Reserve Requirements as a Financial Stability Instrument

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Abstract

We quantify the economic trade-offs of using reserve requirements (RR) with a financial stability objective. We estimate the costs of a tightening in RR by calculating the fall of bank credit and industrial production growth in a panel VAR. Then, we estimate the benefits by calculating the drop in frequency and incidence of financial distress episodes in an early warning system model. We find that RR are an effective financial stability tool. The economic gains from a lower probability of financial distress more than compensate the initial reduction in economic activity. Additionally, we find that the effects of RR, both in terms of costs and benefits, are greater in emerging market economies compared to advanced economies. Finally, we show that single RR and RR by maturity have a greater positive effect, whereas RR by currency could be responding to other objectives such as financial dedollarisation.

Resumen

Este trabajo analiza el costo-beneficio de usar requerimientos de encajes desde un objetivo de estabilidad financiera. Se estima los costos de un incremento de los requerimientos de encaje a través de su impacto en el crecimiento del crédito bancario y de la producción industrial usando un panel VAR. Luego,

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se estima los beneficios calculando la caída en la frecuencia e incidencia de episodios de estrés financiero en un modelo de alerta temprana. Se encuentra que los requerimientos de encaje son una herramienta efectiva para la estabilidad financiera. Las ganancias económicas de una menor probabilidad de crisis financiera más que compensan la reducción inicial en la actividad económica. Asimisom, se encuentra que los requerimientos de encajes son mayores en economías emergentes que en países avanzados. Finalmente, se muestra que una tasa de encaje uniforme o diferenciada por plazos tiene un efecto mayor, mientras que una tasa de encaje diferenciado por monedas podría estar respondiendo a otros objetivos tales como una reducción de la dolarización financiera.

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1 Introduction

The policy objective of reserve requirements (RR) changed after the implementation of inflation targeting regimes. Before, central banks used RR as a substitute to the policy rate to combat high inflation. Now, central banks, especially in emerging markets (EMEs), use RR with a macroprudential objective. Namely, they tighten RR during surges in capital inflows and credit booms driven by accommodative global funding conditions (Hoffman and Loffler (2014), Montoro and Moreno (2011), Klein (2012), Jara, Moreno and Tovar (2009)).

The objective of our paper is to evaluate the effectiveness of RR as a financial stability instrument. We proceed in several steps. First, we dissect the channels through which RR affect financial markets. We stress that the strength of the transmission mechanism depends on the design of RR and the structure of the financial system were they will be implemented. Second, we analyse empirically the trade-offs of implementing RR for a sample of advanced economies (AE) and EMEs. We consider the economic and financial costs in terms of lower industrial production after a tightening in RR. Then, we estimate the economic benefits as the lower frequency and incidence of financial distress episodes.[1] We define financial stress episodes as periods of

[1] We estimate the lower probability of financial distress episode applying an early warning system model (Drehman and Juselius (2013)) and follow Laeven and Valencia (2013) to calculate crisis costs.

simultaneous turmoil in the stock and exchange rate markets (Duprey at al (2015)).

Our results are the following. First, we show that RR are an effective and welfare-improving financial stability tool. We find that the macroprudential benefit of reducing the build-up of financial risk is greater than the costs of smoothing credit cycles. Second, we note that the effectiveness of RR depends on market structure and banks' access to alternative sources of funding other than deposits. Particularly, we find a stronger effect of RR in EMEs, where financial markets are less sophisticated and banking systems are highly concentrated. The effects are more pronounced on reducing the frequency and incidence of financial stress episodes. Finally, the effectiveness of RR strongly depends on the type of liabilities they target. We find that single RR and RR by maturity reduce more financial system vulnerabilities than RR by currency. We conclude that RR are an adequate and effective financial stability policy tool.

For central banks with dual objectives, price and financial stability, the exclusive use of the policy rate is not enough to fulfill them simultaneously (Tinbergen (1952), Medina and Roldos (2014), Agenor et al (2015), Carrillo et al (2017), Agenor and Pereira da Silva (2019)). For example, after the GFC, policies implemented by AE's central banks fuelled a surge of gross financial flows that incited credit booms in EMEs and exacerbated global imbalances (Borio and Disyatat (2011)). EMEs with a floating exchange rate faced additional risks stemming from a domestic currency appreciation.These possible risks included a large exogenous terms of trade shock (Goldberg and Tille (2009)), a devaluation of their accumulated foreign exchange reserves (Loffler et al (2010)) and a self-reinforced currency appreciation driven by expectations (Eichengreen (2008)). In this context, changes in policy rate alone would not have been enough to ensure both price and financial stability. On the one hand, lowering the policy rate to discourage capital inflows would encourage lending at low rates and result in a domestically induced credit boom. On the other hand, for EMEs with high inflation, an increase in the policy rate widens the interest rate differential, intensifies capital inflows, and aggravates the risks outlined above. Furthermore, the credit boom in both scenarios exert upward pressures on inflation. Instead, most EMEs central banks chose tightened RR to tame the credit boom and raised interest rates to control inflation (Montoro and Moreno (2011) and Hoffmann and Loffler (2014)).

The basis of our empirical strategy is a simple model where a tightening in RR is equivalent to a tax on financial (Glocker and Towbin (2012a)). In this specification RR are unremunerated and target all deposits. Higher RR increase bank's marginal cost of funding through deposits, as banks cannot use the share of deposits held as reserves to offer new loans or buy other interest-bearing securities. Then, banks pass the cost of the tax to depositors and borrowers. To depositors by reducing the interest rate paid on deposits and to borrowers by increasing the interest rate charged on loans. The higher lending rate discourages the domestic sector from borrowing from banks and the lower deposit rate discourages foreign investors to lend to domestic banks. Hence, higher RR contract domestic credit without attracting more capital inflows. The magnitude of the change in the loan and deposit rate will depend on the competition of other financial intermediaries with the banking system as a whole and the degree of competition within the banking system (Reinhart and Reinhart (1999)).

In our empirical model, we measure the trade-offs of using RR following Behn et al (2016), who calculate costs and benefits of capital based macroprudential policies in the Euro Area. We obtain the costs by estimating in a panel VAR model the drop in industrial production growth caused by a tightening in RR. The transmission mechanism of RR to industrial production is through bank credit (Edwards and Vegh (1997), Armas et al (2014)). As described above, higher RR will raise lending rates and reduce the quantity of loans. Higher costs and lower quantities of credit to the private sector reduce investment and affect negatively industrial production. To identify the RR shock, we adapt Christiano, Eichenbaum and Evans (1998) strategy of monetary policy shocks and introduce RR shocks.

We define the benefits of RR as the reduction in expected costs associated with periods of financial distress and proceed in three steps. First, we construct a financial distress index based on information from the stock and exchange rate markets and apply a Markov regime-switching model to date financial distress episodes. Second, we estimate a logistic model-based early warning system to assess how predicted crisis probabilities change in response to RR shocks (based on related literature such as Bussiere and Fratzscher (2006) and Gourinchas and Obstfeld (2011)). Finally, we calculate the benefit as the reduction in probability of distress episodes multiplied by the expected industrial production loss resulting from financial crises in our sample, following Laeven and Valencia (2013).

We obtain the RR index from the database of Federico, Vegh and Vuletin (2014) who consider legal changes in RR. By using this database, we ensure that the RR shocks are independent to banks' reserve holdings. For countries that apply different RR depending on the type of deposit and currency we construct a weighted average. The weights equal the share of the type of deposits or currency in total reserves. The weights are fixed to prevent changes in the index driven by endogenous changes in the composition of deposits. In the results section, we provide estimations of the cost and benefits of RR differentiating between the type of RR and differentiating between AEs and EMEs. Overall, we find that the economic benefits from the lower probability and incidence of financial distress episodes are greater than the short-run costs from tighter credit conditions.

The structure of the paper is as follows. In Section 2, we review the related literature. Section 3 describes the data and the construction of the RR index. Section 4 presents a framework of the transmission channels through which RR affect the market for loans and deposits. In section 5, we estimate a panel VAR to obtain the costs of using RR to smooth credit fluctuations. Section 6 estimates the benefits of using RR in terms of preventing financial distress episodes. In this section, we explain how to construct the financial distress index and the process we follow to identify financial stress episodes. Section 7 explores the economic trade-offs of using RR. The last section concludes.

2 Literature Review

Our paper relates to several strands of the literature. First, we contribute to the literature that studies RR as a financial stability instrument and analyse their effect on curbing credit and output growth. Cordella et al (2012) gathers a dataset on quarterly legal RR for 52 countries. They show that an increase in RR increases the interest rate spread and reduces credit and GDP. In addition, they find that RR are an effective instrument when there are concerns about the effects of interest rates on the exchange rate. Arregui et al (2013) evaluate the net benefit of macroprudential policies using cross-country data. They find that RR reduce credit growth, lower the loan to deposit ratio and decrease house price growth. Crespo-Cuaresma et al (2018) apply a Bayesian estimation framework to a large international panel and 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 keeping deposit rates stable or lowering them. For Latin America Tovar, Garcia-Escribano and Vera (2012) find that RR have a moderate and transitory impact in slowing the pace of credit growth. They also find that average RR might be more effective than marginal RR, as they may be more strenuous for financial institutions.

Turning to individual country studies, Glocker and Towbin (2012b) provide evidence of the macroeconomic effects of RR by estimating a VAR model for the Brazilian economy. They pursue a partial identification approach with sign restrictions to identify a RR shock and an interest rate policy shock. They find that a discretionary increase in RR leads to a contraction in domestic credit, an increase in unemployment, an exchange rate depreciation, a current account surplus, and an increase in the price level. Pérez-Forero and Vega (2015) estimate a structural VAR model for Peru and show that shocks to RR by currency produce a negative effect on aggregate credit in their corresponding currencies and a mild effect on both aggregate real economic activity and the price level. In contrast to these studies, the identification of our VAR relies on Cholesky ordering.

Other studies have focused on the use of granular credit data to provide a more robust identification of the credit supply. For Brazil, Barroso et al (2017) use credit register data to study the impact of RR on credit growth. They show that bank credit reacts more to an easing of RR than to a tightening and that these policies have less impact on small and foreign banks. They also find that banks are prone to lend less to riskier firms during easing. 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 and Peydro (2014) show that higher RR lead to a reduction in credit. Banks that are more affected increase their exposure into riskier firms, while larger banks mitigate these effects.

Finally our paper is related to the literature of cost-benefit analysis of macroprudential policies. Behn et al (2016) 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. We adapt their cost-benefit analysis framework to estimate the impact of RR on real and financial variables and on the likelihood of financial distress.

3 A basic framework of RR effects

RR are a regulatory tool that requires banks to hold a fraction of their liabilities, usually deposits, as liquid reserves (Tovar et al (2012)). Central banks choose the rate of return and hold the reserves in the form of cash or sovereign paper. 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.

RR affect domestic and foreign credit through their effect on the loan and deposit rates. In general, a tightening in RR increases the spread between loan and deposit rate. The higher loan rate increases the cost of credit and reduces its availability. The lower deposit rate discourages foreign investors from lending to domestic banks, reducing capital inflows. By contrast, a tightening in the policy rate increases both the lending and deposit rates. The higher deposit rate attracts capital inflows, which increase risks to financial stability in case of sudden reversals.[2]

The appendix presents a simple framework to model the different transmission mechanisms of a tightening in RR. The first transmission mechanism is the *cost channel*, in which banks pass through the cost of RR, modelled as a tax, to borrowers and depositors. Whether the effect is larger on loan or deposit rates depends on the degree of competition of other financial intermediaries with the banking system, as a whole, and within the banking

[2]The effect of a tightening in the policy rate on bank credit has been extensively studied in the bank-lending channel literature. The consensus is that, even with the rise in deposit rates, the intermediation margin widens, which contracts bank credit in equilibrium.

system (Reinhart and Reinhart (1999). To understand how the mechanism works, we consider two extreme cases. 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 2, left panel). By contrast, when banks face a perfectly competitive deposit market and have market power in the loan market, the cost of higher RR is paid by borrowers, who face a higher loan rate (Figure 2, right panel). The model in Appendix B complements these findings by analysing competition between banks. The main implication is that RR are less effective as competition between banks intensifies because the intermediation margin becomes narrower.

As the model shows, the effectiveness of RR depends on the degree 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 EME 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 scope to exercise market power in both the deposit and loan market.

The second channel through which RR affect the loan and deposit rates is the *interest risk channel* (Betancourt and Vargas (2008) and Vargas et al (2009)). So far, we assumed that banks funded loans exclusively through deposits. However, 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 in the loan rate or the quantity of loans. Banks offset their reduction in the demand for deposits with funding through central bank credit. In practice, central bank credit and deposits are not perfect substitutes. The interest risk channel relaxes the assumption of perfect substitutability and studies the case where deposits have a longer maturity than central bank credit. The central bank sets the interest rate on its credit the first period but can change it in future periods. Then, risk adverse banks face an additional cost from the uncertainty on the future interest rate the central bank will charge on its credit. If the costs of deposits increase, the cost of borrowing from the central bank increases due to greater interest rate risk as banks substitute deposits for central bank credit.

The third channel through which RR affect the loan and deposit rates is the *liquidity risk channel* (Alper et al (2014)). The liquidity risk channel studies the case where banks have access to collateralised central bank credit. Then, swapping deposits for central bank credit lowers liquidity buffers that banks use in case of unexpected liquidity shocks. The cost of borrowing from the central bank increases as liquidity risk rises when banks substitute deposits for central bank credit,.

Both the interest rate and liquidity risk channels have the same implications on the effect of RR on the loan and deposit market.[3] A tightening in RR 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/liquidity risk cost. Then, the cost of supplying loans is higher and banks restrict their loan supply. Higher cost of funding translates into higher loan rates and lower credit growth. 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/liquidity risk costs, increasing banks' demand for deposits. We model both channels in Annex 1.

4 Data

Our data considers 27 countries that actively use RR as policy tools, 5 AE and 22 EME.[4]. The time-frame 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 have RR classified by deposit maturity; 2 countries have RR differentiated between domestic and foreign currency deposits and; 4 differentiated by both maturity and currency (Figure

[3]Agenor et al (2015) propose another approach where the cost can be interpreted as a "stigma" effect, which raises funding costs either directly on borrowing from the central bank or indirectly through borrowing from the interbank market. We can adapt the cost function in the simple model of the appendix to incorporate institutional difference between countries.

[4]The countries considered 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

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.[5]

Figure 1 shows that EME 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 of domestic currency deposits. One explanation is that in recent years countries have used RR to foreign currency deposits as an substitute to capital controls.

For our VAR analysis, we use data on the following domestic endogenous variables: industrial production index (IPI), real exchange rate, interest rate, the ratio of bank credit to GDP, and central bank reserves; and on the following exogenous global variables: global interest rate, global risk, global liquidity and global real growth. The details of all variables used can be found in Table 1 on Appendix C.1. Additionally in that section we test for stationarity of all transformed variables in the estimation.

The financial distress index is calculated using two variables: the stock market index and the real exchange rate. The details for both variables can be found on Section C.2. in the Appendix. The analysis for the logistic early warning system model estimates the probability that a given country is in financial distress at each quarter. The vector of regressors in such model includes macroeconomic, financial sector and global variables. The first group of macroeconomic variables includes: year-on-year growth rate of bank credit to GDP ratio (or alternatively real bank credit growth), year-on-year growth rate of real GDP (or alternatively industrial production), year-on year infla-

[5]For 15 countries we obtained data from the Central Bank on the total amount of deposits either by currency, maturity or both. The weights are fixed by calculating an average of the target deposits during the period of study.

tion rate, monetary policy rate, exchange rate, RR. Global variables include global GDP growth, global liquidity and global risk measures. We use a set of financial variables such as bank leverage, profitability and liquidity indicators. Details can be found in Section C.3 on the Appendix.

5 Economic costs of RR

We estimate a panel VAR to quantify the direct effect of RR on credit. We also use this model to contrast the transmission mechanism of RR to that of the policy rate based on the conclusions from the theoretical section. The model we estimate is the following:

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

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

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. All variables are at a quarterly frequency.

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. Then,we can obtain the parameters of interest by estimating the mean effects of the group. The 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.

VARs have been used in studies of monetary policy shocks following the lead of Sims (1980). This type of models require identifying assumptions that must be based on institutional knowledge (such as the policy rule) or economic theory. We identify the RR shock following a similar the strategy that Christiano, Eichenbaum and Evans (1998) use to identify monetary policy shocks. 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 normalize $\varepsilon_{j,t}^{RR}$ 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.[6] The vector $Y_{2,j,t}$ includes the variable that are not included directly in the policy decision rule but react immediately to the RR shock.[7] Our identification strategy is semi-structural in the sense that the aim is to identify only the dynamic response of $Y_{j,t}$ to the RR shock. 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 $Y_{2,t}$.[8]. Then, we can use Cholesky decomposition on the variance–covariance matrix to or-

[6] Kim and Roubini (2000)

[7] 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).

[8] 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)

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

A tightening in RR increases central bank reserves, reduces bank credit, depreciates the real exchange rate, and dampens 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. [9] 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 (2014)). 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.[10]

[9] 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 both the theoretical model presented in the previous section and the extensive empirical evidence (Armas et al (2014), Perez-Forero and Vega (2015), Reinhart and Reinhart (1999), Alper et al (2015), Tovar et al (2012), Brei and Moreno (2018), Barroso et al (2016), Camors and Peydro (2014).

[10] As an alternative, we estimated the effect of RR on quarterly growth of GDP. However, the results were inconclusive. 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. Then the effect on GDP is ambiguous. We chose industrial production growth to focus on the effect of RR on investment.

The policy tools move in the same direction in this exercise.[11] 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 (2012) and Gonzalez-Rozadas and Sola (2014)).

Next, we evaluate the effects of a monetary policy shock. Our purpose is to find empirical evidence that some variables react differently compared to the RR shock.[12] 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.[13] Figure 5 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 (Bo-

[11]The ordering of RR and IR is not obvious, as there are important interactions between both instruments. We perform additional exercises using an alternative ordering of the variables, which we fond robust so we do not report them separately.

[12]Particularly, we are interested in the response of the exchange rate, which we found depreciates after a RR shock. The theoretical model predicts that the exchange rate will appreciate in response to the monetary policy shock.

[13]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.

rio 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.

We repeat the exercise by separating into country groups and by type of RR to find if there are heterogeneous effects in term of size. For instance, we could expect that EM have in general more volatile capital flow cycles, so the exchange rate depreciation channel could strengthen the effectiveness of using RR. First, we divide our sample into EME and AE and estimate separate panel VARs for each group. Figure 6 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. There are several factors that explain this result. First, capital markets in EMEs are undeveloped compared to those in AEs. 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. Higher market power allows banks to offset the rise in the cost of funding by charging it to bank borrowers. 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. Therefore, a shock that contracts bank credit and increases its cost affects industrial production growth more in EMEs than in AEs. These factors highlight why the banking sector in EMEs plays a fundamental role in the propagation and amplification of currency and debt crises (Edwards and Vegh (1997)).

Finally, we study the response of industrial production to a RR shock differentiating by the deposits they target. Figure 7 presents the results. We find that RR that differentiate by type of deposit, maturity, currency and residency have other macroprudential effects. RR tailored to specific targets can help strengthen the liabilities side of banks' balance sheets. First, RR on short-term funding provide incentives for banks to lengthen the maturity of their liabilities. Second RR on funds other than deposits can change the composition of liabilities away from non-core liabilities (eg whole-sale funding). Third, RR on foreign currency deposits can limit banks' currency mismatches and can reduce the dollarisation of the financial system (Bustamante, Cuba and Nivin (2019)). Finally, RR by residency of the counterpart are effectively a tax on foreign liabilities, which discourages capital inflows. The results show that single RR entail a higher cost in terms of lower industrial production than RR by maturity and by currency. These results imply that if RR are differentiated by currency or maturity, banks can substitute funding towards the source with lower RR and the policy will have a smaller effect on credit and the real sector. Most funding in the economy occurs in domestic currency, then it is expected that RR by currency would have a muted effect. Nevertheless, RR by currency are now used more as an alternative to capital controls to curb capital inflows or stop capital outflows.

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. The set of global variables include: (i) Grisk, which uses the VIX index as an indicator of risk in global financial markets, (ii) GIR as an indicator of monetary policy rate in AE, (iii) Gliq as an indicator of global liquidity, and (iv) Ggrowth as an indicator of global economic activity, defined as the average GDP growth in AE, 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 5 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.

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.

6 Benefits of preventing financial distress episodes

Central banks implement RR with the aim of reducing 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. All these effects will reduce the probability of financial stress episodes and can 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 distress episodes by calculating country indices that capture stress in the stock and foreign exchange markets. Second, we estimate a logistic-based early warning system model to determine the marginal reduction in probability of financial distress episodes given a change in RR. Finally we quantify the benefit as the reduction in expected industrial production loss during a financial distress episode.

6.1 Financial Distress Episodes

We follow Duprey, Klaus and Peltonen (2016) (henceforth DKP) to calculate country-specific financial distress indices.[14] 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]. We calculate our own index since the widely used indices are not available for all the countries in our sample and they usually have an annual periodicity. 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.

The first step is to construct two indices of market stress for each segment. For the stock market, the indices are the monthly realized 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:[16]

$$VSTX = \frac{\sum_{i=0}^{19} |\Delta log(rSTX_{t-i})|}{20} \tag{5}$$

$$CSTX_t = 1 - \frac{rSTX_t}{max_{i=0}^{521} rSTX_{t-1}} \tag{6}$$

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 ($REER$), :

[14] DKP calculate the index for 27 European Union countries. They show that their index is able to correctly identify episodes included in crises datasets complied by experts: on average 100% of the banking crises in Laeven and Valencia (2013) and 89% in Reinhart and Rogoff (2011).

[15] DKP also include market stress in the government-bond market captured by volatility in the 10-year government bond yields. However, due to data availability, we did not include this market segment in our analysis.

[16] 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.

$$VFX = |\Delta log(REER_t)| \tag{7}$$

$$CFX_t = |REER_t - REER_{t-6}| \tag{8}$$

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}):[17]

$$\hat{Z} = F_n(Z_t < Z) \qquad Z_t \in VSTX, CSTX, VFX, CSTX \tag{9}$$

$$I_{STX} = \frac{\widehat{VSTX} + \widehat{CSTX}}{2} \tag{10}$$

$$I_{FX} = \frac{\widehat{VFX} + \widehat{CFX}}{2} \tag{11}$$

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:

$$FSI_t = I_t \cdot C_t \cdot I_t' \qquad I_t = [I_{STX}, I_{FX}] \tag{12}$$

$$C_t = \begin{bmatrix} 1 & \rho_{STX,FX,t} \\ \rho_{FX,STX,t} & 1 \end{bmatrix} \tag{13}$$

The FSI and its two components are shown in Figure 8. The results are in line with expected episodes of high financial distress, such as the financial crises in EME in the late 1990s and the global financial crisis.

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

Following Hamilton (1989), we use the FSI as input for the following Markov switching model:

$$FSI_t = \begin{cases} \mu_H + \phi_H FSI_{t-1} + \varepsilon_t^H \\ \mu_L + \phi_L FSI_{t-1} + \varepsilon_t^L \end{cases} \tag{14}$$

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 value of the constant, AR(1) coefficient and variance. Compared to 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 9 shows for each period, the number of countries that experience an episode of high financial stress.

6.2 Logistic Early Warning System Model

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

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

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

Therefore, we estimate the components separately. First, we estimate a model to capture the effect of RR on the probability of financial distress 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 distress in quarter t. The vector of regressors X_{it-1} includes macroeconomic, financial sector and global variables. Details of the variables can be found on section 4 and on Table 1 in the Annex. 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 6. 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 (2013) and Drehmann and Tsatsaronis (2014)).

Columns (4) - (6) show the effectiveness of countercyclical use of RR as a macroprudential policy in EME. Alternatively, Columns (7) to (9) show the results for AE, where only a reduction in RR reduces the probability of crisis. This result might be related to the fact that RR in AE 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 distress, where a better performance of economic activity indicators increases the resilience of the financial sector. Higher inflation increases the incidence of financial distress episodes, especially for EME. 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.

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 distress. This is particularly the case for EME countries, whereas in the sample of AE, 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: single RR, RR by maturity and RR by currency. Table 7 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 single RR. 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 (for instance, Contreras et al (2019) find evidence on the effectiveness of reserve requirements by currency on credit dollarisation).

The second component of the expected loss requires us to estimate the credit and output loss during financial distress episodes (Table 8). 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.[18]

The results for the average expected credit loss shows a larger incidence of financial distress episodes in EME, 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 AE. This result could reflect the shallowness of financial markets and high volatility in EME, 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 single reserve requirement experience slightly larger drops in credit to GDP ratio during episodes of financial distress. However, in terms of output loss, countries with RR by maturity show a greater drop followed by countries with single RR.

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

7 Trade-offs of using RR

The net benefit is calculated by subtracting the benefits, related to the macroprudential aim of lower incidence of financial distress episodes, minus the lower growth rate of industrial production in regular times. We summarize the results for the whole sample in Figure 10. A positive net benefit implies that, even though higher RR lead to lower credit growth and hence to a smaller expansion of economic activity, the benefits of facing episodes of financial turbulence less frequently leads to a less volatile and more sustainable path of credit growth.

We show the one year trade-offs of implementing RR differentiating by group and by type of RR in Figure (Figure 11). Our estimation 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 AE. We find that RR have a larger effect in both costs and benefits for EME than for AE. This result might be related to the higher frequency of periods of financial distress and also to the larger disruption in credit growth when emerging countries face a financial crisis, as these set of countries have more shallow financial markets which make them more exposed to a cut in access to credit.Finally, if we separate the use of RR by type of deposits (Figure 11), we find that single RR and RR by maturity are more effective at reducing financial system vulnerabilities, when compared to countries that use RR by currency. As previously mentioned, this could be related to the objective of having different RR by maturity or currency which might be aimed at changing the composition of credit rather than the level.

8 Conclusions

Before inflation targeting regimes were implemented, RR were used as an alternative policy instrument to control inflation. However, 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 and can provide a counter-cyclical role for managing the credit cycle. Rapid credit growth can lead to an increase in the probability and severity of financial crises. However, when policy makers decide to implement RR there is a need to asses the net benefit of the action on the medium and long term level of real variables.

In this paper we explore the trade-offs of implementing RR from a financial stability perspective. On 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 build-up of systemic risk and the incidence and severity of financial distress episodes. We quantify the cost and benefits of RR in terms of their effect on industrial production. 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 distress. We also find that RR seem to have higher costs and benefits for EME than for AE. This results shows 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 low degree 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 distress in AE.

Finally, we show that the design of RR is also important. We find that single RR and RR by maturity have a positive net effect, but the trade-off 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 distress.

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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:

$$D_s = \sum_{i=1}^{n} D_i = nD_i \qquad L(r_L) = \sum_{i=1}^{n} L_i = nL_i \tag{15}$$

The profit maximisation problem of the bank is the following:

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

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

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

$$R_i = rrD_i$$

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:

$$S^*_{L,D} = r^*_L - r^*_D$$

[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.

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:

- 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.

[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.

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 $\frac{\partial g}{\partial r_B} < 0$.

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.

[22] Mathews and Thompson (2014)

Betancourt and Vargas (2008) and Vargas et al (2009) 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 (2014) 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 1 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 1: Data description and sources

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 2: 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 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 3. 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 3: Summary statistics

B.2 Financial distress index

To estimate the financial distress 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 (2012).

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 1.
gIPI	Year-on-year growth rate of industrial production index	See Table 1.
infl	Year-on year inflation rate	BIS Statistics Warehouse.
IR	Interest rate	See Table 1.
REER	Real Effective Exchange Rate	See Table 1
RR	Reserve requirements index	See Table 1.
Global exogenous variables		
See Table 1.		
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 Pre-tax 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 4: Data description and sources

Appendix C Tables

Table 5: 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.

Table 6: By group of countries: Marginal effects on the probability of a financial distress 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.
In t-8 the policy that reduces the probability of a crisis is a tightening in RR.

Table 7: By type of RR: Marginal effects on the probability of a financial distress episode

		Single			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.

Table 8: Expected Credit and IPI loss during Financial Distress Episodes

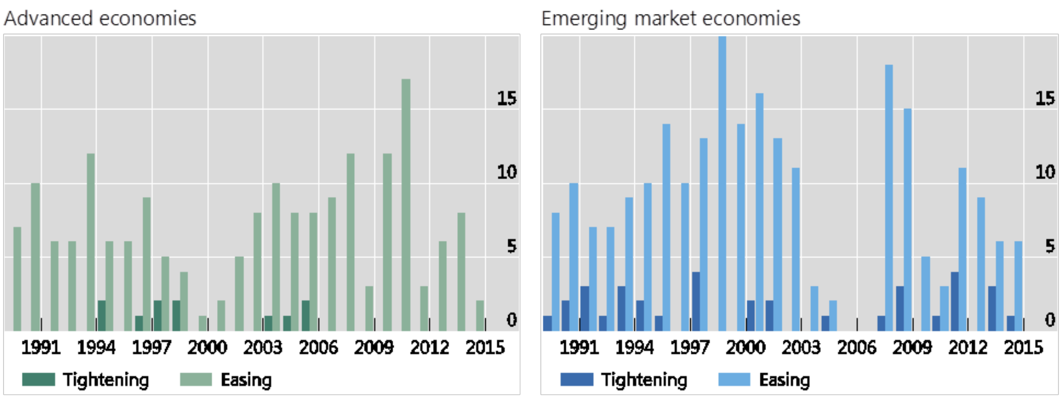
	Credit Loss				IPI Loss			
	t+1	t+2	t+3	t+4	t+1	t+2	t+3	t+4
All	-5.61	-6.31	-10.96	-14.46	-7.05	-8.82	-9.79	-10.99
EME	-6.32	-7.24	-10.92	-17.89	-7.24	-8.64	-9.78	-10.27
AE	-3.24	-3.76	-10.83	-5.15	-6.15	-9.77	-9.81	-14.8
Single	-5.3	-5.17	-10.77	-18.01	-7.48	-9.83	-9.5	-10.9
Currency	-8.01	-8.63	-10.71	-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

Appendix D Graphs

Figure 1

Use of reserve requirements

Number of episodes by country group[1]



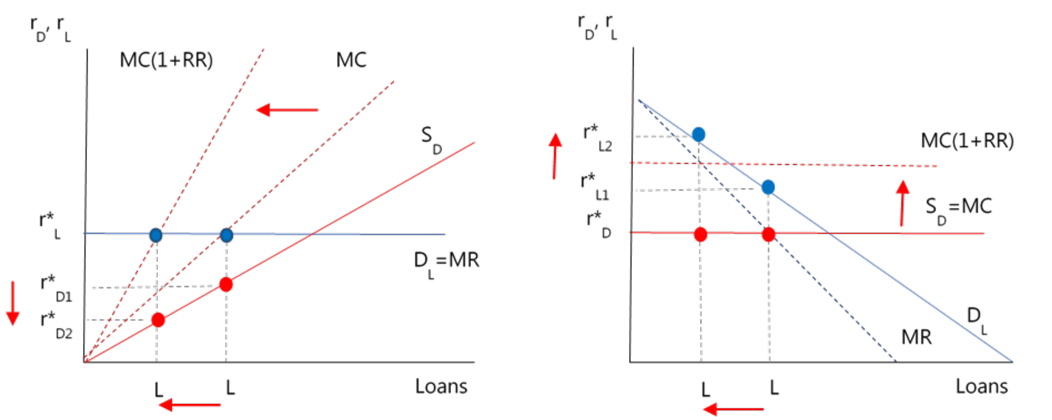
[1]The number of episodes by country group is the annual sum of the quarterly episodes of a change in reserve requirements for each country.

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

Figure 2

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

Perfectly competitive loan market | Perfectly competitive deposit market

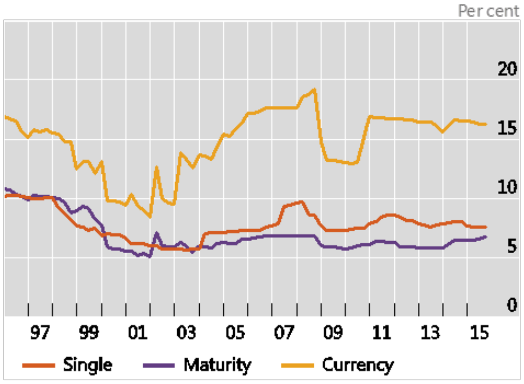


In the left panel banks have monopoly power in the deposit market; while in the right panel, banks have monopoly power in the loan marke D_L is the demand for loans, MR is the marginal revenue from loans, S_D the deposit supply, MC the marginal cost of funding, r_L the loan rat r_D the deposit rate, 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.

Figure 3

Reserve requirements by type

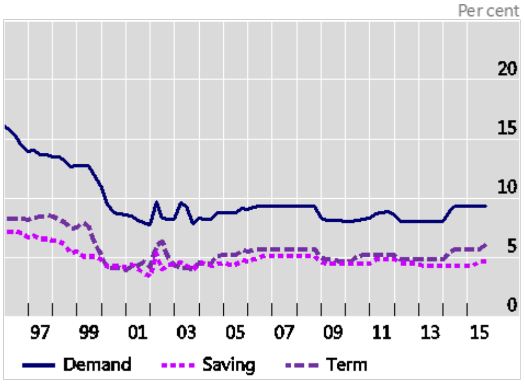
Average reserve requirements index



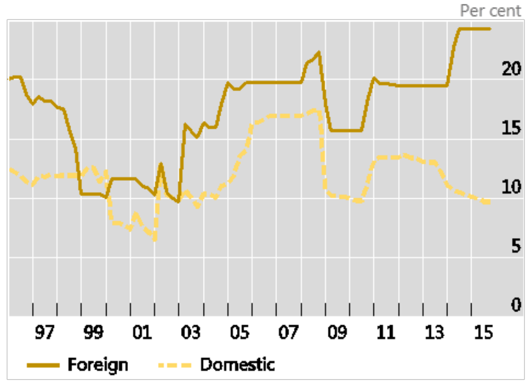
Country Classification

Single	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

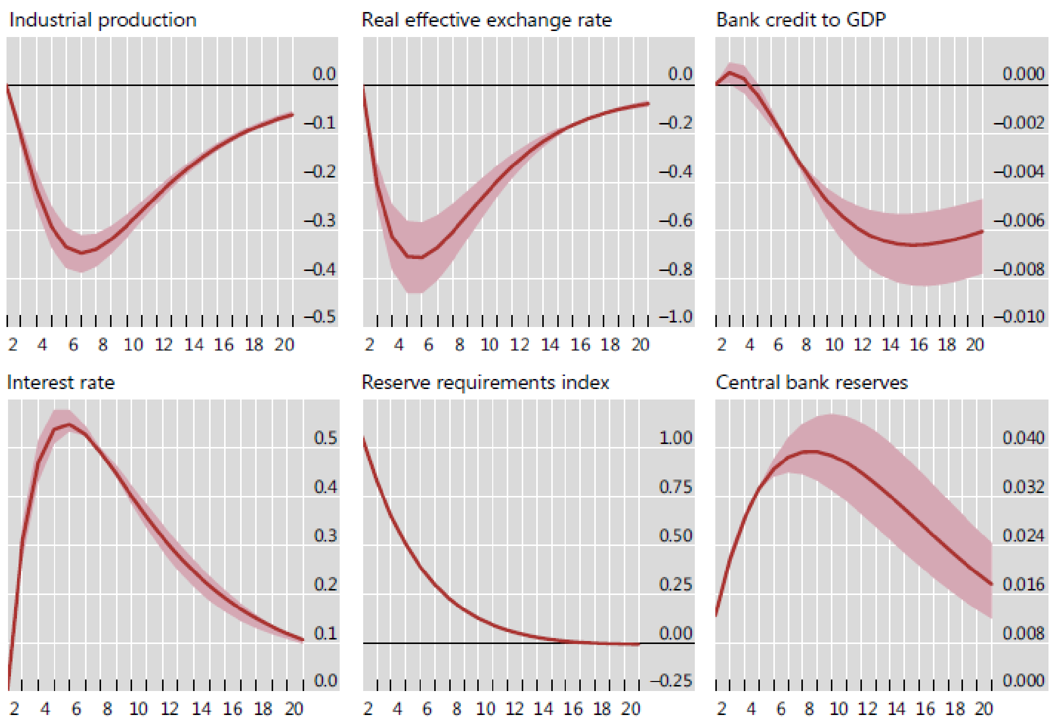


Source: Federico, Vegh and Vuletin (2014). Authors' calculations.

Figure 4

Impulse response of a shock to reserve requirements

Response to one percentage point change in reserve requirement index

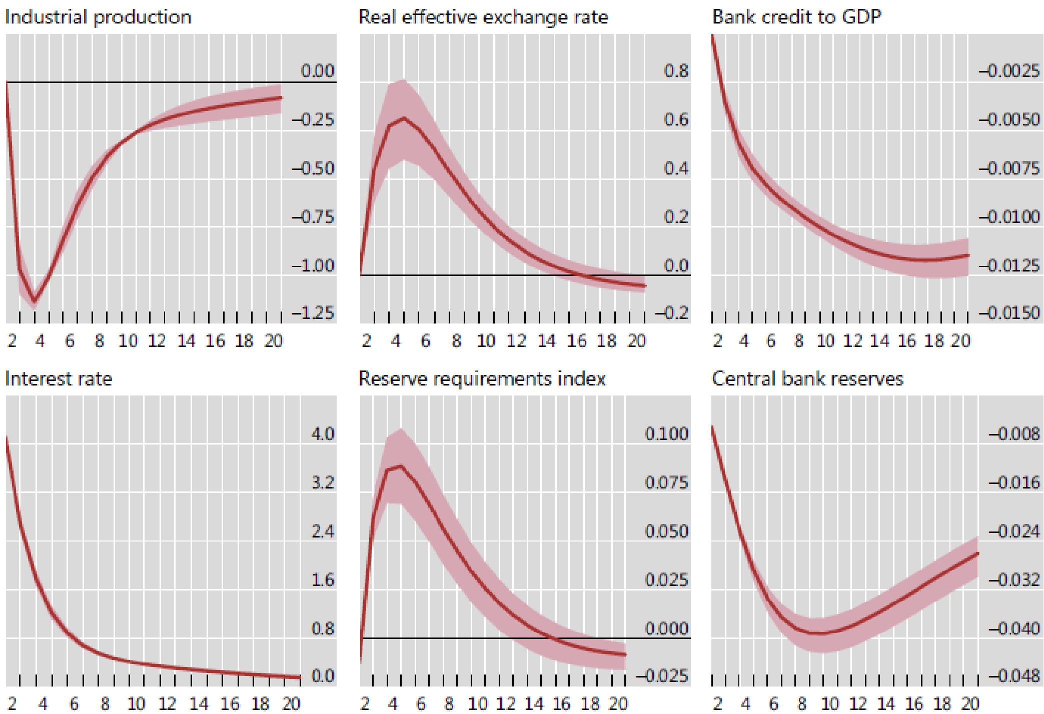


Source: Authors' calculations.

Figure 5

Impulse response to a monetary policy shock

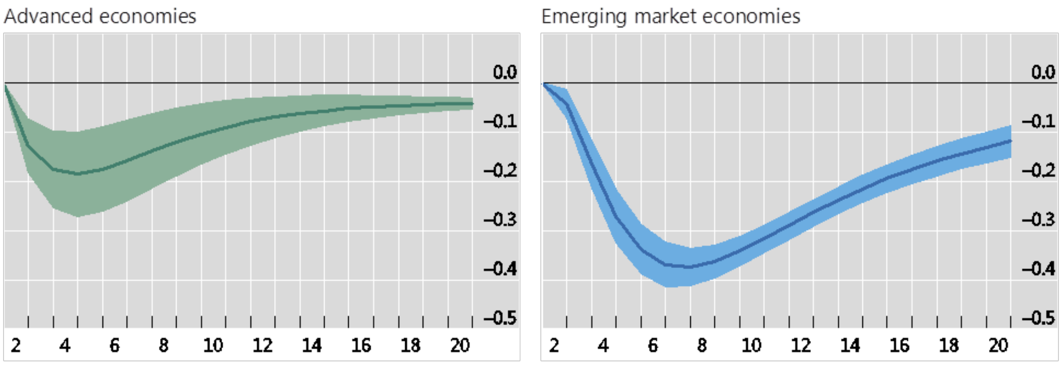
Response to a 100 basis points change in monetary policy



Source: Authors' calculations.

Figure 6

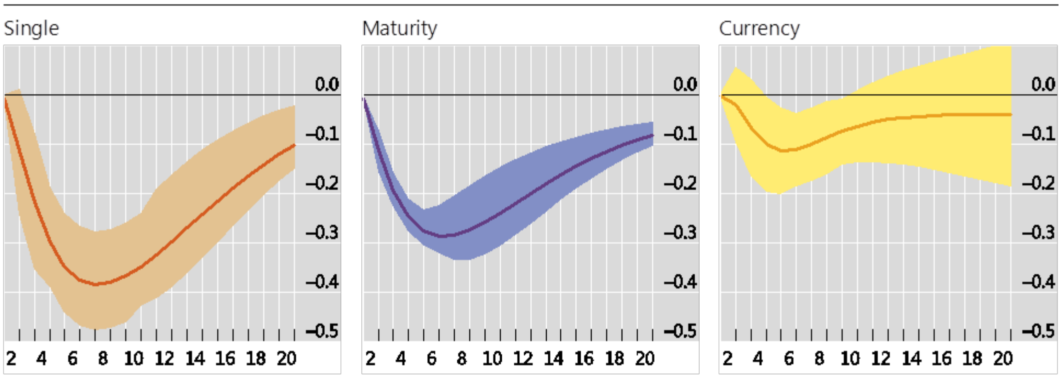
Response of industrial production to a shock to RR by country group



Source: Authors' calculations.

Figure 7

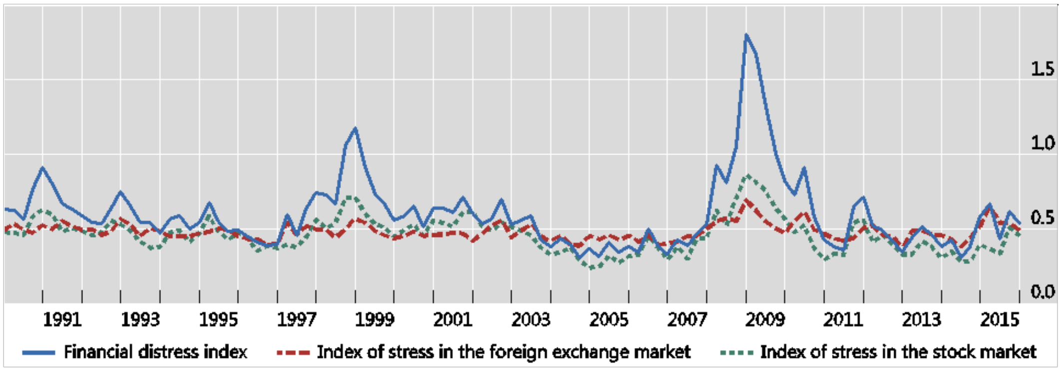
Response of industrial production to a shock to RR by RR type



Source: Authors' calculations.

Figure 8

Financial distress index components

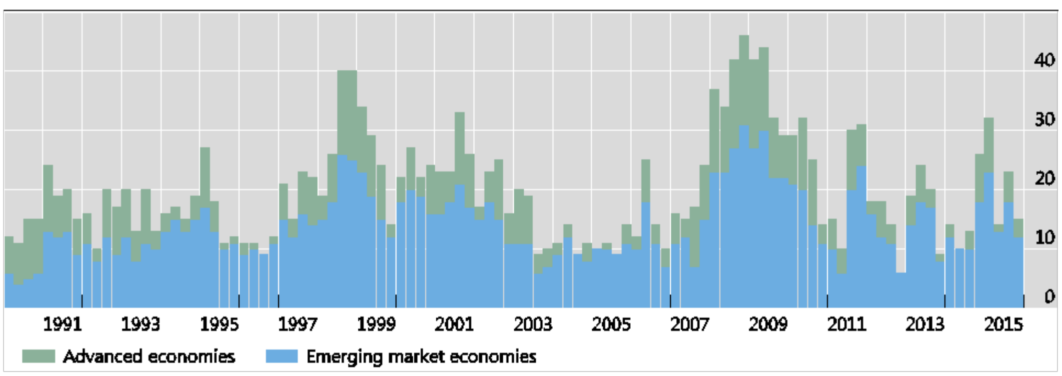


Source: Global financial data, BIS statistics warehouse and Zsolt (2016). Authors' calculations.

Figure 9

Financial stress episodes

Number of episodes



Source: Authors' calculations.

Figure 10

Net benefit of using reserve requirements

Change in annual growth of industrial production

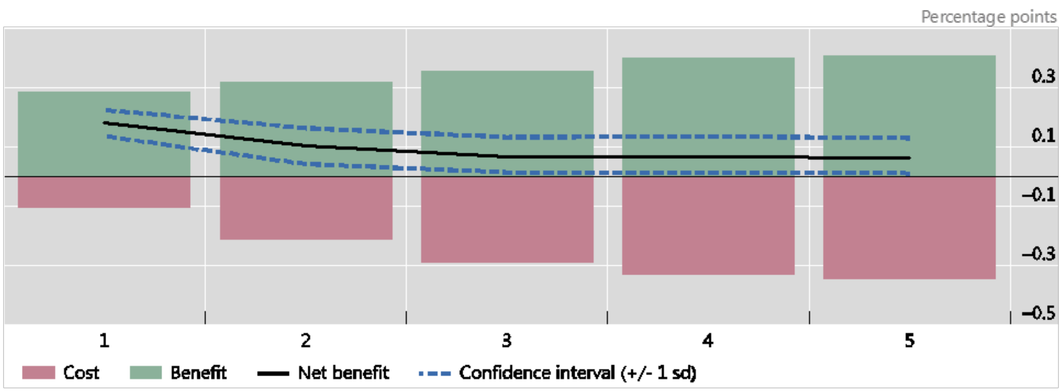


Figure 11

Trade-offs of using reserve requirements

Change in annual growth of industrial production