0606	-.2097	-.2586
Median	-.0735	-.0389	.0200	-.1170	-.0533	-.1605	-.1792
75 %tile	-.1950	-.1319	-.3645	-.2028	-.132	-.4007	-.3608
90 %tile	-.3999	-.0917	-.7298	-.1830	-.1673	-.2899	-.3118

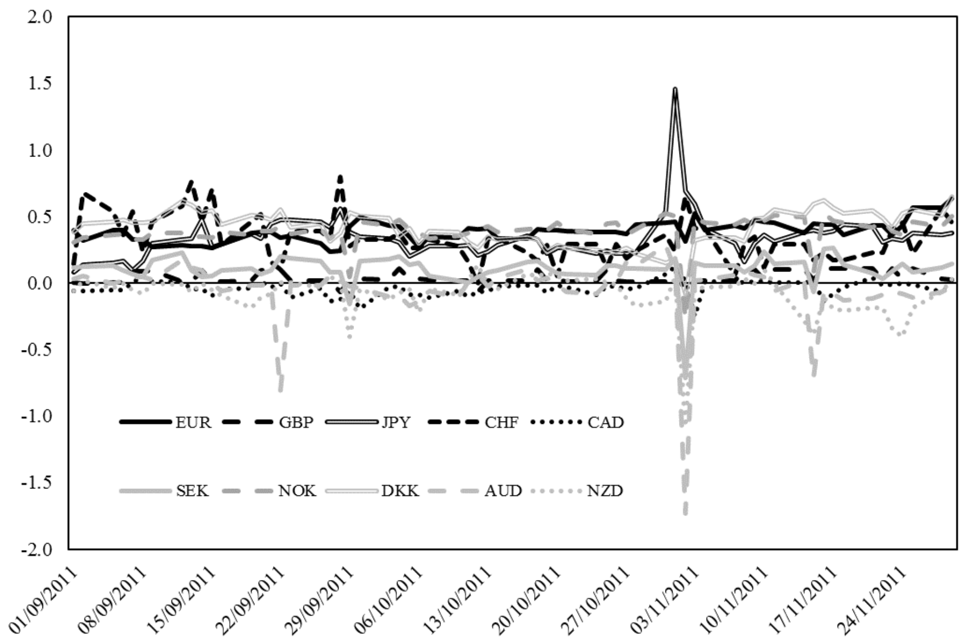
Notes: Swap Line Currencies refers to EUR, GBP, CAD, JPY, CHF (treatment group). Non-swap line currencies refers to AUD, NZD, SEK, NOK, DKK (control group). Column (1): Compares CIP deviations from all quotes in the FX swap market recorded between 23/11/11-29/11/11 versus 8/12/11-13/12/11. Column (2): Changes the post announcement window to 1/12/11-7/12/11, covering the 5 trading days through to the first European auctions at the new rate. Column (3): Extends the event windows to monthly and compares November 2011 to January 2012. Column (4): As Column (3) but uses daily data on CIP deviations based on prices in FX forward and spot markets. Column (5): As Column (1) but Euro excluded from sample. Column (6): As Column (1) but excludes JPY, CAD, AUD and NZD from the sample. Column (7): As Column (1) but restrict sample to EUR, CHF versus NOK, DKK. .

Table A2: The effect of the swap line rate change on CIP deviations: Control Group

	(1) *Baseline: 23/11-29/11 vs 8/12-13/12, Quotes*	(2) *23/11-29/11 vs 1/12-7/12, Quotes*	(3) *Nov vs Jan, Quotes*	(4) *Nov vs Jan, Daily Data*	(5) *23/11-29/11 vs 8/12-13/12, No Euro, Quotes*	(6) *23/11-29/11 vs 8/12-13/12, European Currencies, Quotes*	(7) *23/11-29/11 vs 8/12-13/12, EUR, CHF vs DKK, NOK, Quotes*
Before							
Mean	.0003	.0003	-.0341	.1273	.0003	.2593	.4644
Median	-.0617	-.0617	.0118	.1143	-.0617	.1674	.4590
75 %tile	.0217	.0217	.0868	.4532	.0217	.4183	.5178
90 %tile	.4027	.4027	.3778	.5122	.4027	.4731	.5887
After							
Mean	.1515	.1721	.0610	.2185	.1515	.1683	.6577
Median	.0722	.0963	.0464	.1438	.0722	.0311	.6551
75 %tile	.1130	.1725	.1295	.4064	.1130	.5090	.7653
90 %tile	.5890	.5181	.3510	.6120	.5890	.5846	.7992
Difference							
Mean	.1513	.1718	.0951	.0912	.1512	-.0910	.1934
Median	.1339	.1580	.0346	.0295	.1339	-.1363	.1961
75 %tile	.0913	.1508	.0427	-.0468	.0913	.0907	.2475
90 %tile	.1863	.1154	-.0268	.0998	.1863	.1115	.2105

Notes: Swap Line Currencies refers to EUR, GBP, CAD, JPY, CHF (treatment group). Non-swap line currencies refers to AUD, NZD, SEK, NOK, DKK (control group). Column (1): Compares CIP deviations from all quotes in the FX swap market recorded between 23/11/11-29/11/11 versus 8/12/11-13/12/11. Column (2): Changes the post announcement window to 1/12/11-7/12/11, covering the 5 trading days through to the first European auctions at the new rate. Column (3): Extends the event windows to monthly and compares November 2011 to January 2012. Column (4): As Column (3) but uses daily data on CIP deviations based on prices in FX forward and spot markets. Column (5): As Column (1) but Euro excluded from sample. Column (6): As Column (1) but excludes JPY, CAD, AUD and NZD from the sample. Column (7): As Column (1) but restrict sample to EUR, CHF versus NOK, DKK. .

Figure A3: Pre-trends: one-week Libor CIP deviations versus USD, 01/09/2011-29/11/2011



D.4 Difference-in-differences CIP estimates: robustness

Table A3 considers the robustness of the results in table 1 in the main text on the difference-in-differences estimates of the effect of the swap line on CIP deviations.

The first column shows that our results hold if we weight the quote data to equally weight currencies. Bootstrapped standard errors are complex to compute in weighted quantile regressions, we omit them and note that the point estimates conform to the unweighted baseline where inference is more straightforward.

The second column shows the results on quotes excluding all European currencies. The effects are still present if less dramatic as the CIP deviations for JPY and the CAD were less elevated initially. It is worth emphasizing that this arises due to an increase in the CIP deviations of the control group rather than a fall in the treatment group.

The final six columns are based on daily data. The first three of these show that our results, particularly in the tail of the distribution of CIP deviations, are robust to calculating the deviations using interest on excess reserves rather than LIBOR and to considering two and three month event windows. The sixth column conducts a pre-event falsification test and compares August 2011 to October 2011. We do not obtain statistically significant differences. This suggests that our results are not just a manifestation of a pre-existing trend. The seventh column uses more data to compute standard errors by bootstrapping not just over currencies but also over alternative monthly event

Table A3: Robustness of Difference-in-Differences Results on CIP deviations

	Quote Data		Daily Data					
	(1) *Weighted*	(2) *Non-European Currencies*	(3) *Nov vs Jan, Interest on Excess Reserves*	(4) *2 month window*	(5) *3 month window*	(6) *Falsification (Aug vs Oct)*	(7) *Bootstrap Alternative Monthly Event Windows*	(8) *Nov vs Jan 3 month Tenor*
Mean	-.214	-.162***	.142	-.123	-.075	-.066	-.184**	-.086
		(0.056)	(.096)	(.081)	(.078)	(.090)	(.088)	(.104)
Median	.033	-.182**	-.086	-.113	-.095	-.0465	-.147*	-.044
		(0.083)	(.174)	(.113)	(.116)	(.084)	(.086)	(.197)
75 %tile	-.326	-.116***	-.379***	-.167	-.127	.063	-.156	-.245
		(0.016)	(.137)	(.116)	(.107)	(.160)	(.106)	(.180)
90 %tile	-.607	-.096***	-.305***	-.258**	-.263**	-.179	-.283	-.103
		(0.017)	(.099)	(.104)	(.096)	(.267)	(.218)	(.140)
N	288374	157257	430	850	1,290	440	430	430

Standard errors in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

*Notes: This table presents the equivalent of the difference in differences estimates 5 in table 1 in the main text for alternative specifications. Column (1): Equivalent to Column (1) in table 1 (baseline) but with quote-level observations reweighted so each currency has equal weight. Column (2): Equivalent to baseline but compares JPY, CAD to AUD, NZD. Column (3): As Column (4) in table 1 but recompute the CIP deviation using the interest rate on excess reserves rather than Libor rates. Column (4): As Column (7) in table 1 but two month event window, Oct-Nov 2011 versus Jan-Feb 2012. Column (5): As Column (4) in table 1 but three month event window, Sep-Nov 2011 versus Jan-March 2012. Column (6): Placebo study, August 2011 2011 versus October 2011; daily CIP data versus USD using Libor rates. Column (7): As Column (4) in table 1 but bootstrapped standard errors computed by randomly selecting event months between January 2009 and November 2011 (excluding windows that overlap year end) and block bootstrapping currencies with replacement. Column (8): As Column (4) in table 1 but CIP deviations computed using 3-month tenors. *** denotes significance at the 1% level; ** 5% level;* 10% level. Standard errors, block bootstrapped at the currency level, in brackets (excepting columns(1),(7)).*

Table A4: Difference-in-Differences Results on CIP deviations, Robustness to Operation Dates

	(1) *Nov vs Jan, Quotes, Operation Days Only*	(2) *Nov vs Jan, Quotes, Ex. Operation Days*
Mean	-.360*	-.248
	(.199)	(.171)
Median	-.055	-.002
	(.252)	(.259)
75 %tile	-.590*	-.460
	(.343)	(.360)
90 %tile	-0.683	-.735**
	(.434)	(.354)
N	486399	712319

Notes: Swap Line Currencies refers to EUR, GBP, CAD, JPY, CHF (treatment group). Non-swap line currencies refers to AUD, NZD, SEK, NOK, DKK (control group). Column (1): Compares CIP deviations from all quotes in the FX swap market on the days (allotment and settlement) of swap line operations in November 2011 (excluding the operation alloted on the 30th) with those in January 2012. Column (2): Compares quotes in November 2011 to January 2012 excluding days when an operation took place.

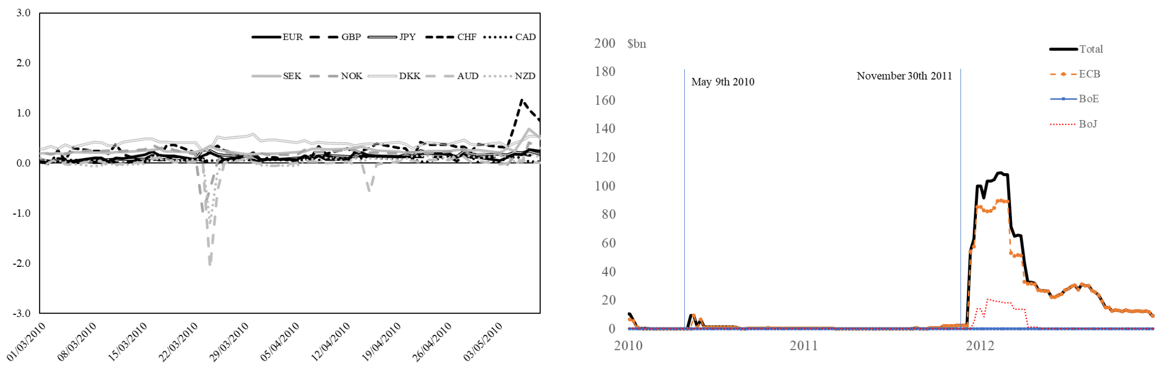
windows centered a month sampled from January 2009-October 2010 (excluding December due to year end volatility). This tightens the standard errors for the effect of the swap line change at the center of distribution (i.e. the mean/median) but reduces the significance of the estimated effect on the tail.

The eighth column uses three-month tenors to compute CIP deviations. In the main text, we focus on the one-week tenors for several reasons: they were the most commonly used, the short maturity and gap between operations provides a sharper test of the theory, and these operations were conducted without a break throughout the sample period. As these were also significant operations with a three-month tenor, the last columns repeats our test with them. The coefficients are negative and quantitatively similar, but lack statistical significance. The swap line funded three-month operations from October 2011 until February 2014 but these only took place monthly which may be of insufficient frequency for our ceiling result to hold. Reflecting this, among the treated currencies there is a substantial mass beyond the ceiling in even after the rate change when 3 month tenors are used.

Our monthly window include dates with both operation and non-operation days. Table A4 includes in the pre and post window CIP deviations only operation (allotment and settlement) dates and its complements. There is an effect beyond the operation days, possibly reflecting anticipation of future operations by market participants, which contaminates the three-month tenor data.

Figure A4: The CIP deviations and swap line drawings around the May 2010 reauthorization

Daily CIP deviations (1W tenor, Libor) *Swap line drawings*



D.5 The May 2010 event

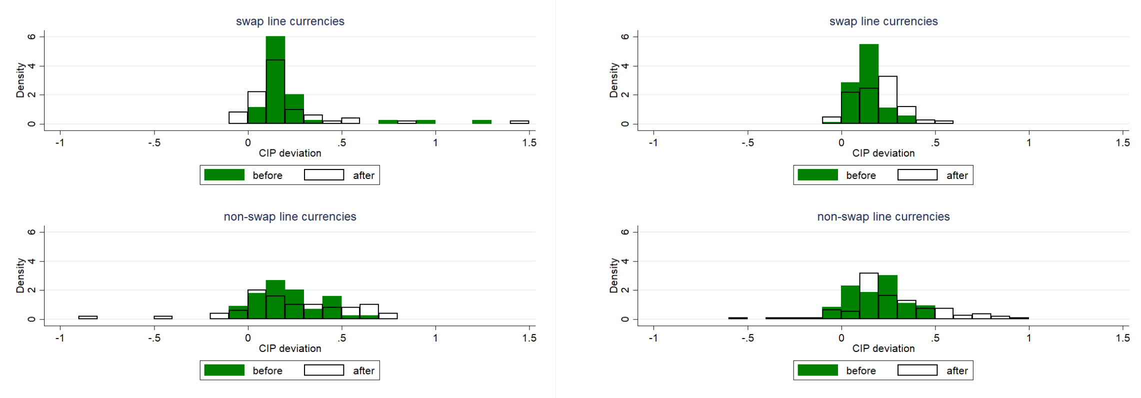
The network of swap lines connecting the Bank of Canada, the Bank of England, the Bank of Japan, the European Central Bank, the Federal Reserve, and the Swiss National Bank, lapsed on 1st February 2010. On May 9th 2010, they were reauthorized with the swap line rate at 100bp over OIS (the same level as it was in January 2010). The period between February and May of 2010 therefore had no swap lines. Note that this sample did not enter any of the empirical results in the main text of the paper and dropping the period does not alter the results in appendix D.8 below. The May 9 reauthorization is significant enough that it could lead to a further test of the theory, and potentially a difference-in-differences test similar to the one in the text.

However, the theory requires that CIP deviations were elevated before the policy change such that a ceiling would be binding. Otherwise, if there is no equilibrium mass of CIP quotes to the right of new ceiling and the impact of the swap lines will be difficult to detect empirically. The left panel of figure A4 shows that in the weeks before the May 9 re-authorization CIP deviations were small. In turn, the right panel plots the drawings on the swap line. These were modest after the reauthorization of the swap lines particularly in comparison to the drawings after the 2011 rate cut. This is also consistent with the newly-imposed ceiling not being binding for most banks.

Reading over the Fed's transcripts reinforces the view that May 2010 is a less informative event to study. The request came form the ECB on the 8th of May, and was approved by the other central banks the next day, with little discussion and no dissent among FOMC members. This is in contrast with the November 2011 event that we studied in the main text, which was negotiated over an extended period and whose terms were strongly debated. The transcripts also suggest that the move was widely anticipated and this is confirmed by reading the financial press, as the reauthorization is barely mentioned in the Financial Times (while the November rate change was

Figure A5: Daily CIP deviations histograms for treated and non-treated currencies around the May 9th swap line reauthorization

Apr 27th - May 7th v May 10th - May 21st *Apr. v Jun line drawings*



on the front page).

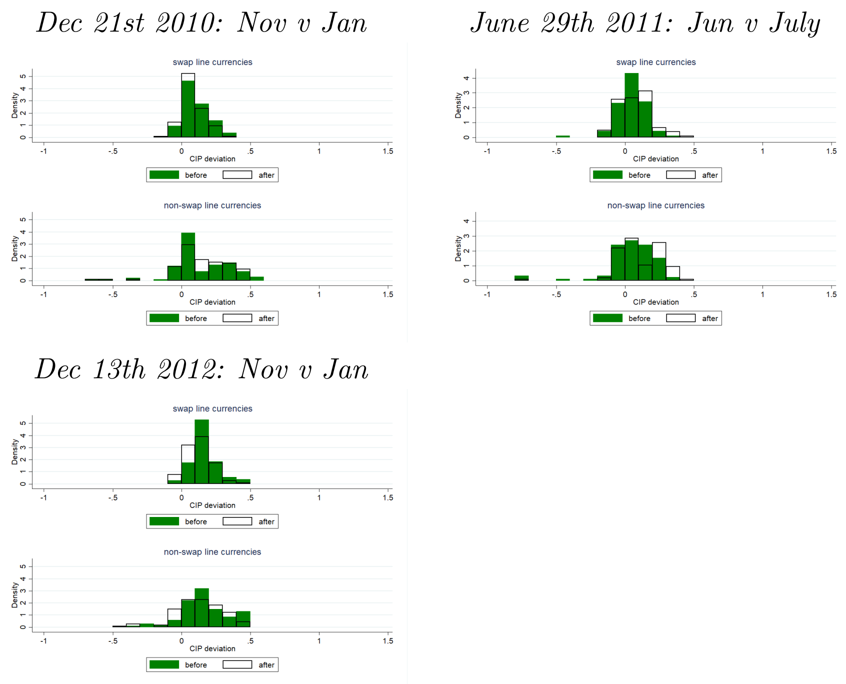
Finally, there were two significant confounding events that make drawing conclusions regarding the effectiveness of the swap line from the May 2010 even more difficult: a major EcoFin/IMF announcement on the 9th, and the UK election on the 5th, which would have differential effects among potential treatment and control groups.

Altogether, the re-authorization happened at a time when a statistical test would have little power, seems to have been anticipated, and there significant confounding events nearby. This makes May 9th event a weaker candidate for a difference-in-differences test. Nonetheless, Figure A5 shows the histograms of CIP around the event using daily data. The left panel compares two weeks before versus two after, the right panel compares April to June. As can be seen, not much can be inferred from the relative movement in CIP deviations.

D.6 Difference-in-differences CIP estimates: extensions as placebos

The change in the swap line rate on November 30th 2011 occurred simultaneously with an extension of the swap arrangements. Our predictions relate to the swap line rate not to the length of the swap line arrangement. To rule out that the extensions explain our results we consider as placebos at three other event dates: December 21st 2010; June 29th 2011 and December 13th 2013. These all correspond to dates where the swap arrangements were extended without any change in the swap rate. Figure A6 summarizes the results in the form of histograms of the distribution of daily CIP deviations over relevant months. As can be seen these extensions are not associated with any major shift in the distribution of CIP deviations.

Figure A6: Daily CIP deviations histograms for treated and non-treated currencies around swap line extensions



D.7 Difference-in-differences CIP estimates: alternative CIP measures

For swap line currencies, Figure A7 presents the equivalent to Figure 4 when computing the CIP deviation using OIS rates rather than LIBOR rates. The shift in the distribution following the tightening of the swap line rate is clear.

D.8 A test using time-series domestic variation

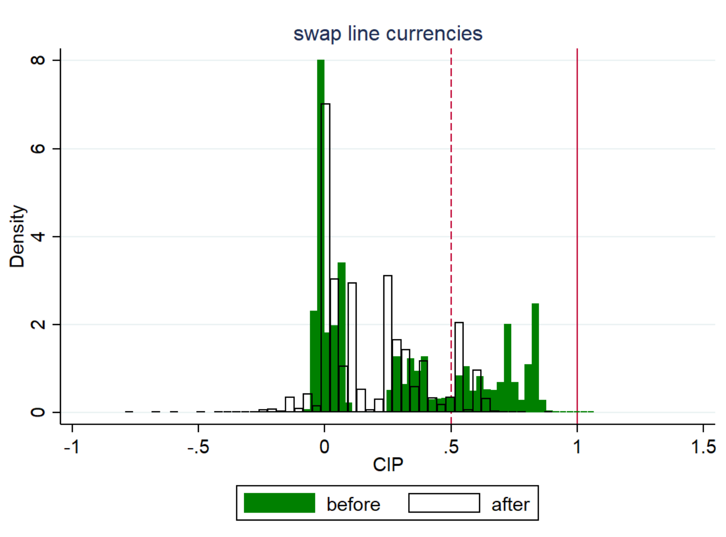
The previous estimates used only U.S.-driven variation in the ceiling, which was useful insofar as this was plausibly exogenous with respect to the CIP deviations. As figure 3 shows for the Euro, and is true for other currencies, there is additional variation in the ceiling because of national monetary policy changes. This comes from changes in central bank deposit rates, which rarely were directly associated with movements in CIP. If times when CIP deviations are larger are also times of national financial turmoil, and this triggers cuts in the difference between policy and deposit rates, then this reverse causality would bias the estimated average effect of the ceiling on the CIP deviations downwards towards zero.

The baseline regression is:

$$x_{j,t} = \alpha_j + \beta c_{j,t} + \varepsilon_{j,t} \tag{A8}$$

where α_j are currency fixed effects, and $c_{j,t}$ is the ceiling on the right-hand side of the equation

Figure A7: Price quote CIP deviation histograms for swap line currencies using OIS rates: 23-29 of November versus 8-13 December



in proposition 1 for currency j. We estimate this equation with the market-close daily data from September 19th, 2009, to December 31st, 2015, clustering standard errors by trading day and by currency.[52]

The first column of table A5 shows an estimated effect of a 1% reduction in the ceiling of 21bp on the CIP deviations. The second column instead estimates a censored regression, including only observations if the CIP deviations were in the 90th percentile of their sample distribution. As expected, the estimates are much larger: near the ceiling, a fall in 1% in the ceiling lowers the CIP deviations by 78bp. The third column adds a time fixed effect. This removes the variation from the Fed's actions, so that all that is left is the variation from changes in deposit rates by the recipient central banks. The estimate falls by half to 12bp, consistent with a downward bias due to reverse causality. The fourth column excludes the period between February and May 2010 when the swap line agreements lapsed. Including this period would attenuate the estimates according to the theory, and indeed excluding it the estimate is slightly higher at 23bp. The fifth column excludes the week before policy meetings so that the arbitrage trade is not exposed to the risk of changes in $i_t^{p*} - i_t^{v*}$ as discussed in section 4. The coefficient falls by a negligible amount to 0.18. The sixth column reflects the fact that the swap line operations happen once a week, with bids typically taken on a Wednesday. Considering only that day of the week, so cutting the sample to 1/5 of its size, slightly increases the point estimate but, as expected, it also increases the standard

[52]Our results are robust to starting on the 13th October 2008 when the swap line drawings became full allotment, fixed rate operations. We have also conducted a block bootstrap exercuse to deal with small cluster bias, and found the results to be unchanged.

Table A5: The effect of swap line ceiling on CIP deviations

	Baseline	Censored	Time Fixed Effect	Exc. Feb-Apr 2010	Exc. week b/f policy mtg	Allotment days	3mth Libor
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Ceiling (c_{it})	0.211***	0.777**	0.118	0.229***	0.1805**	0.2312*	0.2636**
	(0.041)	(0.239)	(0.059)	(0.043)	(0.052)	(0.091)	(0.076)
N	9500	950	9500	9150	7666	1900	8826
Adjusted R^2	0.08	0.16	0.67	0.67	0.08	0.08	0.15

Standard errors clustered by currency and day level in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

*Notes: Estimates of equation (A8). The dependent variable is the 1-week CIP deviation of the CAD, CHF, EUR, GBP, and JPY vis-a-vis the USD. The sample runs from 19th September 2008 (the date of the first multilateral Federal Reserve swap agreement) through to 31st December 2015. All regressions include currency fixed effects. Column (1): panel least squares estimator. Column (2): panel least squares estimator conditional on $x_{j,t}$ being in the 90th percentile of the unconditional distribution. Column (3): includes time fixed effects. Column (4): Removes observations between Febuary and April 2010 when the swap line was suspended. Column (5) Excludes weeks before policy meeting. Column (6): Wednesdays only when European operation are alloted. Column (7): Uses 3 month Libor rates to compute CIP deviations. Standard errors, clustered by currency and date, are in brackets. *** denotes statistical significance at the 1\% level; ** 5% level; * 10% level.*

errors by a factor of 2. The seventh column uses 3 month libor rates and 3 month forwards to compute CIP deviations as an alternative, the coefficient is nearly identical.

E Additional results on the quarter-end spikes

This section describes further results and robustness checks on our empirical analysis in section 5.2.

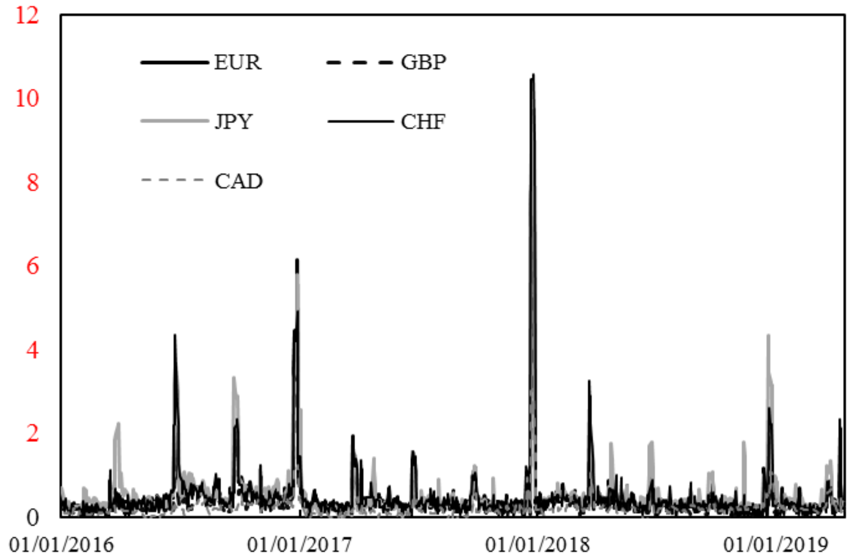
E.1 Spikes in CIP over time

Figure A8 presents one-week OIS CIP deviations vis-a-vis the USD for the five swap line currencies in the period after 2015. Spikes at quarter end sufficient to breach the swap line ceiling are clearly visible.

E.2 Spikes at quarter end: across quarter ends

Figure A9 presents the equivalent of figure 6 across all quarter ends (excluding year ends) between 2016 and 2018 where there were sustained ceiling violations. Note that 2016Q1, 2018Q2 and 2018Q3 did not see an extended period of ceiling violations across most currencies. As can be seen, ceiling violations are typically bracketed by the swap line operations.

Figure A8: CIP deviations after 2015



E.3 Spikes at quarter end: linear probability models

Figure A10 presents the equivalent of panel (a) in figure 7 for the GBP, CHF and JPY. CHF and GBP display similar patterns to the EUR. There is a single Bank of England swap line operation on August 3rd-4th 2016, which had a GBP ceiling violation persisting through the settlement date. Hence, the estimates of $\beta^1_{j,1}$ and $\beta^2_{j,1}$ are not a precise zero for the GBP unlike the CHF and EUR.

For the JPY, ceiling violations regularly persist through a BoJ swap line operation (this is also visible inspecting figure A8). This is despite the BoJ, unlike the SNB or BoE, making positive allotments at the USD operation. As described, this may reflect a long settlement cycle with the BoJ's operation. Alternatively, there may also be stigma for Japanese banks associated with the swap line.

E.4 CIP deviations and the allotments at swap line operations

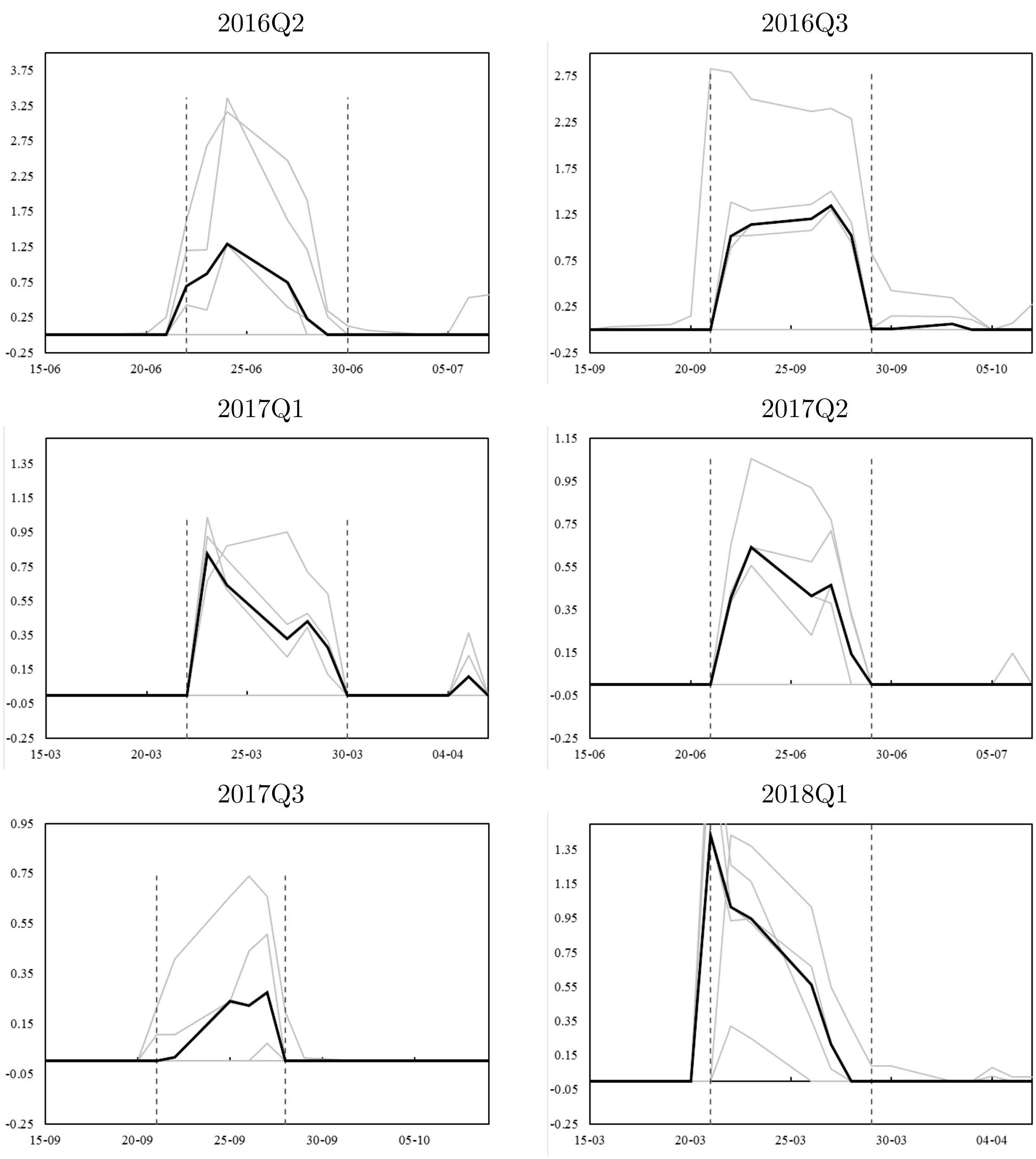
Do higher CIP deviations result in higher drawings from the swap line? Figure A11 shows the allotment at 1-week operations of the ECB and Bank of Japan, the two central banks that had significant drawings even after the intense phase of the crisis, until end 2018.[53]

Let $q_{j,t}$ be the flow of dollars allocated by a central bank in swap-line country j at a one-week operation at date t. We estimate the following regression over time for each country j:

$$\log(q_{j,t}) = \alpha_j + \beta_j x_{j,t-1} + \varepsilon_{j,t}. \qquad \text{(A9)}$$

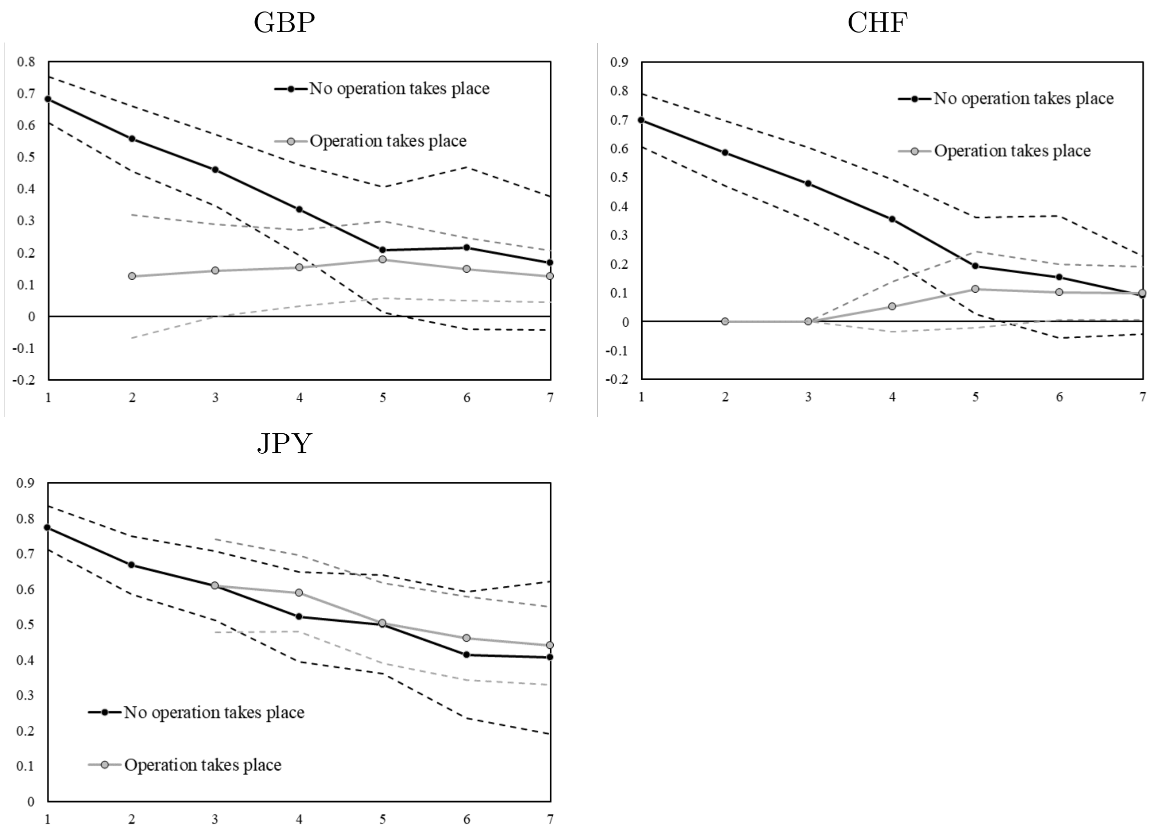
[53] The BoJ commenced 1 week auctions on the 29th of March 2011.

Figure A9: Daily CIP deviation minus swap line ceiling around quarter ends



Notes: See notes to figure 6.

Figure A10: Linear probability estimates of CIP deviation breaking the ceiling: GBP, CHF, JPY.



Notes: See notes to panel (a) in figure 7.

Figure A11: Allotment at USD operations by ECB and BoJ, and CIP deviations

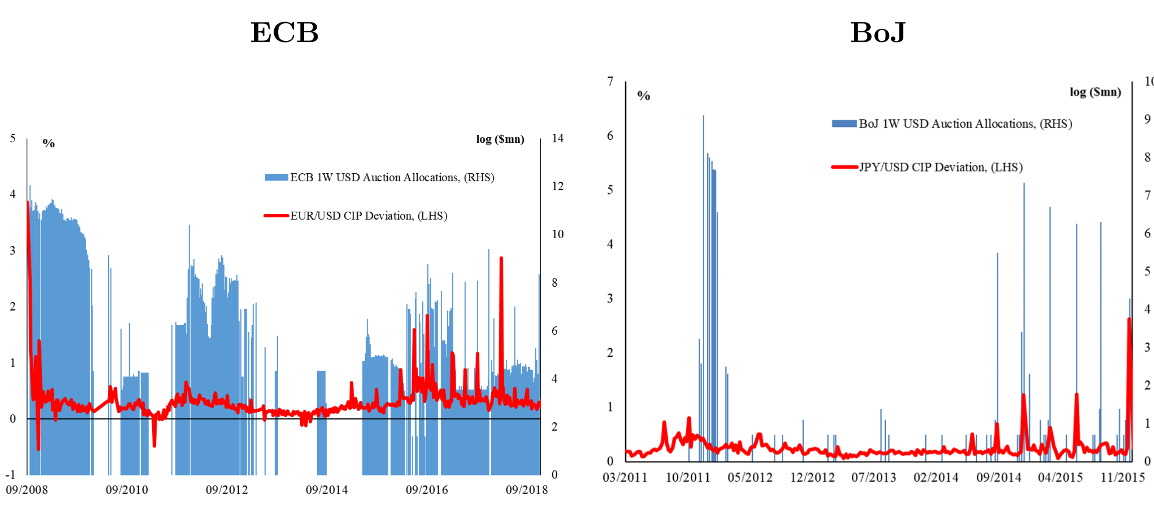


Table A6: Auction allotments and funding costs

	ECB: USD Auctions	BoJ: USD Auctions	ECB: EUR Auctions
	$\log(q_{j,t})$	$\log(q_{j,t})$	$\log(q_{j,t})$
$x_{j,t-1}$: CIP Deviation	1.6202***	1.0009***	
	(0.325)	(0.420)	
$x_{j,t-1}$: 1-week Libor-OIS			4.7942***
			(1.084)
N	360	176	540
Adjusted R^2	0.04	0.14	0.14

*Notes: Estimates of equation (A9). CIP deviation is the 1-week EUR or JPY vis-a-vis the USD on the day prior to the auctions. We consider auctions where a positive amount is alloted between the 19th September 2008 (the date of the first multilateral Federal Reserve swap agreement) through to 31st December 2018. Robust standard errors are in brackets. *** denotes statistical significance at the 1% level; ** 5% level;* 10% level.*

The terms of these dollar operations were announced in advance and were well known at most operation dates. Moreover, as described, these were full allotment auctions, where banks could borrow as much as they wanted at this rate. Thus, the supply of dollars was horizontal and known. Therefore, this regression identifies the demand curve for central bank liquidity.

Table A6 shows the results. The elasticity of demand for dollars by European banks is 1.5%, while that by Japanese banks is 1.0%. Both elasticities are positive, as the theory predicts, and surprisingly close to each other.[54] By way of comparison, the last column of the table presents a different estimate, of the elasticity of euros lent out by the ECB in its 1 week operations with respect to the marginal cost of borrowing, the 1 week euro LIBOR-OIS spread. The elasticity is 4.8%, so the link between CIP deviations and swap line drawings is less strong that that between domestic currency lending facilities and domestic interest rates. [55]

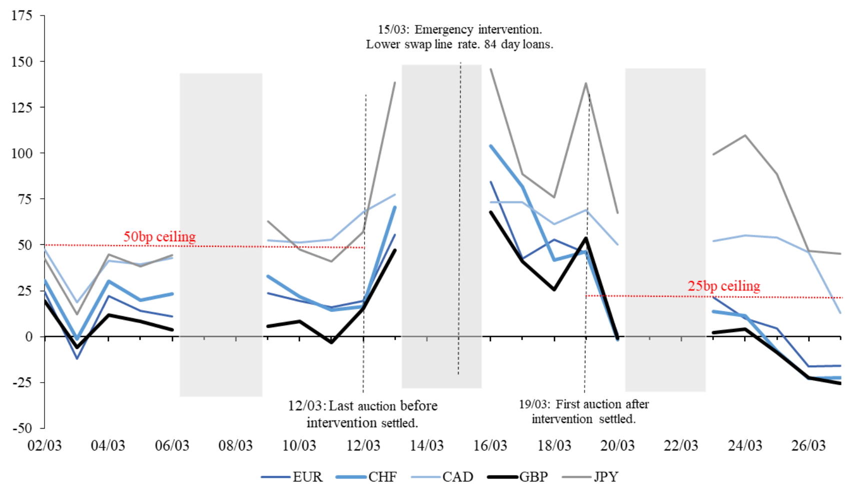
E.5 The Coronavirus crisis of March 2020

The outbreak of the Coronavirus in the first quarter of 2020, and the economic containment measures that followed, created a large shock to dollar funding markets. CIP deviations spiked during the week of March 9-13. On March 15th, the swap line rate was cut by 25bp, and 3-month operations were reinstated. The first bids under the new regime settled on March 19th. On March 20th, the network of central banks announced that from March 23rd onwards, daily operations on the one-week swap would commence. Finally, on March 19th, the Fed extended the swap line arrangements to nine other countries: Australia, Brazil Mexico, Denmark, Korea, Norway, New Zealand, Singapore, and Sweden.

[54] We have also estimated a Heckman model to adjust for any potential selection effect from the operations where no amount was allotted. This yielded very similar results.

[55] From the perspective of the recipients, Rose and Spiegel (2012) find a cross-sectional relation between the amount of dollars lent out by the Fed, and the CDS rates of the recipient countries.

Figure A12: CIP deviations for swap-line currencies in March of 2020



In a companion note, Bahaj and Reis (2020*a*), we explore this episode in more detail, comparing CIP deviations for 17 currencies between old and new members of the network, those with and without operations, and those in and out. Broadly, the results confirm the theoretical predictions and empirical results in this paper. Figure A12 illustrates this for the sample of 5 currencies in this paper.

The figure shows the timing of the March policy interventions and operations aligned with 3-month LIBOR-equivalent dollar CIP deviations (shaded areas denote weekends). It also plots an hypothetical approximate ceiling that ignores the LIBOR-OIS spread and the possibly-binding collateral requirements. After the settlement of the swap line auction on March 12th, CIP deviations spiked, as the crisis flared. The cut in the swap line was announced during the weekend, but it only came into effect once the next operation was settled on Thursday the 19th. During that week, CIP deviations moved downwards but spiked again just before the operation. After the settlement though, CIP deviations for European currencies fell below the new ceiling as the theory predicts. The high yen-dollar CIP deviation persisted until the large drawings by Japanese banks from the swap line were settled on the 26th. Finally, CIP deviations for the Canadian dollar were relatively insensitive to the interventions. This is consistent with the theory, because the Bank of Canada has never had any swap line operation, as of the end of March of 2020.[56]

F Additional results on bond flows estimates

This section describes further results and robustness checks on our empirical analysis in section 6.

[56] It announced it intended to start a US dollar lending facility, should the need arise, on March 20th.

Table A7: Robustness of fixed-effects panel regression on investment flows

	(1)	(2)	(3)
	falsification, four weeks prior	*include lag*	*collapse window, bootstrap errors*
$Post_t \times Swap_a$	0.0087	0.0879*	0.0799*
$\times USDBond_b$	(0.021)	(0.050)	(0.045)
$n_{a,b,t-1}$		-0.1200***	
		(0.014)	
N	127220	205074	41080
bank × *period* f.e.	Yes	Yes	Yes
bank × *bond* f.e.	Yes	Yes	Yes
period × *bond* f.e.	Yes	Yes	Yes

*Notes: Further estimates of equation (8) as robustness of table 2. Column (1): falsification study using an event window of four weeks before. Column (2): include the flow in the previous day as a further explanatory variable. Column (3): collapse the sample into pre- and post announcement with means and bootstraps errors at the firm level. Otherwise, standard errors clustered at the bank and bond level in brackets. *** denotes statistical significance at the 1% level; ** 5% level;* 10% level.*

F.1 Robustness of triple-diff bond flows estimates

Table 2 presented triple-difference estimates of the effect of the swap line on demand for dollar denominated bonds. Table A7 considers the robustness of these estimates.

The first column shows a falsification test, reestimating the regression on an event window four weeks prior to the swap rate change; we find no evidence of an effect, suggesting again that our results are not a manifestation of a pre-existing trend.

The second column introduces the flow in the previous day to show that possible inertia in portfolio adjustment is not affecting our results.

The third column is more conservative with regards to inference. We collapse the observations into pre- and post-event averages to reduce the autocorrelation in our data. We also block bootstrap the standard errors at the bank level to address the fact the we have a relatively small number of banks in our sample. This has no impact on our results.

F.2 Robustness of bank equity returns estimates

Table A8 presents the equivalent to Table 4 when we compute excess returns additionally controlling for the Fama-French size (SML), book to market (HML), profitability (RMW) and investment (CMA) factors from Fama and French (2015). This makes no meaningful difference to the results.

Table A8: Average bank excess returns after swap line rate change: excess returns relative to 4 Fama-French factors

	Swap Line Banks		US Banks	Other Banks
	US Presence	*No US Presence*		
Average	0.0272**	0.0101	0.0048	-0.0033
	(0.0131)	(0.0067)	(0.0105)	(0.0112)
Size Weighted	0.0241**	0.0298***	0.0206***	0.0029
	(0.0122)	(0.0084)	(0.0054)	(0.0106)
N	36	72	309	24

*Notes: Excess returns computed over 3 days using a beta to local market return and the SMB, HML, RMF and CMA Fama-French factors estimated over the 100 days prior to 01/11/11. Swap line countries: Canada, Euro-Area, Switzerland, Japan, United Kingdom. Non swap line: Australia, Norway, Denmark, Sweden, US. Bank returns and resident country sourced from Datastream. US presence taken from "U.S. Agencies and Branches of Foreign Banking Organisations" dataset. Bootstrapped confidence intervals constructed by randomly sampling event dates over the window 01/06/10-31/11/11. *** denotes statistical significance at the 1% level; ** 5% level;* 10% level.*

G Data Sources and Construction

Appendix G.1 describes the data used to measure CIP deviations and the ceiling in section 4. Appendix G.2 the data on bond flows, and appendix G.3 the data on bank equity returns, used in section 3.3. Appendix G.4 describes the data on central-bank auctions used in appendix E.4.

G.1 Financial market data used to construct CIP deviations and ceilings

We obtain the data on interest rates, spot and forward exchange rates primarily from Refinitiv Datastream at a daily frequency. Exceptions include some OIS rates, which are taken from Bloomberg and some central bank policy rates, which are taken directly from the institution's website. Quote data on FX swaps and spot exchange rates are taken from Refinitiv Datascope. Here we list specific data series along with the source used to construct CIP deviations $x_{j,t}$, and swap line ceilings $c_{j,t}$.

Table A9 presents summary statistics by currency vis-a-vis the USD for two alternative measures and samples of daily CIP deviations: (i) where i and i^* are defined as 1-week OIS rates over the period following 19th September 2008 for swap line currencies as used in sections D.8 and 5, and appendix E.4; and (ii) where i and i^* are defined as 1-week LIBOR rates over the period 1st January 2010 to 31st of October 2011 for the treatment and control group so as to summarise deviations in the build up to the change in the swap line rate on the 30th November 2011 as analysed in section 4.2.

For computing libor CIP deviations with a 3 month tenor, as in column (8) of table 1, replace the final two characters in the Libor interest rate tickers below with 3M (rather than 1W) and the final two characters of the forward exchange tickers with 3F (rather than WF).

Swap Line Currencies data:

USD: The 1-week OIS rate is Datastream ticker OIUSDSW. The 1-week LIBOR rate is Datastream ticker BBUSD1W.

EUR: The 1-week OIS rate is Datastream ticker OIEURSW. The 1-week LIBOR rate is Datastream ticker BBEUR1W. The spot price of a USD in EUR is Datastream ticker EUDOLLR. The 1-week forward price of USD in EUR is Datastream ticker EUDOL1W. The ECB deposit facility rate is Datastream ticker EURODEP. The ECB main policy rate is the rate on the short term repo facility, Datastream ticker EURORPS. For the quote data: the 1 week EUR FX swap versus USD has Datascope RIC EURSW=, the spot exchange rate is EUR=.

GBP: The 1-week OIS rate is Datastream ticker OIGBPSW. The 1-week LIBOR rate is Datastream ticker BBGBP1W. The spot price of a USD in GBP is Datastream ticker UKDOLLR. The 1-week forward price of USD in GBP is Datastream ticker UKUSDWF. The BoE main policy rate is the Bank rate, Datastream ticker LCBBASE. The BoE deposit facility rate is Datastream ticker BOESTOD, with policy rate -25bp prior to 20th October 2008. From 5th March 2009 the Bank of England switched to a floor system and we set the deposit facility rate equal to the policy rate. For the quote data: the 1 week GBP FX swap versus USD has Datascope RIC GBPSW=, the spot exchange rate is GBP=.

JPY: The 1-week OIS rate is Bloomberg ticker JYSO1Z Curncy. The 1-week LIBOR rate is Datastream ticker BBJPY1W. The spot price of a USD in JPY is Datastream ticker JAPAYE$. The 1-week forward price of USD in JPY is Datastream ticker: USJPYWF. The BoJ main policy rate is Datastream ticker JPCALLT; the BoJ opened its complementary deposit facility on 31/10/2008, the deposit interest rate has been equal to policy rate since its introduction, hence we always treat the deposit facility rate as the policy rate (see weblink). For the quote data: the 1 week JPY FX swap versus USD has Datascope RIC JPYSW=, the spot exchange rate is JPY=.

CAD: The 1-week OIS rate is Bloomberg ticker CDSO1Z Curncy. The 1-week LIBOR rate is Datastream ticker BBCAD1W. The spot price of a USD in CAD is Datastream ticker CNDOLL$. The 1-week forward price of USD in CAD is Datastream ticker USCADWF. The BoC main policy rate comes directly from the BoC website and the series code is V39078 (Bank Rate). The deposit facility rate is the lower corridor rate, series code V39076. For the quote data: the 1 week CAD FX swap versus USD has Datascope RIC CADSW=, the spot exchange rate is CAD=.

CHF: The 1-week OIS rate is Bloomberg ticker BBCHF1W. The spot price of a USD in CHF is Datastream ticker SWISSF$. The 1-week forward price of USD in CHF is Datastream ticker USCHFWF. For technical reasons, the CHF TOIS fixing in not an effective gauge of risk free interest rates in CHF (and has recently been replaced with SARON). Since the SNB directly targets CHF

LIBOR rates, and the CHF 1-week LIBOR adheres closely to that target (subject to a corridor system) we prefer to use always LIBOR rates for our CHF basis. Our regression results in section D.8 are robust to using the TOIS fixing as an alternative, but with a CHF/USD basis based on TOIS there are persistent and large ceiling violations in 2015. The SNB main policy rate is Datastream ticker SWSNBTI (3 month LIBOR Target). The deposit facility rate is the lower bound on the 3 month LIBOR target, Datastream ticker SWSNBTL. For the quote data: the 1 week CHF FX swap versus USD has Datascope RIC CHFSW=, the spot exchange rate is CHF=.

Non-Swap Line Currencies data: 1-week OIS rates are not always available for all the currencies that are not part of the swap line network. Hence we exclusively compute bases using LIBOR and the central bank interest on excess reserves (this also applies to the equivalent USD interest rates).

AUD: The 1-week LIBOR rate is Datastream ticker GSAUD1W. The spot price of a USD in AUD is the inverse of Datastream ticker AUSTDOI. The 1-week forward price of USD in AUD is Datastream ticker USAUDWF. The interest rate on excess reserves is the RBA cash rate, Datastream ticker RBACASH, less 25 basis points. For the quote data: the 1 week AUD FX swap versus USD has Datascope RIC AUDSW=, the spot exchange rate is AUD=.

DKK: The 1-week LIBOR rate is Datastream ticker CIBOR1W. The spot price of a USD in DKK is Datastream ticker DANISH$. The 1-week forward price of USD in DKK is Datastream ticker USDKKWF. The interest rate on excess reserves is the daily minimum of the Danmarks Nationalbank's official certificates of deposit rate sourced directly from DNB statbank table DNRENTD and the Danmarks Nationalbank's Current Account Rate, Datastream ticker DKFOLIO. For the quote data: the 1 week DKK FX sawp versus USD has Datascope RIC DKKSW=, the spot exchange rate is DKK=.

NOK: The 1-week LIBOR rate is Datastream ticker NWIBK1W. The spot price of a USD in NOK is Datastream ticker NORKRO$. The 1-week forward price of USD in NOK is Datastream ticker USNOKWF. Norway operates a floor system, so the interest rate on excess reserves is the Norges Bank's reserve rate, Datastream ticker NWRESVR. For the quote data: the 1 week NOK FX swap versus USD has Datascope RIC NOKSW=, the spot exchange rate is NOK=.

NZD: The 1-week LIBOR rate is Datastream ticker GSNZD1W. The spot price of a USD in NZD is Datastream ticker NZDOLL$. The 1-week forward price of USD in NZD is Datastream ticker USNZDWF. The interest rate on excess reserves is the RBNZ official cash rate, Datastream ticker: NZRBCSH. For the quote data: the 1 week NZD FX swap versus USD has Datascope RIC NZDSW=, the spot exchange rate is NZD=.

SEK: The 1-week LIBOR rate is Datastream ticker SIBOR1W. The spot price of a USD in SEK is Datastream ticker SWEKRO$. The 1-week forward price of USD in SEK is Datastream ticker

USSEKWF. The interest rate on excess reserves is the Riksbank's deposit facility rate, Datastream ticker SDDEPOS. For the quote data: the 1 week SEK FX swap versus USD has Datascope RIC SEKSW=, the spot exchange rate is SEK=.

Computing CIP deviations from FX swap quotes: We download all available quotes for 1 week FX swaps versus USD for the ten currencies in our sample on Thomson Reuters Datascope over the period November 2011 to 31st January 2012. We then drop quotes that occur over the weekend, on holidays or between 21:40-06:50 London time. This leaves us with 1,763,608 unique quotes across 10 currencies in November 2011 (671,388), December 2011 (534,971) and January 2012 (557,249). We take the mid swap price in swap points and match each quote to the mid-spot exchange rate in the minute that the quote was taken. The mid spot is calculated as the average of the mid open and mid close in the minute interval; these are computed directly by Datascope using the intraday summary feature. This enables us to calculate the implicit outright forward price in the swap and hence the log forward premium. Note that GBP, AUD and NZD swaps and spot exchange rates are quoted in USD per local currency unit and hence we transform the quotes accordingly. We then use the relevant daily interest rate fixing (OIS/LIBOR) to compute the CIP deviation.

Ceiling violations: Daily ceiling violations are defined as the indicator $\mathbf{1}(viol_{j,t}) = \mathbf{1}(x_{j,t} > (i^s_t - i_t) + (i^{p*}_{j,t} - i^{v*}_{j,t}))$ where $x_{j,t}$ is the 1 week OIS CIP deviation vis-a-vis the USD on day t for currency j. In addition, we allow for 2bp of grace before defining the ceiling as violated.

G.2 Bond flow data

G.2.1 Data Sources and Coverage

The starting point is to establish a universe of potentially-traded corporate bonds in November 2011. We do this by breaking out the securities used in any of the following Bank of America/Merrill Lynch Corporate Bond Indices (BAML) as of 30th January 2012[57]: *Global Broad Market Corporate Index; Global Emerging Market Credit Index; Global High Yield Index; U.S. Corporate Master Index; U.S. High Yield Master II Index; Sterling Corporate Securities Index; Sterling High Yield Index; EMU Corporate Index; Euro High Yield Index.* This provides a list of corporate bonds (by ISIN) and their relevant charactistics (Issuer, Rating, Face Value, Currency etc.). From this list we then exclude bonds issued by financials and banks (industries "CASH" and "FNCL" in the BAML data). This leaves us with 8512 unique bonds.

Our data on bond transcations comes from the UK financial conduct authority's (FCA) ZEN dataset. This data is confidential regulatory data collected under the EU Markets in Financial

[57]This is the earliest observation we have, but the index composition is unlikely to change dramatically in the two months since the event. Note that this omits bonds that mature before 30 January 2012 so bonds with only a couple of months of residual maturity are excluded from our sample.

Table A9: CIP deviations summary statistics (1 week vs USD)

	mean	std. dev.	median	25th %-ile	75th %-ile	N
OIS based CIP Deviations: 19 Sep 2008 - 31 Dec 2015						
EUR	.27	.43	.21	.14	.29	1900
GBP	.12	.32	.08	.03	.11	1900
JPY	.29	.44	.19	.14	.27	1900
CHF	.34	.55	.24	.13	.37	1900
CAD	.09	.23	.07	.02	.12	1900
LIBOR based CIP Deviations: Jan-2010 to October-2011						
EUR	.2	.2	.17	.11	.25	767
GBP	.085	.087	.078	.013	.14	767
JPY	.2	.21	.16	.099	.23	767
CHF	.24	.28	.2	.093	.33	767
CAD	.033	.067	.037	-.001	.076	767
SEK	.11	.15	.12	.043	.18	767
DKK	.46	.23	.45	.34	.55	767
NOK	.26	.18	.25	.21	.32	767
AUD	-.0083	.26	.033	-.016	.086	767
NZD	.014	.15	.039	-.019	.09	767

Notes: Sample covers trading days from 19th September 2008 (date of the first multilateral Federal Reserve swap agreement) through to 31st December 2015.

Instruments Directive (better known as MIFID I). The coverage is as follows. (A) All trades by UK-regulated firms in bonds admitted to trading on regulated markets. (B) All trades by EEA-regulated firms in bonds that are (i) admitted to trading on regulated markets, and (ii) issued by entities where the registered office is in the UK. It is useful to breakdown this definition. The term admitted to "admitted to trading on regulated markets" means that the bond is listed on an exchange somewhere worldwide (not necessarily in the UK or EEA). This requirement is also bond specific, not trade specific, so as long as the bond is traded on a regulated market somewhere, OTC transactions in the bond still need to be reported. UK-regulated firms includes the subsidiaries of foreign banks (including EEA banks) that operate in the UK and hence are regulated by the FCA. In the data, the large majority of trades occur in bonds where the issuer is not based in the UK. Hence the second requirement that EEA regulated entities report their trading in UK bonds is less relevant for determining the sample.

If the firms on either side of the trade are covered by the data then we will see both legs of a trade, in that sense there is double counting in our analysis. However, we sum across trades to generate daily flows and since the bonds can be supplied by firms outside the sample it is not the case that the net flow needs to equal zero.

G.2.2 Sample selection

We take the intersection between the bonds in the BAML indices and trades recorded in the ZEN data for trading days between 14th November and the 15th of December 2011 (we exclude bonds issued after 14th November). The sample period consists of the five weeks centred around the swap line rate change on the 30th of November and contains 98,252 individual trades.

Banks: We use a pre-existing Bank of England algorithm to identify most of the firms trading in the dataset; the remainder we identify via web searches on the firm's name. There may be multiple legal entities trading under the umbrella of a given bank or securities firm and we merge these accounts at the group level. One consequence of this is that we cannot distinguish between trades that a bank makes on behalf of clients versus their own books. This is a weakness in the data. We focus solely on the firm that reports the transaction rather than the counterparty. This means that we do not attempt to discern trades that, for whatever reason, are not reported by a firm by looking at trades where that firm is the counterparty. This is for simplicity and to limit mistaken double counting.

159 firms report trades in securities at the intersection between the BAML and ZEN data. To ensure similarities between treatment and control groups we drop firms who are not banks (53 firms). Many banks in the data only trade once or twice over the sample period. Our regression design, as articulated in the main text, uses a balanced panel of net daily flows by trading banks into specific bonds. Therefore we exclude infrequently trading banks to avoid adding large numbers of zeros into the sample. We drop banks who transact in fewer than 4 bonds a day on average and

trade less than 80% of trading days. Adding inactive banks does not meaningfully affect our point estimates but raises the standard errors substantially. This leaves us with 26 banks, 19 of which are headquartered in countries where the central bank had acccess to a swapline.

Bonds: The intersecton between the ZEN and BAML datasets covers 1703 unique bonds. Many of these bonds are infrequently traded and only appear a few times in the dataset: the median bond is traded 30 times and the bond in the 25th percentile traded just 7 times. Furthermore, some bonds have trades that are heavily concentrated in only a couple of days within our sample. Again to avoid a sparse panel, we exclude any bond where it is not the case that at least one trading firm has non-zero net flows into the bond in at least 50% of trading days. This leaves us with 77,086 trades covering 790 unique bonds, issued by 167 unique entities, of which 69 are USD denominated.

G.2.3 Data handling

For each bank we calculate the net flow into a particular bond each trading day. As a measure of bank activity we take the sum of the absolute value of these net flows across all 790 bonds in our sample averaged across the 25 trading days. We then scale the net flow into each bond by each bank by this activity measure. This is the dependent variable in our regression. We set up our dataset as a balanced panel such that when no trades are recorded in a day between a particular bank-bond pair a zero entry for the net flow is added.

The ZEN data can contain erroneous entries. These can substantially distort the results if the trade is recorded at the wrong order of magnitude: e.g. if the return is for 10 million units rather than the 10,000 actually traded. This is apparent in the data: some trades are for many multiples of the outstanding market value of the bond. To circumvent this issue we trim the daily flow data at +/-1%, dropping observations that are very large in absolute magnitude.

We convert all currencies into USD using the prevailing exchange rates on the 1st of November 2011.

G.2.4 Summary Statistics

Table A10 presents summary statistics for the different bonds and banks in our sample. The average bond trades 3.9 times a day with an average trade size of $616,000 and a volume of $2.5mn. The dollar denominated bonds have similar characteristics, both in terms of trading behaviour and residual maturity, face value, etc. If we observed the universe of trades, every bond would be in zero net supply and there would be no net daily flow into any bonds. This is not exactly the case in our data but average net daily flows are typically relatively small. The average bank in our sample trades 119 times per day with an average volume of $76mn. The sum of absolute net flows into all bonds, our activity measure, averages about $45mn per day across our 26 banks.

Table A10: Summary statistics for the bond flows data

	mean	std. dev.	median	25th %-ile	75th %-ile	N
By Bond						
All bonds						
Trades per day	3.9	3.3	2.8	1.8	4.8	790
Daily volume ($ '000s)	2496	2083	1950	1095	3191	790
Average net daily flow ($ '000s)	15	404	15	-195	234	790
Residual Maturity (years)	6.3	6.1	4.6	2.7	7.2	790
High Rating (A- or greater = 1)	0.5	0.5	1	0	1	790
Face Value ($ mn)	1116	643	1024	683	1365	790
USD bonds						
Trades per day	3.6	2.3	3.1	2.1	4.8	69
Daily volume ($ '000s)	1832	2018	1075	419	2007	69
Average net flow ($ '000s)	-35	278	-18	-146	108	69
Residual Maturity (years)	7.2	7.9	4.3	2.5	7.8	69
High Rating (A- or greater = 1)	.61	.49	1	0	1	69
Face Value ($ mn)	1271	734	1000	750	1750	69
By Bank						
Trades per day	119	99	98	30	190	26
Daily volume ($ '000s)	75833	69965	59441	10099	122618	26
Average trade size ($ '000s)	616	314	618	421	793	26
Average net flow ($ '000s)	447	11882	21	-3723	5359	26
Activity measure ($ '000s)	44906	39253	38174	6090	78302	26

G.3 Bank equity returns

We obtain returns on bank equity from Datastream. We extract return indices for all banks listed in datastream in the following markets: U.K., Switzerland, Canada, Japan (non-Euro Area swapline banks); Germany, France, Spain, Italy, Belgium, Portugal, Netherlands, Ireland, Austria (Euro-area swap line banks); Australia, Norway, Denmark, Sweden (banks in countries without a swap line); and the U.S. We extract the total market return for each country to serve as the benchmark for computing excess returns. We exclude banks for where there are gaps in coverage anytime between 1st July 2010 and the 31st of December 2012. We exclude banks with very illiquid stocks where the the price changes in less than 50% of trading days. This leaves us with the sample described in the main text.

The market capitalization of the banks is calculated as of 1st November 2011 and converted into USD using the prevailing exchange rate.

In the robustness section we additionally use the Fama-French size (SML), book to market (HML), profitability (RMW) and investment (CMA) factors to compute excess returns. These are downloaded directly from Ken French's website.

G.4 Data on Central Bank Operations

In appendix E.4 we use data on operations by the ECB and the Bank of Japan. Summary statistics are presented in table A11. The data description for each central bank is below.

ECB: The operation data was downloaded from the ECB's history of open market operations website. Dollar Operations are those where the operation currency is listed as USD. We define a one week operation to include any duration between 5 and 16 days. This maximum is to capture that the regular one week auction is substituted by a two week auction around year end. We focus solely on reverse transactions. This leaves us with 516 operations of which 360 have a positive amount alloted between 19th September 2009 and 31st December 2018. All bar one operation (26th September 2009) have unlimited allotments at a fixed rate (dropping this observation does not affect the results).

Euro operations are all liquidity providing auctions where the operation is denominated in EUR with a duration greater than our equal to 5 days and less than or equal to 13 days. This largely captures the ECB's main refinancing operation. We consider auctions between 1st September 2009 and 31st December 2018: this provides 540 operations all of which have a positive amount allotted.

BoJ: The data was downloaded from Market Operations by the Bank of Japan section of the BoJ's website. We combine details of the BoJ's U.S. Dollar Funds-Supplying Operations against Pooled Collateral from the monthly tables to draw together a database of all USD operations by the BoJ. We then focus on the operations where the duration is between 6 and 21 days (as with the ECB the 21 day operation replaces the weekly operation over the year end of 2012). The first operation took place in 29th of March 2011 and there were 401 in total by the time our sample ends at the 31st December 2018. Of those operation, 176 had a positive amount allotted.

Table A11: Operation summary statistics

	mean	std. dev.	median	25th %-ile	75th %-ile	N
ECB USD Operation						
Amounts Alloted ($mn)	10102	22534	304	75	3729	360
Number of Bidders	6.2	11	2	1	6	360
ECB EUR Operations						
Amounts Alloted (Eur mn)	97277	70879	92542	43935	131179	540
Number of Bidders	150	150	107	71	154	540
BoJ USD Operations						
Amounts Lent ($mn)	196	822	2	1	10	176

Notes: 1 week operations over from 19th September 2008 (date of the first multilateral Federal Reserve Swap Agreement) through to 31st December 2018. Operations where no amount is alloted are excluded.