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by Carlos Cantú, Rocio Gondo and Berenice Martinez

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Reserve Requirements as a Financial Stability Instrument

Carlos Cantú* Rocio Gondo† Berenice Martinez‡

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Abstract

We quantify the trade-offs of using reserve requirements (RR) as a financial stability tool. A tightening in RR reduces the amplitude of the credit cycle. This lowers the frequency and strength of financial stress episodes but at a cost of lower growth in credit and economic activity. We find that the gains from a lower probability and magnitude of financial stress episodes are greater than the costs from the initial reduction in economic activity. In addition, we find that RR have a stronger effect on emerging market economies than in advanced economies, both in terms of costs and benefits. Finally, we find that uniform RR have a stronger effect than RR that differentiate by maturity or currency.

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Keywords: reserve requirements, macroprudential policy, financial stress episodes, early-warning system, financial cycle

*Bank for International Settlements. carlos.cantu@bis.org
†Central Reserve Bank of Peru. rocio.gondo@bcrp.gob.pe
‡Bank for International Settlements. berenice.martinez@bis.org

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1 Introduction

Since the introduction of inflation targeting regimes, central banks in emerging market economies (EMEs) have increasingly used reserve requirements (RR) to minimise financial risks (BIS (2019)). The objective of this paper is to evaluate the effectiveness of these policies. First, we dissect the transmission channels through which RR affect financial markets. Then, we estimate the trade-offs of using RR for a sample of advanced economies (AEs) and EMEs. After a tightening in RR, we calculate the costs as the drop in economic activity, measured by industrial production growth. Then, we quantify the benefits as the lower frequency and magnitude of financial stress episodes.[1] Our results are the following. First, the net benefits of using RR are positive: the economic benefit of a lower probability of financial stress is greater than the initial drop in economic activity. Second, RR have a stronger effect in EMEs than in AEs, both in terms of costs and benefits. Finally, uniform RR have a stronger effect than RR by maturity or by currency.

We base the empirical strategy on a simple model where a tightening in RR is equivalent to a tax on financial intermediation (Glocker and Towbin (2012a)). For each unit of deposits, banks cannot use that share in reserves to offer new loans or buy other interest-bearing securities. Then, higher RR increase banks' marginal cost of funding through deposits. Banks pass this cost to depositors through lower deposit rates and to borrowers through higher loan rates. How much of the tax lenders and borrowers pay depends on the level of competition between banks, the availability of alternative sources of funding and the degree of competition of the banking system with other financial intermediaries (Reinhart and Reinhart (1999)).

The RR index considers legal changes in RR (Federico, Vegh and Vuletin (2014)). In this way we ensure that the RR shocks are independent of banks' reserve holdings. For countries that differentiate RR by the maturity or currency of the deposits, we construct a weighted average. The weights equal the share of the type of deposits in total reserves. The weights are fixed to prevent changes in the index driven by endogenous changes in the composition of deposits.

We follow the methodology of Behn et al (2016) to measure the trade-offs of using RR.[2] We obtain the costs by estimating the drop in industrial production growth after a tightening in RR using a panel VAR model. A tightening in RR

[1] We use a vector autoregressive (VAR) panel model to estimate the drop in industrial production growth and an early warning system model to obtain the probability of financial stress (Drehmann and Juselius (2014), Laeven and Valencia (2013)).

[2] They calculate the costs and benefits of capital based macroprudential policies in the Euro Area.

widens the spread between the loan and deposit rate, which reduces bank credit. Less and more expensive funding reduces firms' output (Edwards and Vegh (1997), Armas et al (2014)). To identify the RR shock, we adapt the strategy that Christiano, Eichenbaum and Evans (1999) use to identify monetary policy shocks.[3]

We define the benefits of RR in terms of reducing the frequency and expected output loss of financial stress episodes. We proceed in three steps. First, we identify financial stress episodes, defined as simultaneous financial market turmoil across a wide range of assets.[4] We then apply a Markov regime-switching model to date financial stress episodes. Second, we estimate a logistic model-based early warning system to assess how predicted crisis probabilities change in response to RR shocks (Bussiere and Fratzscher (2006) and Gourinchas et al (2012)). Finally, we calculate the benefit as the reduction in expected output loss, defined as the product of the reduction in the probability of financial stress and the average loss in industrial production during these episodes (Laeven and Valencia (2013)). Overall, we find that the net benefits of using RR are positive.

The structure of the paper is as follows. In Section 2, we review the related literature. Section 3 describes the data. Section 4 presents a framework of the effects of RR on the financial system. In section 5, we estimate a panel VAR model to obtain the costs of using RR to smooth credit fluctuations. Section 6 estimates the benefits of using RR. In this section, we construct the financial stress index. Section 7 explores the economic trade-offs of using RR. The last section concludes.

2 Literature review

First, we contribute to the literature studying the effects of RR on credit and output growth. Our paper estimates the effects of RR for a panel of AE and EMEs. Consistent with the literature, we find that RR reduce credit and economic activity. Cordella et al (2014) show that a tightening in RR increases the interest rate spread and reduces credit and GDP. Arregui et al (2013) find that higher RR reduce credit growth, the loan to deposit ratio and housing price growth. Crespo-Cuaresma et al (2019) apply a Bayesian estimation framework to a large international panel and

[3]They impose a recursive structure on the contemporaneous relationships of the variables. The underlying assumptions are that some variables react to policy shocks with a lag and that the policy component reacts immediately to macroeconomic shocks that affect the equilibrium value of the other variables. Then, they use a Cholesky decomposition to transform the contemporaneous correlations of the error terms into orthogonal components.

[4]We follow the methodology in Duprey et al (2017) to construct the index. This index reflects uncertainty in market prices, sharp corrections in market prices and commonality across asset classes. The two markets we consider are the stock market and the foreign exchange market.

find that medium levels of RR may be optimal for medium to long-run growth. Montoro and Moreno (2011) study the use of RR as policy instruments in Latin America. They find that higher RR can tighten domestic financing conditions without attracting more capital inflows if they induce banks to raise lending rates while lowering deposit rates. Tovar, Garcia-Escribano and Vera (2015) find that RR have a moderate and transitory impact on slowing credit growth. They also find that average RR might be more effective than marginal RR.

Our paper estimates the effects of RR using a panel VAR model. The identification of the RR shock relies on the recursiveness assumption. This implies that each variable contemporaneously affects all the variables ordered afterwards but it is affected with a delay by them. By contrast, Glocker and Towbin (2012b) pursue a partial identification approach with sign restrictions. They find that a discretionary increase in RR leads to lower domestic credit, higher unemployment, exchange rate depreciation, a current account surplus, and inflation. Pérez-Forero and Vega (2014) estimate a structural VAR model for Peru and show that RR that differentiate by currency reduce credit on the specific currency they target and have a mild effect on economic activity and inflation.

Other studies have focused on the use of granular credit data to provide a more robust identification of effects on credit supply. For Brazil, Barroso et al (2017) use credit register data to study the impact of RR on credit growth. They show that easing of RR has a stronger impact on bank credit than a tightening. They also show that foreign banks and small banks are less affected by these policies. Using a similar methodology, Minaya et al (2017) find that the introduction of additional RR on foreign currency mortgage lending reduced credit dollarisation in Peru. In particular, this policy created incentives for banks to substitute dollar-denominated loans and expand credit in domestic currency. For Uruguay, Camors et al (2019) show that higher RR lead to a reduction in credit. But the effects are weaker for larger banks.

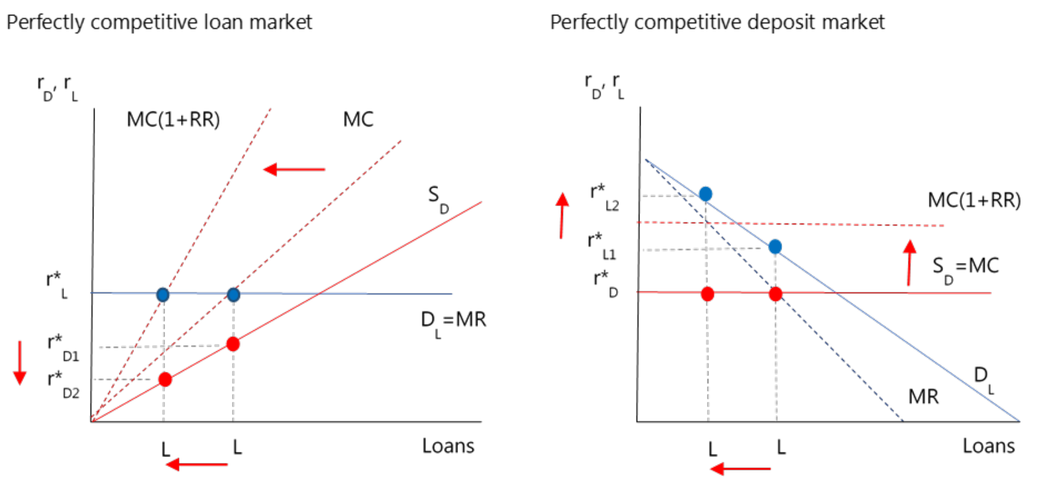
Finally, our paper contributes to the literature of cost-benefit analysis of macroprudential policies. One key difference between the literature cited above and our paper is that we consider the potential benefits from introducing RR on the probability of financial stress. A closely related paper is Behn et al (2016). They develop an integrated early warning global vector autoregressive model to quantify the costs and benefits of capital-based macroprudential policy measures. They find that macroprudential measures are transmitted both via their impact on banking system's resilience and via indirect macro-financial feedback effects.

3 A basic framework of the effects of reserve requirements

RR are a regulatory tool that requires banks to hold a fraction of their liabilities, usually deposits, as liquid reserves (Tovar et al (2015)). Central banks hold the reserves – mostly in cash – and set their rate of return. In most cases, RR are unremunerated (zero rate of return). Nevertheless, even if the rate of return is positive it is always below the market rate and usually below the policy rate (OECD (2018)). Thus, as holding reserves is costly for banks, RR are traditionally modelled as a tax on financial intermediation. For each unit of deposits raised to fund loans the bank pays an implicit per unit tax equal to the RR rate.

Figure 1

Effects of RR on bank lending (L), loan (r_L) and deposit (r_D) rates



In the left panel banks have monopoly power in the deposit market; while in the right panel, banks have monopoly power in the loan marke D_L is the demand for loans, MR is the marginal revenue from loans, S_D the deposit supply, MC the marginal cost of funding, r_L the loan rat r_D the deposit rate, L the amount of loans, and RR the reserve requirements rate. Positive RR are equivalent to a tax on financial intermediatio that increase the marginal cost of funding through deposits.

Appendix A presents a simple framework to model the different transmission channels of a tightening in RR to bank credit. The first is the *cost channel* through which banks pass through the cost of RR to borrowers and depositors. How much of the cost gets distributed between loan and deposit rates depends on the level of competition between banks, the availability of alternative source of funding and the degree of competition of the banking system with other financial intermediaries (Reinhart and Reinhart (1999)). We consider two extreme cases to understand how the mechanism works. The first case is when banks face a perfectly competitive loan market and have market power in the deposit market. A tightening in RR increases the marginal cost of funding loans through deposits, banks lower the deposit rate and depositors pay the tax (Figure 1, left panel). The second case is when banks face a perfectly competitive deposit market and have market power in the loan market. In this case borrowers pay the cost of higher RR through higher loan rates (Figure 1, right panel). The model in Appendix A complements these findings by analysing competition between banks. The main result is that RR are less effective as competition between banks intensifies because the intermediation margin narrows.

The second transmission channel is the *interest risk channel* (Betancourt and Vargas (2008) and Vargas et al (2010)). To explore this channel, we assume that banks have access to alternative sources of funding such as central bank credit. If banks can perfectly substitute deposits for central bank credit then a tightening in RR has no effect on the loan rate or the quantity of loans. Banks offset the reduction in their demand for deposits with funding through central bank credit. In practice, central bank credit and deposits are not perfect substitutes. For instance deposits tend to have a longer maturity than central bank credit. If the central bank can change the interest rate it charges on credit every period then the uncertainty on future interest rate represents an additional cost for risk adverse banks. A tightening of RR raises the cost of funding through deposits and banks increase their demand for central bank credit. The higher demand for central bank credit raises interest risk. Banks then pass through the cost to borrowers by charging higher loan rates.

The third channel is the *liquidity risk channel* (Alper et al (2018)). This channel works in a similar way as the interest risk channel. The difference is that we assume that central bank credit is collateralised with securities (bonds) and that banks face a cost of running into a liquidity shortage. If the central bank tightens RR the cost of funding through deposits rises and banks increase their demand for central bank credit. As banks pledge securities as collateral their liquid assets are lower, which increases their liquidity risk costs. Banks then pass through the cost to borrowers by charging higher loan rates.

We conclude that through these three channels a tightening in RR leads to a higher loan rate and lower quantity of credit. Firms then face higher cost and lower quantity of funding which reduces their production. We model formally the three channels in Appendix A.

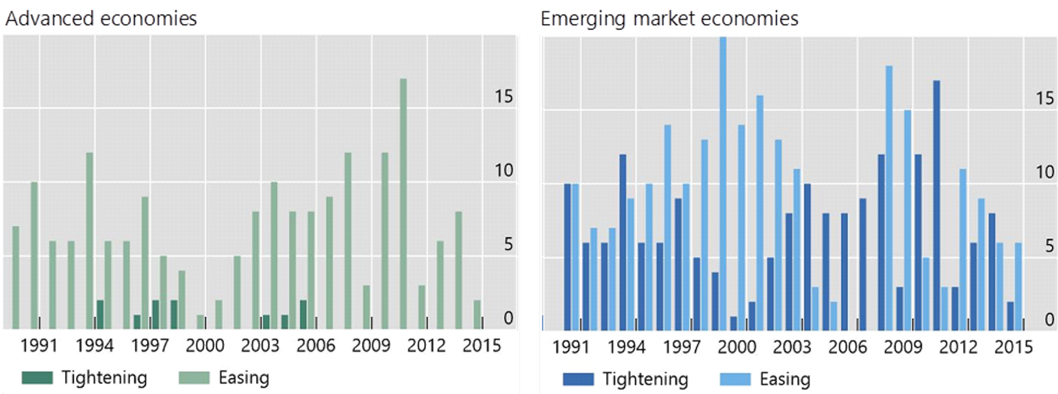
4 Data

The dataset includes 27 countries that have actively used RR as policy tools - 5 AEs and 22 EMEs.[5] The sample period is from 1996Q1 to 2015Q3. The data shows heterogeneity in terms of type of RR instrument: 12 countries have a unique RR rate for all types of deposits; 9 countries differentiate RR by deposit maturity; 2 countries have RR differentiated between domestic and foreign currency deposits and; 4 differentiated by both maturity and currency (Figure 3). We construct the RR index using the data on legal changes by Federico, Vegh and Vuletin (2014). For countries with different RR by maturity and/or currency, we use a weighted average using fixed weights based on the share that each type of deposit/currency has in the country's financial system.[6]

Figure 2

Use of reserve requirements

Number of episodes by country group[1]



[1]The number of episodes by country group is the annual sum of the quarterly episodes of a change in reserve requirements for each country.

Source: Federico, Vegh and Vuletin (2014). Authors' calculations.

[5]The countries in the sample are Argentina, Bangladesh, Brazil, Colombia, China, Costa Rica, Croatia, Czech Republic, Germany, Ecuador, Spain, France, Hungary, Indonesia, India, Lithuania, Latvia, Malaysia, Peru, Philippines, Pakistan, Portugal, Poland, Singapore, South Africa, Thailand and Turkey.

[6]We obtained data from the central banks' websites on the total amount of deposits either by currency, maturity or both. The weights are fixed and we calculate them as the average of the deposits RR target during the period of study.

Figure 3

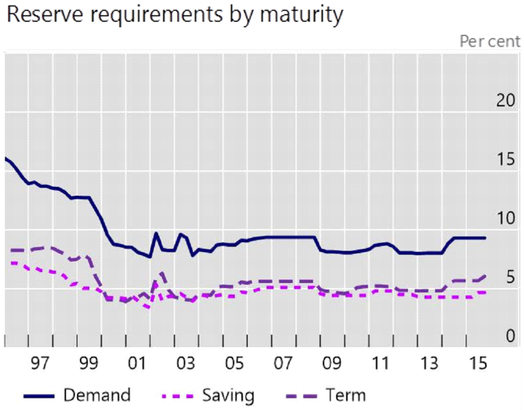
Reserve requirements by type

Average reserve requirements index

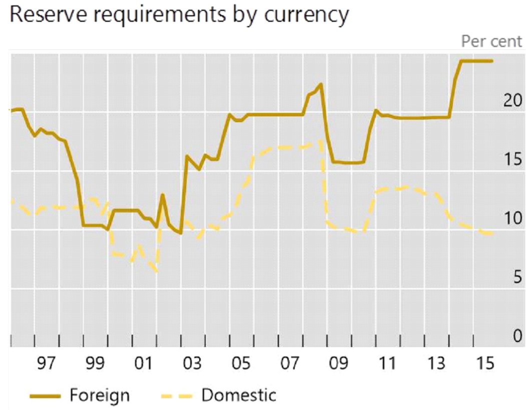
Country Classification

Uniform	Currency & Maturity	
Bangladesh	Argentina	Turkey
China	Costa Rica	Poland
Colombia	**Currency**	**Maturity**
Ecuador	Croatia	Brazil
India	Peru	Czech Rep
Indonesia		France
Lithuania		Germany
Malaysia		Hungary
Pakistan		Latvia
Philippines		Portugal
Singapore		S. Africa
Thailand		Spain

Reserve requirements by maturity



Reserve requirements by currency



Source: Federico, Vegh and Vuletin (2014). Authors' calculations.

Notes: Figure includes 27 countries that have actively used RR as policy tools, 5 AEs and 22 EMEs. For countries with different RR by maturity and/or currency, we use a weighted average using fixed weights based on the share that each type of deposit/currency has in the country's financial system.

Figure 2 shows that EMEs have actively used RR more frequently than AEs. It follows that on average, the level of RR in AEs tend to be lower than in EMEs. That said, in both groups the use of RR has been asymmetrical. There are more episodes of easing than episodes of tightening for both groups. Finally, RR are higher for countries with a unique rate relative to those that differentiate by deposit, maturity and foreign or domestic currency (Figure 3). For RR that differentiate by type of deposit, the rate for time deposits is generally higher than that of saving deposits and term deposits. For RR that differentiate by currency, the rate for foreign currency deposits is higher than that for domestic currency deposits. One explanation is that in recent years countries have used RR on foreign currency deposits as an alternative to capital flow management tools.

For the panel VAR model the domestic variables include: industrial production index (IPI), real exchange rate, interest rate, the ratio of bank credit to GDP and central bank reserves. We also use the following global variables: global interest rate, global risk, global liquidity and global real growth. For the logistic early warning system model and the financial stress index we use: stock market index, real exchange rate, bank credit to GDP, real GDP growth, industrial production growth, inflation rate, monetary policy rate and nominal exchange rate. We also include the following financial variables: bank leverage, profitability and liquidity indicators. Appendix B includes a detailed description of the variables and their sources. We test for stationarity of all transformed variables used in the estimation.

5 Economic costs of reserve requirements

We estimate a panel VAR to quantify the direct effect of RR on credit and economic activity. We estimate the following model:

$$Y_{j,t} = a_{j,0} + \sum_{i=1}^{p} A_{j,i} Y_{j,t-i} + \sum_{i=1}^{p} B_{j,i} X_{t-i} + U_{j,t}, \quad j = 1, ..., 27 \tag{1}$$

$$E(U_{j,t} U'_{j,t}) = \Sigma_j \tag{2}$$

The subindex j references the individual countries. The vector of endogenous variables (Y_t) includes: annual growth in industrial production (IPI), real effective exchange rate ($REER$), ratio of bank credit to GDP ($BC2GDP$), nominal interest rate (IR), RR index (RR) and central bank reserves ($CBRes$). The vector of exogenous variables (X_t) includes global: interest rate, risk, liquidity, commodity price index, and real growth. The frequency is quarterly.

We estimate the model based on the mean-group estimator proposed by Pesaran and Smith (1995). There are two main assumptions. The first assumption is that all countries in the model can be characterised by heterogeneous VAR coefficients but that the coefficients are random processes that share a common mean. We obtain the parameters of interest by estimating the mean effects of the group. [7] The

[7] This assumption might be hard to justify when we estimate the model with all countries together. However, we also estimate separate models for EMEs and AEs.

second assumption is that the residual variance-covariance matrix (Σ_j) is heterogeneous across units but characterised by a common mean. With these assumptions, we can estimate a single and homogeneous VAR model for all the countries in our sample, where the responses correspond to the mean effects across countries.

We identify the RR shock following a similar strategy as Christiano, Eichenbaum and Evans (1998). First, we assume that RR as policy instrument have the following functional form:

$$RR_{j,t} = f_j(\Omega_{j,t}) + \sigma_{j,RR}\varepsilon_{j,t}^{RR} \tag{3}$$

In this case, f is a linear function that represents the feedback rule that depends on the policy maker's information set ($\Omega_{j,t}$). The random variable $\sigma_{j,RR}\varepsilon_{j,t}^{RR}$ is the RR shock, where we interpret $\sigma_{j,RR}$ as the standard deviation of the shock and normalise $\varepsilon_{j,t}^{RR}$ to have unit variance.

Then, we partition the vector of endogenous variables as follows:

$$Y_{j,t} = \begin{bmatrix} Y_{1,j,t} \\ RR_{j,t} \\ Y_{2,j,t} \end{bmatrix} \quad Y_{1,j,t} = \begin{bmatrix} IPI_{j,t} \\ REER_{j,t} \\ BC2GDP_{j,t} \\ IR_{j,t} \end{bmatrix} \quad Y_{2,j,t} = \begin{bmatrix} CBRes_{j,t} \end{bmatrix} \tag{4}$$

The order of the blocks in recursive form implies that the variables in vector $Y_{1,j,t}$ enter directly the policy-maker's decision rule and are not affected contemporaneously by the RR shock, but respond with a lag. That is, the policy-maker bases the decision on setting RR by observing the current values of IPI, REER, BC2GDP and IR. Then after the decision, the variables respond the following period.[8] The vector $Y_{2,j,t}$ includes the variables that are not included directly in the policy decision rule but react immediately to the RR shock.[9] Our model is semi-structural or partially identified in the sense that we only identify the dynamic response of $Y_{j,t}$ to the RR shock and not to the rest of the shocks. That is, we do not make any assumptions on the order of the variables in block $Y_{1,j,t}$ and we only require the assumption on the order of the blocks $Y_{1,t}$ and $Y_{2,t}$.[10]. Then, we can use Cholesky decomposition on the variance–covariance matrix to orthogonalise the reduced form error of the policy instrument (Killian (2011)). Finally, we estimate the impulse response functions and standard errors of the RR shock by means of Monte Carlo simulations

[8] Kim and Roubini (2000)

[9] Our assumption on the decision rule of the policy maker relies on the findings of theoretical models proposed by Fernandez and Guidotti (1996), Glocker and Towbin (2012a), Kashyap and Stein (2012).

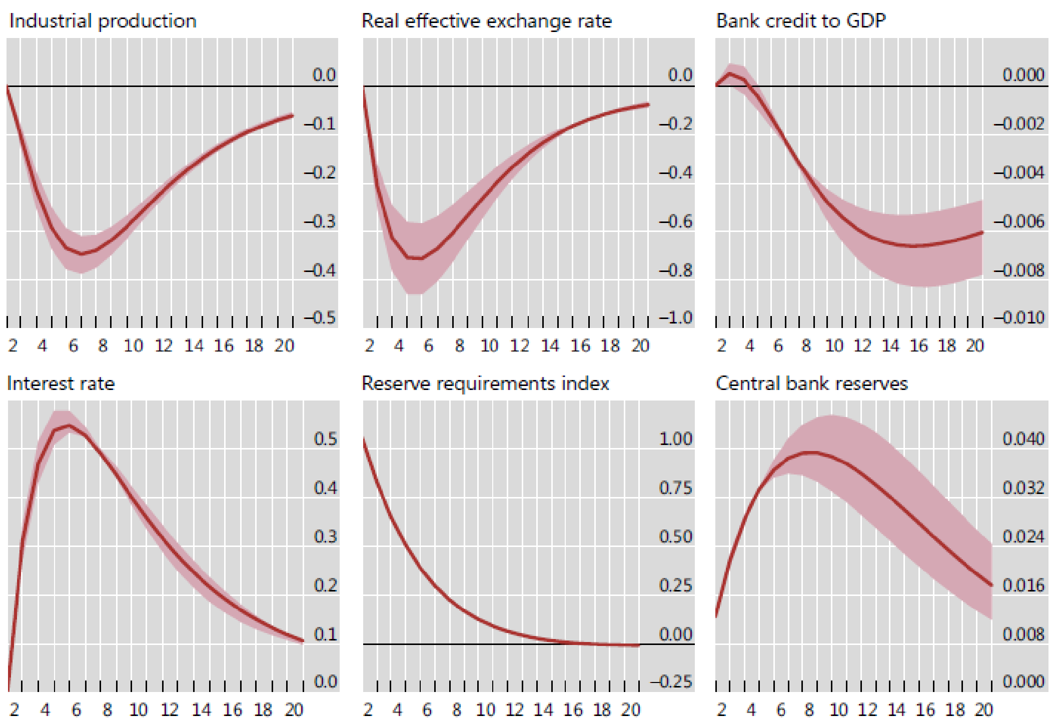
[10] The assumption of a slow moving block is standard in the VAR literature that studies monetary policy. This assumption relies on some rigidities in the adjustment of economic variables that prevent an immediate response to changes in policy (Glocker and Towbin (2012a)

(Hamilton (1994)). Figure 4 shows the response of the endogenous variables to a one standard deviation shock in RR.

Figure 4

Impulse response of a shock to reserve requirements

Response to one percentage point change in reserve requirement index



Source: Authors' calculations.

Notes: estimations based on a panel var for 22 EMEs and 5 AEs for quarterly data. Endogenous variables are industrial production, real effective exchange rate, ratio of bank credit to GDP, nominal interest rate, RR index and central bank reserves. The vector of exogenous variables includes global: interest rate, risk, liquidity, commodity price index, and real growth. More details on the variables can be found in Table 4 and Table 5

A tightening in RR increases central bank reserves, reduces bank credit, depreciates the real exchange rate and reduces industrial production growth. We explain the transmission channel of each of the responses individually. First, higher RR increase the fraction of deposits that banks hold as liquid reserves at the central bank. Second, a tightening in RR leads to higher lending rates, lower deposit rates and a contraction in bank credit.[11] Third, the lower deposit rate attracts less foreign investment leading to lower capital inflows and a depreciation in the real exchange rate (Gonzalez-Rosada and Sola (2014) and Agenor et al (2018)). A reinforcing mechanism works through the *risk-taking channel* (Bruno and Shin (2012)). The depreciation in the real exchange rate and higher domestic funding costs weakens domestic banks' balance sheet positions. Funding constraint for banks become more stringent, leading to a reduction in leverage. From the point of view of foreign investors, the loan book of domestic banks becomes more risky, which dampens capital inflows even more and depreciates the real exchange rate further. Finally, changes in RR affect the real side of the economy through the loan market. As the GFC showed, disturbances in the financial sector can have significant negative effects on the real side of the economy (Gertler and Gilchrist (2018)). The contraction in bank credit and its higher cost restrict firms' funding and new investment project become more expensive. The drop in firms' investment contracts industrial production growth. We quantify the economic cost of tightening RR as the reduction in industrial production growth.[12]

The policy tools move in the same direction in this exercise.[13] Other works found a similar result. There are two sources of inflation from the supply side of the economy. First, the increase in the loan rate raises funding costs. Second, the depreciation in the exchange rate increases imported inputs costs. Both raise overall production costs, which increase inflation. In response the central bank tightens the interest rate (Glocker and Towbin (2012a) and Gonzalez-Rozadas and Sola (2014)). We estimate a similar model but for a change in the policy rate to compare the responses. The analysis is in Appendix C.

[11]We do not include lending and deposit rates as variable in our VAR since there is not enough comparable and reliable data to construct these series for our sample of countries and period of study. However, our estimation results are consistent with the theoretical model presented in the previous section and the extensive empirical evidence (Armas et al (2014), Perez-Forero and Vega (2014), Reinhart and Reinhart (1999), Alper et al (2018), Tovar et al (2015), Brei and Moreno (2018), Barroso et al (2017), Camors and Peydro (2019).

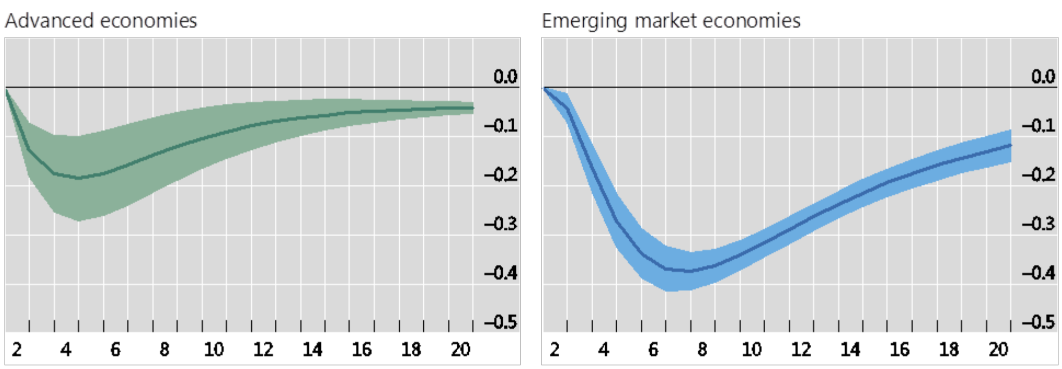
[12]We choose industrial production instead of GDP as our economic activity variable for two reasons. First, the transmission mechanism of RR in the model works through firms' funding costs (price and quantity of credit) which have a stronger link with investment and production. Second, the effects on GDP can be ambiguous as a tightening in RR has a negative effect on investment but a positive effect on consumption and exports. The lower deposit rate encourages consumption spending and the depreciation in the exchange rate increases exports. We ran an exercise using GDP as our economic activity variable and the effects were not conclusive. Then the effect on GDP would be lower than the effect on industrial production.

[13]The ordering of RR and IR is not obvious, as there are important interactions between both instruments. We perform additional exercises alternating the order of these variables and the results did not change.

We repeat the exercise dividing our sample into EMEs and AEs and estimate separate panel VARs for each group. Figure 5 shows the response of the annual growth in industrial production to a one standard deviation RR shock by country group. We find that the contraction in industrial production growth is greater for EMEs than for AEs. Several factors explain this result. First, capital markets in AEs are more developed than in EMEs. A tightening in RR increased the cost of deposits, which banks are less able to offset due to the fewer alternatives for deposits as a source of funding. Second, banking sectors in EMEs are highly concentrated. Greater market power allows banks to pass through the higher cost of funding directly to borrowers, resulting in higher loan rates. Third, most firms in EMEs critically depend on bank credit to fund their operations. Undeveloped capital markets make it difficult or impossible for firms to raise funds by issuing equity or commercial paper. Then higher funding costs and lower bank credit have a greater effect on EMEs' industrial production than for AEs. As an additional exercise, we analyse the effect of global financial factors on the behaviour of domestic variables and the policy reaction of EME to this shocks, especially in terms of monetary policy and the use of RR. This analysis is in appendix C.

Figure 5

Response of industrial production to a shock to RR by country group



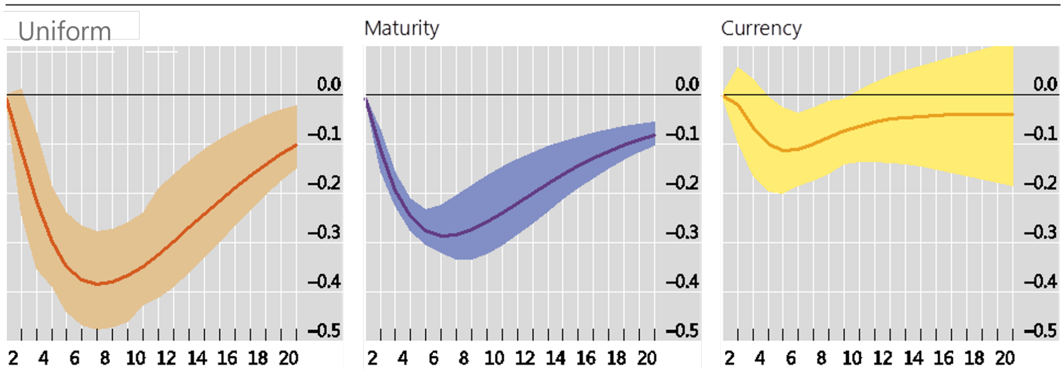
Source: Authors' calculations.

Notes: estimations based on a panel VAR for 22 EMEs and 5 AEs with quarterly data. Endogenous variables are industrial production, real effective exchange rate, ratio of bank credit to GDP, nominal interest rate, RR index and central bank reserves. The vector of exogenous variables includes global: interest rate, risk, liquidity, commodity price index, and real growth. More details on the variables can be found in Table 4 and Table 5

Finally, we study the response of industrial production to an RR shock, differentiating by the deposits they target. Figure 6 presents the results. RR that have specific targets show a weaker effect on industrial production than uniform RR. We provide two explanations. First, when RR differentiate between currency or maturity, banks can substitute funding towards the source with lower RR, weakening the effect of the policy. A second explanation is that tailored RR can help strengthen the liabilities side of banks' balance sheets, which results in a smaller drop in credit. For example, RR on short-term funding provide incentives for banks to lengthen the maturity of their liabilities. Alternatively, RR on funds other than deposits can change the composition of liabilities away from non-core liabilities (eg wholesale funding). For RR that differentiate by currency and residency the argument is similar. RR on foreign currency deposits can limit banks' currency mismatches and can reduce the dollarisation of the financial system (Bustamante, Cuba and Nivin (2019)). RR by residency of the counterparty are effectively a tax on foreign liabilities, which discourages capital inflows. Most funding in the economy occurs in domestic currency, then it is expected that RR by currency would have a muted effect.

Figure 6

Response of industrial production to a shock to RR by RR type



Source: Authors' calculations.

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6 Economic benefits of reserve requirements

Central banks implement RR to reduce the amplitude of the credit cycle, which reduces financial stress and systemic risk. If the economy is overheating RR can slow credit by increasing lending rates and limit excess leverage of borrowers. In a downswing, RR can reduce liquidity constraints faced in the banking system. RR can also improve the funding structure of banks by building liquidity buffers against risky sources of funds and reduce bank's dependence on short-term foreign funding and wholesale domestic funding. These effects reduce the probability of financial stress episodes and prevent losses in the real economy. In this section, we proceed in three steps to estimate the economic benefits of RR. First, we date financial stress episodes. Second, we estimate a logistic-based early warning system model to determine the marginal reduction in probability of financial stress episodes given a change in RR. Finally, we quantify the benefit by multiplying the reduction in probability and the average reduction in industrial production loss during a financial stress episode.

6.1 Financial stress episodes

We follow the methods in Duprey, Klaus and Peltonen (2017) (henceforth DKP) to obtain country-specific financial stress indices. Their strategy follows a model-based approach that identifies episodes based on market prices.[14] Financial stress is defined as simultaneous financial market turmoil across a wide range of assets, reflected by the uncertainty in market prices, sharp corrections in market prices and the degree of commonality across asset classes. The special feature of the index is that it captures co-movements in key financial markets. In particular we focus on market stress in the stock and foreign exchange markets.[15] Appendix D contains the technical details on how we constructed the index. The span of the index depends on data availability but for the longest series it starts from January 1970 and for all countries ends in December 2015.

[14]A model-based approach is broader than expert-detected episodes. The latter focus on information from financial institutions and usually rely on qualitative information or on past policy actions. Still, we compare the episodes identified using the DKP approach with the databases of Laeven and Valencia (2013) and Reinhart and Rogoff (2011). Our index correctly identifies over 90% of the episodes contained in these databases. Another disadvantage of the widely used databases of crises episodes is that they have an annual periodicity.

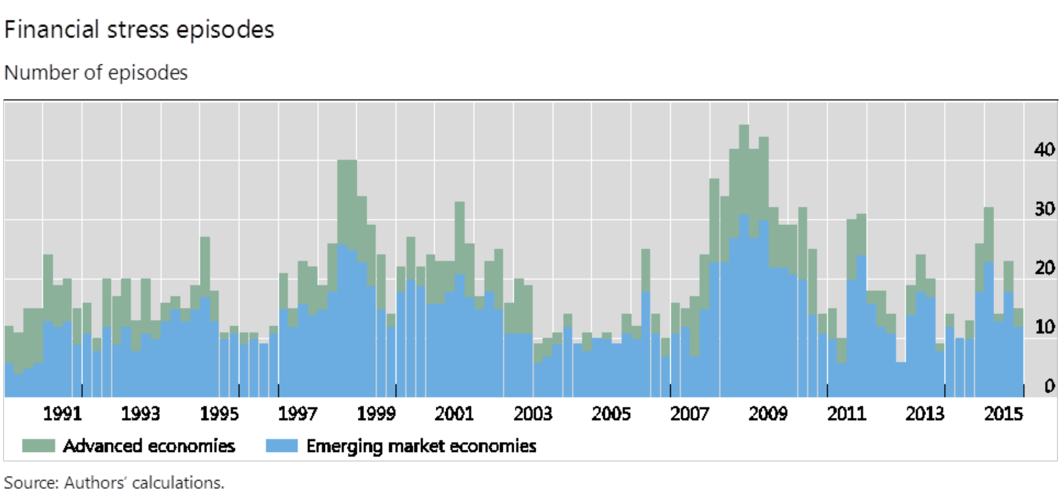
[15]DKP also include market stress in the government-bond market captured by volatility in the 10-year government bond yields. However, markets for 10-yr government bonds in EMEs have developed recently and data are scare so we did not include this market segment in our analysis

We use the financial stress index to obtain episodes of high financial stress by estimating the following Markov switching model (Hamilton (1989)):

$$FSI_t = \begin{cases} \mu_H + \phi_H FSI_{t-1} + \varepsilon_t^H \\ \mu_L + \phi_L FSI_{t-1} + \varepsilon_t^L \end{cases} \tag{5}$$

where $\varepsilon_t^i \sim N(0, \sigma_S^2)$, $S \in H, L$ and $\{H, L\}$ correspond to the high and low financial stress states respectively. We allow for different values of the constant, AR(1) coefficient and variance. Compared with other model specification, this model had the lowest Schwarz Bayesian information criterion, which shows that our choice has a better fit. We then predict the probabilities of being in each state and transform the index into a binary variable that takes the value of 1 if the country is in a high financial stress period and 0 otherwise. Figure 7 shows for each period the number of countries that experience an episode of high financial stress.

Figure 7



Notes: episodes obtained following Duprey, Klaus and Peltonen (2017). Our approach focuses on market stress in the stock and foreign exchange markets. Please see Appendix D for the technical details.

6.2 Logistic early warning system Model

We consider two indicators that show the benefit of RR in terms of reducing the frequency of financial stress episodes. One indicator considers the effect on credit, where we calculate the expected credit loss during a financial stress episode, defined as the product of a reduction in the probability of financial stress and the average credit loss during these episodes. A second indicator considers a similar methodology but from a macroeconomic perspective. We analyse the expected output loss defined as the product of a reduction in the probability of financial stress and the average loss in industrial production during these episodes.

$$benefit = -\Delta prob * creditloss$$

$$benefit = -\Delta prob * IPIloss$$

First, we estimate a model to capture the effect of RR on the probability of financial stress episodes. We follow the literature on early warning models that calculate the determinants of episodes of financial crisis. We estimate a panel logit for the following equation:

$$P(y_{it} = 1) = \frac{exp(\alpha_i + X'_{it}\beta)}{1 + exp(\alpha_i + X'_{it-1}\beta)}$$

where $P(y_{it} = 1)$ refers to the probability that country i is in financial stress in quarter t. The vector of regressors X_{it-1} includes macroeconomic, financial sector and global variables. We also include country dummies to account for unobserved heterogeneity across countries. The results for marginal effects obtained from the logistic model are presented in Table 1. Columns (1) - (3) show the results for the whole sample of countries. The growth rate of the credit to GDP ratio has a positive and significant impact on the probability of financial vulnerability, associated with the idea that overheating of credit growth increases the buildup of systemic risk in the banking sector. Similar results are obtained when we consider either changes in the credit to GDP ratio (Column (1) and (2), see Behn et al (2016)) or the credit-to-GDP gap, which is used to set other macroprudential policies such as the Basel III countercyclical capital buffer (see Drehmann and Jusselius (2014) and Drehmann and Tsatsaronis (2014)).

Columns (4) - (6) show the effectiveness of countercyclical use of RR as a macroprudential policy in EMEs. Alternatively, Columns (7) to (9) show the results for AEs, where only a reduction in RR reduces the probability of crisis. This result might be related to the fact that RR in AEs have been mostly used during the great financial crisis to loosen financial conditions. Both domestic and global GDP growth negatively affect the probability of financial stress, where a better performance of economic activity indicators increases the resilience of the financial sector. Higher inflation increases the severity of financial stress episodes, especially for EMEs. These results could be associated with higher cost of debt repayment in nominal terms, which could increase default rates. Other global factors such as global risk measures increase the probability of financial vulnerability. Bank specific factors do not show a significant effect.

Table 1: By group of countries: Marginal effects on the probability of a financial stress episode

	All			Emerging			Advanced		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
RR_{t-1}	1.53^{*}	2.25^{*}	2.50^{*}	1.37^{*}	2.11^{*}	2.32^{*}	-0.50	-3.08	-2.65
RR_{t-8}	-1.10^{*}	-0.97^{**}	-0.96^{*}	-1.01^{*}	-1.15^{**}	-1.13^{**}	1.37	10.0^{***}	8.65
Δ Credit to GDP_{t-1}	0.32^{*}	0.31^{**}		0.20^{***}	0.16^{***}		1.13^{*}	0.88^{***}	
Credit to GDP gap_{t-1}			0.74^{*}			0.47^{***}			4.56^{***}
GDP_{t-1}	-3.82^{*}	-2.07^{*}	-1.89^{*}	-2.70^{*}	-1.68^{*}	-1.52^{*}	-7.56^{*}	-3.60^{*}	-2.64^{*}
$Inflation_{t-1}$	0.76^{*}	1.50^{*}	1.43^{*}	0.58^{*}	1.50^{*}	1.43^{*}	2.73^{*}	0.16	-0.22
Policy $rate_{t-8}$		0.49^{**}	0.48^{**}		0.45^{**}	0.44^{**}		0.29	-0.43
Exchange $rate_{t-1}$		-0.14	-0.19^{***}		-0.16	-0.19		-0.18	-0.34^{**}
Global $risk_{t-1}$		0.13^{*}	0.13^{*}		0.11^{*}	0.11^{*}		0.16^{*}	0.14^{*}
Global $growth_{t-1}$		-4.29^{*}	-4.55^{*}		-3.55^{*}	-3.80^{*}		-4.95^{*}	-5.89^{*}

$*, **, ***$ refer to $P-value < 1\%$, 5% and 10%, respectively.
Coefficient estimate based on a panel logit for the probability that a country is in financial stress. The vector of regressors also includes country dummies to account for unobserved heterogeneity across countries. In t-8 the policy that reduces the probability of a crisis is a tightening in RR.

Table 2: By type of RR: Marginal effects on the probability of a financial stress episode

	Uniform			Maturity			Currency		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
RR_{t-1}	1.82^{**}	1.97^{**}	2.01^{**}	1.52^{**}	2.47^{*}	2.80^{*}	0.32	0.59	0.78
RR_{t-8}	-2.29^{*}	-1.83^{**}	-1.74^{**}	-0.25	-0.23	-0.57	-0.20	-0.22	0.40
Δ Credit to GDP	0.03	0.22		0.68^{*}	0.50^{**}		0.75^{**}	1.68^{*}	
Credit to GDP gap			0.48^{***}			3.57^{*}			0.50
GDP	-3.31^{*}	-2.01^{*}	-1.90^{*}	-4.75^{*}	-2.6^{*}	-1.82^{***}	-3.55^{*}	-3.67	-2.84
Inflation	2.72^{*}	2.08^{*}	1.96^{*}	3.32^{***}	1.65^{*}	1.56^{*}	0.11	1.98^{**}	1.55^{***}
Policy $rate_{t-8}$		0.35	0.38		0.84^{**}	0.72^{**}		1.38^{**}	0.77
Exchange rate		0.40^{***}	0.34^{***}		-0.48^{*}	-0.60^{*}		-0.24	-0.26
Global risk		0.14^{*}	0.14^{*}		0.12^{*}	0.12^{*}		0.06^{**}	0.07^{*}
Global growth		-3.02^{**}	-3.29^{*}		-6.24^{*}	-6.61^{*}		-1.43	-1.25

$*, **, ***$ refer to $P-value < 1\%$, 5% and 10%, respectively.
Coefficient estimate based on a panel logit for the probability that a country is in financial stress. The vector of regressors also includes country dummies to account for unobserved heterogeneity across countries.

A counter cyclical behaviour of the reserve requirement index is associated with a decrease in financial turbulence episodes, where a tightening of RR some periods ahead and an easing in the period right before reduces the probability of financial stress. This is particularly the case for EMEs, whereas in the sample of AEs, a loosening of RR could reduce the materialisation of volatility in financial markets.

We also estimate the logistic early warning model by separating countries into types of differentiated RR: uniform RR, RR by maturity and RR by currency. Table 2 shows similar results across types for most variables to the ones reported for the whole sample. However, RR are more effective in reducing financial turbulence when used counter cyclically in those countries with a uniform RR.

The second component of the expected loss requires us to estimate the credit and output loss during financial stress episodes (Table 3). For that purpose, for each indicator (credit and IPI) we consider the mean loss associated with those episodes in our sample. We follow the methodology developed by Laeven and Valencia (2013) where the loss during each episode is calculated as the cumulative wedge between the observed variable relative to a pre-crisis trend. We consider the cumulative loss one year after the date of the episode.[16]

Table 3: Expected credit and IPI loss during financial stress episodes

	Credit Loss				IPI Loss			
	t+1	t+2	t+3	t+4	t+1	t+2	t+3	t+4
All	-5.61	-6.31	-10.96	-14.46	-7.05	-8.82	-9.79	-10.99
EME	-6.32	-7.24	-10.92	-17.89	-7.24	-8.64	-9.78	-10.27
AE	-3.24	-3.76	-10.83	-5.15	-6.15	-9.77	-9.81	-14.8
Uniform	-5.3	-5.17	-10.77	-18.01	-7.48	-9.83	-9.5	-10.9
Currency	-8.01	-8.63	-10.71	-15.33	-9.85	-8.92	-10.49	-9.15
Maturity	-5.7	-7.12	-10.67	-15.98	-6.6	-8.22	-9.95	-11.04

Notes: Mean loss associated with those episodes in our sample following Laeven and Valencia (2013) where the loss during each episode is calculated as the cumulative wedge between the observed variable relative to a pre-crisis trend. "t" is equivalent to a quarter

The results for the average expected credit loss shows a larger effect of financial stress episodes in EMEs, where the average reduction in the credit to GDP ratio after one year is of 17.82 percentage points, compared to that of 5.15 percentage points for AEs. This reflects the shallowness of financial markets and high volatility in EMEs, so that an episode of financial turbulence would reduce credit lines to those agents who already had access to credit and also disrupt the natural process of financial deepening. With respect to the type of reserve requirement, countries with a uniform reserve requirement experience slightly larger drops in credit to GDP ratio during episodes of financial stress. However, in terms of output loss, countries with RR by maturity show a greater drop followed by countries with uniform RR.

[16] As a robustness check, we also consider other horizons (1, 2 and 3 quarters) to calculate the cumulative loss.

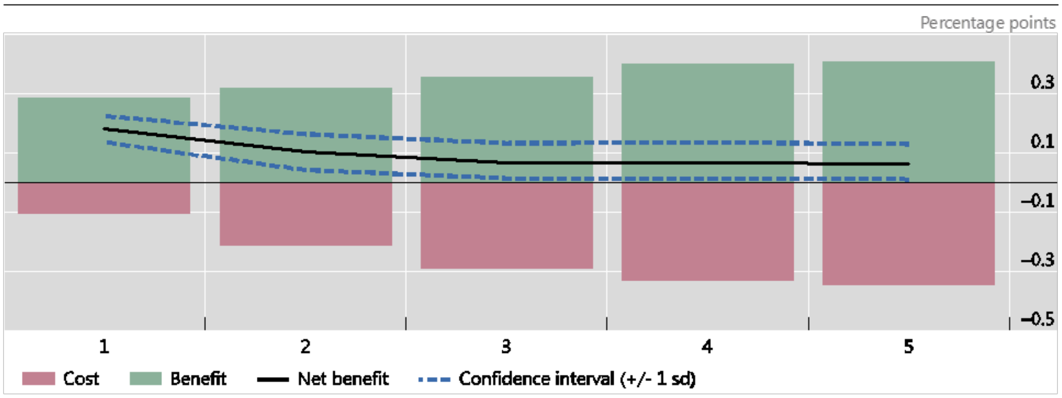
7 Economic trade-offs of reserve requirements

We calculate the net benefit as the difference between the drop in industrial production growth from the VAR model minus the gain in industrial production growth from the reduced probability of financial stress. We summarise the results for the whole sample in Figure 8. The net benefit is positive.[17] A tightening in RR leads to lower credit growth, which can result in a smaller expansion of economic activity. But the benefits from less frequent and severe financial stress episodes compensates this loss. The use of RR lead to a less extreme path for credit growth and greater economic gains.

Figure 8

Net benefit of using reserve requirements

Change in annual growth of industrial production



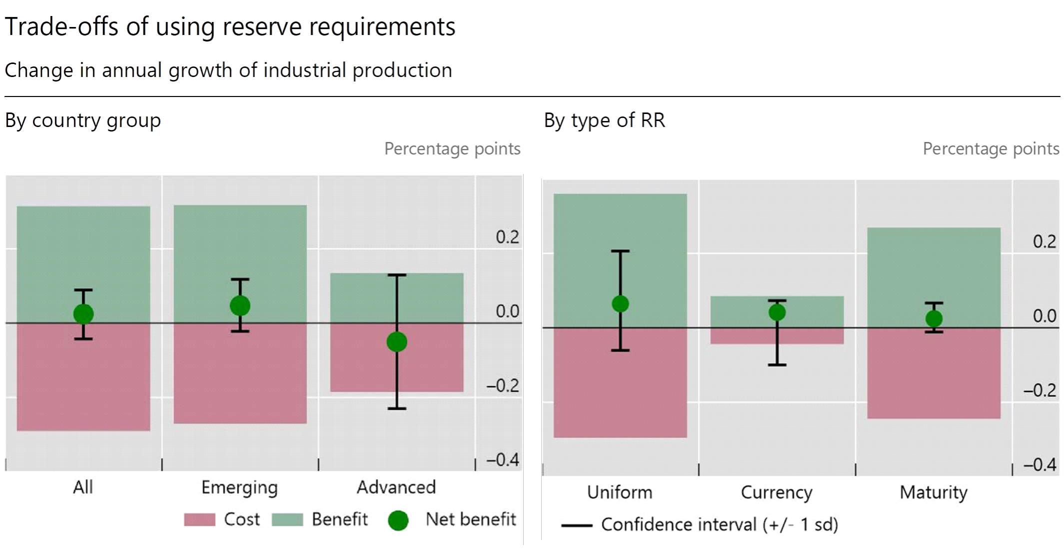
Notes: Net benefit is the difference between the drop in industrial production growth from the VAR model minus the gain in industrial production growth from the reduced probability of financial stress.

We compare the effects of RR in EMEs and AEs and differentiating by the type of deposit targeted (Figure (Figure 9)). Our results show that the trade-offs are positive, except when we restrict the sample to the countries with RR by currency and when we only consider AEs. We find that RR have a greater effect on both costs and benefits for EMEs than for AEs. The effectiveness of RR depends on the degree

[17]These estimates represent a lower bound of the expected credit and IPI loss. Alternatively, we can consider the expected loss differentiating by groups between episodes where RR were active and where RR were not active. The benefit would then product of the reduction in probability times the difference between the average loss without RR and with RR. We confirm that the expected benefit using this methodology would be higher than the one reported.

of competition in the banking sector and the availability of substitutes to banking products for financing and investing. In EMEs, banks are the main source of credit to firms. By contrast, in AE, banks compete with other sources of financing such as issuance of bonds, equities, and commercial paper. Additionally, banking systems in EMEs are highly concentrated and entry costs are high. Then, in EMEs, RR should have a greater impact on domestic and foreign credit as banks have greater market power in both the deposit and loan markets. For the same reason, financial stress episodes in EMEs tend to be more severe. Thus, a lower frequency of these episodes result in greater gains for EMEs than for AEs. Finally, if we separate the use of RR by type of deposits (Figure 9), we find that uniform RR and RR by maturity are more effective at reducing financial system vulnerabilities when compared to countries that use RR by currency. Having RR differentiated by categories might have other objectives, such as for example targeting a change in the composition of credit rather than reducing the build up of systemic risk. For instance, higher RR for dollar-denominated deposits than domestic currency deposits could be used to reduce financial dollarisation but its effect on total credit could be limited.[18]

Figure 9



Notes: net benefit as the difference between the drop in industrial production growth from the VAR model minus the gain in industrial production growth from the reduced probability of financial stress.

[18]For instance, Contreras et al (2019) find evidence on the effectiveness of reserve requirements by currency on credit dollarisation.

8 Conclusions

The use of RR as a macroprudential measure reflects the development of a new approach to prudential regulation and supervision of the financial system (Lim et al (2011)). RR are intended to solve an externality where banks issue too much short-term debt and fund excessive loans. They can thus provide a countercyclical role for managing the credit cycle. Bank credit is the main source of firms' funding, especially in EMEs, so a reduction in credit can affect economic activity. But rapid credit growth can lead to an increase in the probability and severity of financial crises. When policy makers decide to implement RR there is a need to quantify these two effects.

In this paper we explore the trade-offs of using RR. On the one hand, RR can reduce credit and output as banks pass to agents the higher costs of funding and restrict financing conditions. On the other hand, RR can reduce the incidence and severity of financial stress episodes. We quantify the cost and benefits of RR in terms of their effect on industrial production growth. For the complete sample, we find that the trade-offs of implementing RR are positive. This implies that the immediate credit and output loss is compensated by the benefits associated with the reduction in probability of financial stress. We also find that RR result in higher costs and higher benefits for EMEs than for AEs. One reason is that the strength of the transmission mechanism of RR into the financial system depends on the banking system's market structure and the degree of financial development. The effects of RR on the cost and availability of credit will be higher in banking systems with a low of financial development and where banks have a stronger monopoly power. In these cases, banks are better able to pass the cost of the implicit tax to agents since there are less substitutes for financing. However, this also means that RR are less effective at reducing the probability of financial stress in AEs.

Finally, we show that the design of RR is also important. We find that uniform RR and RR by maturity have a positive net effect, but the trade-offs are less clear for countries that implement RR by currency. Overall, our results show that RR are an essential instrument that countries can use to build resilience in the financial sector and reduce financial stress.

References

[1] P.-R. Agénor, K. Alper, and L. P. da Silva, "External shocks, financial volatility and reserve requirements in an open economy", *Journal of International Money and Finance*, vol. 83, pp. 23–43, 2018.

[2] K. Alper, S. D. Mahir Binici, H. Kara, and P. Ozlu, "Reserve requirements, liquidity risk, and credit growth", *Koc University Working Paper Series*, 2014.

[3] A. Armas, P. Castillo, and M. Vega, "Inflation targeting and quantitative tightening: effects of reserve requirements in Peru", *Economia*, no. 15.1, 2014.

[4] N. Arregui, J. Benes, I. Krznar, S. Mitra, and A. Oliveira, "Evaluating the net benefits of macroprudential policy: a cookbook", *IMF Working Paper*, no. 167, July 2013.

[5] Bank for International Settlements, *Anual Economic Report*. 2019.

[6] J. Barroso, R. Gonzalez, and B. Van Doornik, "Credit supply responses to reserve requirement: loan-level evidence from macroprudential policy", *ECB Working Paper Series*, no. 674, November 2017.

[7] M. Behn, M. Gross, and T. Peltonen, "Assessing the costs and benefits of capital-based macroprudential policy", *ECB Working Paper Series*, no. 1935, July 2016.

[8] Y. R. Betancourt and H. Vargas, "Encajes bancarios y la estrategia de inflación objetivo", *Borradores de Economia*, no. 533, 2008.

[9] C. Borio and W. Fritz, "The response of short-term bank lending rates to policy rates: a cross-country perspective", *BIS Working Papers*, no. 27, 1995.

[10] M. Brei and R. Moreno, "Reserve requirements and capital flows in Latin America", *BIS Working Papers*, no. 741, 2018.

[11] V. Bruno and H. S. Shin, "Capital flows and the risk-taking channel of monetary policy", *Journal of Monetary Economics*, vol. 71, pp. 119–132, 2015.

[12] M. Bussiere and M. Fratzscher, "Towards a new early warning system of financial crises", *journal of International Money and Finance*, vol. 25, no. 6, pp. 953–973, 2006.

[13] J. Bustamante, W. Cuba, and R. Nivin, "Determinants of credit growth and the bank-lending channel in Peru: A loan level analysis", *BIS Working Papers*, no. 803, 2019.

[14] C. D. Camors, J.-L. Peydró, and F. R. Tous, *Macroprudential and monetary policy: loan-level evidence from reserve requirements*. Universitat Pompeu Fabra, Department of Economics and Business, 2019.

[15] L. J. Christiano, M. Eichenbaum, and C. L. Evans, "Monetary policy shocks: What have we learned and to what end?", *Handbook of macroeconomics*, vol. 1, pp. 65–148, 1999.

[16] A. Contreras, R. Gondo, E. Ore, and F. Perez, "Assessing the impact of credit de-dollarization measures in Peru.", *BCRP Working Papers*, no. 2019-004, 2019.

[17] T. Cordella, P. Federico, C. Vegh, and G. Vuletin, *Reserve requirements in the brave new macroprudential world*. The World Bank, 2014.

[18] J. C. Cuaresma, G. von Schweinitz, and K. Wendt, "On the empirics of reserve requirements and economic growth", *Journal of Macroeconomics*, vol. 60, pp. 253–274, 2019.

[19] M. Drehmann and M. Juselius, "Evaluating early warning indicators of banking crises: Satisfying policy requirements", *International Journal of Forecasting*, vol. 30, no. 3, pp. 759–780, 2014.

[20] M. Drehmann and K. Tsatsaronis, "The credit-to-GDP gap and countercyclical capital buffers: questions and answers", *BIS Quarterly Review*, March 2014.

[21] T. Duprey, B. Klaus, and T. Peltonen, "Dating systemic financial stress episodes in the eu countries", *Journal of Financial Stability*, vol. 32, pp. 30–56, 2017.

[22] O. for Economic Co-operation and Development, "Reserve Requirements: Current Use, Motivations and Practical Considerations", *Note by Secretariat*, 2018.

[23] S. Edwards and C. Vegh, "Banks and macroeconomic disturbances under predetermined exchange rates", *Journal of Monetary Economics*, no. 40, pp. 239–278, 1997.

[24] M. Eichenbaum and C. Evans, "Some empirical evidence on the effects of shocks to monetary policy on exchange rates", *The Quarterly Journal of Economics*, vol. 110, no. 4, pp. 975–1009, 1995.

[25] P. Federico, C. A. Vegh, and G. Vuletin, "Reserve requirement policy over the business cycle", *NBER Working Paper*, no. 20612, 2014.

[26] R. Fernández and P. Guidotti, "Regulating the banking industry in transition economies: exploring interactions between capital and reserve requirements", *Policy Reform*, vol. 1, pp. 109–134, 1996.

[27] L. Fransson and O. Tysklind, "What effect does monetary policy have on interest rates?", *Sveriges Riksbank Working Papers*, no. 1, 2016.

[28] M. Gertler and S. Gilchrist, "What Happened: Financial Factors in the Great Recession", *Journal of Economic Perspectives*, no. 32, pp. 3–30, 2018.

[29] C. Glocker and P. Towbin, "Reserve requirements for price and financial stability: when are they effective?", *International Journal of Central Banking*, vol. 8, no. 1, 2012a.

[30] ——, “The macroeconomic effects of reserve requirements”, *WIFO Working Papers*, no. 420, February 2012b.

[31] M. Gonzalez-Rosada and M. Sola, “Towards a new inflation targeting framework: the case of Uruguay”, *IDB Working Papers*, no. 486, February 2014.

[32] P.-O. Gourinchas and M. Obstfeld, “Understanding past and future financial crises”, *VoxEU,(1 February)*, 2012.

[33] J. Hamilton, “A new approach to the economic analysis of nonstationary time series and the business cycle”, *Econometrica*, vol. 57, no. 2, pp. 357–384, 1989.

[34] D. Hollo, M. Kremer, and M. Lo Duca, “Ciss-a composite indicator of systemic stress in the financial system”, 2012.

[35] A. Kashyap and J. Stein, “The optimal conduct of monetary policy with interest on reserves”, *American Economic Journal: Macroeconomics*, vol. 4, no. 1, pp. 266–282, 2012.

[36] L. Killian, “Structural Vector Autoregressions”, *mimeo*, 2011.

[37] S. Kim and N. Roubini, “Exchange rate anomalies in the industrial countries: A solution with a structural VAR approach”, *Journal of Monetary Economics*, no. 45, pp. 561–586, 2000.

[38] M. Klein, “A theory of the banking firm”, *Journal of Journal of Money, Credit and Banking*, no. 3, pp. 205–218, 1971.

[39] L. Laeven and F. Valencia, “Systemic banking crises database”, *IMF Economic Review*, no. 61, pp. 225–270, 2013.

[40] C. Lim, F. Columba, A. Costa, P. Kongsamut, A. Otani, M. Saiyid, T. Wezel, and X. Wu, “Macroprudential Policy: What instruments and how to use them? Lessons from country experiences”, *IMF Working Paper*, no. 238, 2011.

[41] S. Löffler A. and F. Schobert, “Inflation Targeting by Debtor Central Banks in Emerging Market Economies”, *CESifo Working Papers*, no. 3138, 2010.

[42] E. Minaya, J. Lupu, and M. Cabello, “Macroprudential policies in Peru: the effects of dynamic provisioning and conditional reserve requirements ”, *BIS Working Papers*, November 2017.

[43] M. Monti, *Deposit, credit and interest rate determination under alternative banking objectives*, ser. in: G. P. Szego and K. Shell (eds), *Mathematical Methods in Investment and Finance*. North-Holland, 1972.

[44] C. Montoro and R. Moreno, “The use of reserve requirements as policy instrument in Latin America”, *BIS Quarterly Review*, March 2011.

[45] A. Moreno Jara and C. Tovar, “The global crisis and Latin America: Financial impact and policy responses”, *BIS Quarterly Review*, pp. 53–68, 2009.

[46] F. Pérez-Forero and M. Vega, “The dynamic effects of interest rates and reserve requirements”, *Central Reserve Bank of Peru Working Papers*, no. 18, 2014.

[47] M. H. Pesaran and R. Smith, “Estimating long-run relationships from dynamic heterogenous panels”, *Journal of Econometrics*, no. 68, pp. 79–113, 1995.

[48] C. M. Reinhart and K. S. Rogoff, “From financial crash to debt crisis”, *American Economic Review*, vol. 101, pp. 1676–1706, 2011.

[49] C. M. Reinhart and V. R. Reinhart, “On the use of reserve requirements in dealing with capital flow problems”, *International Journal of Finance Economics*, vol. 4.1, pp. 27–54, 1999.

[50] C. Tovar, M. Garcia-Escribano, and V. Mercedes, “Credit growth and the effectiveness of reserve requirements and other macroprudential instruments in Latin America”, *IMF Working Paper*, no. 142, December 2015.

[51] H. Vargas, Y. Betancourt, N. Rodriguez, and C. Varela, “Effects of reserve requirements in an inflation targeting regime: the case of Colombia”, *BIS Working Papers*, no. 54, 2010.

[52] D. Zsolt, “Real effective exchange rates for 178 countries: a new database”, *Bruegel Working Paper*, July 2016.

Appendix A A Simple Model of Reserve Requirements and Bank Lending

The model is an oligopoly extension of the Monti-Klein model (Klein (1971) and Monti (1972)). The set up of the model is the following:

- There are n identical banks in the market.
- A representative bank (i):
  - has no physical capital in its assets and no equity in its liabilities.
  - raises funds through customer deposits (D_i).
  - has three types of assets: loans (L_i), reserves (R_i), and bonds (B_i).[19]
  - faces the same loan rate (r_L), deposit rate (r_D), and interest rate on bonds (r_B) as the rest of the banks.
  - faces a cost of servicing loans and deposits: $C(D_i, L_i)$, separable in deposits and loans, $\frac{\partial C}{\partial D_i} \geq 0$ and $\frac{\partial C}{\partial L_i} \geq 0$.
- The central bank:
  - sets the rate of unremunerated reserve requirements (rr).
  - sets the interest rate on bonds (r_B) (policy rate).
- The respective interest rates of loan and deposits are given by the market demand and aggregate supply in each market:
  - The inverse supply of deposits is given by: $D_s^{-1} = r_D(D_s)$.
  - The inverse demand for loans is given by: $L_d^{-1} = r_L(L_d)$
  - The equilibrium condition is:

$$D_s = \sum_{i=1}^{n} D_i = nD_i \qquad L(r_L) = \sum_{i=1}^{n} L_i = nL_i \tag{6}$$

The profit maximisation problem of the bank is the following:

$$\max_{D_i, L_i, R_i, B_i} \quad \pi = r_L(L_d)L_i + r_B B_i - r_D(D_s)D_i - C(D_i, L_i)$$

$$\text{subject to} \quad D_i = L_i + B_i + R_i$$

$$R_i = rrD_i$$

[19] Bonds can be interpreted as a risk-free, short-term, liquid asset such as treasury bills or deposits in the interbank market.

Substituting the budget constraints and recognising that the interest rates for loan and deposits are determined by their respective markets:

$$\max_{D_i,L_i} \quad \pi = r_L\left(\frac{1}{n}\sum_{i=1}^{n} L_i\right)L_i + r_B((1-rr)D_i - L_i) - r_D\left(\frac{1}{n}\sum_{i=1}^{n} D_i\right)D_i - C(D_i, L_i)$$

Banks maximise profits taking as given the actions of other banks. Then, the first order conditions are given by:

$$\frac{\partial \pi}{\partial D_i} = r_B(1-rr) - \frac{r_D'}{n}D_i - r_D - \frac{\partial C}{\partial D_i} = 0 \implies r_D = r_B(1-rr) - \frac{r_D'}{n}D_i - \frac{\partial C}{\partial D_i}$$
$$\frac{\partial \pi}{\partial L_i} = \frac{r_L'}{n}L_i + r_L - r_B - \frac{\partial C}{\partial L_i} = 0 \implies r_L = r_B + \frac{\partial C}{\partial L_i} - \frac{r_L'}{n}L_i$$

Defining the interest elasticity of deposit demand and the absolute value of the interest elasticity of loan demand as:

$$\varepsilon_D = \frac{r_D}{r_D' D_i} \qquad \varepsilon_L = \left|\frac{r_L}{r_L' L_i}\right|$$

The equilibrium interest rates for deposits and loans are:[20]

$$r_D^* = \frac{r_B(1-rr) - \frac{\partial C}{\partial D_i}}{1 + \frac{1}{\varepsilon_D n}}$$

$$r_L^* = \frac{r_B + \frac{\partial C}{\partial L_i}}{1 - \frac{1}{\varepsilon_L n}}$$

We define the intermediation margin as the difference between the loan and deposit rate:

$$S_{L,D}^* = r_L^* - r_D^*$$

A.1 Change in policy rate, reserve requirements and market structure

For simplicity, assume that $\frac{\partial C}{\partial L_i} = \frac{\partial C}{\partial D_i} = 0$. Then:

[20] Note that in this simple model the equilibrium in the deposits and loans markets are determined independently. This would change if, for example, the cost function was not separable or if the banks were risk adverse and the yield on loans ans deposits was uncertain.

- An increase in the policy rate increases r_L^*, r_D^* and $S_{L,D}^*$.[21]
- An increase in reserve requirements lowers r_D. There is no change in r_L, then $S_{L,D}$ increases.
- As $n \to \infty$ (perfect competition) then $r_D^* \to r_B(1-rr)$, $r_L^* \to r_B$, and $S_{L,D}^* \to rr \cdot r_B$

The last statement helps explain why reserve requirements can be thought of as a tax on financial intermediation. A bank will sell deposits up to the point where the marginal cost of deposits (r_D^*) equals its marginal return. If $rr = 0$, the marginal return is r_B, but if $rr > 0$ then only a fraction $(1 - rr)$ can be reinvested and the marginal return is $r_B(1 - rr)$. This is equivalent to setting a tax on all deposits equal to rr.

Additionally, the model shows that in less competitive markets, the intermediation margin is higher and changes in reserve requirements have a greater effect on the deposit rate.

A.2 Extensions: effects of reserve requirements on the loan market

In the model reserve requirements do not have an effect on the loan rate or on the amount of loans. The reason is that the equilibrium in the market of loans can be determined separately from the equilibrium in the market for deposits. We present three extensions to the basic model to study the effect of reserve requirements on the loan market.

A.2.1 Deposit supply and intermediation margin

A straightforward extension is to define the supply of deposits as positively dependent on the intermediation margin:[22] $D_s = h(r_L - r_D)$ with $(h' > 0)$. Substituting in the balance sheet constraint, we obtain the loan supply function:

$$L = -B - (1 - rr)D \implies L_s = g(r_L - r_D, rr, r_B)$$

with $\frac{\partial g}{\partial r_L - r_D} > 0$ $\frac{\partial g}{\partial rr} < 0$ and $\frac{\partial g}{\partial r_B} < 0$.

[21] The derivative of the equilibrium spread with respect to r_B is positive if and only if: $1 + \frac{1}{\varepsilon_D n} > (1 - rr)\left(1 - \frac{1}{\varepsilon_L n}\right)$. Let $rr = 0$ then $1 + \frac{1}{\varepsilon_D n} > 1 - \frac{1}{\varepsilon_L n} \iff \frac{1}{\varepsilon_D n} + \frac{1}{\varepsilon_L n} > 0$; and let $rr = 1$ then $1 + \frac{1}{\varepsilon_D n} > 0$. By the intermediate value theorem, the effect is always positive.

[22] Mathews and Thompson (2014)

Define the loan demand as: $L_d = L(r_L)$ with $L' < 0$ then market equilibrium implies: $L(r_L) = g(r_L - r_D, rr, r_B)$. Taking the total differential we obtain:

$$L' dr_L = \frac{\partial g}{\partial r_L - r_D}(dr_L - dr_D) + \frac{\partial g}{\partial rr} drr + \frac{\partial g}{\partial r_B} dr_B$$

For a given deposit and policy rate ($dr_D = dr_B = 0$), the change in the loan rate when there is an increase in reserve requirements is:

$$\frac{dr_L}{drr} = \frac{-\frac{\partial g}{\partial rr}}{\frac{\partial g}{\partial r_L - r_D} - L'} > 0$$

Notice that we can obtain the previous result that an increase in reserve requirements reduces the deposit rate (for a given loan rate and policy rate):

$$\frac{dr_D}{drr} = \frac{\frac{\partial g}{\partial rr}}{\frac{\partial g}{\partial r_L - r_D}} < 0$$

Then, an increase in reserve requirements will increase the loan rate and reduce the deposit rate in equilibrium.

A.2.2 Interest rate risk channel

Reserve requirements have no effect on the loan market if banks have access to close substitutes to deposits for funding. One example of a funding substitute is central bank credit. If there is an increase in reserve requirements, then the cost of deposits is higher and banks reduce their demand for deposits while increasing their demand for central bank credit. If the policy rate is constant, then the marginal cost for banks does not change and neither does the loan rate or amount of loans.

Betancourt and Vargas (2008) and Vargas et al (2010) propose an extension to the model where reserve requirements affect the loan market through the interest rate risk channel. The key assumptions are the following:

- Two-period extension of the base model.
- Banks are risk adverse.
- Central bank credit and deposits are imperfect substitutes:
  - Deposits and loans have a two-period maturity and are negotiated at known interest rates (set by the equilibrium in the loan and deposit market).
  - Central bank credit has a one-period maturity and is negotiated at a known interest rate in the first period and an unknown interest rate in the second period (set by the central bank in both periods).

An increase in reserve requirements raises the cost of deposits, reducing the demand for deposits and increasing the demand for central bank credit. If banks rely more on central bank credit they face a higher interest rate risk. Then, the cost of supplying loans is higher and banks restrict their loan supply. The effect on the loan market is a higher loan rate and a lower amount of loans in equilibrium.

The effect on the deposit market is ambiguous. On the one hand, higher reserve requirements increase the costs of funding through deposits, reducing banks' demand for deposits and increasing their demand for central bank credit. On the other hand, the higher demand for central bank credit increases interest rate risk costs, increasing banks' demand for deposits.

We obtain a similar dynamic in the baseline model if we define the cost as a function of central bank credit (CB_i) and the policy rate and remove the market for bonds. The cost will depend on deposits and loans through the budget constraint:

$$CB_i + (1 - rr)D_i = L_i \implies C(D_i, L_i) \equiv f(CB_i, r_T) = f(-(1 - rr)D_i + L_i), r_T)$$

The cost represents the interest rate risk bank's face when substituting funding from deposits to central bank credit. Since we are only interested in the dynamics and not in obtaining a closed form solution, without loss of generality, we can also assume that the cost includes the payment to the central bank for the credit:

$$\frac{\partial f}{\partial r_T} > 0 \quad and \quad \frac{\partial f}{\partial CB} = g(CB, r_T) > 0, \quad \frac{\partial g}{\partial CB} > 0$$

Then, the equilibrium loan and deposit rate, obtained from the FOC are given by:

$$r_D^* = \frac{(1 - rr) \cdot g(CB^*, r_T)}{1 + \frac{1}{\varepsilon_D n}} \qquad r_L^* = \frac{g(CB^*, r_T)}{1 - \frac{1}{\varepsilon_L n}}$$

Then, given an increase in reserve requirements, banks increase their funding through central bank credit which increases the costs related to interest rate risk. In equilibrium the loan rate is higher but the effect on the deposit rate is uncertain.

A.2.3 Liquidity risk channel

Alper et al (2018) propose another extension to the base model where reserve requirements have an effect on the loan market through the liquidity risk channel. The key assumptions of their model are:

- Central bank credit and deposits are imperfect substitutes:

- Central bank credit is collateralised.
- Securities (bonds) pledged as collateral cease to be liquid assets during the term of borrowing. ($CB_i = B_i^{IL}$)

- Total bond holdings of the bank are fixed in the short run and are equal to the sum of encumbered and unencumbered bonds: ($B_i = \overline{B} = B_i^L + B_i^{IL}$)
- Banks face a cost of running into a liquidity shortage: $C(B_i^L)$ with $C' < 0$

The liquidity risk channel implies that the swap of deposits with central bank credit depletes banks' liquid assets which prompts them to tighten their loan supply due to liquidity concerns.

An increase in reserve requirements raises the cost of deposits, reducing the demand for deposits and increasing the demand for central bank credit. The rise in central bank credit increases the costs related to liquidity risk. Then, the cost of supplying loans is higher and banks restrict their loan supply. The effect on the loan market is a higher loan rate and a lower amount of loans in equilibrium. As in the previous extension, the effect on deposit rates is uncertain and depends on the magnitude of the expected cost of liquidity shortage.

Formally, banks solve the following problem:

$$\begin{aligned}
\max_{D_i,L_i,R_i,B_i^L,B_i^{IL},CB_i} \quad & r_L(L_d)L_i + r_T\overline{B} - r_D(D_s)D_i - r_T CB_i - C(B_i^L) \\
\text{subject to} \quad & D_i = L_i + B_i + R_i \\
& R_i = rrD_i \\
& \overline{B} = B_i^L + B_i^{IL} \\
& CB_i = B_i^{IL}
\end{aligned}$$

This problem is equivalent to the base model, which yields the following equilibrium loan and deposit rates:

$$r_D^* = \frac{(1-rr)(r_T - C')}{1 + \frac{1}{\varepsilon_D n}} \qquad r_L^* = \frac{r_T - C'}{1 - \frac{1}{\varepsilon_L n}}$$

The result is equivalent to the one related to the interest rate risk channel. An increase in reserve requirements raises the loan rate and has an undetermined effect on the deposit rate which depends on the difference between the policy rate and the cost of running into a liquidity shortage.

Appendix B Data description

B.1 VAR estimation data

Our VAR analysis includes endogenous and exogenous variables (global variables). Table 4 shows the description and the source for all variables.

Variable	Description	Data sources
Exogenous variables		
RR	Reserve requirements index (in levels)	Federico, Veg and Vuletin (2014).For countries with different RR by maturity and/or currency, we use a weighted average using fixed weights based on deposits in the financial system of each country.For 15 countries we obtained data from the Central Bank on the total amount of deposits either by currency, maturity or both.
Endogenous variables		
IPI	Industrial production index (first difference)	Global Financial Dataset (GFD) and complemented with national sources and the OECD-MEI.
IR	Interest rate (in levels)	We select for each country one of three possible rates: money market rate, overnight interest rate and monetary policy rate.We select the interest rate based on data availability and the strength of its link with the financial system. For Argentina, Bangladesh, Lithuania, Singapore and South Africa we use the money market rate; for Colombia, Czech Republic, Ecuador, Indonesia, Latvia, Malaysia, Pakistan, Philippines, Thailand and Turkey we use the overnight interest rate; for the rest of the countries we use the monetary policy rate. The three interest rates come mostly from national sources and complemented using IMF-IFS and GFD.

Continued on next page

Table 4: Data description and sources

Visual inspection of RR suggest that there is no trend on the variables, this is confirm with formal statistical proof Levin-Lin-Chu unit-root test at 1% significance-level. Industrial production growth is a stationary variable by construction. Interest rate and real exchange rate are stationary according to economic theory, this is also

Variable	Description	Data sources
Endogenous variables (continued)		
REER	Real effective exchange rate (in levels)	BIS Statistics Warehouse, IMF-IFS and national sources.
BC2GDP	Ratio of bank credit to GDP (in log)	Bank credit is obtained from BIS Statistics Warehouse, for countries with no data we construct it using claims on private sector by banking institutions and other depository corporations obtained from IMF-IFS. The nominal GDP used to create ratios is obtained from GFD and complemented with national sources.
CBRes	Central Bank Reserves (in log)	Total Reserves excluding Gold, Foreign Exchange, US Dollars, IMF-IFS.
Global exogenous variables		
GIR	Global interest rate	Average of long-term government bonds in the US, core EU and Japan and global growth by the quarterly global growth in real economic activity. All series come from the IMF-IFS statistics.
Grisk	Global risk	Measured by the VIX index from Bloomberg.
GLiq	Global liquidity	Measured as total cross-border and local claims to all sectors obtained from the BIS global liquidity indicators
GGrowth	Global real growth	US, core EU and Japan global growth by the quarterly global growth in real economic activity. All series come from the IMF-IFS statistics.

Table 5: Data description and sources

confirmed with the unit-root test. Central Bank Reserves and the ratio of bank credit to GDP are both scale using the GDP this controls for any nominal trend present on the variables.

The summary statistics for the variables is presented on table 6. The main difference between advanced and emerging market economies is on: reserve requirements and industrial production. Emerging markets show on average a higher level of reserve requirement and bigger deviations from it across countries. Industrial production and interest rate is higher for emerging markets than for advanced economies however we can't reject that both means are equal for both variables.

Variable	Full sample		Advanced economies		Emerging markets	
	Mean	Std. Dev	Mean	Std. Dev	Mean	Std. Dev
RR	8.29	7.74	1.32	1.03	9.88	7.72
IPI	3.77	7.28	1.86	7.49	4.20	7.16
IR	7.63	10.5	2.15	1.05	8.88	11.3
REER	96.1	20.1	97.6	6.35	95.8	22.1
BC2GDP	3.71	1.09	2.68	1.76	3.94	0.67
CBRES	3.05	1.60	3.25	1.37	3.00	1.65

Table 6: Summary statistics

B.2 Financial stress index

To estimate the financial stress index we use two variables: the stock market index (STX) and the real Exchange rate (REER). Data on STX is from GFD and the for the majority of the countries the REER corresponds to BIS Effective Exchange Rates, narrow definition. For Argentina, Bangladesh, Hungary, India, Peru, Thailand and Turkey, we use the REER from Darvas, Zsolt (2016).

B.3 Logistic Early Warning System Model

The vector of regressors in the logistic early warning system model includes macroeconomic, financial sector and global variables.

Variable	Description	Data sources
Macroeconomic variables		
gBC2GDP	Year-on-year growth rate of bank credit to GDP ratio	See Table 4.
gIPI	Year-on-year growth rate of industrial production index	See Table 4.
infl	Year-on year inflation rate	BIS Statistics Warehouse.
IR	Interest rate	See Table 4.
REER	Real Effective Exchange Rate	See Table 4
RR	Reserve requirements index	See Table 4.
Global exogenous variables		
See Table 4.		
Financial variables		
BLev	Bank Leverage	BLev is computed as the ratio of Total equity excluding pref-shares and hybrid capital accounted for as equity to Total Assets . All components from Fitch Connect.
BProf	Profitability	BProf is computed as the ratio of sum of Pretax Profit , and Profit loss from discontinued operations to Total Assets . All components from Fitch Connect.
BLiq	Liquidity Ratio	BLiq is computed as the ratio of sum of Cash and due from Banks Non-Earning Assets, and Loans and Advances to Banks to Total Assets . All components from Fitch Connect.

Table 7: Data description and sources

Appendix C Responses to monetary policy and external shocks

In this appendix, we evaluate if variables react in a different way to a monetary policy shock compared to the RR shock. Particularly, we are interested in the response of the exchange rate, which we found depreciates after an RR shock. The theoretical model predicts that the exchange rate will appreciate in response to the monetary policy shock. We follow a similar identification strategy as the one for the RR shock to identify the monetary policy shock (IR) and assess the different responses. That is, we assume that there is a linear function that determines the interest rate and represents the feedback rule that depends on the policy maker's information set. The monetary policy shock is defined as the innovations that cannot be explained by the feedback rule. We keep the same order as in the previous specification which implies that RR respond immediately to the change in the policy rate.[23] Figure 10 shows the dynamic response of the variables of interest to a one standard deviation shock in the policy rate.

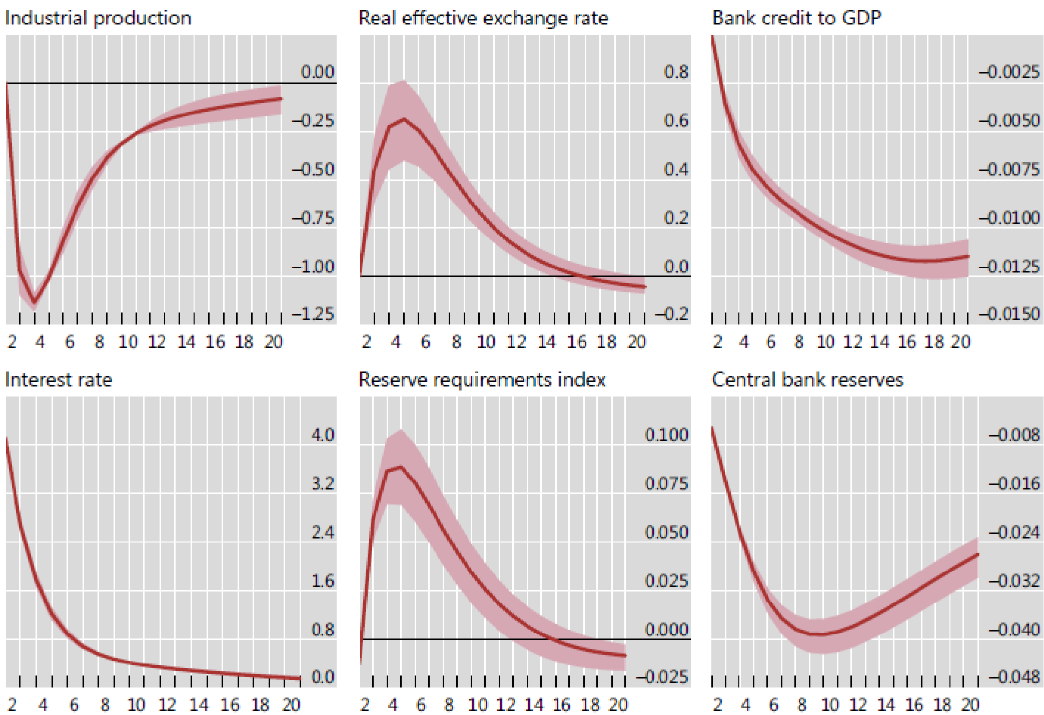
A tightening in the policy rate depletes central bank reserves, reduces bank credit, appreciates the real exchange rate, and contracts industrial production growth. The effect on central bank reserves and the real exchange rate is opposite to their effect for a tightening in RR. First, central bank reserves fall since it needs to withdraw liquidity to implement the higher interest rate. Second, the driving mechanism behind the different response of the real exchange rate is that an increase in the policy rate raises the deposit rate, while an increase in RR reduces the deposit rate. Higher policy rates increase other interest rates in the economy with a stronger effect on short-term rates (Borio and Fritz (1995), Fransson and Tysklind (2016)). However, the rise in lending rates is higher than the deposit rate, widening banks' intermediation margin (Kashyap and Stein (2012). The higher deposit rate attracts capital inflows, which appreciate the real exchange rate (Eichenbaum and Evans (1995), Kim and Roubini (2000)). The *risk-taking channel* magnifies the effect. The stronger real exchange rate strengthens banks' balance sheets and reduces funding constraints, leading to greater leverage, higher capital inflows, and an even stronger real exchange rate. Finally, the same mechanism as in the RR shock apply to the rest of the variables. The higher policy rate leads to lower bank credit and an increase in its cost, which contract industrial production growth. The response of RR is positive but muted. The central bank tightens RR to curb capital inflows and contain the appreciation of the real exchange rate.

[23] Monetary policy decisions are prescheduled. Central banks usually take advantage of the announcement of the policy rate to announce changes in RR. However, the schedule of announcements of changes in RR is not fixed and can be made at the central bank's discretion in response to macroeconomic events. Either way, we perform an exercise switching the order of the two policy instruments and find robust results.

Figure 10

Impulse response to a monetary policy shock

Response to a 100 basis points change in monetary policy



Source: Authors' calculations.

Notes: estimations based on a panel var for 22 EMEs and 5 AEs for quarterly data. Endogenous variables are industrial production, real effective exchange rate, ratio of bank credit to GDP, nominal interest rate, RR index and central bank reserves. The vector of exogenous variables includes global: interest rate, risk, liquidity, commodity price index, and real growth. More details on the variables can be found in Table 4 and Table 5

As an additional exercise, we analyse the effect of global financial factors on the behaviour of domestic variables and the policy reaction of EMEs to these shocks, especially in terms of monetary policy and the use of RR. The set of global variables include: risk in global financial markets, monetary policy rate in AEs, global liquidity, global economic activity, defined as the average GDP growth in AEs, and (v) GCommP as a control for commodity prices. All of these variables enter as exogenous variables in the VAR model for each country, as our sample considers many EMEs.

Table 8 presents the estimated coefficients of the global variables in the reduced form estimation of each equation for the domestic variables. Our results show that an increase in global risk generates an exchange rate depreciation, possibly associated with capital outflows following a flight to quality behaviour. Our indicator of economic activity reacts with a reduction in IPI growth, where higher uncertainty and risk leads to lower production. Monetary policy reacts with an increase in the monetary policy rate, possibly due to a higher weight of inflation in the monetary policy reaction function, where the pass-through of exchange rate depreciation to prices outweighs the effect of lower aggregate demand.

Table 8: Effect of global variables on domestic variables

	$Grisk$	GIR	$GLiq$	$GGrowth$	$GCommP$
IPI	−0.009∗	−0.546∗	0.264∗	0.439∗	0.040∗
REER	0.000	−0.788∗	0.003∗	0.127∗	0.018∗
Credit to GDP	0.000	−0.001∗	0.000	0.000	0.000
Interest rate	0.005∗	0.140∗	0.040∗	−0.082∗	−0.003∗
RR index	0.000	−0.001∗	0.000	0.000	0.000

∗, ∗∗, ∗ ∗ ∗ refer to $P - value < 1\%$, 5% and 10%, respectively.
Notes: estimations based on a panel var for 22 EMEs and 5 AEs for quarterly data. Endogenous variables are industrial production, real effective exchange rate, ratio of bank credit to GDP, nominal interest rate, RR index and central bank reserves. More details on the variables can be found in Table 4 and Table 5

We capture the scenario of monetary policy normalisation (gradual increase in monetary policy rates, a reduction in the size of central banks' balances in AE and lower liquidity in global financial markets) through an increase in GIR and a reduction in $Gliq$. Similar to an increase in global risk, a reduction in global liquidity also leads to an exchange rate depreciation and a reduction in IPI growth. However, given that lower global liquidity translates into lower external funding for the domestic banking sector, monetary policy reacts by lowering policy rates in order to reduce funding costs and smooth fluctuations along the credit cycle.

An increase in monetary policy rates in AE is associated to an exchange rate depreciation due to higher expected returns in AE that would create capital outflows from EME. Lower funding to EME would also lead to a reduction in credit growth, lower investment and lower IPI growth. Monetary policy is expected to react by increasing interest rates due to higher inflationary pressures from exchange rate pass-through to inflation. On the other hand, macroprudential policies such as reserve requirements are expected to be used as a complement to the monetary policy rate, where RR decrease in order to boost credit growth and react countercyclically.

Appendix D Financial Stress Index

The first step is to construct two indices of market stress for each segment. For the stock market, the indices are the monthly realised volatility ($VSTX$) and the cumulative maximum loss ($CSTX$). The $VSTX$ corresponds to the monthly average of absolute daily log-returns of the real stock price index ($rSTX$). The $CSTX$ is calculated as the maximum loss compared to the highest level of the stock market over two years:[24]

$$VSTX = \frac{\sum_{i=0}^{19} |\Delta log(rSTX_{t-i})|}{20} \tag{7}$$

$$CSTX_t = 1 - \frac{rSTX_t}{max_{i=0}^{521} rSTX_{t-1}} \tag{8}$$

For the foreign exchange market the indices are the realised volatility (VFX) and the cumulative change CFX over six months. The VFX is computed as the absolute value of the monthly change of the real effective exchange rate ($REER$), :

$$VFX = |\Delta log(REER_t)| \tag{9}$$

$$CFX_t = |REER_t - REER_{t-6}| \tag{10}$$

The intuition behind the second indicator is that more severe stress implies a greater adjustment of the real economy which can cause longer lasting changes in the real effective exchange rate. To convert each indicator into a common unit, we calculate the empirical cumulative density function (CDF) over an initial window of 10 years that expands progressively to take into account new data points. We transform each pair of indicators into percentiles according to the progressive CDF and then add them to obtain individual stress indices (I_{STX} and I_{FX}):[25]

$$\hat{Z} = F_n(Z_t < Z) \qquad Z_t \in VSTX, CSTX, VFX, CSTX \tag{11}$$

$$I_{STX} = \frac{\widehat{VSTX} + \widehat{CSTX}}{2} \tag{12}$$

$$I_{FX} = \frac{\widehat{VFX} + \widehat{CFX}}{2} \tag{13}$$

[24] The return on the stock market index is divided by the consumer price index to obtain real returns. Before computing volatilities, we divide the data by a 10 year trailing standard deviation. For the first two years of the $CSTX$ we consider the maximum loss compared to a rolling window of 522 days.

[25] As in DKP we follow Hollo et al (2012) for the transformation into a common unit and the aggregation of the indices.

We aggregate the two indices by weighting them by their time-varying cross correlation (ρ_i, j, t), which are calculated using an exponentially weighted moving average. In this way periods of high stress in both market segments will result in a higher composite index. On the other hand, movements that reflect a non-systematic component or diversification of risk among market segment, which which result in lower correlations, will yield a lower composite index. Then the financial stress index (FSI) is calculated as:

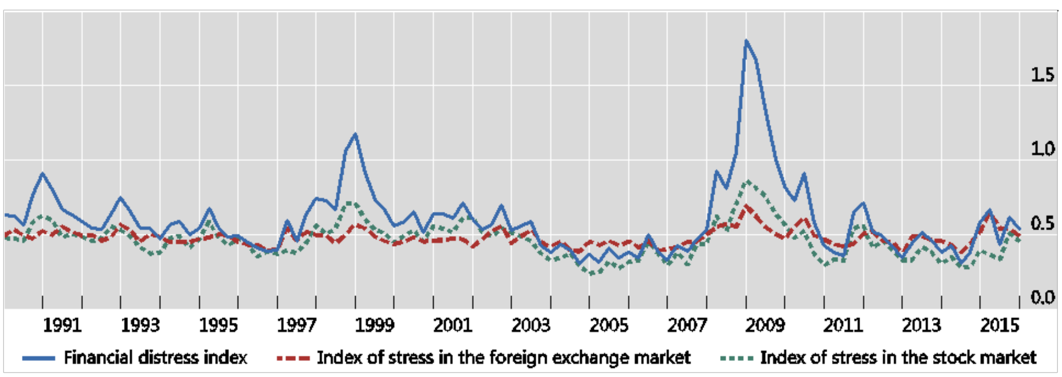
$$FSI_t = I_t \cdot C_t \cdot I_t' \qquad I_t = [I_{STX}, I_{FX}] \tag{14}$$

$$C_t = \begin{bmatrix} 1 & \rho_{STX,FX,t} \\ \rho_{FX,STX,t} & 1 \end{bmatrix} \tag{15}$$

The FSI and its two components are shown in Figure 11. The results are in line with expected episodes of high financial stress, such as the financial crises in EME in the late 1990s and the global financial crisis.

Figure 11

Financial distress index components



Source: Global financial data, BIS statistics warehouse and Zsolt (2016). Authors' calculations.

Notes: financial stress index is calculated using the index of stress in the foreign exchange market (I_{FX}) and the index of stress in the stock market (I_{STX}). It is computed by weighting them by their time-varying cross correlation, which are calculated using an exponentially weighted moving average. I_{STX} and I_{FX} are calculated as indicators into percentiles according to the progressive CDF of the realised volatility and the cumulative change over six months.

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