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David VanHoose, Professor of Economics and Herman Lay Professor of Private Enterprise, Hankamer School of Business, Baylor University.

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Enzo Dia*, David VanHoose†

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† *Professore Associato, Dipartimento di Economia, Metodi Quantitivi e Strategie di Impresa, Università degli Studi di Milano Bicocca, Piazza Ateneo Nuovo 1, Milano 20126, Italy.*

‡ *Professor of Economics and Herman Lay Professor of Private Enterprise, Hankamer School of Business, Baylor University, One Bear Place #98003, Waco, TX 76798*

Abstract

A linchpin of the Federal Reserve's unconventional policies has been payment of interest on reserves, of which 16 to 44 percent have been held by foreign banks with U.S. subsidiaries, at a rate typically several basis points higher than other funds rates. This paper constructs a model with competition among domestic banks, foreign banks with domestic subsidiaries, and other foreign banks in dollar-denominated common and local retail markets for loans and deposits. The paper shows that the interest rate on reserves influences not only loan and deposit rates domestically but also in Eurodollar-denominated foreign retail markets. The paper also explores implications for steady-state adjustments and dynamic responses of balance sheets and retail rates to parameter changes and exogenous shocks.

JEL classification: G21, G28, E43
Keywords:

1 Introduction

Much has been written concerning implications of the Federal Reserve's post-2008 unconventional polices. Most studies have focused on the impacts of these policies on financial markets and on the nature of and transmission of resulting monetary adjustments. Not as widely discussed have been a key unconventional-policy linchpin, which has been the Fed's

*Email: enzo.dia@unimib.it.
†Corresponding author. Email: David_VanHoose@baylor.edu

payment of interest on reserves at an administered rate. Since early 2009, the Fed's interest rate on reserves typically has been set equal to or above the federal funds rate. During much of 2008-2018 and 2020-2022 intervals, in fact, the Fed established an interest rate on reserves at or above the upper range of its target for the federal funds rate. These interest-on-reserves settings, as demonstrated by Dutkowsky and VanHoose (2017, 2020) gave private banks strong incentives to substitute away from lending in the federal funds market in favor of holding interest-bearing reserves over and above those reserves they had been required by the Fed to hold prior to March 2020. Indeed, as discussed by Bech and Klee (2011) and Afonso et al. (2013), over lengthy periods, government-sponsored institutions, such as the Federal Home Loan banks, the Federal National Mortgage Association, and the Federal Home Loan Mortgage Corporation, have been the primary lenders of federal funds. Private bank borrowers of these funds typically have placed them on reserve at Federal Reserve banks to earn interest at the higher interest rate available on balances held in Fed reserve accounts.

Among the institutions earning interest on reserves at a higher rate than has often been available in private overnight markets have been foreign banks with U.S. subsidiaries that maintain reserve accounts with the Fed. Figure 1 shows that these non-U.S. depository institutions have consistently maintained hundreds of billions of dollars of reserves at Federal Reserve banks.[1]

Figure 2 indicates that these large volumes of reserves held at the Fed by foreign banks with U.S. operations have accounted for between 16 percent and about 44 percent of total reserves maintained with Federal Reserve banks since 2008. A consequence is that significant fractions of the Fed's total interest payments on reserves have been transmitted to non-U.S. depository institutions, a fact emphasized by Selgin (2019) and publicized at times by the U.S. financial news media—see, for instance, Cherney (May 8th, 2014), Tracy and Hilsenrath (September, 29th, 2014), and Burne (December 23rd, 2015).

The important role that foreign banks play in U.S. banking markets is a byproduct of the large amount of dollar–denominated retail banking transactions that foreign banks conduct outside of the United States. Over the course of the past six decades, foreign banks—mainly European and primarily based in London—have accumulated ever larger dollar–denominated deposits. Subsequently, these banks have allocated their dollar deposits for loans to third parties rather than remitting the foreign currency to their home central banks or

[1] McCauley and McGuire (2014) provides evidence on the evolution over time of these foreign claims and the instruments that foreign banks use to finance their reserve holdings.

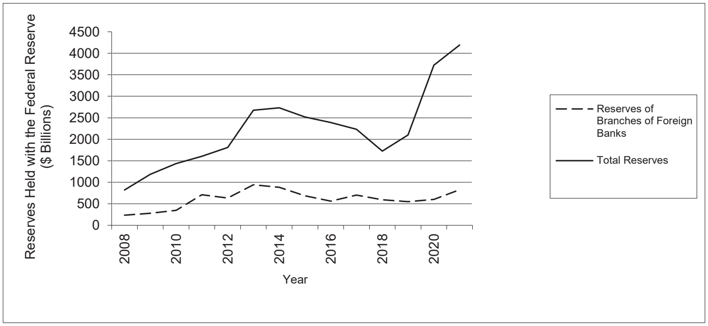

Figure 1: Nominal reserves held with Federal Reserve banks (Source: Board of Governors of the Federal Reserve System).

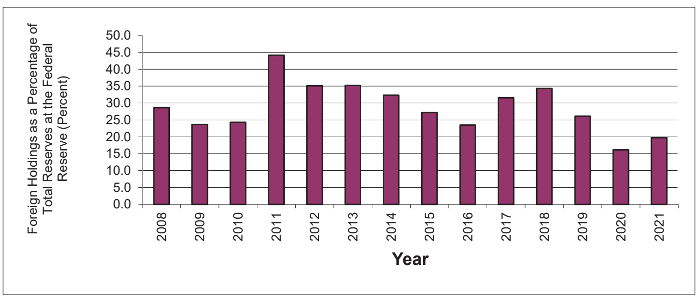

Figure 2: Reserves of subsidiaries of foreign banks as a percentage of total reserves held with Federal Reserve banks (Source: Board of Governors of the Federal Reserve System).

depositing the funds in their accounts in the United States.[2] Based on BIS data, McCauley et al. (2015) indicate that dollar-denominated credit to nonfinancial borrowers outside the United States had reached $8 trillion by 2014, with foreign holdings of more than $5 trillion comprising almost three-fourth of the total. This credit is largely financed by means of foreign dollar deposits, albeit with non-U.S. banks more dependent on wholesale dollar funding than their domestic counterparts, as documented by He and McCauley (2013a).

Hence, two sets of separate, but strictly interconnected and quantitatively important dollar–denominated retail banking markets exist: domestic U.S. dollar loan and deposit markets and Eurodollar–denominated foreign loan and deposit markets, with some foreign banks with U.S. subsidiaries operating in both markets. In this paper, we model the interactions across these retail banking markets, with particular emphases on reserve holdings with the Federal Reserve and on the responses of banks' balance sheets to changes in the Fed's interest rate on reserves, regulatory innovations, and quantitative easing.

To the best of our knowledge, the academic literature has not explored important implications of the Fed's annual payments of billions of dollars in interest on reserves to both U.S. and non-U.S. banks for retail bank loan and deposit markets. Perhaps one reason for the neglect of this issue has been a natural tendency to emphasize broader monetary and macroeconomic effects of the "QE" expansions of the Fed's balance sheet over the course of the financial-meltdown and pandemic periods, which payment of interest on reserves at a rate at or above short-term funds rates was instrumental in allowing the Fed to engineer. Another reason may be the challenges inherent in seeking to analyze interactions among the bank recipients of interest on reserves within various retail banking markets of different nations. A number of contributions have sought to examine effects of different policies across national banking systems—see, for example, Acharya (2003), Dell'Ariccia and Marquez (2006), and Beck et al. (2013)—albeit within stylized models that tend to focus more attention on the interplay among bank regulators rather than on the market effects of interactions among nations' banks. Indeed, surprisingly little attention has been given to the global banking ramifications of the Federal Reserve's interest-on-reserves-based policy procedure. An important recent exception is Acharya et al. (2022), who emphasize fundamental shifts in bank balance-sheet choices and resulting modifications in patterns of behavior in global retail banking markets under the new procedure. They note the tendency for banks' supply of dollar-denominated reserves to "create its own demand for reserves over time," resulting in sluggish dynamics in reserve adjustments to Federal Reserve policy changes. They also note

[2] Schenk (1998) provides a detailed analysis of the early development of the Eurodollar market.

altered adjustments of spreads between retail rates on dollar-denominated loans and deposits in response to changes in aggregate liquidity and variations in open-market interest rates.

In our view, understanding the nature of these recent shifts in global retail banking patterns requires a careful assessment of the implications of the Fed's payment of interest on the large volumes of reserves held with the Fed by both U.S. and foreign banks for their profit-maximizing balance-sheet decisions and competitive interactions in retail loan and deposit markets. This paper provides a banking framework that is amenable to an evaluation of the implications of the Fed's interest-on-reserves policy for both U.S. and non-U.S. dollar-denominated retail banking markets. Our model of imperfectly competitive loan and deposit markets involving banks based in two nations enables us to analyze the direct effects of the Fed's payment on interest on reserves on choices of competing domestic banks and U.S. subsidiaries of foreign banks and upon equilibrium loan and deposit rates in these markets.

The model also reveals spillover effects that this policy generates for local domestic retail markets and likewise for Eurodollar–denominated foreign retail markets in which foreign banks are the only competitors. Direct effects arise because the Fed's payment of interest on reserves at or above the interbank funds rate causes the interest rate on reserves to be a fundamental determinant of the balance-sheet choices of U.S. banks and of foreign banks with U.S. operations. Consequently, the interest rate on reserves set by the Fed naturally emerges as the key rate to which U.S. retail market loan and deposit rates ultimately are linked. Furthermore, because foreign banks with U.S. subsidiaries whose decisions are so heavily influenced by the Fed's interest rate on reserves also compete with other foreign banks in Eurodollar–denominated foreign loan and deposit markets, that U.S. policy rate also has potentially significant impacts on equilibrium loan and deposit rates in the Eurodollar–denominated foreign retail markets. Ultimately, therefore, cross-national spillovers arising from the Fed's administration of its interest rate on reserves affect the interplay across the determinations of both domestic and foreign dollar–denominated loan and deposit rates. Our model thereby implies that Fed policy choices regarding its interest rate on reserves have a major bearing on retail loan and deposit market outcomes in the United States, in nations whose banks have a significant operating presence within the United States, and in nations in which industrial corporations make considerable use of the Eurodollar-based financing, such as developing countries with relatively small domestic financial markets.

We then analyze numerical solutions of the model for both steady-state equilibria and the responses to exogenous shocks, focusing on the implications for global retail banking markets. Steady-state implications include small adjustments of both domestic and foreign deposits to variations in most parameter values, with the exception of substantial responses to significant quantitative-easing actions on the part of the domestic central bank. In contrast, consistent with the patterns in aggregate U.S. loan data documented by Dutkowsky and VanHoose (2018), steady-state global lending responds minimally to domestic quantitative-easing operations, which also have small impacts on market loan rates. Steady-state variations in other key parameters including, for instance, increased capital requirement ratios or higher deposit insurance expenses, tend to generate more significant effects on total loans and retail loan rates. Global responses of domestic and foreign banks' steady-state reserve holdings to quantitative easing and changes in other key parameters generally are more significant than banks' other balance-sheet adjustments, with more domestic banks' steady-state responses being absolutely larger than those of foreign banks. Implications of dynamic balance-sheet adjustments to shocks include the result that holdings of reserves by foreign banks with domestic subsidiaries are more responsive to a change in the domestic central bank's interest rate on reserves than domestic banks, which is consistent with the data. Both domestic and foreign banks with domestic operations respond to an increase in the interest rate on reserves by increasing their deposit liabilities but also by contracting their lending. Consistent with the steady-state analysis and the conclusions for Acharya et al. (2022), dynamic responses to quantitative-easing shocks have significant positive effects on domestic bank deposits, substantial positive effects on global reserve holdings, and small effects on global retail loan markets. Our work is also related to Acharya and Rajan (2022), who analyze the interactions between the balance sheets of banks and the central bank, but their focus is on liquidity creation and systemic risk following changes in the availability of liquidity induced by monetary policy.

The next section lays out the model we utilize to examine these issues. Section 2 provides an exposition of the basic procedures utilized in solving and analyzing the model within the context of a special case of the model that yields tractable analytical expressions that reveal the fundamental implications noted in the preceding paragraph. Section 3 calibrates the banking framework to the data and provides analyses of the steady-state and dynamic implications of the model for global retail banking markets. Section 4 concludes by summarizing these results and discussing this paper's implications for future research.

2 A Model of Domestic and Foreign Loan and Deposit Markets with Interest on Reserves of Domestic Banks and of Foreign Banks with Domestic Operations

In the model that follows the subscript 1 (domestic, or "U.S") or 2 (foreign, or, for instance, "Eurozone") applies to the location of flows of profits or of asset or liability market activity by a bank, respectively; all retail banking markets are assumed to be imperfectly competitive. There are n_1 identical domestic banks, $n_2^{'}$ identical foreign banks with domestic subsidiaries, and n_2 identical foreign banks with no domestic operations. As indicated in Table 1, the n_1 domestic banks compete head-to-head within a local, or "home", domestic retail loan market for which informational or other entry barriers preclude competition from any foreign banks. In addition, these n_1 domestic banks compete in common loan and deposit markets on an equal footing with the $n_2^{'}$ foreign banks with domestic subsidiaries. The $n_2^{'}$ foreign banks with domestic subsidiaries also compete with the n_2 foreign banks with no domestic operations in eurodollar-denominated foreign loan and deposit markets in which entry barriers result in negligible domestic competition. Naturally, assumed entry barriers might be relaxed, but the presumed market settings are of sufficient number to capture the fundamental set of cross-national interactions. In principle, the identical-banks assumption could also be relaxed but at the cost of considerable reduction in expositional simplicity and solution tractability.

2.1 The Structures of the Loan and Deposit Markets

The n_1 identical domestic banks engage in lending operations in two imperfectly competitive domestically based retail loan markets, via application of a Cournot-rivalry banking framework based on Dia and VanHoose (2018). As indicated in Table 1, the first of these loan markets is a purely local, "home" market populated only by the n_1 domestic banks, each one of which at time t extends an amount of home loans denoted L_{h1t}^{i}, with an aim to maximize profits subject to the Cournot-rivalry assumption of given lending decisions of other rivals and to the presumed linear home market loan demand relationship, where r_{Lh1t} is the domestic home-market loan rate and the overbar indicates a long-run average value. The second retail loan market is one in which the n_1 domestic banks engage in competition in common with the second group of banks made up of $n_2^{'}$ foreign banks with domestic subsidiaries. In this loan market, each one of the domestic banks lends a quantity L_1^i, and lending at each one of the $n_2^{'}$ foreign banks with domestic operations is $L_{1t}^{j'}$. The final retail loan market is a Eurodollar-denominated local foreign market. In this loan market, the n_2' foreign banks that maintain domestic operations compete with n_2 foreign banks that have no domestic operations. The profit-maximizing quantity of lending in this foreign local market by each one of the $n_2^{'}$ banks with domestic operations is $L_{h2t}^{j'}$, and the profit-maximizing lending volume in this market by each one of the n_2 foreign banks with no domestic operations is L_{h2t}^{j}.

Table 1: **Structure of the market**

Market	**Competing Banks**	**Market Constraint Faced by Rival Banks**	**Total Market Quantity**
Domestic Home Loan Market	n_1 Domestic Banks	Home market loan demand: $L_{h1t} = \eta^{-1}(\eta+1)\overline{L}_{h1} - \overline{L}_{h1}(\eta\overline{r_{Lh1}})^{-1}r_{Lh1t}$, first-order approximation to $L_{h1t} = \left[\Sigma_{Lh1}(r_{Lh1t})^{-1}\right]^{\frac{1}{\eta}}$	$n_1 L_{h1t}^{i} = L_{h1t}$
Common Loan Market	n_1 Domestic Banks and $n_2^{'}$ Foreign Banks with Domestic Subsidiaries	Common market loan demand: $L_{1at} = \eta^{-1}(\eta+1) - \overline{L}(\eta\overline{r_L})^{-1}r_{Lt}$ first-order approximation to the more general loan demand function given by $L_{1at} = \left[\Sigma_{L1}(r_{Lt})^{-1}\right]^{\frac{1}{\eta}}$	$n_1 L_{1t}^{i} + n_2^{'} L_{1t}^{j'} = L_{1t} + L_{1t}^{'} = L_{1at}$
Domestic Deposit Market	n_1 Domestic Banks and $n_2^{'}$ Foreign Banks with Domestic Subsidiaries	Domestic deposit market supply: $D_{1at} = \overline{D}_1(\varepsilon\overline{r_{D1}})^{-1}r_{D1t} + \varepsilon^{-1}(\varepsilon+1)\overline{D}_1 + CBF_{1t}$ first-order approximation to the more general deposit supply function by $D_{1at} = \left[\Sigma_{L1}(r_{D1t})^{-1}\right]^{\frac{1}{\eta}}$	$n_1 D_{1t}^{i} + n_{2t}' D_1^{j'} = D_{1t} + D_{1t}' = D_{1at}$
Foreign Home Loan Market	$n_2^{'}$ Foreign Banks with Domestic Subsidiaries and n_1 Foreign Banks with No Domestic Operations	Home loan market demand: $L_{h2at} = \eta^{-1}(\eta+1)\overline{L}_{h2} - \overline{L}_{h2}(\eta\overline{r_{Lh2}})^{-1}r_{Lh2t}$, first-order approximation to the more general loan demand function given by $L_{h2a} = \left[\Sigma_{Lh2}(r_{Lh2t})^{-1}\right]^{\frac{1}{\eta}}$	$n_2^{'} L_{h2t}^{j'} + n_2 L_{h2t}^{j} = L_{h2t}^{'} + L_{h2t} = L_{h2at}$
Foreign Deposit Market	$n_2^{'}$ Foreign Banks with Domestic Subsidiaries and n_1 Foreign Banks with No Domestic Operations	Foreign deposit market supply: $D_{2at} = \overline{D}_2(\varepsilon\overline{r_{D2}})^{-1}r_{D2t} + \varepsilon^{-1}(\varepsilon+1)\overline{D}_2$, first-order approximation to the more general deposit supply function by $D_{2at} = \left[\Sigma_{L1}(r_{D2t})^{-1}\right]^{\frac{1}{\eta}}$	$n_1 D_{2t}^{i} + n\prime_{2t} D_{2t}^{j'} = D_{2t} + D_{2t}' = D_{2at}$

One source of deposit funding by the n_2' foreign banks with domestic operations is assumed to be the domestic deposit market, in which each bank chooses a profit-maximizing quantity of deposits, $D_{1t}^{j\prime}$. These foreign banks with domestic subsidiaries engage in Cournot-rivalry with the n_1 domestic banks, each one of which selects a profit-maximizing amount of deposits, D_{t1}^{i}. To maintain a streamlined, tractable structure for our banking analysis, as in Dutkowsky and VanHoose (2017) we assume that any change in the monetary base on the part of the domestic central bank is willingly accepted (or released) by the public as an increase (or decrease) in deposit supply, which we capture via the term CBF_{1t}. The other deposit-funding source for the n_2' foreign banks with domestic subsidiaries is the foreign Eurodollar-denominated deposit market, in which each foreign bank with domestic operations chooses a profit-maximizing quantity of deposits, $D_{1t}^{j\prime}$. These foreign banks with domestic subsidiaries compete with the n_2 foreign banks without domestic operations, each one of which selects a profit-maximizing amount of deposits, D_{2t}^{j}.

2.2 Banks' Profit Functions

The expected discounted stream of profits of a typical bank among each of the three groups—the n_1 domestic banks, the n_2' foreign banks with domestic subsidiaries, and the n_2 foreign banks with no domestic operations—appear in Table 2, where the discount factor is $b^t = \frac{1}{1+r}$, where r is the subjective rate of time discount, which for the sake of simplicity is assumed to be identical across the bank groups. A domestic bank derives gross per-dollar revenues from its lending activities in the common market in which it also competes with foreign banks with domestic subsidiaries and in its home market with purely domestic competition that determines the market loan rates r_{Lt} and r_{Lh1t}. Each dollar of lending within these markets, however, may be, depending on the bank's loan-monitoring choice, subject to respective per-dollar default rates δ_1 and δ_{h1}. If the bank does not monitor its loans in the respective loan markets, in which case $\beta_1 = 0$ and $\beta_{h1} = 0$, then it must incur these default rates that reduce its net return from lending, but if it incurs respective per-dollar costs c_1 and c_{h1} to monitor the loans, then $\beta_1 = 1$ and $\beta_{h1} = 1$, and the incidence of loan default is eliminated.

The second element that can reduce the net lending return is a linear cost a_{1t}, that is assumed to be the same for both forms of lending by the domestic bank. An example of a factor that can generate such a cost is deposit insurance premiums, which in the United States are now linked more closely to the size of a bank's risky asset portfolio than to its deposits.

The third element, τ_{1t}, is any explicit tax rate that might be imposed on both forms of the bank's lending that is subject to potential default. The possibility of such a tax is incorporated within the model because taxes on risky assets have at various times been proposed in

Profit function for a typical bank among the n_1 domestic banks:

$$\pi_{1t}^{i} = \sum_{0}^{\infty} b^t E\{\{[1-(1-\beta_1)\delta_1] r_{Lt} - a_{1t} - \tau_{1t}\} L_{1t}^{i} + \{[1-(1-\beta_{h1})\delta_{h1}] r_{Lh1t} - a_{1t} - \tau_{1t}\} L_{h1t}^{i}$$
$$+ r_{Xt} X_{1t}^{i} - r_{D1t} D_{1t}^{i} - r_{Et} E_{1t}^{i} - \left(\frac{\mu_1 + \beta_1 c_1}{2}\right)\left(L_{1t}^{i}\right)^2 - \left(\frac{\mu_{h1} + \beta_{h1} c_{h1}}{2}\right)\left(L_{h1t}^{i}\right)^2$$
$$- \frac{\omega_1}{2}\left(D_{1t}^{i}\right)^2 - \frac{\rho}{2}\left(D_{1t}^{i} - D_{1t-1}^{i}\right)^2 - \frac{\sigma}{2}\left(E_{1t}^{i}\right)^2 - \frac{\psi_1}{2}\left(X_{1t}^{i}\right)^2\}. \quad (1)$$

Profit function for a typical bank among the $n_2^{'}$ foreign banks with domestic subsidiaries and subject to foreign capital regulation:

$$\pi_{2}^{j'} = \sum_{0}^{\infty} b^t E\{\left\{\left[1-\left(1-\beta_2^{'}\right)\delta_2^{'}\right] r_{Lt} - a_{2t}^{'} - \tau_{2t}^{'}\right\} L_{1t}^{j'} + \left\{\left[1-\left(1-\beta_{h2}^{'}\right)\delta_{h2}^{'}\right] r_{Lh2t} - a_{2t}^{'} - \tau_{2t}^{'}\right\} L_{h2t}^{j'}$$
$$+ r_{Xt} X_{1t}^{j'} - r_{D1t} D_{1t}^{j'} - r_{D2t} D_{2t}^{j'} - r_{Et} E_{2t}^{j'} - \left(\frac{\mu_2^{'} + \beta_2^{'} c_2^{'}}{2}\right)\left(L_{1t}^{j'}\right)^2 - \left(\frac{\mu_{h2}^{'} + \beta_{h2}^{'} c_{h2}^{'}}{2}\right)\left(L_{h2t}^{j'}\right)^2$$
$$- \frac{\omega_2^{'}}{2}\left(D_{1t}^{j'}\right)^2 - \frac{\rho}{2}\left(D_{1t}^{i} - D_{1t-1}^{i}\right)^2 - \frac{\rho}{2}\left(D_{2t}^{i} - D_{2t-1}^{i}\right)^2 - \frac{\omega_2^{'}}{2}\left(D_{2t}^{j'}\right)^2 - \frac{\sigma}{2}\left(E_{1t}^{j'}\right)^2 - \frac{\sigma}{2} - \frac{\psi_2^{'}}{2}\left(X_{2t}^{j'}\right)^2\}. \quad (2)$$

Profit function for a typical bank among the n_2 foreign banks without domestic operations:

$$\pi_{2}^{j} = \sum_{0}^{\infty} b^t E\{\{[1-(1-\beta_{h2})\delta_{h2t}] r_{Lh2t} - a_{2t} - \tau_{2t}\} L_{h2t}^{j} + \overline{r_{Ft}} F_{2t}^{j} - r_{D2t} D_{2t}^{j}$$
$$- r_E E_{2t}^{j} - \left(\frac{\mu_2 + \beta_2 c_2}{2}\right)\left(L_{h2t}^{j}\right)^2 - \frac{\omega_2}{2}\left(D_{2t}^{j}\right)^2 - \frac{\rho}{2}\left(D_{2t}^{i} - D_{2t-1}^{i}\right)^2 \frac{\sigma}{2}\left(E_{2t}^{j}\right)^2 - \frac{\psi_2}{2}\left(F_{2t}^{j}\right)^2\}. \quad (3)$$

Table 2: Profit functions of banks within each of the three groups

the United States and have actually implemented in a number of other nations. The domestic bank also pays interest on deposit funds raised in competition with other domestic banks and with foreign banks with domestic subsidiaries at the domestic market deposit rate r_{D1t}, and for every dollar of equity it raises the bank must pay the required rate of return on equity r_{Et} that is assumed to be the same for all banks in the model. Inclusion of the parameter ρ captures deposit-adjustment costs that generate intertemporal dynamics within banks' balance sheets, as in Cosimano (1987, 1988) and Elyasiani et al. (1995), and Dia and Giuliodori (2012).

Dutkowsky and VanHoose (2017, 2020)) refer to "three regimes" arising from Fed policy regarding interest on reserves. In one that corresponds to the pre-2008 regime, interest on reserves is nonexistent. Consequently, a bank's relatively small per-dollar liquidity benefit from holding reserves in excess of any required (prior to March 2020 in the United States) is dwarfed by the opportunity cost of surplus funds not sold in the interbank market. In this regime, a net-surplus bank typically holds virtually no excess reserves and lends in an active federal funds market. In another that is associated with the 2008-2018 and 2020-2022 periods, the Fed pays a rate sufficiently higher than the interbank market rate to induce substantial desired holdings and essentially removes the incentive for a profit-maximizing private bank to lend in an interbank market. In a third regime, observed briefly and mainly during the interval between late 2018 and early 2020, the Fed roughly equalizes the interest rate paid on reserves with the interbank rate, which results in significant reserve holdings alongside at least some private interbank lending.

Both to keep the analysis as simple as possible given the complexities that already arise in a two-country setting and in light of the fact that only briefly since 2008 has the third regime applied, we assume throughout the analysis that the interest rate on reserves is sufficiently higher than interbank rates in both nations to induce banks that hold reserves in the domestic country to eschew lending in the interbank market. Hence, the domestic profit function in Table 2 indicates a domestic banks holds excess reserves (X^i_{1t} for the individual bank and $n_1 X^i_{1t} = X_{1t}$in the aggregate) but neither borrow nor lend in an interbank market—an assumption that could be relaxed if we allowed for the presence of government-sponsored institutions. These banks earn the administered interest rate established by the domestic central bank (the "Fed"), r_{Xt}, on these balances as a flow of revenues. Given the Federal Reserve's elimination of reserve requirements in March 2020, we assume that there are no domestic reserve requirements, and we simplify by extending that assumption as well to the foreign country, although this assumption could readily be relaxed.

Our analysis recognizes that alternative Federal Reserve policy regimes establish different transmission mechanisms for monetary policy. Under the Fed's pre-October-2008 policy procedure, the federal funds rate was a market-determined interest rate that arose endogenously from interactions of demand and supply dynamics involving the interactions of banks with deficit liquidity positions vis-à-vis those possessing surplus liquidity positions. Although the Fed was able to keep the federal funds rate within a desired range and very close to a target value, it did so indirectly via open market operations that influenced other market interest rates and, through the risk and term structures of interest rates, the market federal funds rate. Naturally, balance-sheet adjustments in response to Fed policy actions involved contractions or expansions of positions by deficit versus surplus banks that involved different overall balance-sheet adjustments by the two groups of banks.

In contrast, under the Fed's policy procedure in place since late October 2008—except for a brief period of tentative "balance-sheet unwinding" between mid-2018 and early 2020—the Fed has set the interest rate for remuneration of the its own reserve liabilities at administered levels typically several basis points higher than the federal funds rate. As a consequence, with the exception of the short 2018-2020 interval, private bank lending in the federal funds market has been minimal, with the bulk of the dramatically smaller activity in this market involving lending by government-sponsored enterprises that do not have reserve accounts with the Fed. These institutions, which include Federal Home Loan banks, the Federal National Mortgage Association, and the Federal Home Loan Mortgage Corporation, lend surplus funds to private banks at the several-basis-points-lower federal funds rate. This differential compensates private banks for going to the trouble to hold those funds on reserve with the Fed at its higher interest rate on reserves. In contrast to the differing responses of banks' balance sheets to Fed policy actions under the pre-October-2008 regime, although large domestic banks and foreign banks with U.S. subsidiaries naturally hold the largest volumes of interest-bearing reserves with the Fed, all banks' balance-sheet positions adjust qualitatively similarly to Fed policy actions under the post-October-2008 regime.[3]

A common feature of both regimes is that the reserve positions of banks adjust endogenously to changes in key parameters and to stochastic disturbances. Under the pre-October-2008 procedure with an active federal funds market, the Fed engaged in open-market operations to the extent necessary to provide banks with the level of reserves required to be consistent with surplus and deficit positions that banks were willing to maintain at the Fed's target federal funds rate. Under the post-October-2008 procedure, the Fed has released re-

[3]Fegatelli (2022) discusses how monetary policy is conducted in the euro area in a very similar fashion under the current "floor" system.

serves through special direct lending and auction programs and its quantitative-easing another other unconventional operations aimed at assuring financial-market stabilization in the wake of the 2008 crisis and again during the Covid-19 pandemic and its aftermath. In our model, therefore, both domestic and foreign banks endogenously adjust their reserve balances under the latter procedure in response to changes in the interest rate paid on reserves or quantitative-easing operations by the domestic central bank or to variations in other key parameters or stochastic shocks.

Finally, the typical domestic bank generally incurs implicit labor- and physical-capital-related resource costs arising from various expenses from managing its loan and reserve assets and its deposit liabilities and equity capital, E_1^i—costs that Dia and VanHoose (2019) document have accounted for economically significant fractions of banks' total expenses in recent years. The parameters μ_1, μ_{h1}, ω_1, and ψ_1 govern these generally assumed quadratic expenses, for common loans, home loans, deposits, and reserve holdings of domestic banks. The parameter σ governing equity management expenses is assumed to be the same for all banks.

The profit function for a typical bank among the $n_2^{'}$ foreign banks with domestic operations is largely analogous to that of a domestic bank, with the prime symbol denoting association with these banks and the subscript 1 or 2 again designating the market location of the bank's trading of the indicated asset or liability. A foreign bank with domestic subsidiaries naturally competes with domestic banks in both the common loan market and in the domestic deposit market and holds reserves with the domestic central bank. It receives interest on reserves at the administered interest rate on reserves assumed to sufficiently exceed any available interbank funds rate to induce no activity in such a market. In addition, the foreign banks with domestic subsidiaries compete against the other n_2 foreign banks without domestic operations in the foreign home loan market and in the foreign deposit market. Domestic banks are assumed not to participate in either of these foreign markets. As indicated in the table, in general parameters could differ for these foreign banks. For instance, non-U.S. institutions do not incur deposit insurance expenses, which would tend to depress the value of the linear cost term $a_{2t}^{'}$ relative to the a_{1t} term applicable to domestic banks, ceteris paribus. The value of the loan tax rate imposed on the $n_2^{'}$ foreign banks with domestic subsidiaries, $\tau_{2t}^{'}$, might in the foreign home loan market be set at the same value imposed by foreign regulatory authorities on the n_2 foreign banks without domestic operations, τ_{2t}, or it might in the common market be the same as the tax rate τ_{1t} imposed on the n_1 domestic banks by domestic authorities. As discussed at the outset in the following section, we assume that the $n_2^{'}$ foreign banks with domestic subsidiaries confront domestically determined capital requirements but foreign-specified capital requirements, hence the two separate equity capital components generating expenses for these banks in Table 4.

Finally, the profit function for a typical bank among the n_2 foreign banks without domestic operations displayed in Table 2 reiterates that these banks participate in only three markets. They compete with the $n_2^{'}$ foreign banks with domestic subsidiaries in the foreign home loan market and with those same banks in the foreign deposit market. Because these banks are not eligible to hold reserves with the domestic central bank, any surplus funds are sold in a foreign interbank funds market at an interest rate, $\overline{r}_{Ft}$, that for the sake of simplicity is assumed to be exogenous to the model.

2.3 Profit-Maximizing Quantity Choices under Cournot Rivalry

A bank within each of the three groups maximizes its profits displayed in Table 2 subject to four key types of constraints. The first of these are binding regulatory equity capital constraints. For each one of the n_1 domestic banks, these constraints are given by $E_{1t}^{i} = \theta_1 L_{1t}^{i} + \theta_1 L_{h1t}^{i}$, where θ_1 is the capital-requirement ratio established by the domestic regulatory authority. For each one of the n_2 foreign banks without domestic operations, the relevant constraint is $E_{2t}^{j} = \theta_2 L_{2t}^{j}$, where θ_2 is the capital-requirement ratio established by the foreign regulatory authority. For each one of the $n_2^{'}$ foreign banks with domestic subsidiaries, separate binding capital constraints are given by $E_{1t}^{j'} = \theta_1 L_{1t}^{j'}$ and $E_{2t}^{j'} = \theta_2 L_{h2t}^{j'}$, where capital requirements are determined by the location of the bank's activities, with the ratio θ_1 is applied by the domestic regulator to the common-market loans $L_{1t}^{j'}$ of the foreign bank with foreign subsidiaries but for that same bank, θ_2 is applied by the foreign regulator to the foreign-home-market loans of that bank.

The second set of constraints are those associated with each bank's balance sheet. For each one of the n_1 domestic banks, with the capital requirement constraint taken into account, the relevant balance-sheet constraint is $(1-\theta_1)L_{1t}^{i} + (1-\theta_1)L_{h1t}^{i} + X_{1t}^{i} - D_{1t}^{i} = 0$. For each one of the $n_2^{'}$ foreign banks with domestic offices that consequently operate in retail banking markets in both nations, the constraint is $(1-\theta_1)L_{1t}^{j'} + (1-\theta_2)L_{h2t}^{j} + X_{1t}^{i'} - D_{1t}^{i'} - D_{2t}^{i'} = 0$. Finally, for each one of the n_2 foreign banks that operate only in foreign retail and interbank markets, the balance-sheet constraint is $(1-\theta_2)L_{h2t}^{j} + F_{2t}^{j} - D_{2t}^{j} = 0$.

The third set of constraints are the market demand relationships applicable in each market in which a bank operates. For instance, each one of the n_1 domestic banks chooses its own domestic-home-market lending taking the lending choices of all other rival domestic banks as given, while recognizing that, from the individual domestic bank's point of view, $r_{Lh1t} = (\eta_{h1}+1)\overline{r}_{h1L} - \eta_{h1}\overline{r}_{h1}\left(\overline{L}_{h1}\right)^{-1}\left(L^{i}_{h1t}+\hat{L}^{i}_{h1t}\right)$, where $\hat{L}^{i}_{h1t}$ denotes the domestic home loans of all domestic banks other than i. Similarly, domestic and foreign banks with domestic subsidiaries set a loan interest rate in the common market $r_{Lt} = (\eta+1)\overline{r}_{L} - \eta\overline{r}_{L}\left(\overline{L}\right)^{-1}\left(L^{i}_{1t}+\hat{L}^{i}_{1t}+L^{'}_{1t}\right)$, where $\hat{L}^{i}_{1t}$ denotes the common-market loans of all domestic banks other than i. In the domestic deposit market, each domestic and foreign bank with domestic subsidiaries take the deposit choices of all other rival banks as given, while recognizing that, from that domestic bank's perspective, $r_{D1t} = (\varepsilon-1)\overline{r}_{D1} + \varepsilon\overline{r}_{D1}\left(\overline{D}_{1a}\right)^{-1}CBF_{1t} + \overline{r}_{D1}\left(\overline{D}_{1a}\right)^{-1}\left(D^{i}_{1t}+\hat{D}^{i}_{1t}+D^{'}_{1t}\right)$, where $\hat{D}^{i}_{1t}$ denotes desire deposits of all domestic banks other than i.

Analogous reasoning indicates that each foreign bank, both with and without domestic subsidiaries chooses its own foreign-home-market lending taking the lending choices of all other rival foreign banks as given while recognizing that $r_{Lh2t} = (\eta_{h2}+1)\overline{r}_{Lh2} - \eta_{h2}\overline{r}_{h2}\left(\overline{L}_{h1}\right)^{-1}\left(L^{j}_{h2t}+\hat{L}^{j}_{h2t}\right)$, where $\hat{L}^{j}_{h2t}$ denotes the domestic home loans of all foreign banks with domestic subsidiaries other than j. Finally, in the foreign deposit market, each foreign bank takes into account that $r_{D2t} = (\varepsilon-1)\overline{r}_{D2} + \varepsilon\overline{r}_{D2}\left(\overline{D}_{2a}\right)^{-1}\left(D^{j'}_{2t}+\hat{D}^{j'}_{2t}+D_{2t}\right)$, where $\hat{D}^{j'}_{2t}$ denotes deposits of all other foreign banks.

Steady-state profit-maximizing balance-sheet choices, aggregated across each of the three groups of banks and expressed as semi-reduced-form solutions in terms of yet-to-be-determined retail market interest rates, are displayed in Tables 3, 4, and 5, where $\overline{R}_{D1} = (\varepsilon-1)\overline{r}_{D1} + \varepsilon\overline{r}_{D1}\left(\overline{D}_{1a}\right)^{-1}CBF_{1t}$ and $\overline{R}_{D2} = (\varepsilon-1)\overline{r}_{D2}$. To assist in streamlining the exposition, the complexity of the expressions is reduced by paring the range of channels through which resource costs generate cross-interactions across the banks' balance sheets. The expressions in Table 3 reflect an assumption that $\psi_1 = 0$, so that maintaining reserves with the domestic central bank effectively amounts to "earmarking" the otherwise idle but nonetheless interest-earning (at the rate r_{Xt}) funds as cash holdings with the domestic central bank.

The n_1 domestic banks' optimal combined loans in the common market in which they compete with the $n^{'}_{2}$ foreign banks with domestic subsidiaries sensibly respond positively to the market interest rate available contemporaneously on such lending (r_{Lt}) and negatively to the current market interest rate that alternatively can be earned through substituting into lending in the domestic home loan market (r_{Lh1t}). Higher long-run average values of these rates have opposing effects on the domestic banks' desired lending volumes in the common loan market, and magnitudes of all these effects naturally are conditioned by the capital-requirements ratio, default rates on any unmonitored loans, and costs related to any loan

All n_1 domestic banks:

Total profit-maximizing lending by domestic banks in the common market:

$$L_1 = \frac{\left[\mu_{h1} + \beta_{h1} c_{h1} + \sigma(\theta_1)^2\right]\left[1-(1-\beta_1)\delta_1\right]\left[(n_1+1)r_L - \eta \bar{r}_L\left(\overline{L}\right)^{-1} L_1' - (\eta+1)\bar{r}_L\right]}{\left[\mu_1 + \beta_1 c_1 + \sigma(\theta_1)^2\right]\left[\mu_{h1} + \beta_{h1} c_{h1} + \sigma(\theta_1)^2\right] - \sigma^2(\theta_1)^4}$$
$$- \frac{-\sigma(\theta_1)^2 (n_1+1)\left[1-(1-\beta_{h1})\delta_{h1}\right] r_{Lh1} + \sigma(\theta_1)^2 (\eta_{h1}+1)\bar{r}_{Lh1}}{\left[\mu_1 + \beta_1 c_1 + \sigma(\theta_1)^2\right]\left[\mu_{h1} + \beta_{h1} c_{h1} + \sigma(\theta_1)^2\right] - \sigma^2(\theta_1)^4}$$
$$- \frac{(\mu_{h1} + \beta_{h1} c_{h1})\left[n_1 a_1 + n_1 \tau_1 + n_1 \theta_1 r_E + n_1 (1-\theta_1) r_X\right]}{\left[\mu_1 + \beta_1 c_1 + \sigma(\theta_1)^2\right]\left[\mu_{h1} + \beta_{h1} c_{h1} + \sigma(\theta_1)^2\right] - \sigma^2(\theta_1)^4}. \quad (4)$$

Total profit-maximizing lending by domestic banks in the domestic home market:

$$L_{h1} = \frac{\left[1-(1-\beta_{h1})\delta_{h1}\right](n_1+1) r_{Lh1} - \sigma(\theta_1)^2 \left[1-(1-\beta_1)\delta_1\right]\left[(n_1+1)r_L - \eta \bar{r}_L\left(\overline{L}\right)^{-1} L_1' - (\eta+1)\bar{r}_L\right]}{\left[\mu_1 + \beta_1 c_1 + \sigma(\theta_1)^2\right]\left[\mu_{h1} + \beta_{h1} c_{h1} + \sigma(\theta_1)^2\right] - \sigma^2(\theta_1)^4}$$
$$- \frac{\left[\mu_1 + \beta_1 c_1 + \sigma(\theta_1)^2\right](\eta_{h1}+1)\bar{r}_{Lh1}}{\left[\mu_1 + \beta_1 c_1 + \sigma(\theta_1)^2\right]\left[\mu_{h1} + \beta_{h1} c_{h1} + \sigma(\theta_1)^2\right] - \sigma^2(\theta_1)^4}$$
$$- \frac{(\mu_1 + \beta_1 c_1)\left[n_1 a_1 + n_1 \tau_1 + n_1 \theta_1 r_E + n_1 (1-\theta_1) r_X\right]}{\left[\mu_1 + \beta_1 c_1 + \sigma(\theta_1)^2\right]\left[\mu_{h1} + \beta_{h1} c_{h1} + \sigma(\theta_1)^2\right] - \sigma^2(\theta_1)^4}. \quad (5)$$

Total profit-maximizing deposits issued by domestic banks in the domestic market:

$$D_1 = \left(\frac{1}{\omega_1}\right)\left[n_1 r_X - (n_1+1) r_{D1} - \overline{R}_{D1}\right]. \quad (6)$$

Total profit-maximizing reserve balances held by domestic banks with the domestic central bank:

$$X_1 = D_1 - L_1 - L_{h1}. \quad (7)$$

Table 3: Steady-state profit-maximizing balance-sheet quantity choices for domestic banks in terms of interest rates and exogenous parameters, aggregated and simplified by assuming that $\psi_1 = 0$

monitoring efforts. In addition, the profit-maximizing aggregate level of domestic lending in the common loan market responds negatively to an increase in sources of expenses that raise the banks' linear costs (a_{1t}) or to increases in any imposed domestic tax on lending (τ_{1t}), and a higher required rate of return on equity (r_{Et}). *Ceteris paribus*, total domestic lending in the common loan market also responds negatively to an increase in the domestic central bank's administered interest rate on reserves (r_{Xt}), which increases domestic banks' incentive to allocate additional higher-interest-bearing funds to their assumed zero-resource-cost-generating reserve accounts with the central bank. Finally, an increase in total common-market lending on the part of foreign banks with domestic subsidiaries induces a substitution on the part of domestic banks away from common-market lending and in favor of lending in the domestic home market, hence the negative effect of L'_{1t} on total desired domestic banks' lending in the common market indicated in Table 3. The effects of the contemporaneous and long-run average values of the common- and home-market loan rates naturally are reversed for total profit-maximizing home-market lending, while increases in linear loan expenses, any tax imposed on lending, the required rate of return on equity, and the interest rate paid on reserves by the domestic central bank have effects on desired home-market lending that are qualitatively the same as those on common-market lending.

The assumption $\psi_1 = 0$ generates portfolio separation for the domestic banks, so their preferred level of deposit funding is not linked to their asset-allocation decisions but instead depends directly on the interest rate that the domestic central bank pays on reserves, negatively on the current market deposit rate, and positively on the long-run average value of the deposit rate. Total desired reserve holdings depend on all the various elements that are exogenous to each one of the domestic banks, with higher contemporaneous market loan rates relative to long-run average values of loan rates inducing substitutions away from reserves in favor of lending. Because a higher linear cost, loan tax rate, required rate of return on equity, or central bank's interest rate on reserves induces domestic banks to substitute away from loans, any one of these changes would generate higher optimal reserve holdings, *ceteris paribus*, although an increase in the interest rate on reserves has a countervailing effect because of the increased incentive for the bank to issue additional deposits. A higher current market deposit rate relative to the steady-state deposit rate gives domestic banks an incentive to reduce their reserve holdings.

The expressions displayed in Table 4 provide semi-reduced-form steady-state solutions for the total desired common-market lending, home-market lending, deposits, and reserve holdings of foreign banks with domestic deposits under the expositionally simplifying as-

All n_2' foreign banks with domestic subsidiaries:

Total profit-maximizing lending by foreign banks with domestic subsidiaries in the common market:

$$L_1' = \frac{\left[1-\left(1-\beta_2'\right)\delta_2'\right]\left[\left(n_2'+1\right)r_L - \eta\overline{r}_L\left(\overline{L}\right)^{-1}L_1 - (\eta+1)\overline{r}_L\right] - \left[n_2'a_2' + n_2'\tau_2' + n_2'\theta_1 r_E + n_2'(1-\theta_1)r_X\right]}{\left[\mu_2' + \beta_2'c_2' + \sigma(\theta_1)^2\right]}. \quad (8)$$

Total profit-maximizing lending by foreign banks with domestic subsidiaries in the foreign home market:

$$L_{h2}' = \frac{\left[1-\left(1-\beta_{h2}'\right)\delta_{h2}'\right]\left[\left(n_2'+1\right)r_{Lh2} - (\eta_{h2}+1)\overline{r}_{Lh2}\right] - \left[n_2'a_2' + n_2'\tau_2' + n_2'\theta_2 r_E + n_2'(1-\theta_2)r_X\right]}{\left[\mu_{h2}' + \beta_{h2}'c_{h2}' + \sigma(\theta_2)^2\right]}. \quad (9)$$

Total profit-maximizing deposits issued by foreign banks with domestic subsidiaries in the domestic market:

$$D_1' = \left(\frac{1}{\omega_2'}\right)\left[n_2'r_X - \left(n_2'+1\right)r_{D1} - \overline{R}_{D1}\right]. \quad (10)$$

Total profit-maximizing deposits issued by foreign banks with domestic subsidiaries in the foreign market:

$$D_2' = \left(\frac{1}{\omega_2'}\right)\left[n_2'r_X - \left(n_2'+1\right)r_{D2} - \overline{R}_{D2}\right]. \quad (11)$$

Total reserve balances held by foreign banks with domestic subsidiaries with the domestic central bank:

$$X_1' = D_1' + D_2' - L_1' - L_{h2}'. \quad (12)$$

Table 4: Steady-state profit-maximizing balance-sheet quantity choices for foreign banks with domestic subsidiaries and subject to foreign capital regulation in terms of interest rates and exogenous parameters, aggregated and simplified by assuming that $\psi_2' = 0$

All $n_2^{'}$ foreign banks without domestic operations:

Total profit-maximizing lending by foreign banks without domestic operations in the foreign home market:

$$L_{h2} = \frac{(n_2+1)[1-(1-\beta_{h2})\delta_{h2}]r_{Lh2} - (\eta+1)\overline{r}_{Lh2} - n_2 a_2 - n_2\tau_2 - n_2\theta_2 r_E + n_2(1-\theta_2)\overline{r}_F}{\left[\mu_{h2} + \beta_{h2}c_{h2} + \sigma(\theta_2)^2\right]}. \quad (13)$$

Total profit-maximizing deposits issued by foreign banks without domestic operations in the foreign market:

$$D_2 = \left(\frac{1}{\omega_2}\right)[n_2\overline{r}_F - (n_2+1)r_{D2} - \overline{R}_{D2}]. \quad (14)$$

Funds sold by foreign banks without domestic operations in the foreign interbank market:

$$F_2 = D_2 - L_{h2}. \quad (15)$$

Table 5: Steady-state profit-maximizing balance-sheet quantity choices for foreign banks with no domestic operations in terms of interest rates and exogenous parameters, aggregated and simplified by assuming that $\phi_2 = 0$

sumption $\psi_2' = 0$. These expressions are more complicated than those in 3 because of the fact that foreign banks with domestic subsidiaries face binding capital requirements imposed by both the foreign and domestic regulatory authorities.

Given the maintained assumption that this rate is sufficiently high relative to the foreign interbank funds rate, these banks with foreign operations choose to hold reserves with the domestic central bank rather than to lend any funds in the foreign interbank market. This policy environment accounts for most notable aspect of the desired balance-sheet decisions of foreign banks with domestic subsidiaries: Just as is true for domestic banks, the domestic central bank's administered interest rate on reserves is a fundamental determinant of profit-maximizing decision-making by foreign banks with domestic subsidiaries.

Table 5 shows that, in contrast, the balance-sheet choices of foreign banks without any domestic operations hinge solely on foreign interest rates and parameters. The explicit forms of the semi-reduced-form expressions for these banks' optimal total volumes of foreign home lending, foreign deposits, and net lending of funds in the foreign interbank lending at the exogenous interbank rate $\overline{r}_F$ reflect the assumption, again made for expositional simplicity, that $\phi_2 = 0$. Under this parameter setting, lending in the foreign interbank entails minuscule real resource expenses, which yields portfolio separation for the foreign banks without domestic operations. Consequently, optimal asset and liability decisions by these banks are independent. Foreign home bank lending increases with a higher current foreign home loan rate relative to the long-run average value of that rate and decreases with a higher linear expense, foreign tax rate, rate of return on equity, or value of the foreign interbank rate. Desired deposits for the foreign banks without domestic operations respond positively the foreign interbank rate and negatively to the contemporaneous foreign deposit rate relative to the long-run average value of that rate. Finally, desired sales of funds in the foreign interbank market are positively related to the foreign interbank rate and to the linear expense, foreign tax rate, rate of return on equity and negatively related to the foreign home loan rate.

In the general case with non-zero values of ψ_1, ψ_2', and ϕ_2, the semi-reduced-form solutions for the loan and deposit quantities would be much more complex expressions than displayed in the former tables. Furthermore, solving an 11-equation system combining those more complicated relationships with the loan demand and deposit supply equations would be required. Even with the simplifying assumption of zero values for these parameters, in which deposit quantities and rates can be determined separably from the loan quantities and rates in Tables 3 through 5, a 7-equation system must be solved for the four loan quantities and three loan rates (with deposit levels and rates determined separately). Consequently, our next step is to utilize calibrated numerical steady-state solutions of the model and dynamic extensions to evaluate further key implications of the model.

3 Analysis of Alternative Market Equilibria

Obtaining reduced-form solutions for the balance-sheet quantities and retail loan and deposit rates forthcoming within this model of three groups of banks in partial cross-country competition is feasible but quite unwieldy, even in the special cases reported in the above tables. Our analytical approach, therefore, entails quantitatively calibrating the model's parameters. Doing so enables us to conduct both a quantitative steady-state analysis within a zero-shock setting without dynamic deposit adjustments and a quantitative evaluation of responses of banks' balance sheets and retail-market loan and deposit rates to individual shocks to key policy and other parameters.

3.1 Calibration Strategy

To set average long-term values, we assume that all lending and deposit taking activities are either domestic or foreign, with no foreign presence in the domestic market. We assume average-long term values of equity of 10 percent of loans and average long-term values of reserves of 10 percent of deposits, in line with the traditional reserve requirements. Hence, we require the following simplified balance-sheet constraints to hold:

$$0.9 * \overline{L_{1t}} + 0.9 * \overline{L_{h1t}} = 0.9 * \overline{D_{1t}}, \tag{16}$$

$$0.9 * \overline{L_{2t}} + 0.9 * \overline{L_{h2t}} = 0.9 * \overline{D_{2t}}. \tag{17}$$

Finally, we assume $\overline{L_{1t}} = 0.1\overline{L_{h1t}}$ and $\overline{L_{2t}} = 0.1\overline{L_{h2t}}$ and we normalize $\overline{D_{1t}} = \overline{D_{2t}} = 1$, so that $\overline{L_{h1t}} = \overline{L_{h2t}} = 0.9$ and $\overline{L_{1t}} = \overline{L_{2t}} = 0.1$.

The basic model is calibrated to match the long-run value of bank loan rates obtained from annual FDIC aggregate data as an average over the 1994-2019 period. We obtain a value of $\overline{r_L} = 0.0638$ by dividing total interest revenue on loans by total loans and then taking the mean over time.[4] Similarly, we obtain the average long-term value of the deposit rate, $\overline{r_D} = 0.0171$, by dividing total deposit interest costs by total deposits.[5] We approximate

[4]The value over the entire 1934-2019 period is very similar, 0.0665.

[5]The deposit rate net of account service charges in low-explicit-rate environments can conceivably yield negative values.

the wholesale funds rate with the average annual 3-Month London Interbank Offered Rate (LIBOR) based on U.S. dollar, and we obtain an average value for the 1994-2019 period of $\overline{r_F} = 0.02854$. The value of the parameter $a = 0.0193$ is the difference between the ratio of total non-interest income to total loans and the ratio of total non-interest costs to total loans for FDIC insured US banks, while the average value of the ratio between provisions and total loans that provides a measure of our loan losses parameter is $\delta_\gamma = 0.008$.

We choose an inverse loan demand elasticity benchmark value of $\eta_1 = \eta_2 = 0.8$ that corresponds to a loan demand parameter just above one, which is in line with the very small value found for the United States by Cosimano and Hakura (2011).[6] We then choose to use the same value also for the Eurodollar loan market, because we do not want the balance-sheet optimal responses to be induced by different degrees of loan-demand elasticity, which albeit possibly realistic, would produce strong asymmetric effects on bank balance sheets for reasons that are not of particular interest for this research. We assume that common lending has a more elastic demand, so that $\eta = 0.5$. We assume that the number of domestic banks is double that of purely foreign banks, so that $n_1 = 12$ and $n_2 = 6$ to reflect the larger number of banks in the United States in comparison to most other countries. We assume that the number of foreign banks operating in the domestic market is $n'_2 = 6$. We choose an inverse deposit supply elasticity parameter $\epsilon_1 = \epsilon_2 = 2$. This value corresponds to a value of 0.5 for the direct elasticity, which is a rough average between some recent estimates for the US by Tanner et al. (2021), who find values between 0 and 0.3 or Egan et al. (2017), who find an elasticity of 0.56 for insured deposits and 0.16 for uninsured deposits, and those of Dick (2008) or Drechsler et al. (2017) who found larger values (respectively between 1.8 and 3.0, and 5.3). Again, we assume an analogous value for the Eurodollar deposit market. Our results are sensitive to the choice of the elasticity parameters, and this is particularly the case for the amount of reserves X_{1t} and X'_{1t} that are subject to fewer frictions than other balance sheet quantities. The general pattern of results is robust to substantial changes in the value of the elasticity parameters, and reasonable steady-state values of reserves can always be obtained by inducing small changes in the intercept of the deposit supply schedule, as is the case following any change in the balance sheet of the central bank.

We initially assume that monitoring reduces loans losses by a 10-percentage-point factor so that $\beta_\gamma = 0.1$, while we use a set of cost parameter values, symmetric across both classes of banks, obtained from Dia and VanHoose (2018). Finally, we assume a required rate of

[6]Cosimano and Hakura (2011) actually find a value slightly lower than one that is incompatible with these kinds of models, but the values of the parameter for all other countries range from -1.83 for Germany to 5.90 for Sweden.

return on equity $r_E = 0.10$ and a capital requirement ratio $\theta_\gamma = 0.10$. All our results are robust to substantial changes in cost parameter values.

3.2 Steady-state Market Equilibria

Table 6: Model numerical solutions analyze the steady-state impact of changes in key policy variables. We display aggregate values for common lending from the domestic $\boldsymbol{L_1}$, and foreign banks $\boldsymbol{L_2}$; domestic lending from domestic $\boldsymbol{L_{h1}}$ and foreign banks $\boldsymbol{L'_{h1}}$; foreign lending from foreign banks $\boldsymbol{L_{h3}}$; domestic deposits in domestic banks $\boldsymbol{D_1}$; foreign $\boldsymbol{D'_2}$ and domestic $\boldsymbol{D'_1}$ deposits by foreign international banks; foreign deposits in foreign local banks $\boldsymbol{D_2}$; domestic $\boldsymbol{X_1}$ and foreign $\boldsymbol{X'_1}$ banks' reserves; lending (borrowing) to the central bank by foreign local banks $\boldsymbol{F_2}$; interest rates on domestic $\boldsymbol{r_{D1}}$ and foreign $\boldsymbol{r_{D2}}$ deposits; interest rates on international $\boldsymbol{r_L}$, domestic $\boldsymbol{r_{Lh1}}$, and foreign $\boldsymbol{r_{Lh2}}$ loans.

L_1	L_2	L_{h1}	L'_{h1}	L_{h2}	D_1	D'_2	D'_1	D_2	X_1	X'_1	F_2	r_{D1}	r_{D2}	r_L	r_{Lh1}	r_{Lh2}
Benchmark values, $r_F = 0.00195$, $r_X = 0.00125$, $CBF_1 = 0.175$																
0.128	0.064	1.312	0.678	0.539	1.463	0.163	0.618	0.262	0.167	0.113	-0.222	-0.006	-0.003	0.034	0.040	0.046
Benchmark values, $r_F = 0.00195$, $r_X = 0.00125$, $CBF_1 = 0.175$, **higher capital requirement**: $\theta_1 = 0.11$.																
0.115	0.075	1.297	0.678	0.539	1.462	0.163	0.618	0.262	0.206	0.104	-0.222	-0.006	-0.003	0.035	0.041	0.046
Benchmark values, $r_F = 0.00195$, $r_X = 0.00125$, $CBF_1 = 0.175$, **higher deposit insurance cost**: $a_1 = 0.0203$.																
0.115	0.075	1.296	0.678	0.539	1.462	0.163	0.618	0.262	0.192	0.103	-0.222	-0.006	-0.003	0.035	0.041	0.046
Benchmark values, $r_F = 0.00195$, $r_X = 0.00125$, **larger quantitative easing**: $CBF_1 = 0.185$.																
0.128	0.064	1.312	0.679	0.538	1.523	0.163	0.650	0.263	0.227	0.145	-0.222	-0.006	-0.003	0.034	0.040	0.046

Notes: Calibrated values of the benchmark model, unless otherwise specified in text of the table, for $\beta_1 = \beta_{h1} = 0.1 = \beta_{h2} = 0.1$, $\theta_1 = \theta_2 = 0.1$, $\tau_1 = \tau_2 = 0$, $\mu_1 = \mu_2 = mu_{h1} = \mu_{h2} = 0.03$, $c_1 = c_2 = c_{h1} = c_{h2} = 0.02$, $\psi_1 = \psi_2 = \phi_2 = 0.001$, $\omega = 0.05$, $\sigma = 0.04$, $\delta_1 = \delta_2 = \delta_{h1} = \delta_{h2} = 0.01$, $a_1 = a_2 = 0.0193$, $\overline{r_F} = 0.0285$, $r_E = 0.104$, $n_1 = 12$, $n_2 = 6$, $n_3 = 6$, $\eta = 0.5$, $\eta_1 = 0.8$, $\eta_2 = 0.8$, $\epsilon_1 = 2$, $\epsilon_2 = 2$, $\overline{rf} = 0.0285$, $\overline{rl} = 0.0638$, $\overline{rlh_1} = 0.0638$, $\overline{rlh_2} = 0.0638$, $\overline{rd_1} = 0.0171$, $\overline{rd_2} = 0.0171$, $\overline{L} = 0.1$, $\overline{Lh_1} = 0.9$, $\overline{Lh_2} = 0.9$, $\overline{D_1} = 1$, $\overline{D_2} = 1$.

Table 6 displays numerical solutions of steady-state impacts of changes in key policy variables on the aggregate balance-sheet variables and the interest rates, within a low-interest rate environment. We assume that the interest rate on funds is equal to 12.5 basis points, while the rate on reserves is equal to 19.5 basis points. We keep the spread between the two rates at 7 basis points, because between early 2009 and early 2018 and then again between early 2020 and mid-2022, the Federal Reserve typically maintained a 7-basis-point differential between the interest rate on reserves and the U.S. federal funds rate (applying to the federal funds market in which remaining lenders were government-sponsored institutions absent from the model). We simplify by assuming that wholesale funds markets are globally integrated. The policy changes that we analyze are higher domestic capital requirements, larger deposit insurance costs, and a larger quantitative easing. The first row of the table provides the results from a benchmark calibration and each of the following rows display the steady-state results following the change in a single policy parameter.

The general pattern of our results suggests that changes in the steady-state level of deposits and deposit rates are always negligible, with the exception of a substantial increase in domestic deposits held in both domestic banks and foreign banks with domestic subsidiaries following a larger quantitative easing. On the contrary, both higher domestic capital requirements and larger deposit insurance costs produce a substantial decline in domestic and common lending by domestic banks, while changes in quantitative easing generate negligible effects on steady-state loan equilibria and interest rates. The effects of policy changes on reserves are instead always substantial.

The intuition behind the results is that reserves are much more sensitive to parameter changes than are other balance-sheet items. This is the case for two reasons. First, in line with the literature, we assume non-linear cost parameters on reserves of a smaller order of magnitude than those for loans and deposits. Second, again in line with the empirical evidence from the literature, market power enables banks to internalize in their choices and take into account the fact that larger equilibrium loan quantities are associated with lower interest rates and larger equilibrium deposit quantities are associated with higher deposit interest rates. For both reasons, following any shock, changes in loans and deposit are much smaller than those of reserves, the quantity of which can be adjusted at much more lower cost and thereby provide a useful and profitable buffer.

The increase in steady-state deposits following quantitative easing affects almost exclusively reserves on the asset side, while the effects on steady-state loans and interest rates on loans are truly negligible (they are of the fourth digit, meaning a few basis points). Hence our model helps shedding light on the empirical conundrum highlighted in the empirical literature finding that the effects on lending of quantitative easing policies may have been negligible.[7]

[7] See for instance Chakraborty et al. (2020) and Thornton (2015). Rodnyansky and Darmouni (2017) and Kandrac and Schlusche (2021), on the contrary, find a significant effects of QE on lending, however, these last models have been criticized because their identification strategy does not allow disentangling the effects of quantitative easing from that of other policy variables such as changes in reserves rates. In another related article, Diamond et al. (2020) develop and estimate a structural model of the U.S. banking system to analyze the effect of changes in the size of the balance sheet of the FED on bank lending, finding that the increase in reserve supply has produced a substantial decline in firm loans and mortgages. Finally, Fabo et al. (2021) and

Following quantitative easing, reserves held at the domestic central bank by both domestic banks and affiliates of foreign banks rise, but absolute increases at domestic banks are larger.

In all these policy experiments, the long-run steady-state spillovers on the Eurodollar loan market are very small, because foreign banks adjust their dollar denominated balance sheets to keep equilibrium lending values steady. In particular, in sharp contrast to their counterparts with domestic subsidiaries, in a low-interest-rate environment, local foreign banks borrow wholesale funds market and become net lenders only when interest rates on reserves and wholesale funds are higher. These local foreign bank are constrained by the availability of dollar-denominated deposits, and in a low-interest-rate environment, consistent with McCauley et al. (2015), they choose to borrow to expand their dollar-denominated balance sheets.

Table 7: Model numerical solutions analyze the steady-state impact of changes in key policy variables. We display aggregate values for common lending from the domestic $\boldsymbol{L_1}$, and foreign banks $\boldsymbol{L_2}$; domestic lending from domestic $\boldsymbol{L_{h1}}$ and foreign banks $\boldsymbol{L'_{h1}}$; foreign lending from foreign banks $\boldsymbol{L_{h3}}$; domestic deposits in domestic banks $\boldsymbol{D_1}$; foreign $\boldsymbol{D'_2}$ and domestic $\boldsymbol{D'_1}$ deposits by foreign international banks; foreign deposits in foreign local banks $\boldsymbol{D_2}$; domestic $\boldsymbol{X_1}$ and foreign $\boldsymbol{X'_1}$ banks' reserves; lending (borrowing) to the central bank by foreign local banks $\boldsymbol{F_2}$; interest rates on domestic $\boldsymbol{r_{D1}}$ and foreign $\boldsymbol{r_{D2}}$ deposits; interest rates on international $\boldsymbol{r_L}$, domestic $\boldsymbol{r_{Lh1}}$, and foreign $\boldsymbol{r_{Lh2}}$ loans.

L_1	L_2	L_{h1}	L'_{h1}	L_{h2}	D_1	D'_2	D'_1	D_2	X_1	X'_1	F_2	r_{D1}	r_{D2}	r_L	r_{Lh1}	r_{Lh2}
Benchmark values, $r_F = 0.0285$, $r_X = 0.0292$, $CBF_1 = 0.04$																
0.070	0.048	0.915	0.449	0.413	1.244	0.505	0.247	0.531	0.367	0.304	0.160	0.020	0.018	0.058	0.063	0.066
Benchmark values, $r_F = 0.0285$, $r_X = 0.0292$, $CBF_1 = 0.04$, **higher capital requirement**: $\theta_1 = 0.11$.																
0.070	0.048	0.915	0.410	0.455	1.002	0.531	0.115	0.500	0.126	0.235	0.091	0.021	0.018	0.058	0.063	0.066
Benchmark values, $r_F = 0.0285$, $r_X = 0.0292$, $CBF_1 = 0.04$, **higher deposit insurance cost**: $a_1 = 0.0203$.																
0.066	0.051	0.911	0.449	0.413	1.244	0.505	0.247	0.531	0.364	0.302	0.160	0.020	0.018	0.058	0.063	0.066
Benchmark values, $r_F = 0.0285$, $r_X = 0.0292$, **quantitative tightening**: $CBF_1 = 0$.																
0.079	0.040	0.926	0.448	0.414	1.002	0.506	0.116	0.530	0.097	0.183	0.158	0.021	0.018	0.058	0.062	0.066

Notes: Calibrated values of the benchmark model, unless otherwise specified in text of the table, for $\beta_1 = \beta_{h1} = 0.1 = \beta_{h2} = 0.1$, $\theta_1 = \theta_2 = 0.1$, $\tau_1 = \tau_2 = 0$, $\mu_1 = \mu_2 = mu_{h1} = \mu_{h2} = 0.03$, $c_1 = c_2 = c_{h1} = c_{h2} = 0.02$, $\psi_1 = \psi_2 = \phi_2 = 0.001$, $\omega = 0.05$, $\sigma = 0.04$, $\delta_1 = \delta_2 = \delta_{h1} = \delta_{h2} = 0.01$, $a_1 = a_2 = 0.0193$, $\overline{r_F} = 0.0285$, $r_E = 0.104$, $n_1 = 12$, $n_2 = 6$, $n_3 = 6$, $\eta = 0.5$, $\eta_1 = 0.8$, $\eta_2 = 0.8$, $\epsilon_1 = 2$, $\epsilon_2 = 2$, $\overline{rf} = 0.0285$, $\overline{rl} = 0.0638$, $\overline{rlh_1} = 0.0638$, $\overline{rlh_2} = 0.0638$, $\overline{rd_1} = 0.0171$, $\overline{rd_2} = 0.0171$, $\overline{L} = 0.1$, $\overline{Lh_1} = 0.9$, $\overline{Lh_2} = 0.9$, $\overline{D_1} = 1$, $\overline{D_2} = 1$.

Greenlaw et al. (2018) provide other skeptical views on the effects of QE.

Table 7 displays numerical solutions for the steady-state impacts of changes in key policy variables when interest rates on funds and reserves are very close to their long-run averages, assuming that the wholesale funds rate is equal to 285 basis points, while the interest rate on reserves is 7 basis point higher, as often has been the case in the United States since 2008. Supportive of our calibration strategy is the fact that the steady-state results that we obtain are very close to the long-run averages assumed in the calibration. We repeat the former exercises but this time experiment with a quantitative tightening policy. The results are very similar to those of the previous case, since the changes considered do not involve the long-run average values. However, in this higher-rate environment, the incentive to hold reserves becomes proportionally stronger for foreign banks, while conversely domestic institutions operate with a higher loan-to-deposit ratio and reduce reserve holdings. Furthermore, in this higher-rate environment foreign local banks lend their excess deposits in the wholesale funds market.

3.3 Dynamics

We now analyze the effects of a set of zero-mean, serially uncorrelated, and independent shocks, hitting respectively the linear cost terms a_{1t}, a_{2t}, the interest rates on local foreign wholesale funds r_{Ft}, the interest rate on domestic central bank reserves r_{Xt}, the intercept term of aggregate deposit supply CBF_t, and the intercept terms of domestic and common loan demand L_{h1t}, and L_{1at}. We label these respective shocks as ϵ_t^{a1}, ϵ_t^{a2}, ϵ_t^{rf}, ϵ_t^{rx}, ϵ_t^{D1}, ϵ_t^{Lh1}, and ϵ_t^{L1a}. We have assumed AR(1) processes for linear cost terms, interest rates and the intercept of the deposit supply and loan demand schedules with a persistency parameter equal to 0.90.

Figure 3 displays impulse response functions of X_1 and X_1' to a 75-basis-points shock a_1, a_2, r_F, r_X, D_1, D_2, L_{h1}, L_{h2}, and L. The responses of X_1 and X_1' are in the same direction following all of the shocks, with the exception that shocks hitting the linear cost terms a_1 and a_2 generate opposite responses.

Figure 4 displays the impulse responses following a 75-basis-points shock to a_1.[8] When the shock hits domestic lenders, since lending becomes less profitable they substitute away from common and local lending in favor of reserves. Foreign banks with domestic subsidiaries respond by substituting away from holding reserves with the domestic central bank in favor of boosting common-market lending. The lower lending by domestic banks in the common market, however, is not fully offset by foreign banks' lending, and overall lending

[8] In the actual data, the standard deviation of a_1 is 0.0035, so that the shock we consider is twice as large.

in the common market declines. When the shock hits the costs of foreign banks, a case illustrated in Figure 5, domestic and foreign responses are reversed and foreign banks respond by increasing reserve balances with the domestic central bank. We do not display the response to a loan–losses shock hitting the parameter δ, or to a shock produced by an increase in tax rates from the zero level assumed so far, but the pattern is identical. Hence, shocks to linear costs, loan losses, or bank taxes generate substantial cross-market spillovers. Loan rates rise following either shock as banks pass the resulting higher cost on to their borrowers.

The responses of X_1 are larger when shocks originate in the domestic country, with the important exception of r_X shocks that produce substantially stronger responses of X_1'. Foreign banks with domestic operations are more sensitive than their domestic counterparts to shocks to the interest rate on reserves, because they have a smaller foreign lending market that they share with pure domestic local foreign banks. Consequently, foreign banks with domestic subsidiaries can increase their domestic deposit liabilities to boost their reserve holdings and to benefit from the higher interest rate paid by the domestic central bank.

Figure 6 displays the impulse responses following 75-basis-points shock to r_X.[9] Following the shock, domestic local and common lending decline, while interest rates on loans rise as banks substitute reserves for loans. Foreign lending declines because the lower lending from foreign banks with domestic subsidiaries is not fully offset by the higher lending from foreign local banks. This implication is consistent with the findings of He and McCauley (2013b), who show that in response to a lower dollar Libor rate, dollar-denominated loans extended by banks in mainland China grow faster. In the domestic market, because of higher loan rates, all bank assets including reserves become more profitable following the increase in the rate on reserves, and so banks desire larger deposits and increase deposit rates to attract more deposits. Consequently, banks respond to a reserve-rate shock not only by reshuffling the asset portfolio and contracting retail lending, but also, and to a substantial extent, by increasing their deposit liabilities. This portfolio-size effect partially offsets the standard portfolio-reallocation response, and in this way banks smooth the impact on retail borrowers of any monetary policy shock. This result highlights the importance of using banking models that do not feature portfolio separation for policy analysis. The result is at odds with the predictions from Drechsler et al. (2017), because our model belongs to a large class of banking models in which bank deposits rise following increases in the monetary policy rate (the reserve rate in our case), as discussed by Repullo (2020).

Finally, the pass-through to the interest rate on loans is substantial, but not full, with

[9]The size of the shock is chosen to match the most recent policy innovations from the Federal Reserve.

interest rates on common lending rising by 60 basis points while rates on domestic lending rise slightly less. The impact on the Eurodollar loan interest rate is substantial, above 30 basis points, but much smaller than that on foreign local markets, because retail interest rates in the Eurodollar-denominated banking markets are anchored to the wholesale funds rate r_F. A caveat is that this result arises because of the unrealistic assumption of a large shock to r_X uncorrelated to r_F, while the two rates normally move in tandem.

Figure 7 displays the impulse responses following a shock to aggregate domestic deposit supply induced by quantitative easing. Domestic lending rises following the shock, but the size of the increase is very small, consistent with the empirical evidence providing evidence of rather weak effects of QE on lending. Reserves of both classes of banks operating in the domestic retail banking markets, on the contrary, rise substantially, with the increases being of a far larger order of magnitude in comparison to the lending increases. Aggregate deposits rise substantially in the domestic deposit market, while they decline in the foreign deposit market. Spillovers on foreign lending and deposit markets are of a small order of magnitude. These implications closely match the empirical results obtained and discussed by Acharya et al. (2022).

Figure 8 displays the impulse responses following a shock to domestic local loan demand L_{h1}. Following the shock, domestic banks accommodate in full the higher demand in the local market, mainly by reducing reserves and only marginally by reducing loan supply in the common loan market, with this latter decrease offset by greater lending on the part of foreign banks with domestic subsidiaries. The domestic loan interest rate rises at impact, while the corresponding increase of the common market loan rate is of a lower order of magnitude and the spillover effect on the retail Eurodollar loan rate is even smaller. Domestic deposit quantities and interest rates rise following the shock, but the size of the responses are of smaller order of magnitude than those of loans, indicating that loan demand shocks are initially largely accommodated by changes in reserves holdings.

One key implication of the analysis is that reserves that domestic banks and foreign banks with domestic subsidiaries hold with the domestic central bank function as buffers that are adjusted following any shock.[10] Consequently, even though portfolio separation does not hold in this model, the use of these reserves as buffers permit both sets of banks to insulate at least partially their balance sheets from asset- or liability-side shocks. Another key implication is that the domestic central bank's payment of interest on these reserves strongly influences the optimal buffering adjustments of reserves on the part of both groups

[10]A similar mechanism operates in other dynamic models of banking, as in Dia (2013).

of banks. Domestic banks' reserve responses typically are smoother and more persistent than those of foreign banks with domestic subsidiaries, which matches a key feature of observed data on U.S. and foreign banks' holdings of reserves with the Federal Reserve.

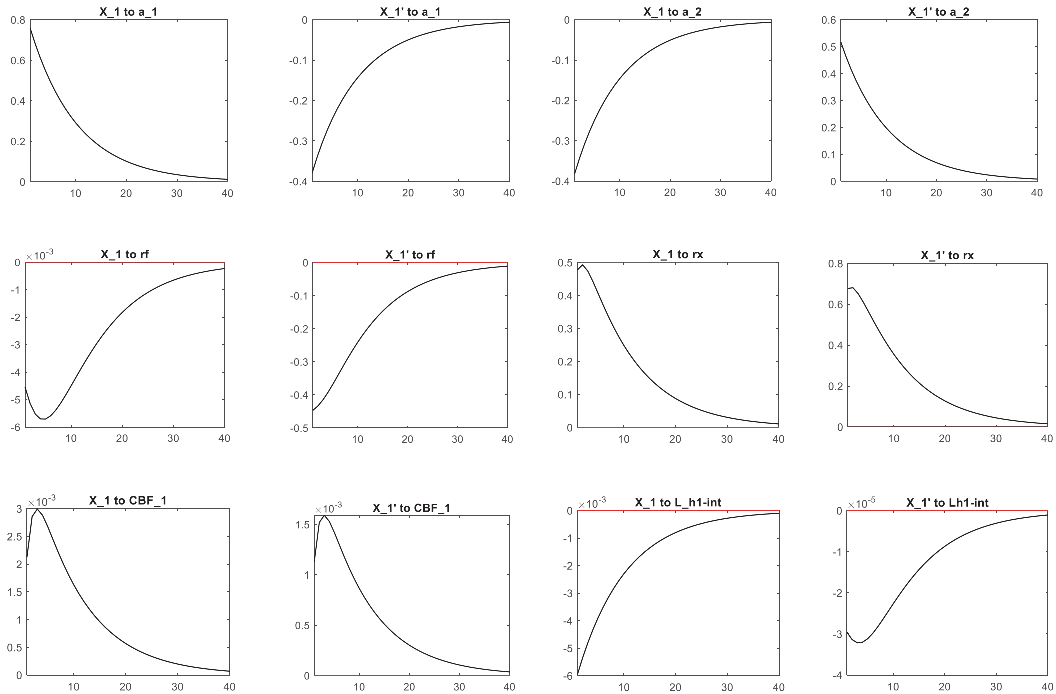

Figure 3: Impulse response functions of X_1 and X_1' to a 75-basis-points shock to a_1, a_2, r_F, r_X, CBF_1, L_{h1-int}.

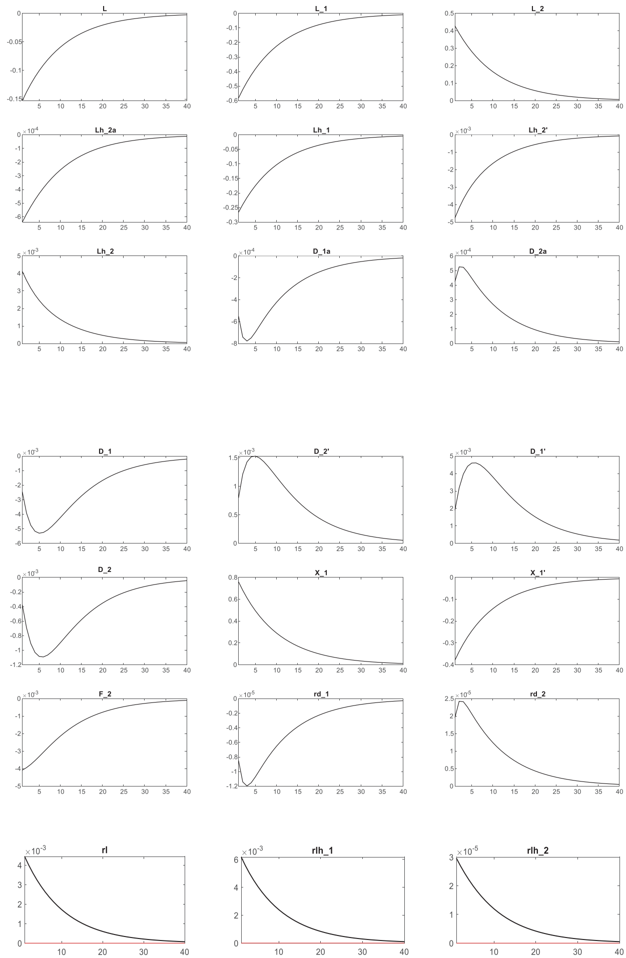

Figure 4: Impulse responses following a 75-basis-points shock to linear lending costs of domestic banks a_{1t}.

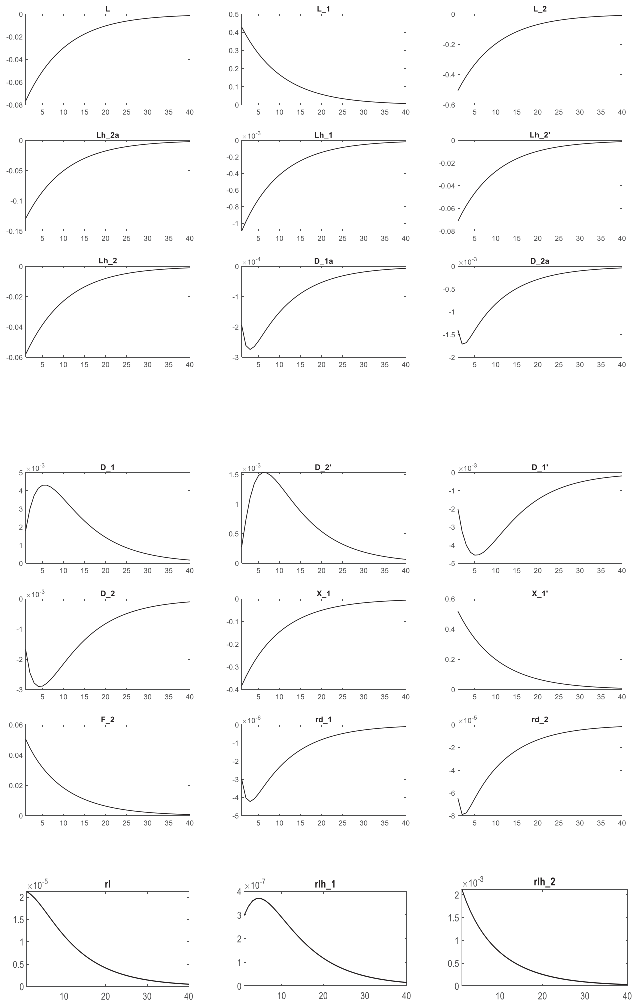

Figure 5: Impulse responses following a 75-basis-points shock to linear lending costs of foreign banks a_{2t}.

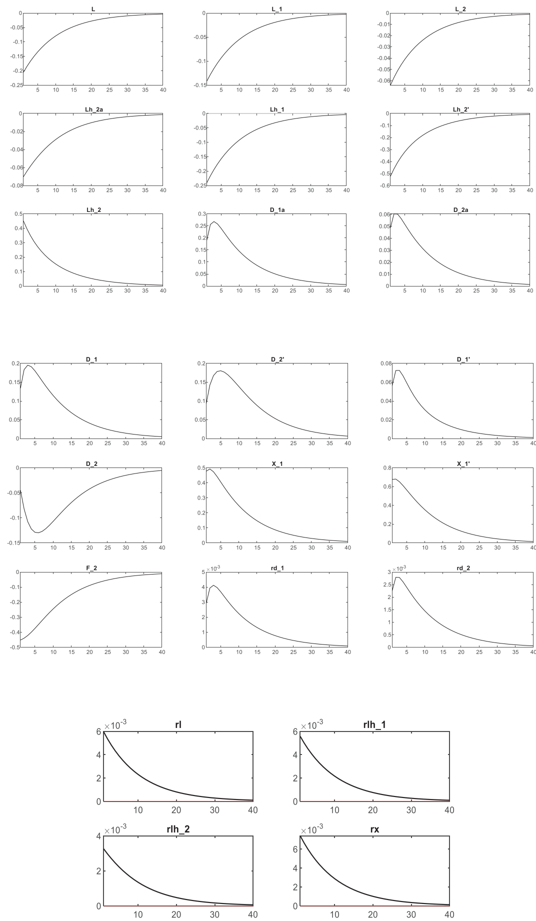

Figure 6: Impulse responses following a 75-basis-points shock to the administered domestic interest rate on reserves r_{Xt}.

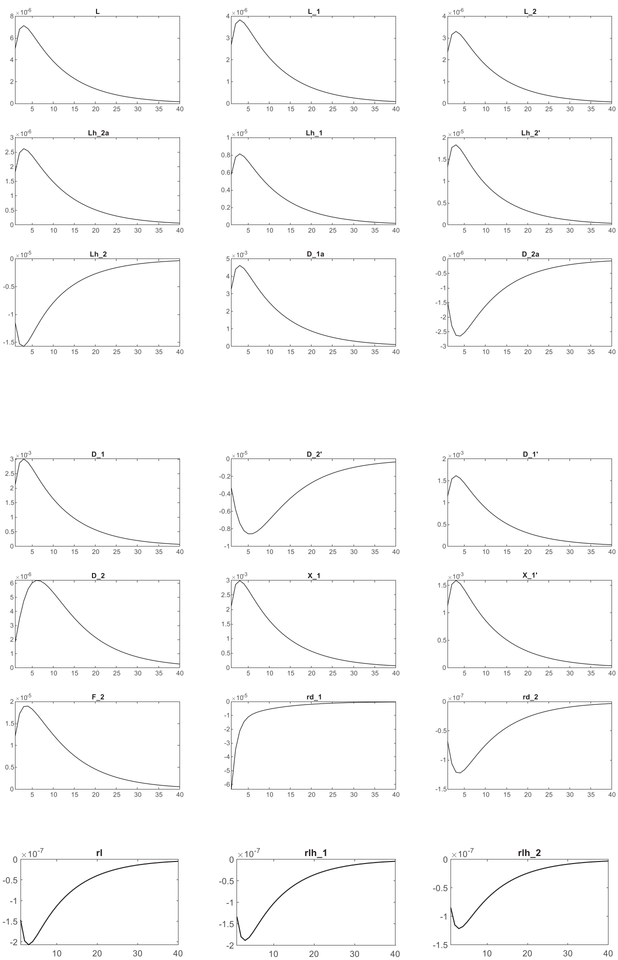

Figure 7: Impulse responses following a 75-basis-points shock to the intercept of aggregate domestic deposit supply CBF_{1t}.

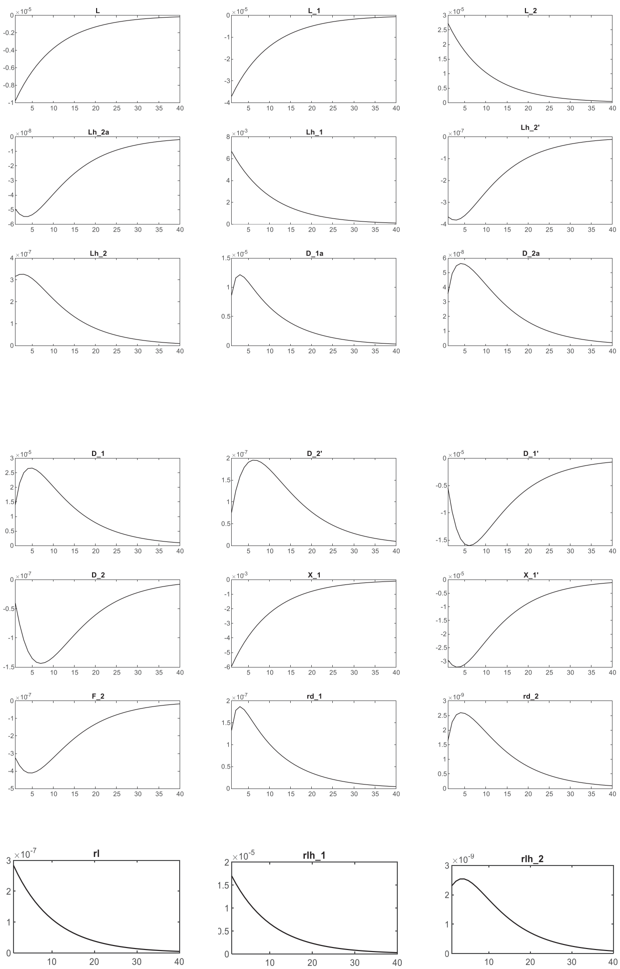

Figure 8: Impulse responses following a 75-basis-points shock to the intercept of domestic loan demand L_{h2-int}.

4 Conclusion

The high degree of liquidity and minimal costs of adjusting reserve holdings underpin the traditionally proportionately significant steady-state alterations of reserves to changes in the steady-state conditions faced and dynamic impulse responses to shocks to policy instruments and to parameters that affect banks' revenues and expenses. Our analysis has shown that this longstanding role of buffering reserve adjustments holds true as well within the current environment in which domestic banks and foreign banks with U.S. subsidiaries hold substantial interest-bearing reserve balances with the Fed. In addition, our analysis has demonstrated that in response to quantitative easing, changes in these banks' reserve holdings amid associated variations in deposit liabilities dwarf much smaller alterations in their loan portfolios. This implication, which emerges from both steady-state and dynamic analyses of the model, accords with real-world experience, as documented by Acharya et al. (2022). So do contrasting predictions that domestic and foreign banks' adjustments of their dollar-denominated loan portfolios predominate in the face of boosts in regulatory required capital ratios or increased deposit insurance expenses. The model's predicted dynamic responses by banks to an increase in the interest rate paid on reserves by the domestic central bank also matches actual experience, with foreign banks undertaking proportionately more responsive adjustments to their reserve positions than do domestic banks. Indeed, overall the model's implications are consistent with the essential conclusions that Acharya et al. (2022) derive from the available data.

Until now, the theory of retail banking has had little to say about the substantive alterations of the environment faced by banks engaged in cross-national as well as local competition in dollar-denominated loan and deposit markets. Our analysis has filled this gap in the literature. Nevertheless, our analysis has been predicated on a simplified background environment. Consistent with the settings faced by banks operating in global dollar-denominated retail markets between 2008 and mid-2018 and since early 2020, we have assumed that the interest rate paid by the domestic central bank is always sufficiently higher than global wholesale funds rates to hinder active funds trading by domestic and foreign banks with domestic operations that hold reserves with the domestic central bank. When the Fed tentatively and slowly began to unwind its balance sheet between mid-2018 and the onset of the Covid-19 crisis in early 2020, it set the interest rate on reserves close to and even sometimes equal to wholesale funds rates, and Dutkowsky and VanHoose (2020) show in the context of a closed-banking-system setting that the resulting behavioral changes were not insignificant. Although the Fed's post-mid-2022 unwinding so far has involved keeping the interest rate on reserves above wholesale rates, broadening the analysis to contemplate this alternative policy approach would be a useful extension.

Another simplifying assumption of our model is a presumed quiescence of foreign central banks. Allowing for active policymaking by another central bank and explicit inclusion of a broadened range of additional financial markets undoubtedly would broaden the applicability of our framework to a wider array of policy issues. We leave these and other potential extensions for future research.

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