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Abstract[1]

This paper studies from an empirical and theoretical perspective the systemic and bank-level effects of imposing reserve requirements (RR) in foreign currency in an economy with a heavily dollarized financial system. The paper empirically characterizes banks' responses to the RR carried out by the Peruvian Central Bank since 2008 with the objective of stabilizing the financial market and meeting its policy targets. The results suggest that the RR is effective in reducing the overall level of credit in the economy and that banks' response in terms of credit and deposits is very heterogeneous depending on their ex ante preference for foreign funding ratio, i.e., the ratio of deposits in dollars to total loans. Motivated by the empirical insights, the paper builds a DSGE small-open-economy model with financial frictions *à la* Gertler-Karadi-Kiyotaki, where bank heterogeneity and financial dollarization are introduced to evaluate the effectiveness of the differential RR in reducing financial dollarization and improving financial resilience.

JEL classifications: E44, E65, E58, G21

Keywords: Macroprudential policy, Currency risk, Reserve requirements, Emerging market economies

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1 Introduction

The financial crisis of 2008-2009 has triggered a renewed interest in capital flow management measures as tools with the potential of reducing the exposure to international capital flows volatility, financial fragility, and, therefore, the probability of crises. This renewed interest has enriched both the policy and the academic discussion on the topic (see, among others, Bianchi, 2011; Bianchi and Mendoza, 2018; Andreasen *et al.*, 2019). However, with the exception of a few examples, Ahnert *et al.* (2018) and Aguirre and Repetto (2017), little progress has been made in understanding how capital controls and macroprudential policies can help reduce financial currency exposure. For many EMEs currency risk exposure is a pervasive concern due to high levels of financial dollarization. As a result, many countries, such as Brazil, Peru, and Uruguay have implemented specifically tailored capital controls and macroprudential regulations to reduce this risk. In this paper, we contribute to the literature by analyzing the consequences (and effectiveness) of reserve requirements (RRs) imposed on foreign currency deposits with the objective of reducing foreign exchange risk and financial fragility, both in the financial system and the overall economy.

Although most central banks from advanced economies have reduced their reliance on RRs as a policy instrument, RRs have been actively used as a monetary policy instrument in a number of EMEs. Their use in EMEs has been motivated by the fact that a single instrument, the interest rate, may not be sufficient to deal with the challenges that these economies face. Federico *et al.* (2014) estimate that, in contrast to industrial countries, approximately two-thirds of developing countries have used RRs as a macroeconomic (countercyclical) stabilization tool. More specifically, given the financial dollarization in EMEs, several central banks have imposed a differentiated RR on foreign-currency deposits when there is a concern that bank reliance on such deposits is excessive.

In this paper, we perform an empirical and theoretical analysis of the bank-level effects of the RRs by currency actively used by the Peruvian Central Bank since mid-2008. To tackle the issue, we begin by conducting an empirical investigation to extract key insights that we then use to build a DSGE small open economy with financial frictions and financial dollarization. We choose to focus on the Peruvian financial system, as it has historically presented a high level of dollarization even by EME standards. Although reforms in the financial system and the implementation of the inflation targeting regime since 2002 have managed to reduce financial dollarization, it still remains one of the main vulnerabilities of the Peruvian economy.

Using data from 2004 to 2017 from the "Superintendencia de Bancos, Seguros y AFP de Perú" (SBS), we characterize the main bank-level responses to currency-specific RRs. Our preliminary empirical results suggest that the RRs in U.S. dollars were effective in curbing deposit and credit growth but with an heterogeneous reaction across banks depending on their ex ante, i.e., before the RR was implemented, foreign funding ratio (BFFR), defined as the ratio of deposits in U.S. dollars to total loans. More specifically, banks with a higher BFFR reduced their deposits in U.S. dollars, total deposits, and deposit dollarization relatively more than banks with a lower BFFR after RRs in U.S. dollars were implemented, while the opposite is true for credit in U.S. dollars, total credit, and credit dollarization.

Motivated by these empirical insights, and in order to gain a deeper understanding of the main mechanisms at play, we construct a DSGE small-open-economy model with financial frictions *à la* Gertler-Karadi-Kiyotaki that is rich enough to include the most important margins of bank adjustment. More specifically, we introduce bank heterogeneity and financial dollarization to evaluate the effectiveness of the differential RR in reducing financial dollarization and improving financial resilience (Gertler and Kiyotaki, 2010; Gertler and Karadi, 2011; Akinci and Queralto, 2018).

In this economy, households use the flow of profits they receive from the banks and non-financial firms they own to consume and save through bank deposits. The rest of the world lends to the domestic banks in foreign currency. Non-financial firms produce tradable goods that are used for consumption and investment, and capital. Capital-producing firms finance themselves with loans from banks that face a borrowing constraint, following Gertler and Kiyotaki (2010) but with two main differences. First, domestic banks operate in both local and foreign currency. Second, domestic banks are heterogeneous: there are two types of banks that differ in their BFFR. We calibrate the model with Peruvian data and then introduce the QE shock and the currency-specific RR.

The QE shock prompts a credit boom in the small open economy, leading to higher net worth for banks, higher assets prices, higher loans in foreign currency and an increase in investment and consumption (on impact). The initial shock motivates a substitution between foreign and domestic currency, away from the latter. When we introduce the RR on foreign currency deposits, the initial effects of the QE shock are smoothed and the credit boom caused by the QE is considerably smaller, as in our empirical analysis. The low-type BFFR bank counteracts the effect of the high-type BFFR because it tends to hold more domestic deposits than foreign one. The resulting heterogeneous responses of the two types of banks is mostly consistent with our empirical findings: i) high-type banks reduce their deposits in foreign currency and total deposits relatively more than low-type banks, as found in the data, although they increase deposit dollarization relatively more than low-type banks; ii) high-type banks reduce their credit in foreign currency and credit dollarization relatively less than low-type banks, although they reduce total credit relatively more than low-type banks. We are working on an extension of our baseline model to address these issues.

The rest of the paper is organized as follows. We first present a brief literature review. Section 2 discusses the main characteristics and historical evolution of the Peruvian financial system. Section 3 presents the empirical analysis. In Section 4 we describe the model and in Section 5 the numerical exercises in which we model foreign quantitative easing and the domestic reaction. Finally, Section 6 concludes.

Literature Review This paper is related to an increasing literature that studies the impact of non-conventional policy tools on credit conditions and on systemic risks. We first focus on the links and contribution to the empirical strand of the literature, and then on the links and contribution to the theoretical one.

Forbes *et al.* (2015) and Frost *et al.* (2020), when looking at the international experience, find a greater effectiveness of macroprudential policies relative to capital controls in influencing key macroeconomic outcomes. Additionally, Aizenman *et al.* (2014) find that macroprudential policies can help peripheral economies to (re)gain monetary independence from center economies. Specifically focusing on foreign exchange regulations on banks, Ahnert *et al.* (2018) show that they appear to be successful in mitigating banks' vulnerability, but that they partially shift the snowbank of foreign exchange vulnerability to other sectors.

For the case of Peru, Garcia-Escribano (2010) identifies RRs as having a positive role in the process of de-dollarization in Peru, together with macroeconomic stability and the development of the capital market in soles. Additionally, Vega *et al.* (2014) show that Peruvian

RRs were effective in curbing credit growth. We contribute to this literature by analyzing the role of bank heterogeneity in shaping the ultimate effect of RRs and by complementing our analysis with a theoretical explanation of the main mechanisms at play.

Keller (2019) also studies how capital controls carried out by the Central Bank of Peru during the aftermath of the 2008 Financial Crisis affected domestic and foreign lending of Peruvian banks. However, her focus is on a different type of capital control: she looks at the limits on foreign currency forward holdings of domestic banks, while we look at reserve requirements. She empirically shows that this type of capital control prompts unintended effects: banks increase lending in foreign currency, while they reduce lending in denominated in domestic currency. In contrast, the capital control that we study (empirically and theoretically) helps in smoothing the effect of an unintended increase in credit in the emerging economy.

In terms of theoretical literature, our model builds on the closed-economy macroeconomic frameworks with financial frictions of Gertler and Kiyotaki (2010) and Gertler and Karadi (2011). We follow Akinci and Queralto (2018) to open the economy and incorporate agency frictions that are more severe for foreign debt than for domestic deposits. Additionally, as in Céspedes *et al.* (2004) and Kalemli-Ozcan *et al.* (2016), we consider the balance sheet channel of exchange rate changes in the presence of foreign-denominated debt.

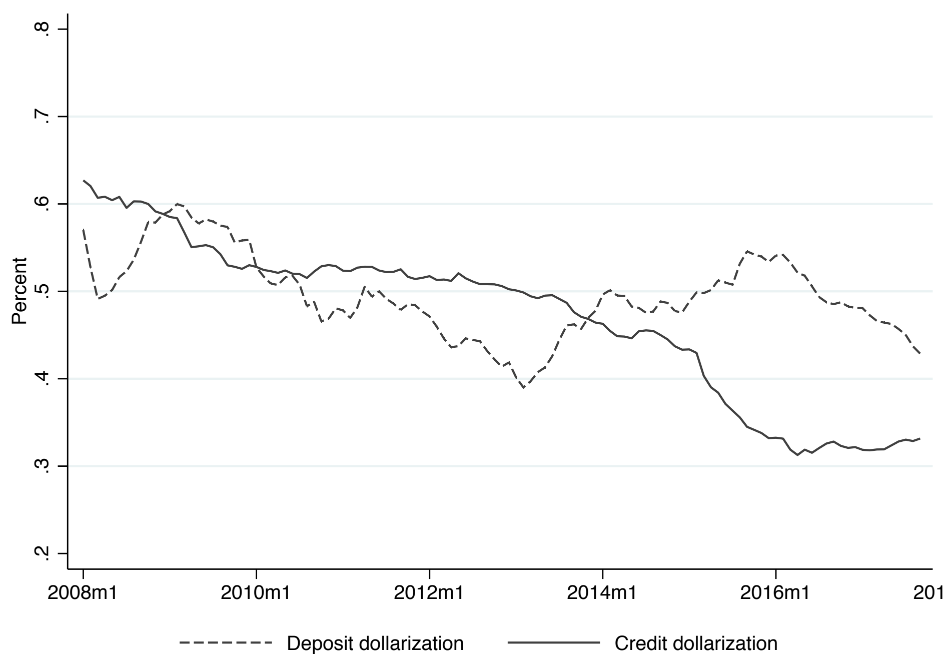
The distinctive feature of our work compared to these papers is that we focus on a small open economy with bank heterogeneity in terms of banks' preferences for foreign currency exposure. This allows us to match our empirical results with the model and study a shock that resembles the QE policy of the Federal Reserve Board and RRs on foreign currency deposits with which the Central Bank of Perú responded.

2 The Peruvian Financial System

The Peruvian financial system has historically presented a level of dollarization, even much higher than the average Latin American economy. The prevailing high inflation during the 1970s and the hyperinflation of 1988-90 were two of the main reasons why households have typically preferred to store foreign currency assets. Reforms in the financial system and in the conduct of monetary and fiscal policies since the 1990s, and the implementation of the inflation targeting regime since 2002, have managed to stabilize prices to annual inflation of 2.8 percent on average between 2002 and 2015.

On top of the inflation targeting regime, the Central Bank has also implemented specific de-dollarization policies since the early 2000s through the active use of macro-prudential tools such as RRs and foreign exchange interventions, among other instruments. The important reduction of inflation, complemented with Central Bank de-dollarization policies, significantly reduced financial dollarization, which has declined steadily from levels closed to 80 percent to less than 30 percent for credit and around 45 percent for deposits; see Figure 1. The progressive development of capital markets with trading of assets in domestic currency also played an important role, as pointed out by Garcia-Escribano (2010). Despite this undisputed reduction, financial dollarization remains the main vulnerability of the Peruvian economy, posing major challenges to monetary policy.

Figure 1 Banking Sector Dollarization



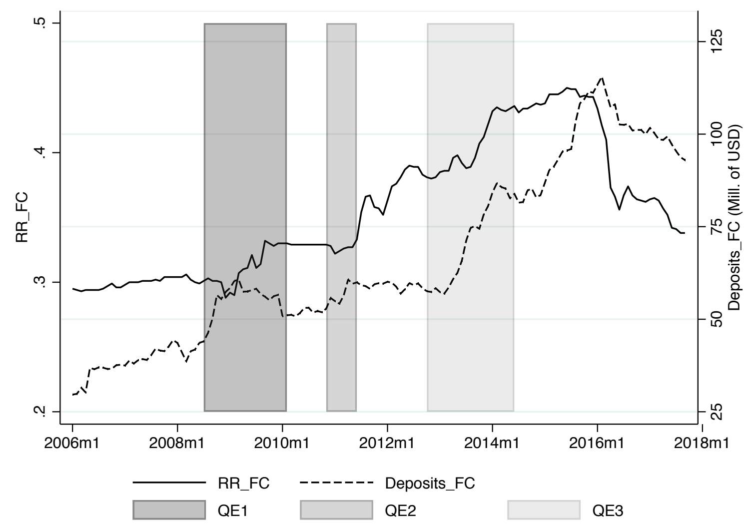
Notes: Deposit dollarization is defined as the ratio of deposits in U.S. dollars over total deposits, while credit dollarization is the ratio of credit in U.S. dollars over total credit. *Source:* Banco Central de la Reserva del Perú.

Financial dollarization is particularly troublesome during periods of financial distress. During events of higher volatility of the exchange rate three main concerns arise: pass-through to domestic inflation, liquidity risks, and credit risks. Liquidity risk is associated with the central bank's inability to act as lender of last resort to back up the dollarized liabilities of the banking system. Additionally, dollarization implies specific credit risks linked to the existence of currency mismatches; this increases the default probability of agents that borrow in U.S. dollars but whose cash flows do not increase with the value of the foreign currency. These sources of financial vulnerability create negative externalities and potential undesirable consequences for financial stability, justifying policy intervention and the use of precautionary policy measures.

In this context, the financial crisis of 2008-2009 and the ensuing policy of QE followed by the Federal Reserve Board posed a difficult threat to the Peruvian economy. During 2008, Peru faced a highly volatile macroeconomic environment. Prior to the Lehman Brothers bankruptcy in September 2008, Peru confronted high capital inflows, substantial increases in international prices of food and fuel, and economic overheating, which generated inflationary pressures. This scenario created a policy dilemma: if the authorities raised interest rates to control headline inflation and credit growth, they risked attracting even more capital inflows (see Montoro and Moreno, 2011). The events after the Lehman bankruptcy led to yet another dilemma. With the worsening of the global financial crisis, gross capital inflows contracted sharply and conditions in the money market deteriorated rapidly, in both foreign and domestic currency. With still higher inflation than the target, policymakers needed to stabilize financial markets and counter the sharp contraction in external demand while also ensuring that inflation expectations remained anchored. During 2011 and 2012, the low levels of international interest rates and the appreciation of the domestic currency in Peru that followed the Federal Reserve Board's QE policies generated a rebound in the expansion of U.S. dollar credit, slowing the process of credit de-dollarization.

To weather the different phases of this storm, the Peruvian Central Bank actively used, among other tools, RRs in U.S. dollars, i.e., RR^{FC}, and in soles, i.e., RR^{DC}, neither of which had registered significant changes since 2004. The RRs were calibrated to increase/reduce the cost of lending and curb/foster credit growth as the level of deposits in dollars responded to the QE and the international situation (see Figure 2). The full pool of monetary policy measures implemented during the crisis allowed the Central Bank to maintain inflation convergence towards the goal of 2 percent, while at the same time guaranteeing that the hardening of

Figure 2 Reserve Requirement in Foreign Currency, Deposits in U.S. Dollars, and Quantitative Easing Periods in the United States



Source: Banco Central de la Reserva del Perú.

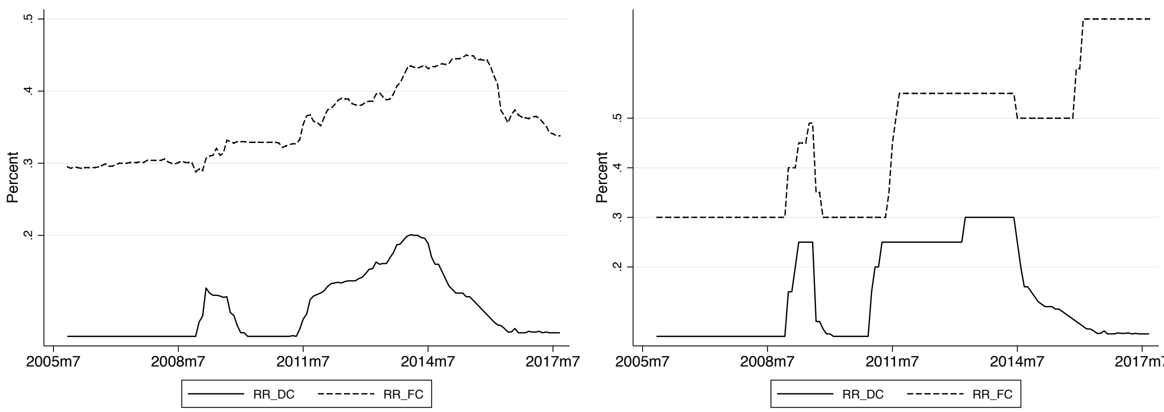
external credit conditions did not affect internal ones. Since then, RRs have continued to be actively used in Peru to achieve monetary policy objectives. The Central Bank has used RRs in a more cyclical fashion by raising their average and marginal levels during periods of capital flow surges and cutting them during capital reversal episodes. By increasing RRs in foreign currency during periods of intense capital inflows, banks' incentives to lend in U.S. dollars fall. At the same time, this approach creates a foreign currency buffer to reduce banks' vulnerability to capital reversals. Panels (a) and (b) of Figure 3 present the evolution of the average and marginal RR, respectively, from 2005 to 2017. In both cases, the RR^{FC} and the RR^{DC} show a period of almost no movement until mid-2008 and a high degree of variability thereafter.

3 Empirical Analysis

The three main objectives of the empirical analysis are to analyze how changes in the RR^{FC} affected i) banks' decisions, ii) their currency risk exposure, and iii) whether these effects where shaped by specific banks' characteristics.

To design our empirical exercise, we build on the insights of previous studies. Banks'

Figure 3 Evolution of Reserve Requirement



(a) Evolution of Average Reserve Requirement **(b)** Evolution of Marginal Reserve Requirement

Note: The solid line corresponds to the reserve requirement in domestic currency (RR_DC), while the dashed line plots the reserve requirement in foreign currency (RR_FC).
Source: Banco Central de la Reserva del Perú.

basic operation in the simplest economy consists of taking deposits from households and lending to firms. However, a large literature has shown that banks' operations becomes trickier once we take into account that banks can potentially run with households' deposits. To prevent this scenario, borrowing constraints are introduced; see, among many others, Kiyotaki and Moore (1997) and Bernanke *et al.* (1999). Furthermore, when banks also take deposits internationally, these borrowing constraints should also reflect that banks' ability to divert deposits could be different depending on the location of depositors, as in Akinci and Queralto (2018) and Cuadra and Nuguer (2018). Ceteris paribus, banks with higher foreign funding ratio (BFFR), i.e., the ratio between deposits in U.S. dollars and total credit, are more likely to be constrained and therefore more affected by the RR^{FC}. Thus in our empirical exercise we focus specifically on whether banks with different levels of BFFR are affected differently by the RR^{FC}.

To calculate banks' preferences for BFFR, we use bank information for 2007-2008, during which the RR^{FC} barely moved.[2] Fixing this as a characteristic of the bank, we then explore how banks with different BFFR react to the changes introduced in RRs from mid-2008 until September 2017. Figure A.1 in the Appendix presents for each bank in the sample

[2]Our results are robust to calculating the average BFFR over the full period during which the RR did not move, i.e., 2004-2008.

the evolution of its BFFR throughout the 2008-2017 period together with the ex ante BFFR calculated over the 2007-2008 period.[3] It is worth noting that for several banks the effective BFFR decreases with time, distancing itself from the ex ante BFFR parameter. This is expected as the overall level of financial exposure and dollarization of the system is moving in that direction during the period. However, in terms of our identification, we do not need the exposure-preference parameter to capture the average level of exposure but the relative ordering of banks in terms of their exposure.

3.1 Data

The empirical analysis requires three key ingredients: a measure of the RR^{FC}, measures of bank performance, and control variables at the bank and country level.

We obtain the information on the evolution of the RR^{FC} from the Central Bank of Peru. On our baseline regression, we focus on the effect on changes on the average RR^{FC} because it is expected to have a stronger impact on banks credit supply than an increase in the marginal rate, since the former is not as contingent on the growth of banks' deposits as the latter (see, for example, Tovar *et al.*, 2012).

For the measures of bank performance and bank control variables, we use bank-level panel data from the statistical database of the SBS from June 2004 to September 2017. The SBS data provide monthly detailed information on banks' operations such as credit and deposit volumes in U.S. dollars and soles, returns, liquidity ratios, and capital adequacy ratios, among other variables. Table A.1 in the Appendix presents the summary statistics of the main variables at the firm level. Our final sample has 1,394 observations from 12 different banks.

Finally, we also include a comprehensive set of controls at the country level to account for other changes that might be taking place in the economy and that could affect credit demand. To this end, we use standard macroeconomic controls: economic growth, inflation, real exchange rate, sovereign rating, the local interest rate in dollars and soles, and the ratio of net capital inflow to GDP. Table A.2 in the Appendix shows the summary statistics of the macroeconomic indicators during our period of analysis.

[3] To check the Online Appendix please go to `http://www.iadb.org/document.cfm?id=EZSHARE-1993837609-199`.

Sample representativity Our identification strategy forces us to keep only the banks that were operative before January 2008, as we need the estimation of the BFFR to be exogenous from the implementation of the RR. As a result, our sample must leave out the three banks that started operations after 2008, i.e. the Banco Azteca del Perú, Banco Cencosud, and Banco ICBC. In spite of that, our sample is representative of the banking sector in Peru as the included banks represent over 97 percent of the total assets, credits, and deposits of the total banking system, which consisted of 16 banks as of September 2017; see Table A.3 in the Appendix. Furthermore, the sample represents over 97 percent of credits in U.S. dollars and over 99 percent of deposits in U.S. dollars.

3.2 Empirical Strategy

Our baseline econometric model is:

$$Outcome_{it} = \alpha_0 + \alpha_1 RR^{FC}_{t-1} + \alpha_2 RR^{FC}_{t-1} \times BFFR_i + \alpha_3 X_{it} + \alpha_4 Y_{t-1} + A_i + B_{dm} + \epsilon_{it} \quad (1)$$

where the subscript it refers to bank i, and time t. $Outcome_{it}$ refers to the vector of banks' outcome variables under analysis: for both credit and deposits we consider their levels in dollars, their total value, and the dollarization ratio. All our bank-level variables are expressed in logs. The interaction term, $RR^{FC}_{t-1} \times BFFR_i$, in equation (1) captures the heterogeneity in the impact of the RR^{FC} on banks' performance across banks with different ex ante BFFR. X_{it} is a set of time-varying bank characteristics–i.e., ROA, total assets, the ratio of deposits in domestic currency to assets, and the liquidity ratios in domestic and foreign currency. Y_{t-1} is the vector of macroeconomic variables lagged one period, A_i is a vector of bank dummy variables that account for bank fixed effects, and B_{dm} is a vector of monthly dummies that account for month fixed effects. Bank fixed effects control for endogeneity arising from time-invariant bank characteristics. Errors are clustered for robustness at the bank level.

Table 1 presents the results of our baseline regression. The macro variables in our baseline regression allow us to control for aggregate factors other than the RR^{FC} that might be influencing the response of banks. Despite this, there might be unobservables at the aggregate level that could be correlated with RR^{FC}, which could potentially induce a bias into our estimation. To ensure that macro-level variables are not biasing the results, Table 2 presents our baseline regression including time fixed effects. The disadvantage of this approach is that now we can only observe the effect of the RR^{FC} interacted with the BFFR variable while we miss the direct effect of the RR^{FC}. However, the coefficients of the interaction maintain their sign and significance levels, which suggests that our baseline regression does a reasonable job at controlling for relevant aggregate confounding factors in terms of the identification of α_2.

Table 1 Effects of Reserve Requirement in Foreign Currency, RR^{FC}: Full Period.

VARIABLES	(1) FC Deposits Full Period	(2) Tot. Deposits Full Period	(3) Deposit Dollarization Full Period	(4) FC Credit Full Period	(5) Tot. Credit Full Period	(6) Credit Dollarization Full Period
RR_FC	0.488***	0.176**	0.312**	-1.434***	-0.258***	-1.176***
	(0.179)	(0.072)	(0.124)	(0.241)	(0.064)	(0.224)
RR_FC*BFFR	-1.177***	-0.598***	-0.579***	2.855***	0.327***	2.528***
	(0.270)	(0.113)	(0.176)	(0.323)	(0.084)	(0.299)
RR_DC	0.131***	0.049***	0.082***	0.885***	0.040***	0.845***
	(0.040)	(0.016)	(0.029)	(0.057)	(0.013)	(0.054)
RR_DC*BFFR	-0.038	0.013	-0.051	-0.960***	-0.026	-0.934***
	(0.055)	(0.023)	(0.039)	(0.087)	(0.019)	(0.083)
ROA	0.030**	0.023***	0.007	-0.007	-0.004	-0.003
	(0.013)	(0.005)	(0.008)	(0.007)	(0.002)	(0.007)
Total Assets	1.154***	1.056***	0.098***	0.423***	0.953***	-0.530***
	(0.048)	(0.019)	(0.032)	(0.043)	(0.014)	(0.042)
Deposits Soles/Total Assets	-1.215***	0.879***	-2.094***	0.752***	0.202***	0.549***
	(0.116)	(0.056)	(0.071)	(0.131)	(0.043)	(0.120)
Liquidity Ratio Soles	0.009	0.006	0.003	-0.495***	-0.171***	-0.324***
	(0.047)	(0.021)	(0.032)	(0.045)	(0.019)	(0.042)
Liquidity Ratio Dollars	0.714***	0.215***	0.499***	-0.372***	-0.371***	-0.000
	(0.063)	(0.020)	(0.054)	(0.070)	(0.027)	(0.065)
Interest Rate Soles	-0.035***	-0.012***	-0.023***	-0.015**	-0.010***	-0.005
	(0.007)	(0.003)	(0.005)	(0.008)	(0.002)	(0.007)
Interest Rate Dollars	-0.013	-0.002	-0.011	0.002	0.002	0.000
	(0.013)	(0.005)	(0.009)	(0.015)	(0.005)	(0.014)
RER (var)	-0.359	-0.104	-0.255	2.220***	0.251	1.969***
	(0.487)	(0.198)	(0.336)	(0.480)	(0.170)	(0.459)
Inflation	-0.045*	-0.013	-0.032*	0.037	-0.002	0.039
	(0.023)	(0.009)	(0.017)	(0.029)	(0.008)	(0.028)
Growth	-0.152	-0.058	-0.094	-0.035	-0.001	-0.034
	(0.131)	(0.051)	(0.094)	(0.150)	(0.044)	(0.146)
Sov. Rating	-0.217***	-0.070***	-0.147***	-0.152***	0.011	-0.163***
	(0.019)	(0.008)	(0.013)	(0.019)	(0.007)	(0.018)
Net Inflows/GDP	-0.007***	-0.002***	-0.005***	-0.001	-0.002***	0.001
	(0.002)	(0.001)	(0.001)	(0.002)	(0.000)	(0.001)
Observations	1,394	1,394	1,394	1,394	1,394	1,394
R-squared	0.988	0.997	0.951	0.987	0.998	0.952
Bank FE	YES	YES	YES	YES	YES	YES
Time FE	NO	NO	NO	NO	NO	NO

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Notes: This table examines the effect of RR_{t-1}^{FC} and the interaction of RR_{t-1}^{FC} with BFFR on banks' outcome variables: Credit and deposits in U.S. dollars (FC credit and FC deposits, respectively), total, and dollarization. All regressions include a constant term, bank fixed effects, and robust errors. T-statistics in parenthesis. ***, **, and * indicate significance at the 1%, 5%, and 10% level.

In Figure 4 we show the magnitude of the impact of RR_{t-1}^{FC} on bank performance

Table 2 Robustness Check: Time Fixed Effects

VARIABLES	(1) FC Deposits Full Period	(2) Tot. Deposits Full Period	(3) Deposit Dollarization Full Period	(4) FC Credit Full Period	(5) Tot. Credit Full Period	(6) Credit Dollarization Full Period
RR_FC*BFFR	-0.911***	-0.522***	-0.389**	2.578***	0.364***	2.214***
	(0.245)	(0.109)	(0.159)	(0.303)	(0.084)	(0.279)
RR_DC*BFFR	-0.067	0.004	-0.071**	-0.931***	-0.030	-0.902***
	(0.051)	(0.022)	(0.036)	(0.084)	(0.019)	(0.078)
Observations	1,394	1,394	1,394	1,394	1,394	1,394
R-squared	0.990	0.997	0.959	0.988	0.998	0.957
Controls	YES	YES	YES	YES	YES	YES
Bank FE	YES	YES	YES	YES	YES	YES
Time FE	YES	YES	YES	YES	YES	YES

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

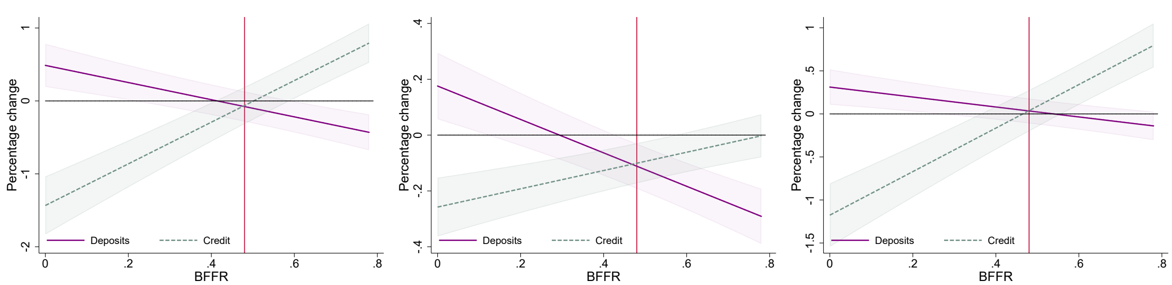
Notes: This table examines the effect of RR^{FC}_{t-1} and the interaction of RR^{FC}_{t-1} with BFFR on the banks' outcome variables: Credit and deposits in U.S. dollars (FC Credit and FC Deposits, respectively), total, and dollarization. All regressions include a constant term, bank fixed effects, time fixed effects, and robust errors. T-statistics in parenthesis. ***, **, and * indicate significance at the 1%, 5%, and 10% level, respectively.

across different characteristics (deposits and credit in foreign currency, Figure 4a, their total values, Figure 4b, and the dollarization ratios, Figure 4c) by calculating the partial effect of RR^{FC}_{t-1} at different levels of BFFR:

$$\frac{\partial Outcome_{it}}{\partial RR^{FC}_{t-1}} = \alpha_1 + \alpha_2 \times BFFR_i$$

where the median value of BFFR in the sample is 0.482 (and is the vertical red line in the Figure).

Figure 4 Effects of Reserve Requirement in Foreign Currency Interacted with BFFR on Deposits and Credit: Full Period



(a) Foreign Currency **(b)** Total **(c)** Dollarization

Notes: Each panel depicts graphically the respective regression results from Table 1. In each panel, the vertical axis measures the percentage change in the corresponding dependent variable triggered by the RR^{FC} for each level of BFFR, which is measured in the horizontal axis. The shaded areas are the corresponding 95% confidence intervals.

The key empirical lessons from the analysis are:

1. The RR^{FC} reduces total deposits and total credit for the median bank, while there is no significant effect for the median bank in terms of either credit or deposits in dollars or dollarization ratios.

2. The effect of the RR^{FC} is heterogenous depending on the ex ante level of BFFR.

   (a) Banks with high BFFR reduce their deposits in foreign currency, total deposits, and deposit dollarization relatively more than banks with low levels of BFFR.

   (b) The opposite is true for credit in foreign currency, total credit, and credit dollarization.

3.2.1 Robustness Checks

This section shows that our results are robust to several alternative specifications such as: i) restricting our sample to periods when QE was active, ii) excluding the largest banks, iii) considering the differential RR between deposits in dollars and deposits in soles, iv) considering the marginal rather than the average RR, and v) evaluating the interaction of capital intensity with different macroeconomic variables as controls.

In unreported regressions we perform additional exercises to test the robustness of our results to alternative assumptions and specifications. For instance, one relevant concern is the potential correlation among our macroeconomic controls. In particular, the monetary policy interest rate presents a high correlation between them and also with the sovereign rating, while the nominal exchange rate is also highly correlated with the sovereign rating. To make sure that these correlations do not affect our results, we run our regressions eliminating one of each of the regressors at a time and find that our coefficients of interest remain unchanged.

Subsamples: Periods of quantitative easing The QE policy implemented by the Federal Reserve Board as a response to the global financial crisis was active for a significant portion of our period of study, as shown in Figure 2. It is therefore relevant to understand if our results still hold when restricting our sample to the months when QE was active. In Table A.4 in the Appendix we present the results and show that they remain significant and qualitatively unchanged when restricting the sample to these sub-periods. As expected, though, our standard errors increase, as we are significantly reducing the number of observations.

Subsamples: Excluding big banks As is typical of financial systems in Latin America, the Peruvian banking sector is very concentrated. In particular, the two biggest banks, Banco de Crédito and Banco Continental, account for over 60 percent of the total assets of the banking sector, and the third largest bank, Scotiabank, accounts for an additional 15 percent of assets. Thus, to make sure that these banks are not driving our results, we replicate our analysis leaving them out of our sample. Table A.5 in the Appendix shows that our results are qualitatively unchanged, with all relevant coefficients maintaining their sign and significance levels.

Alternative measures for RR: Differential effect Since 2008, RR^{FC} and RR^{DC} were used differently with $RR^{FC} \geqslant RR^{DC}$ for the whole period. It is thus possible to interpret that banks had to keep RR^{DC} for any type of deposits and an additional $RR^{dif} = RR^{FC} - RR^{DC}$ for deposits in U.S. dollars. In this context, it could be the case that it is actually the excess RR over RR^{DC} what is affecting bank decisions instead of RR^{FC} directly. To make sure that banks' reactions to these differential go in line with our results, Table A.6 in the Appendix presents the estimation of our baseline regression when considering RR^{dif} instead of RR^{FC}. The results are consistent, both in signs and significance, to those obtained when considering the level of RR^{FC} instead of its difference with respect to RR^{DC}.

Alternative measures for RR: Marginal effect As previously mentioned, we have chosen to focus our baseline regression on the effect of changes on the average RR^{FC} because it has been shown to have a stronger impact on banks' credit supply than an increase in the marginal rate, since the former is not as contingent on the growth of banks' deposits as the latter (see, for example Tovar *et al.*, 2012). However, Table A.7 in the Appendix presents the results of considering the effect of the marginal instead of the average RR^{FC} to make sure that they are in line. As expected, the effects of considering the marginal rate are weaker but, when significant, they are consistent with our baseline results.

Interaction of capital intensity with macroeconomic controls Another potential concern is that the interaction between the RR and $BFFR$ variables could be capturing the effect of an interaction between $BFFR$ and other macroeconomic variables. To make sure this is not the case, Table A.8 presents the results of replicating our baseline regression introducing, one at a time, each of these alternative interactions. The results show that all of their coefficients of interest maintain their sign, while 80 percent maintain their sign and significance. The coefficients of interest are affected the most when we include the interactions of $BFFR$ with the interest rates in domestic and foreign currency. This is expected, as these rates also react to the RR and present a very high correlation with the RR (over 75 percent in both cases).

4 The Model

Using the insights of our empirical results we construct a model with two main features: i) financial dollarization (in deposits to banks and loans to firms), and ii) heterogeneity in banks' preference for currency exposure, i.e., different BFFR. The model is a small open real economy augmented with financing frictions as in Gertler and Kiyotaki (2010), Gertler and Karadi (2011), and Akinci and Queralto (2018). We conceptualize our economy as an emerging market that receives the effects of what advanced economies do, with foreign variables signaled with a *. The emerging economy consists of households, banks, capital-producing firms, and good producers.

Households use the flow of profits they receive from the banks and non-financial firms they own to consume and save through bank deposits. Non-financial firms produce tradable goods that are used for consumption and investment, and capital. Capital-producing firms finance themselves with loans from banks. Banks face a borrowing constraint that follows the modeling in Gertler and Kiyotaki (2010). EME banks operate in both the local and foreign currency, i.e., they receive deposits from domestic households (in soles) and foreign households (in U.S. dollars) and they make loans to domestic firms in domestic and foreign currency. Additionally, EMEs' banks are heterogeneous. More specifically, there are two type of banks that differ in the ratio of their foreign liabilities (expressed in real domestic currency) to total assets, BFFR, as defined by Akinci and Queralto (2018). We present all the equations and derivations of the model in Appendix B.

4.1 Households

The representative household maximizes its expected discounted utility subject to its budget constraint, choosing a consumption basket, C_t, labor, L_t, and deposits, D_t. A fraction f of households are bankers, while the rest are workers. Workers supply labor to non-financial firms and return their wages, W_t, to the households. Each of the bankers manages a financial intermediary and transfers non-negative profits back to its household subject to its flow of funds constraint, Π_t. Inside these profits, but we write them separately for convenience, banks face a quadratic adjustment cost on changing the ratio of foreign deposits to domestic deposits.[4] Households know this and therefore internalize this decision as well. Within the family, there is perfect consumption insurance. The household thus solves:

$$\max_{C_t,L_t,D_t} \mathbb{E}_t \sum_{t=0}^{\infty} \beta^t \left(\ln C_t - \frac{\chi}{1+\eta} L_t^{1+\eta} \right),$$
$$\text{subject to: } C_t + D_t = W_t L_t + R_{t-1} D_{t-1} + \Pi_t - \frac{\kappa_b}{2} \left(\frac{\mathcal{Q}_t D_t^*}{D_t} - \frac{\mathcal{Q}_{ss} D_{ss}^*}{D_{ss}} \right)^2, \tag{2}$$

where β is the subjective discount factor, $\chi \in (0,1)$ is the labor share parameter that ensures that labor equals $\frac{1}{3}$ in the non-stochastic steady state, and $\mathbb{E}_t$ is the expectation operator conditional on the information available at date t. The Frisch labor elasticity corresponds to η and the parameter of the portfolio adjustment cost is κ_b. The household gets income from working for the non-financial firms, $W_t L_t$, the return on the loans made last period, $R_{t-1} D_{t-1}$, and the profits from owning banks and the non-financial firms, Π_t, discounted by the adjustment cost on changing the ratio of domestic to foreign deposits. All sources of households' income are expressed in real terms.

We define the consumption bundle, C_t, as a CES aggregator of domestically produced

[4] We follow Schmitt-Grohé and Uribe (2003) on how to close the small open economy. Here we choose the portfolio adjustment cost strategy, choosing the external debt elasticity interest rate or another form of adjustment cost does not change the main results. The strategy that we follow gives us more flexibility when it comes to Blanchard-Kahn conditions.

goods, $C_{h,t}$, and imported goods, $C_{f,t}$:

$$C_t = \left[(1-\omega)^{\frac{\rho}{1+\rho}} C_{h,t}^{\frac{1}{1+\rho}} + \omega^{\frac{\rho}{1+\rho}} C_{f,t}^{\frac{1}{1+\rho}} \right]^{1+\rho} \tag{3}$$

where ρ is the elasticity of substitution between domestic and foreign goods and ω is the share of imported consumption in total consumption.

The price of domestically produced goods is $P_{h,t}$, and the price of imported goods is $P_{f,t}$, while $P_{C,t}$ is the price of the final consumption good. We assume producer currency pricing, i.e., $P_{f,t} = e_t P^*_{h,t}$, where e_t is the nominal exchange rate. The real exchange rate is defined as $\mathcal{Q}_t = e_t \frac{P^*_{C,t}}{P_{C,t}}$. All the first order conditions are standard and presented in Appendix B.1.

4.2 Good Producers

A continuum of mass unity of retail (intermediate) firms produce output using capital and labor that they combine using a Cobb-Douglas technology. Firms buy capital from capital good producers and borrow from banks to do so. This output is used for investment and for domestic and foreign consumption.

To obtain funds to buy new capital, good producers issue securities, s_t, to local banks. Good producers can borrow in domestic, s_t^s, and foreign currency, s_t^{usd}, where security prices are given by q_t. Total borrowing is S_t and is defined by:

$$q_t S_t = q_t \left(s_t^s + s_t^{usd} \mathcal{Q}_t \right), \tag{4}$$

where $\mathcal{Q}_t$ is the real exchange rate between the rest of the world and the EME and q_t is the price of both types of loans since both securities have the same underlying asset. Each period, capital depreciates at the rate δ.

As in the previous literature, we assume that good producers do not face any friction when obtaining funds from banks and that they can commit to pay all future gross profits to the creditor bank in the currency set at the beginning of the period. In this context, each unit of security is a state-contingent claim to the future returns on one unit of investment. By perfect competition, the price of new capital equals the price of the security, and good producers earn zero profits state-by-state.

The problem of the firms and its first order conditions are standard and presented in Appendix B.2. The relevant equations for the rest of the model correspond to the rate of return on loans denominated in domestic and foreign currency:

$$R^{s}_{k,t+1} = \frac{q_{t+1}(1-\delta) + Z_{t+1}}{q^{s}_{t}} \tag{5}$$

$$R^{usd}_{k,t+1} = \frac{q_{t+1}\mathcal{Q}_{t+1}(1-\delta) + Z_{t+1}}{q_{t}\mathcal{Q}_{t}}, \tag{6}$$

where the capital gross return is defined as

$$Z_t = \alpha P_{D,t} L_t^{1-\alpha} K_t^{\alpha-1}. \tag{7}$$

4.3 Capital Producers

Capital producers use final output, Y_t, to make new capital subject to convex adjustment costs in the gross rate of investment as in Christiano *et al.* (2005). The objective of capital producers is to maximize their expected discounted profits, choosing investment, I_t,

$$\max_{I_t} \mathbb{E}_t \sum_{j=t}^{\infty} \Lambda_{t,j} \left\{ q_j I_j - \left[1 + f\left(\frac{I_j}{I_{j-1}}\right)\right] I_j \right\},$$

where $\Lambda_{t,j}$ is capital producers' real stochastic discount factor, and because these firms are owned by households, it is the same for them. The first order condition yields the price of capital goods, which equals the marginal cost of investment:

$$q_t = 1 + f\left(\frac{I_t}{I_{t-1}}\right) + \frac{I_t}{I_{t-1}} f'\left(\frac{I_t}{I_{t-1}}\right) - \mathbb{E}_t \Lambda_{t,t+1} \left(\frac{I_{t+1}}{I_t}\right)^2 f'\left(\frac{I_{t+1}}{I_t}\right), \tag{8}$$

where

$$f\left(\frac{I_t}{I_{t-1}}\right) = \frac{\kappa}{2}\left(\frac{I_t}{I_{t-1}}\right)^2.$$

Profits, which arise only out of the steady state, are redistributed lump sum to households.

4.4 Banks

Banks get funds from households and retained earnings from previous periods to buy securities (loans) from domestic good producers. Banks are owned by households, and, in order to limit bankers' ability to save and overcome being financially constrained, we allow for turnover between bankers and workers inside a household. We assume that with i.i.d. probability σ a banker continues being a banker next period, while with probability $1-\sigma$ it exits the banking system and becomes a worker, transferring retained earnings back to the household. To keep the number of workers and bankers fixed, each period a share of workers become bankers. As a bank needs positive funds to operate, every new banker receives a start-up constant fraction ξ of total assets of the banks.

Banks' objective is to maximize their lifetime net worth through their financing operations. Banks receive deposits in domestic currency from domestic households and in foreign currency from foreign households, and they lend to domestic non-financial firms in domestic and foreign currency.

To mimic the RR^{FC}, banks need to keep a fraction τ_t of foreign deposits immobilized, in other words, τ_t is the fraction of foreign deposits that domestic banks cannot use to fund loans. Nevertheless, in the next period they have to pay the corresponding interest rate to households for the full amount of the deposit in foreign currency. [5]

In terms of the dynamics of τ_t, we assume that initially it is triggered by the credit boom, and it then follows an AR(1) process:

$$\tau_t = \mathbb{E}_t \frac{S_{t+1}}{S_t} \varepsilon_{QE,t} + \rho_\tau \tau_{t-1}, \tag{9}$$

where the first term corresponds to the growth in credit that the consolidated government wants to smooth out and ρ_τ is the persistence of the policy shock. According to this rule, the central bank activates the RR whenever the credit is growing due to a quantitative easing shock. The latter policy is announced by the foreign central bank. The balance sheet of a

[5] One could also interpret τ_t as the differential RR on deposits in U.S. dollars with respect to the RR on deposits in soles. As shown in the robustness checks of the empirical analysis, the same insights apply.

bank thus reads:

$$q_t\left(s^s_{i,t}+\mathcal{Q}_t s^{usd}_{i,t}\right)+\mathcal{Q}_t d^*_{i,t}\tau_t = d_{i,t}+\mathcal{Q}_t d^*_{i,t}+n_{i,t},$$
$$\text{or } q_t\left(s^s_{i,t}+\mathcal{Q}_t s^{usd}_{i,t}\right) = d_{i,t}+\mathcal{Q}_t d^*_{i,t}(1-\tau_t)+n_{i,t}, \tag{10}$$

where $q_t s^s_{i,t}$ is the real value of domestic loans, $q_t \mathcal{Q}_t s^{usd}_{i,t}$ is the real value of loans denominated in foreign currency, $d_{i,t}$ is the real value of deposits from domestic households, $\mathcal{Q}_t d^*_{i,t}$ is the real value of dollar deposits from foreign households, and $n_{i,t}$ are the retained earnings, or net worth.

There are two representative banks, and they differ in their steady state values of the foreign funding ratio, $x_{i,ss}$, i.e., the ratio of the bank's foreign liabilities to total assets at the steady state (the subscript ss indicates variables at the steady state). This variable is the same one that we described in the empirical analysis as BFFR and is defined as:

$$x_{i,ss} \equiv \frac{\mathcal{Q}_{ss} d^*_{i,ss}}{q_{ss}\left(s^s_{i,ss}+\mathcal{Q}_{ss} s^{usd}_{i,ss}\right)}, \tag{11}$$

with $i \in \{h, \ell\}$, and $x_{h,ss} > x_{\ell,ss}$. We assume that both banks face the same securities' prices. In what follows, we describe the problem of a generic bank, keeping in mind that there are two type of banks with different $x_{i,ss}$. The banker's budget constraint indicates that the uses of the bank in one period, i.e., the new loans, and the payment of the interest rate on deposits, have to be smaller than or equal to the resources, which correspond to the return on the loans made last period and the new deposits net of the reserve requirement:

$$q_t s_{i,t}+R_{t-1}d_{i,t-1}+R^*_{t-1}\mathcal{Q}_t d^*_{i,t-1} \leq R^s_{kt}q_{t-1}s^s_{i,t-1}+R^{usd}_{kt}q_{t-1}s^{usd}_{i,t-1}\mathcal{Q}_t+d_{i,t}+\mathcal{Q}_t d^*_{i,t}(1-\tau_t), \tag{12}$$

where $s_{i,t} = s^s_{i,t} + s^{usd}_{i,t}\mathcal{Q}_t$. This equation also reflects that from the deposits in U.S. dollars that bankers receive, a fraction τ_t cannot be used to fund loans. Thus, the evolution of net worth is defined by:

$$n_{i,t} = R_{kt}q_{t-1}s_{i,t-1} + R^{usd}_{kt}q_{t-1}s^{usd}_{i,t-1}\mathcal{Q}_{t-1} - R_{t-1}d_{i,t-1} - R^*_{t-1}\mathcal{Q}_t d^*_{i,t-1}. \tag{13}$$

By combining equations (10) and (12), we obtain:

$$n_{i,t} = (R_{kt} - R_{t-1})q_{t-1}s^{s}_{i,t-1} + (R^{usd}_{kt} - R_{t-1})q_{t-1}s^{usd}_{i,t-1}\mathcal{Q}_{t-1} + \left[R_{t-1} - \left(R^{*}_{t-1} + \tau_t\right)\frac{\mathcal{Q}_t}{\mathcal{Q}_{t-1}}\right]\mathcal{Q}_{t-1}d^{*}_{i,t-1} + R_{t-1}n_{i,t-1}. \tag{14}$$

Equations (12) and (14) show that we can interpret the role of the RR in two alternative ways. The first is to interpret this RR as a tax on quantities, as in equation (12). In this sense, EME banks have available $(1 - \tau_t)\,\mathcal{Q}_t d^{*}_{i,t}$ to use as resources, instead of $\mathcal{Q}_t d^{*}_{i,t}$. The second option is to see the RR as a tax on the cost of the foreign deposits, as in equation (14). Banks pay τ_t extra for every unit of deposit that they get from abroad; however foreign households continue receiving R^{*}_{t-1}. In both cases available funds for banks are lower.

4.4.1 Banks' Problem

At the end of period t, bank i maximizes the present value of future dividends, taking into account the probability of continuing being a banker in the next periods; the value of the bank is defined by

$$V_{i,t} = \mathbb{E}_t \sum_{s=1}^{\infty}(1-\sigma)\sigma^{s-1}\Lambda_{t,t+s}n_{i,t+s}, \tag{15}$$

where $V_{i,t}$ is a shortcut for $V_t(s^{s}_{i,t}, s^{usd}_{i,t}, x_{i,t}, n_{i,t})$ which is the maximized value of $V_{i,t}$ given an asset and liability configuration and an RR at the end of period t.

Following the previous literature, we introduce a simple agency problem to motivate the limited ability of the bank to obtain funds. Once households make deposits, the bank may transfer a fraction θ of assets back to its own household. If a bank diverts assets, it defaults on its debt and shuts down. Its creditors can re-claim the remaining $1-\theta$ fraction of assets. As a result, households are willing to supply funds to the bank as long as the value of the bank exceeds the benefits that the banker might get from running away. Thus, following incentive compatibility constraint must hold for each bank individually to ensure that a bank does not divert funds,

$$V_{i,t} \geq \theta\left(1 + \frac{\gamma}{2}x^{2}_{i,t}\right)q_t s_{i,t}. \tag{16}$$

The last term corresponds to the fraction of divertible assets with which the bank can run away. We follow Gertler *et al.* (2012) and Akinci and Queralto (2018) in the functional form of the incentive compatibility constraint. Because $\gamma > 0$, running away with foreign households' deposits is easier than running away with domestic deposits. We believe this is a natural assumption, as it captures the notion that it is harder for foreign creditors to monitor borrowers and enforce contracts than it is for domestic creditors.

Banks therefore maximize equation (15) subject to the incentive compatibility constraint (16). We present the derivation of the problem in detail in Appendix B.4. One important aspect is that the bank is indifferent between lending in domestic or foreign currency to domestic firms.

Aggregating Banks Now, we can aggregate between banks with high and low leverage on foreign currency. Total deposits denominated in soles and decided by households and total deposits denominated in foreign currency and chosen by foreign agents are, respectively:

$$D_t^s = D_{h,t}^s + D_{\ell,t}^s, \text{ and } D_t^* = D_{h,t}^* + D_{\ell,t}^*. \tag{17}$$

Total loans to firms in domestic currency are determined by matching the steady state share that corresponds to each type of loans with the data (the share of loans in U.S. dollars to loans in soles for each type of bank):

$$S_t^s = S_{h,t}^s + S_{\ell,t}^s. \tag{18}$$

In the Appendix, equation B.38, we define the maximum ratio of bank assets to net worth (leverage ratio) that satisfies the incentive constraint, $\phi_{i,t}$, so we can write the budget constraint of the bank as:

$$q_t \left[I_t + (1-\delta)K_t\right] = \phi_{\ell,t}N_{\ell,t} + \phi_{h,t}N_{h,t}. \tag{19}$$

We aggregate demand for securities by bank, $S_{i,t}$, and aggregate the net worth in each banking sector $N_{i,t}$ to get

$$q_t S_{i,t} = \phi_{i,t}N_{i,t} \quad \text{or} \quad D_{i,t}^s + (1-\tau_t)D_{i,t}^*\mathcal{Q}_t\epsilon_{qe,t} = (\phi_{i,t}-1)N_{i,t}. \tag{20}$$

In the last equation we incorporate the quantitative easing shock that resembles the policy that the advanced economies carried out to mitigate the effect of their financial crisis domestically;

it brings an external increase in deposits in foreign currency. We assume it follows a standard AR(1) process: $\epsilon_{qe,t} = \rho_{qe}\epsilon_{qe,t-1} + \varepsilon_{qe}$.

Total net worth of each type of banks, $N_{i,t}$, equals the sum of the net worth of existing bankers $N_{i,o,t}$, and of entering bankers, $N_{i,y,t}$, $N_{i,t} = N_{i,o,t} + N_{i,y,t}$. Net worth of existing bankers equals earnings on assets held in the previous period net the costs (foreign and domestic deposits), multiplied by the share that survive until the current period, σ:

$$N_{i,o,t} = \sigma \left[q_{t-1} \left(R^s_{kt} S^s_{i,t-1} + R^{usd}_{kt} S^{usd}_{i,t-1} \mathcal{Q}_t \right) - R_{t-1} D^s_{i,t-1} - R^*_{t-1} \mathcal{Q}_t D^*_{i,t-1} \right].$$

Given that households transfer to each new banker a share of the total assets of the existing bankers, and if we assume that this share is $\frac{\xi}{1-\sigma}$, we thus get:

$$N_{i,y,t} = \frac{\xi}{1-\sigma} (1-\sigma) q_{t-1} \left(R_{kt} S^s_{i,t-1} + R^{usd}_{kt} S^{usd}_{i,t-1} \mathcal{Q}_t \right). \tag{21}$$

Hence, total net worth of each bank i becomes:

$$N_{i,t} = (\sigma + \xi) q_{t-1} \left(R_{kt} S^s_{i,t-1} + R^{usd}_{kt} S^{usd}_{i,t-1} \mathcal{Q}_t \right) - \sigma R_{t-1} D^s_{i,t-1} - \sigma R^*_{t-1} \mathcal{Q}_t D^*_{i,t-1}, \tag{22}$$

which corresponds to a standard law of motion of net worth for the Gertler and Kiyotaki (2010)-type of models.

4.5 Resource Constraint

The market clearing condition for the home good is

$$Y_t = C_{h,t} + C^*_{f,t} + I_t \left[1 + \frac{\kappa}{2} \left(\frac{I_t}{I_{t-1}} \right)^2 \right] + \frac{\kappa_b}{2} \left(\frac{\mathcal{Q}_t D^*_t}{D_t} - \frac{\mathcal{Q}_{ss} D^*_{ss}}{D_{ss}} \right)^2, \tag{23}$$

where the last term corresponds to the portfolio adjustment cost that the small open economy pays for changing the steady state rate of domestic and foreign deposits. The balance of payments, obtained by aggregating the budget constraints of agents in the economy, is given by:

$$\mathcal{Q}_t (R^*_{t-1} D^*_{t-1} - D^*_t) = P_{D,t} Y_t - C_t - I_t \left[1 + \frac{\kappa}{2} \left(\frac{I_t}{I_{t-1}} \right)^2 \right] - \frac{\kappa_b}{2} \left(\frac{\mathcal{Q}_t D^*_t}{D_t} - \frac{\mathcal{Q}_{ss} D^*_{ss}}{D_{ss}} \right)^2. \tag{24}$$

5 Bringing the Model to the Data

5.1 Calibration

Table 3 Calibration of Baseline Model

Households	Symbol	Value	Source/Target
Discount factor	β	0.9951	Magud and Tsounta (2012)
	β^*	0.9975	Holston *et al.* (2017)
Inverse Frisch elasticity of labor supply	η	3.79	Justiniano *et al.* (2010)
Labor scale parameter	χ	214	$L_{ss} = \frac{1}{3}$
Trade price elasticity	$\frac{1+\rho}{\rho}$	1.5	Erceg *et al.* (2007)
Trade openness	ω	0.2	$exports/GDP = 0.11$
Domestic prices in equilibrium	$P_{D,ss}$	0.85	
Portfolio adjustment cost	κ_b	0.001	Schmitt-Grohé and Uribe (2003)
Good producers			
Capital depreciation rate	δ	0.027	$I/GDP = 0.21$
Capital share	α	0.3	Standard value
Capital Producers			
Investment adjustment cost	κ	2.85	Justiniano *et al.* (2010)
Banks			
Survival rate	σ	0.972	Gertler and Kiyotaki (2010)
Transfer rate	ξ	0.003	Gertler and Kiyotaki (2010)
Fraction of divertable assets	$\{\theta_H, \theta_L\}$	$\{1.1818, 1.0632\}$	$R_k/R = 2.069^{\frac{1}{4}}$
Home bias in bank funding	$\{\gamma_H, \gamma_L\}$	$\{0.3388, 0.4248\}$	$x_i = \{0.5, 0.22\}$
Macroeconomic parameters			
Investment to GDP	I_GDP	0.209	Central Bank of Peru
Gov. expenditure to GDP	G_GDP	0.110	Central Bank of Peru
Trade balance to GDP	T_GDP	0.0516	Central Bank of Peru
Shocks and Policy parameters			
Quantitative easing shock $\epsilon_{qe,t}$	$\varepsilon_{qe,t}$	$N(0, \sigma_{\varepsilon_{qe}} = 0.01)$	Generic exercise
	ρ_{qe}	0.3	Avg. duration of QE
Reserve requirement τ	ρ_τ	0.2	Generic exercise

We calibrate the model to match key features of the Peruvian economy during the period 2000-2019, a period that captures both 4 years of practically inactive RRs, from 2004 to 2008, and almost 10 years of a very active use of RRs. Macroeconomic ratios and parameters are calculated using data from 2000Q1-2019Q4 of the Central Bank of Peru. We explicitly state when parameters differ across bank types; otherwise, they are the same. Table 3 reports the values of the calibrated parameters.

With respect to the parameters in the utility function, we calibrate the different discount factors in the small open economy and in the rest of the world (taking the United States as benchmark), and the labor share parameter and the inverse of the Frisch elasticity of labor supply for the small open economy. For the EME discount factor, we rely on estimates of Peru's long-run neutral rate from Magud and Tsounta (2012) of about 2 percent, and accordingly calibrate β to 0.951. We set the foreign discount factor, β^*, to 0.9975, to match an implied a steady-state real-risk free interest rate of 1 percent per year for the U.S. natural rate (see, for example, Holston *et al.*, 2017). The labor share parameter in the utility function, χ, ensures that labor equals one third of the hours in the steady state, while we follow estimates from Justiniano *et al.* (2010) for the inverse Frisch elasticity of labor supply, η. The high value of χ is a characteristic of this type of models, see calibration in Gertler and Kiyotaki (2010) and Cuadra and Nuguer (2018). The portfolio adjustment cost parameter, κ_b, follows Schmitt-Grohé and Uribe (2003).

Turning to parameters governing international trade, we follow Erceg *et al.* (2007) and set the trade price elasticity, $\frac{1+\rho}{\rho}$, to 1.5. We set the size of the small-open economy relative to abroad, ω, to 0.2, which implies a steady-state exports-to-GDP ratio of 11 percent, as in the data.

The capital share, α, is set to the conventional value of 0.3. We use the depreciation rates of capital, δ, to match the long-run investment-to-GDP ratio, 0.2091. We rely on estimates from Justiniano *et al.* (2010) for the investment adjustment cost parameter, κ.

Regarding the parameters of the banking system, we set the survival rate of banks, σ, to 0.972, implying an expected horizon of 9 years. We set the transfer to the entering bankers, ξ, to 0.003; the last two parameters follow Gertler and Kiyotaki (2010). We match the steady-state share of loans made by banks with a high foreign funding ratio, i.e., 0.5, and low foreign funding ratio, i.e., 0.22, as we see in the Peruvian banking data. To hit the foreign funding ratio in the steady state of high and low-type banks from above, we calibrate the home bias in bank funding, γ_i, to be 0.3388 and 0.4248, for high and low banks, respectively. The share of divertible assets, θ_i, is set to match the steady state spread between the expected rate of return on capital and the rate of return on deposits and the differences that come from different γ_i. The spread rate in Peru is set at 2.69 percent on a quarterly basis following the average EMBI between 2000-Jan-1 and 2019-Dec-31, so that the resulting θ_i parameters are

1.2 and 1, for high and low banks, respectively. We also match the data-ratio of loans in foreign to domestic currency for high and low banks, 1.83 and 0.8, respectively.

Finally, we set several parameters to match different ratios from the Peruvian economy using the Central Bank of Peru data from 2000Q1 to 2019Q4. We use the trade-balance-to-GDP ratio, which equals 0.0516 during this period, to make sure that the current-account steady-state value equals zero. We also add an extra term in the balance of payment to account for the total government expenditure-to-GDP ratio and close the model. We approximate the total government expenditure-to-GDP ratio as the sum of public investment and consumption, yielding a value of 0.1106.

The QE shock is first presented to understand the mechanism behind the results that we found in the empirical part. Due to this is that we are picking a generic value of 0.01 for the standard deviation and 0.3 for the autoregressive component, QE lasts on average 1 year, as in the data. Regarding the reserve requirement, the initial magnitude is given by the size of QE and the growth in credit, while we set the autoregressive component to be lower than the one from QE and following the empirical evidence, we can see that after mid-2008 the Central Bank of Peru starts to use this policy actively.

5.2 Main Mechanisms at Play

Our objective is to understand the effectiveness of the RR in curbing credit growth and financial dollarization. The Peruvian central bank decided to implement the RR as a response to the fluctuating capital flows triggered by the QE policy that the Federal Reserve Board carried out after the 2008 Financial Crisis. Then, to understand the effectiveness of the RR, we need to incorporate both shocks into our model. To ease the exposition, we first look at the effects of QE alone, incorporating the QE as an increase in foreign deposits in domestic banks. Second, we incorporate an RR on foreign deposits, which smooths the effects of the QE shock, and compare both cases. Finally, we compare the results that we get in the model with those from the empirical analysis[6].

[6] In order to focus on the pure effects of the RR we are abstracting from the conventional monetary policy response that the Federal Reserve Board carried out during this period, together with the reaction of the Central Bank of Peru.

5.2.1 Response to a Quantitative Easing Shock

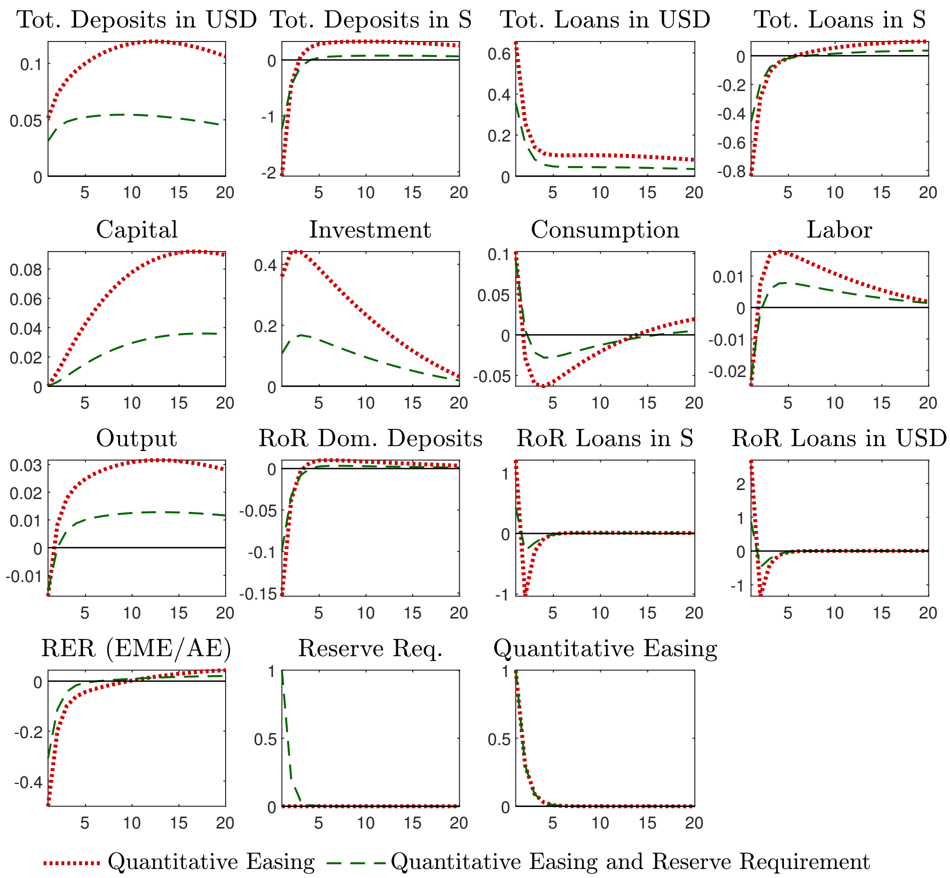
The QE shock is a positive inflow of foreign deposits into the domestic banking system. The red-dotted lines of Figures 5 and 6 present the reaction of the main variables of interest to the shock. The increase in U.S. dollar-denominated deposits leads the banking system to substitute away from domestic deposits. The domestic interest rate goes down, increasing the net worth of the banks to the point that they find it optimal to reduce total deposits. The higher net worth prompts a relaxation of the banks' borrowing constraint, which leads banks to lend more in foreign currency while substituting away from loans in domestic currency. Dollarization of bank assets and liabilities increases, leaving the economy more vulnerable to foreign exchange risk.

Due to the initial shock, the real exchange rate appreciates, triggering an increase on imports and a reduction in exports. These current account effects explain the initial reduction in output and the initial increase in consumption. The credit boom in the economy brings about higher investment and a higher price of capital, leading to a positive effect of the financial accelerator mechanism.

Due to the banks' different BFFR, on impact, high and low banks react in opposite directions: high (low) banks increase (reduce) their deposits in foreign currency. Deposits in domestic currency, on impact, fall for both types, and as a result of the size of this reduction, total deposits decrease for both types.

Loans in foreign currency increase for high banks, with a decrease in loans in domestic currency. Low-type banks have more loans in domestic currency than in foreign, so total loans for these banks fall while they increase for high-type banks, leading the credit boom in the economy. Both rates of return on loans in foreign and domestic currency fall due to the increase in the price of capital; however, the effect is stronger for the foreign currency rate of return. As a result, low-type banks can fund their loans in foreign currency with less deposits in U.S. dollars.

Figure 5 Impulse Response Functions to a Quantitative Easing Shock and the Small-Open-Economy Response (aggregate variables)



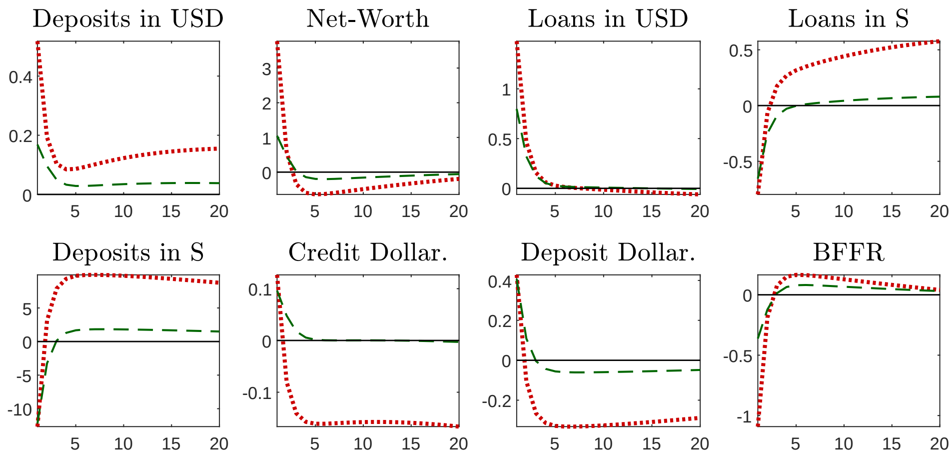
Notes: The vertical axis corresponds to the percentage deviation from the steady state, while the horizontal axis corresponds to quarters after the shock. We plot the following variables (in the same order as they appear): D_t^*, D_t^s, S_t^{usd}, S_t^s, K_t, I_t, C_t, L_t, Y_t, R_t, $R_{k,t}^s$, $R_{k,t}^{usd}$, $\mathcal{Q}_t$, τ_t, $\epsilon_{qe,t}$.

5.2.2 Response to a QE Shock When the Reserve Requirement in Foreign Currency is Active

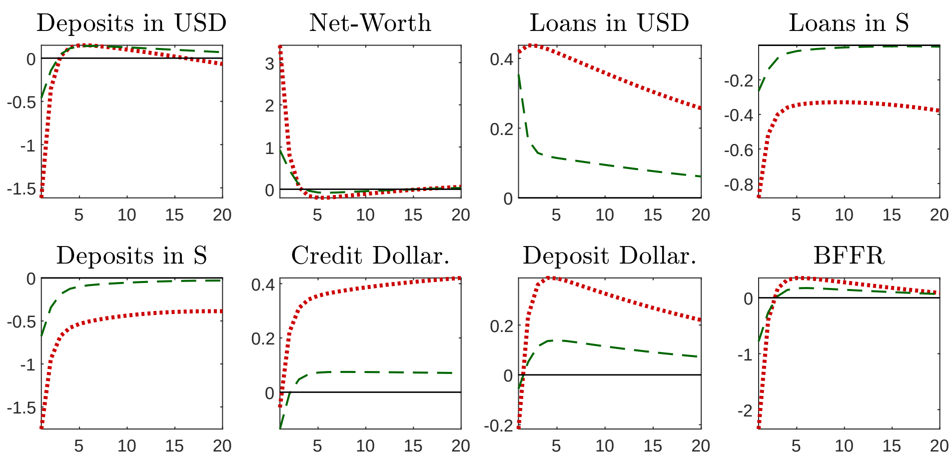
The green-dashed lines in Figures 5 and 6 show the response of the economy to the QE when the RR in foreign currency, similar to the one that the Central Bank of Peru carried out actively from mid-2008 onwards, is active. As explained in the model description, we can think of the RR as a share of the foreign deposits that the bank cannot lend but that still accrue interest payments.

Figure 6 Impulse Response Functions to a Quantitative Easing Shock and the Small-Open-Economy Response for High and Low Banks

(a) High-BFFR Variables



(b) Low-BFFR Variables



Quantitative Easing — — Quantitative Easing and Reserve Requirement

Notes: y axis corresponds to the percentage deviation from the steady state, while x axis are quarters after the shock. We plot the following variables (in the same order as they appear): $D^*_{i,t}$, $N_{i,t}$, $S^{usd}_{i,t}$, $S^s_{i,t}$, $D^s_{i,t}$, $S^{usd}_{i,t}\mathcal{Q}_t/(S^{usd}_{i,t}\mathcal{Q}_t + S^s_{i,t})$,$D^*_{i,t}\mathcal{Q}_t/(D^*_{i,t}\mathcal{Q}_t + D^s_{i,t})$, and $x_{i,t}$, where i corresponds to h and ℓ, for the high and low-BFFR, respectively.

When comparing to the case of only the QE shock, the RR manages to reduce the inflow of foreign deposits, while total deposits in domestic currency also fall but by a lower percentage. Credit in foreign currency increases remarkably less when the RR is in place, allowing for a smaller decrease in domestic currency loans. As a result, the credit boom in foreign currency shrinks, leading to smoother reaction of the real variables, i.e., investment, consumption, and output.

The policy is more effective in curbing the increase of foreign currency loans of the high-type banks. Regarding loans in domestic currency, without the RR policy, they decrease for both types of banks; however, the small-open economy policy smooths more the reaction of this variable for the low-type bank.

Finally, looking at the different levels of dollarizations, it turns out that dollarization in deposits increases less in both scenarios both policies for low-type banks, while they display similar behavior in terms of credit.

To better understand the contribution of considering bank heterogeneity in our theoretical analysis, as robustness check and in Appendix E.1 we contrast the effects of QE in our baseline model with two type of banks to one in which there is no bank heterogeneity. Bank heterogeneity brings a smoother effect on the real variables since the low-type banks counteract the effect of the high-type banks. This shows that bank heterogeneity is relevant to measure the aggregate effects on the economy and the size of the banks, and the distribution of this heterogeneity also matters for the economy as a whole.

5.2.3 Reserve Requirement Effects: Comparison of the Model with the Data

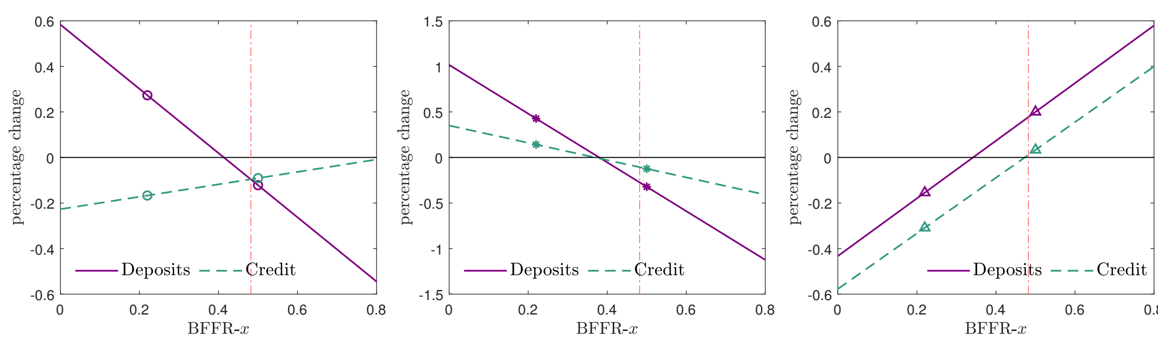
The results from the model are mostly consistent with our empirical insights. To better see this, Figure 7 plots the percentage changes triggered by the RR in the model with the QE shock in the same outcome variables analyzed in the empirical analysis (see Figure 2), as a function of the BFFR. The first subplot graphs the response of credit and deposits in foreign currency, the second subplot graphs the response of total credit and deposits, and the third subplot graphs the response of credit and deposits dollarization. The percentage change corresponds to the average response during the first four quarters after the shock. The values of x, i.e., BFFR, that we calibrate in the model are 0.22 for low-type banks, and 0.5 for high-type banks, as specified in Table 3 and then we linearly extrapolate to the full interval of values of BFFR in the data.

As in the empirical analysis, the model finds that total credit and deposits are reduced for the median value of BFFR, see fact 1 in Section 3.2. However, the model also finds that deposits in credit in dollars are also reduced by the RR, while in the empirical analysis this effect was non-significant.

Additionally, the model results show that the effect of the RR is heterogenous depending on the bank-type with respect to BFFR. More specifically, the empirical insight 2a states that high-type banks reduce their deposits in foreign currency, total deposist, and deposit dollarization relatively more than low-type banks. This result also holds in the model with the exception of deposit dollarization, which actually increases with BFFR. The increase in deposit dollarization with BFFR is a result of domestic deposits in high banks being more heavily reduced than in low-type banks.

The empirical finding 2b states that high-type banks increase their credit in foreign currency, total credit, and credit dollarization relatively more than low-type banks. In this case the model matches banks' behavior for credit in foreign currency and credit dollarization, but it fails to match the response in terms of total credit. The reason behind this mismatch is that credit in domestic currency increases in the data while it goes down in the model as a consequence of modelling loans in foreign and domestic currency as substitutes and not as complements. We are working on an extension of our baseline model to address these issues.

Figure 7 Model Results: Differential Reaction of High- and Low-Bank Exposure to Foreign Funding



(a) Foreign Currency **(b)** Total **(c)** Dollarization

Notes: Each panel depicts graphically the results from the difference between the model with quantitative easing and reserve requirement and a model with only quantitative easing. In each panel, the vertical axis measures the average of the first four periods of this difference, measured as percentage change in the corresponding dependent variable for each level of x, which is measured in the horizontal axis. The vertical line corresponds to the median value of BFFR in the data, 0.48, while the two marks in each of the subplots correspond to the low and high BFFR of the data and the model, 0.22 and 0.5, respectively.

6 Conclusion

The 2008-2009 financial crisis prompted advanced economies' central banks to carry out different policies to increase liquidity in their financial systems, this included the QE programs that the Federal Reserve Board carried out between 2009 and 2014. From an EME point of view, these policies prompted high capital inflows that were not necessarily related to the fundamentals of the domestic economies. EMEs' policymakers reacted by carrying out different policies, among which reserve requirement in foreign currency for dollarized economies was widely used.

In this paper, we perform an empirical and theoretical analysis of the bank-level effects of the RRs by currency actively used by the Peruvian Central Bank since mid-2008. To tackle the issue, we begin by conducting an empirical investigation to extract key insights that we then use to build a DSGE small-open economy with financial frictions and financial dollarization. Our preliminary empirical results suggest that the RRs imposed in deposits in U.S. dollars were effective in curbing credit growth but with a heterogeneous reaction across banks depending on their ex ante BFFR. In general, banks with a higher BFFR tend to reduce their deposits in U.S. dollars, total deposits, and deposit dollarization relatively more than banks with a lower BFFR after the RRs in U.S. dollars was implemented, while the opposite is true for credit in U.S. dollars, total credit, and credit dollarization.

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