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by Javier Garcia-Cicco, Markus Kirchner, Julio Carrillo, Diego Rodriguez, Fernando Perez, Rocio Gondo, Carlos Montoro and Roberto Chang

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Financial and real shocks and the effectiveness of monetary and macroprudential policies in Latin American countries*

Javier Garcia-Cicco and Markus Kirchner (Central Bank of Chile); Julio Carrillo (Bank of Mexico); Diego Rodriguez (Bank of the Republic, Colombia); Fernando Perez (Central Reserve Bank of Peru); Rocio Gondo (Bank for International Settlements); Carlos Montoro (formerly Bank for International Settlements and currently Central Reserve Bank of Peru) and Roberto Chang (Rutgers University).†,‡

Abstract

This work compares the impact of monetary and macroprudential policies on financial and real sectors in four Latin American countries: Chile, Colombia, Mexico and Peru, and explores the commonalities and differences in the reaction to shocks to both the financial and real sector. In order to do that, we estimate a New Keynesian small open economy model with frictions in the domestic financial intermediation sector and a commodity sector for each country. Results suggest that financial shocks are important drivers of output and investment fluctuations in the short run for most countries, but in the long run their contribution is small. Furthermore, we evaluate the ability of macroprudential policies to limit the impact on credit growth and its effect on real variables. In a scenario of tighter financial conditions, monetary policy becomes expansionary due to both lower inflation (given the exchange rate appreciation) and weaker output growth, and macroprudential policies further contribute to restoring credit and output growth. However, in the case of a negative commodity price shock, macroprudential policies are less effective but useful as a complement for the tightening of monetary policy. Higher inflation (due to the exchange rate depreciation) and higher policy rates lead to a contraction in output growth, but macroprudential policies could alleviate this by improving credit conditions.

JEL Classification: E52, F41, F47.

Keywords: Central Banking, Monetary Policy, Macroprudential Policy, Financial Frictions.

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† Other central bank authors have also contributed to this project, including Francisco Adame, Pablo Robles, Jessica Roldan, Carlos Zarazúa and Miguel Zerecero (Bank of Mexico) and Paul Castillo and Marco Ortiz (Central Reserve Bank of Peru).

‡ Corresponding author: Rocio Gondo (rocio.gondomori@bis.org).

1. Introduction

Two questions are of particular interest for central bank policymakers in Latin America. The first is how to assess the impact of monetary and macroprudential policies on the financial and real sectors. Recent interest in this question has been stimulated by the Global Financial Crisis, which revealed that financial imbalances could have a very large and lasting impact on the financial sector and on economic activity.[1] The potential role of macroprudential policies in possibly mitigating such imbalances, and the interaction of such policies with monetary policy have generated a growing body of research. An additional consideration is the importance of other policies which may be driven by both financial stability or macroeconomic considerations (eg foreign exchange market intervention, changes in reserve requirements or capital flow management policies) in some inflation targeting countries.[2]

The second question is how to allow for commodities to play a role in the analysis of financial stability issues. Commodity exports are sizable in many emerging countries, including the ones analysed in this paper, although their relative importance differs across countries. Large commodity price fluctuations observed in the recent decade have led policymakers to focus on the macroeconomic effects of these price swings in major commodity exporting economies.[3]

This paper contributes to the literature by presenting a framework that allows for a comparative analysis of the effects of financial shocks in four Latin American countries, while at the same time being able to capture some differences among them. We develop a common model of a small open economy with a financial intermediation sector and a commodities sector. The model builds upon existing New Keynesian (DSGE) models already used for monetary policy analysis in central banks around the world, and is sufficiently detailed to be applicable to Latin American countries.

We estimate different versions of the model for Chile, Colombia, Mexico, and Peru. Thereby, our project stresses both some commonalities and some differences among these countries. About the differences, the four countries have varying degrees of exposure to commodity price fluctuations, as well as to external financial factors. They depend heavily on capital flows and external financing conditions; at the same time, their domestic financial systems are less developed than those of advanced economies and are highly concentrated in the banking sector. Entrepreneurs tend to face high borrowing costs, which in some cases depends on

1 It should be noted, however, that emphasis on financial frictions and the macroeconomy has been a priority in emerging markets at least since the sequence of financial and currency crisis of the late 1990s.

2 See Céspedes, Chang and Velasco (2014), where unconventional monetary policies are taken to include widely used policies in Latin America such as foreign exchange market interventions and reserve requirements, and in some cases capital flow management policies.

3 As mentioned by Fornero et al (2015), this issue is especially relevant in a period of falling commodity prices and tightening of financial conditions in advanced economies, where external factors play an important role in affecting macroeconomic variables, especially in the case of commodity exporting countries. Particularly relevant for monetary policy, the fall in commodity prices has translated into exchange rate depreciation and passthrough to inflation has become a challenge for inflation targeting countries to meet their targets.

factors such as imperfect competition or regulation. This being said, financial frictions are more severe in some countries than in others.

The exercise yields a rich set of results. Some particularly notable ones are:

First, with the exception of Chile, a short-run variance decomposition suggests that financial shocks are important drivers of output and investment fluctuations, although these effects tend to dissipate in the long-run. However, these result reflects that the model estimates large financial shocks rather than the financial transmission mechanism.[4] Furthermore, a long-run variance decomposition shows that foreign factors are the main drivers in Chile and Peru, whereas in Colombia and in Mexico investment efficiency shocks are important.[5]

Second, the use of expansionary macroprudential policies (ie lower capital requirements and LTV ceilings) to counter tightening credit growth is especially effective in restoring financial conditions and therefore boosting credit, investment and GDP growth. This result contrasts with the use of financial policies under a scenario of a negative real shock, in which fine-tuning financial policies are less effective, but are useful as a complement for monetary policy, given the trade-off between higher inflation due to the exchange rate depreciation and lower GDP growth given the tightening in credit conditions.

Third, financial frictions can amplify the impact of commodity price fluctuations. In the event of a fall in commodity prices, negative income effects lower consumption, investment and output and these effects are larger when financial frictions are important. The pass-through effect of a real exchange rate depreciation increases demand for non-commodity exports and tends to raise inflation due to higher prices of imported goods and higher demand for domestic goods. Lower demand tends to lower inflation, but this is not enough to offset the effect of the real depreciation. Monetary authorities increase the policy rate to contain inflation. When we add financial frictions, we show that the negative impact of a commodity price shock is amplified because, in addition, credit spreads widen. This effect is not the same across countries: even if all export commodities, its economic importance varies.

Finally, we find that, while macroprudential tools such as capital requirements and LTV ceilings can limit the impact of the shock on credit, an analysis of the GDP to credit sacrifice ratio indicates that policymakers would have to give up a much larger amount of GDP in order to dampen credit growth via macroprudential policies in Chile and Colombia, whereas the impact on GDP would be smaller in Mexico and Peru.

Related literature

This work relates to two strands of the literature. The first extends standard New Keynesian (DSGE) models used in policy analysis to include a financial sector that interacts with the real sector and allows to study the role of macroprudential policies.

4 The financial transmission mechanism creates very mild amplification effects, in line with related literature (see, for instance, BGG and Gertler et al (2007)), partly related to the fact that in local perturbation approximations as applied in the present analysis the effects of the external finance premium are linear.

5 However, this evidence should be weighted by the ability of the estimated models to replicate relevant moments of the data, a factor that varies from country to country.

Early models with financial frictions in emerging market economies include Cook and Devereux (2006) and Gertler et al (2007). More recently, using a small open economy (SOE) model with financial frictions, Cespedes, Chang, and Velasco (2017) analyse the effectiveness of unconventional policies widely used in Latin America, such as foreign exchange intervention and reserve requirements.

Regarding models with financial frictions and macroprudential policy, Bianchi (2011) considers a nonlinear quantitative model for a small open economy calibrated to Argentina, whereas Agénor et al (2014) analyse the impact of countercyclical capital regulation in a middle-income SOE model subject to sudden capital inflows. Our work extends this strand of the literature, particularly in terms of financial frictions in the domestic banking sector, by combining it with a commodity exporting sector and analysing the implications of macroprudential policies to macroeconomic stability.

Also, several papers in the BIS CCA Research Network on "Incorporating financial stability considerations into central bank policy models" discuss models used by the countries under study to examine the macroeconomic implications of financial policies. Garcia-Cicco and Kirchner (2015) analyse the macroeconomic implications of considering financial factors in the Taylor rule for Chile, whereas Gonzalez et al (2015) consider whether policies such as FX intervention and regulation complement monetary policy in a model for Colombia where the surge in commodity prices leads to a resource reallocation from tradable to non-tradable sector, exacerbated by financial frictions.

Carrillo et al (2015) consider variants of a New Keynesian DSGE model with financial frictions for the Mexican economy and include the interaction between monetary and macroprudential policy and their welfare implications. Castillo et al (2015) present a two-good small open economy model with financial frictions for the Peruvian economy, with an asymmetry in the ability to collateralize assets, so that only the tradable sector can borrow from abroad.

A second strand of the literature investigates the effect of external shocks on macroeconomic variables. For example, Canova (2005) finds that the financial channel is a key transmission mechanism for US shocks on the macroeconomic performance of Latin American countries.

With respect to commodity prices, Gruss (2014) studies the implications of a commodity price downturn on output growth in Latin America using a global VAR and finds that output growth for commodity exporters is expected to fall even if prices remain stable.

In terms of policy implications, on the one hand, Catao and Chang (2013) theoretically analyse optimal monetary policy in an open economy New Keynesian model. Fornero et al (2015) study the effects of monetary and fiscal policy on investment in an estimated DSGE model for Chile and find that both policies affect investment in the non-mining sector, but the mining sector is mainly linked to commodity prices and sectoral productivity.

In this regard, our work also analyses the importance of commodity price shocks, but accounting for the financial channel, in the form of frictions in the domestic banking sector, that serves as an amplification mechanism. In this scenario, macroprudential policies serve as a complementary tool to monetary policy to foster macroeconomic and financial stability.

The next section describes the model, emphasising the specific assumptions introduced to capture the empirical regularities just mentioned. The third section presents the estimation results for each country. A fourth section presents an analysis of credit cycles, effectiveness of macroprudential policy and interaction with monetary policy. A fifth section includes policy exercises with the estimated model, in particular the effects of i) a financial shock such as a sudden increase in the credit spread and ii) a real shock such as sudden drop in commodity prices, and the implications of using alternative policy instruments to counteract the tightening of financial conditions.

2. The model

A survey to the central banks participating in the project identified ingredients that a model should ideally include to capture the empirical regularities of the countries being studied:

- Small open economy
- Production with labour and capital as inputs
- Tradable, non-tradable and commodity sectors
- Nominal rigidities and indexation in prices and wages
- Incomplete passthrough in prices of imported goods
- Banking sector financing with financial frictions that generate time-varying interest rate spreads
- Traditional real rigidities such as: investment adjustment costs, habit formation in consumption and variable capital utilisation.
- Monetary policy performed using the short-term interest rate as the policy instrument, following a Taylor rule.

Existing small open economy models incorporate many but not all of these features. Our strategy is to consider, as a starting point, a baseline model with most of the listed features, such as Christiano, Trabandt and Walentin (2011, henceforth CTW), and extend it in two ways: (i) to accommodate domestic financial intermediaries (banks), so as to enrich the modelling of interest rate spreads and allow for a discussion of macroprudential policies, and (ii) to include a commodity sector.

The baseline already considers a new Keynesian model with nominal rigidities, similar to the ones used for monetary policy analysis by central banks in Latin America. In particular, CTW considers Calvo wage setting and price setting frictions on intermediate domestic goods, which are then combined to produce a homogeneous domestic good. In this model there are three types of final goods: consumption, investment and exports, all produced by combining the domestic homogeneous good with imported inputs.

2.1 Modelling the financial sector and interest rate spreads[6]

The baseline CTW model does not include domestic financial intermediaries: households borrow or lend from the rest of the world in frictionless capital markets and accumulate productive capital. However, in order to analyse the impact of financial stabilisation policy, we need to reformulate the structure of the domestic economy and financial flows.

Our model assumes that capital is accumulated by a set of agents called entrepreneurs. There is also a set of financial intermediaries or banks that collect deposits from households and lend to entrepreneurs. This structure gives rise to two domestic spreads: the difference between the interest rates that banks pay on deposits and the safe rate; and the difference between the bank's lending rate and the deposit rate.

In order to model the determination of these spreads, we follow Alpanda, Cateau and Meh (2014, henceforth ACM) who assume that spreads increase with measures of debtor's leverage. Spreads reflect the origination fee for bank loans, which are an increasing function of leverage. This approach is pragmatic and flexible, allowing for the analysis of relevant financial variables, and of the impact of macroprudential instruments.[7]

2.1.1 Households

There is a continuum of homogeneous households indexed by $h \in [0,1]$. Their lifetime utility function depends positively on consumption $(c_{h,t})$ and negatively on labour $(H_{h,t})$. b is a parameter controlling external habits, σ_h^{-1} is the Frisch elasticity of labor supply, ψ is a normalizing constant that affects labour at the deterministic steady-state, ς_τ^c and ς_τ^h are preference shocks affecting consumption demand and labour supply. The objective of the household is thus:

$$max_{c_{h,t},L_{h,t}^D,B_{h,t},B_{h,t}^*,W_{h,t}} E_t \sum_{\tau=t}^{\infty} \beta^{\tau-t} \left[\varsigma_\tau^c ln\left(c_{h,\tau} - bc_{h,\tau-1}\right) - \varsigma_\tau^h \psi \frac{H_{h,\tau}^{1+\sigma_h}}{1+\sigma_h} \right]$$

Households are subject to the budget constraint, which in real terms is given by:

$$c_{h,\tau} + \left(1+\Upsilon_\tau^D\right)\frac{L_{h,\tau}^D}{P_\tau} + \frac{B_{h,\tau}}{P_\tau R_\tau} + \frac{S_\tau B_{h,\tau}^*}{P_\tau \Phi_\tau R_\tau^*} \leq \frac{W_{h,\tau}}{P_\tau} H_{h,\tau} + R_{D,\tau-1}\frac{L_{h,\tau-1}^D}{P_\tau} + \frac{B_{h,\tau-1}}{P_\tau} + \frac{S_\tau B_{h,\tau-1}^*}{P_\tau} + \frac{\Lambda_{h,\tau}}{P_\tau} \quad (1)$$

The left side shows household expenditures on consumption, on monitoring deposits and investment in domestic and foreign bonds. Monitoring costs considers nominal deposits $\left(L_{h,t}^D\right)$ and the unitary monitoring cost $\left(\Upsilon_\tau^D\right)$. Domestic bonds $\left(B_{h,t}\right)$ are purchased at a nominal price of $1/R_t$, while foreign bonds $\left(B_{h,t}^*\right)$ are purchased at a nominal price of $1/\Phi_t R_t^*$, where R_t^* is the risk-free interest rate in foreign currency and Φ_t is the country risk-premium.

6 This section benefits from the contributions of Francisco Adame and Julio Carrillo (Bank of Mexico).

7 However, this approach is not fully micro-founded, and the functional forms used to introduce credit-market imperfections may raise concerns for policy evaluation exercises.

On the right side are the sum of income from labour, deposits, financial wealth (foreign and domestic bonds) and a term Λ_t which includes additions to wealth. Labour income depends on hours worked $(H_{h,t})$ and the nominal wage rate $(W_{h,t})$. Deposits pay an interest rate, $R_{D,t-1}$. The additional wealth term $\Lambda_t = -TR_t + \Pi_t + D_t^B + D_t^E$ comprises nominal net lump-sum taxes from the government (TR_t), profits (Π_t) and dividends from banks and entrepreneurs (D_t^B, D_t^E).

Our assumption on the country risk premium is:

$$\Phi_t = \bar{\Phi} exp\left\{-\phi_a\left(a_t - \bar{a}\right) - \phi_s\left[R_t^* - R_t - \left(R^* - R\right)\right] + \phi_t + \phi_{cp,t}\right\} \tag{2}$$

which depends negatively on the stock of foreign assets and on the interest rate spread between risk-free bonds in foreign and domestic currency, and positively on two shock to the country-risk premium.[8] The first term considers deviations of the normalised (detrended) stock of foreign assets (a_t) from a long-run mean $(\bar{a})$.[9] The second term includes the spread between the foreign and domestic interest rates $(R_t^* - R_t)$ from the long-run spread, to allow for delayed exchange rate overshooting. Finally, ϕ_t is an unobserved risk shock and $\phi_{cp,t}$ is an observed shock to the country premium.

We assume that the observable country spread corresponds to $\overline{\Phi} exp\left\{-\phi_a\left(a_t - \bar{a}\right) + \phi_{cp,t}\right\}$, which has an endogenous component reflecting fundamentals (as reflected by a_t) and an exogenous one reflecting deviations from fundamentals.

More importantly, the term $1 + \Upsilon_\tau^D$ allows for the deposit interest rate to deviate from the safe rate. Intuitively, this *bank funding spread* considers transaction costs of maintaining a bank deposit account. In the spirit of ACM, we assume that this spread depends on the balance sheet of the banking system:

$$1 + \Upsilon_\tau^D = \left(\frac{\gamma_t}{capb_t / L_t^E}\right)^{\chi_D} exp\left(\tilde{\varepsilon}_{D,t}\right), \tag{3}$$

where γ_t is the capital requirement ratio, $capb_t$ is the bank capital and L_t^E is the total nominal value of bank loans given to entrepreneurs. The term in parenthesis refers to the relative effective bank capital ratio with respect to the requirement and χD is the elasticity of monitoring costs with respect to this gap $\tilde{\varepsilon}_{D,t}$ an AR(1) shock.

2.1.2 Entrepreneurs

There is a continuum of entrepreneurs indexed by $i \in [0, 1]$. These agents act as small business units, owned by households, whose main purpose in period t is to buy the

[8] Even though the country risk-premium follows a reduced form specification, we discipline each of these components by estimating the model using data for each country.

[9] This specification ensures that there exists a unique steady state. Under incomplete markets, this has nontrivial implications because it yields a different equilibrium to the one obtained using global methods.

stock of capital K_{it} from capital producers at price p_t^K. Entrepreneurs also decide how much to borrow from banks L_t^E and how much to pay to households as dividends $\left(D_t^E\right)$.

In time $t+1$, entrepreneurs rent their capital K_{it} to the productive sector at the nominal rate Z_{t+1}, and sell the non-depreciated capital $\left(1-\delta\right)K_{i,t}$ at price p_t^K; δ is the depreciation rate of capital. Their objective is to maximise the discounted stream of real dividends, subject to their relevant cash-flow condition. The entrepreneur's lifetime utility is:

$$max_{D_{i,t}^E,k_{i,t},l_{i,t}^E} E_t \sum_{\tau=t}^{\infty} \beta_E^{\tau-t} \frac{\lambda_{P,\tau}}{\lambda_{P,t}} \left[\nu_{E,\tau} \frac{D_{i,\tau}^E}{P_\tau} \right]$$

which depends on real dividends $\left(\frac{D_{i,\tau}^E}{P_\tau}\right)$ which are subject to a shock $\nu_{E,\tau}$ that distorts their valuation. β_E is the discount factor and $\lambda_{P,t}$ is the shadow price associated to the household's budget constraint.

Entrepreneurs are subject to their budget constraint in real terms:

$$\begin{aligned} &\frac{D_{i,\tau}^E}{P_\tau} + \frac{P_\tau^k}{P_\tau}\left[K_{i,\tau} - \left(1-\delta\right)K_{i,\tau-1} + \tau_K \delta K_{i,\tau-1}\right] + R_{\tau-1}^E \frac{L_{i,\tau-1}^E}{P_\tau} \\ &\leq \left(1-\tau_K\right)\frac{Z_\tau}{P_\tau}K_{i,\tau-1} + \frac{L_{i,\tau}^E}{P_\tau} - \frac{\vartheta^E}{2}\left(\frac{D_{i,\tau}^E / D_{i,\tau-1}^E}{\pi_\tau} - \mu_a\right)^2 \frac{D_\tau^E}{P_\tau} \end{aligned} \tag{4}$$

The left-hand side shows expenses, including dividend payments, purchase of new investment goods and interest payments on bank loans. $R_{\tau-1}^E$ is the nominal interest rate of bank loans and τ_K is a tax on capital.

The right hand side contains income receipts, including income from renting capital and new bank loans net of the dividend adjustment costs. μ_a is the steady state growth rate of technological progress (ie $\mu_a = \bar{a}_t / \bar{a}_{t-1}$ is the level of technology that would prevail if there were no shocks) and ϑ^E is a level parameter governing the adjustment costs of real dividends.

Notice that dividend adjustments costs are proportional to aggregate dividends, given by D_t^E. Adjustment costs are introduced by ACM and Jermann and Quadrini (2012) to capture the smoothness of dividends observed in the corporate finance literature.

2.1.3 Banks

A continuum of competitive banks, indexed by $j \in \left[0,\ 1\right]$, use deposits and retained earnings to finance one-period-maturity loans to entrepreneurs. The objective of a representative bank is to maximize the present value of real dividends payouts, ie:

$$max_{D_{j,t}^B,\ l_{j,t}^E,l_{j,t}^D} E_t \sum_{\tau=t}^{\infty} \beta^{\tau-t} \frac{\lambda_{P,\tau}}{\lambda_{P,t}} \left[\nu_{B,\tau} \frac{D_{j,\tau}^B}{P_\tau} \right]$$

Similar to entrepreneurs, real bank dividends $\left(\frac{D^B_{i,t}}{P_t}\right)$ are subject to a shock $\nu_{B,t}$ that distorts their valuation. β is the discount factor and $\lambda_{P,t}$ is the shadow price associated to the household's budget constraint. Notice that the bank stochastic discount factor is $\beta^{\tau-t}\frac{\lambda_{P,\tau}}{\lambda_{P,t}}$, as households are the shareholders of the bank, but they apply a higher discount rate than entrepreneurs.[10]

The bank cash-flow condition, in real terms, is given by:

$$\frac{D^B_{j,\tau}}{P_\tau} + R_{D,\tau-1}\frac{L^D_{i,\tau-1}}{P_\tau} + \left(1+\Upsilon^E_\tau\right)\frac{L^E_{j,\tau}}{P_\tau} \leq R_{E,\tau-1}\frac{L^E_{j,\tau-1}}{P_\tau} + \frac{L^D_{j,\tau}}{P_\tau} - \frac{\vartheta^b}{2}\left(\frac{D^B_{i,\tau}/D^B_{i,\tau-1}}{\pi_\tau} - \mu_a\right)^2 \frac{D^B_\tau}{P_\tau} \tag{5}$$

The left hand side considers bank expenses, including dividend payments, interest payments on deposits received from households $\left(L^D_{j,t}\right)$, and monitoring costs on loans to entrepreneurs. Υ^E_t is the nominal monitoring cost and $L^E_{j,t}$ are loans to entrepreneurs.

The right hand side considers bank income, including interest income from loans to entrepreneurs, income from new deposits, net of real bank dividend adjustment costs. $R_{E,t}$ is the interest rate of loans and ϑ^b is a level parameter that governs the quadratic cost of adjusting bank real dividends.

There is an origination cost incurred by banks when extending loans to entrepreneurs, Υ^E, which is assumed to be given by:

$$1+\Upsilon^E_t = \left(1+\Upsilon^E_{t-1}\right)^{\chi_{E1}}\left[\chi_{E0}\left(\frac{1-m_t}{n_t/(p^k_t K_t)}\right)^{\chi_{E3}}\right]^{1-\chi_{E1}} exp\left(\tilde{\varepsilon}_{E,t}\right), \tag{6}$$

where the first term considers a persistence component. The second term considers the effect of borrowers leverage, χ_{E0} is a level parameter, m_t is the regulatory LTV ratio of entrepreneurs and χ_{E3} is the elasticity of monitoring costs with respect to borrowers leverage. $\tilde{\varepsilon}_{E,t}$ is a shock to banks transaction costs.

Net worth of entrepreneurs is given (in real terms) by:

$$n_t = p^k_t K_t - \frac{L^E_t}{P_t}$$

and the balance sheet of banks, in real terms, is given by:

$$\frac{\mathrm{L^E_t}}{\mathrm{P_{t\ t}}} = \frac{\mathrm{L^D_t}}{\mathrm{P_t}} + \frac{\mathrm{capb_t}}{\mathrm{P_t}} \tag{7}$$

Table 1 lists the exogenous shocks that are included in the financial sector of the model, all following AR(1) processes.

[10] This follows ACM. Intuitively, while all agents are forward looking, we need to assume that their discount factors differ in order to have a defined flow of funds allocation at the steady state. Thus, households and banks discount the future at rate $\beta_H = \beta_B = \beta$, and entrepreneurs do so at rate β_E. With $\beta > \beta_E$, we ensure that at the steady state households save, banks lend and keep positive dividends, and entrepreneurs borrow.

Shocks: Financial sector

Table 1

Shock to deposit spread	$\tilde{\varepsilon}_{D,t}$
Shock to credit spread	$\tilde{\varepsilon}_{E,t}$
Shock to the valuation of bank dividends	$\nu_{B,\tau}$
Shock to the valuation of entrepreneurs dividends	$\nu_{E,\tau}$
Shock to bank capital	$capb_t$

In order to analyse the implications of incorporating a domestic banking sector to the model, we present a numerical analysis of the effect of a 1% credit spread shock on macroeconomic and financial variables under the baseline calibration from CTW. The values of additional parameters are shown in Table 2. These parameters are used as reference for the estimations later on. Just as reference to depict how the transmission mechanism works in the model, we use intermediate values compared to the ones obtained later in the four-country estimations, given that there is a large variance between the countries. The main conclusions follow through, as presented later in Section 3.

Parameter Values: Financial sector

Table 2

	Calibration	Estimation Interval
χ^{E1} (Credit spread persistence)	0.8	[0.43;0.87]
χ^{E3} (Elasticity of monitoring cost to leverage)	0.1	[0.64;1.58]
χ^{D} (Elasticity of monitoring cost to bank capital)	1.0	[0.48;1.63]
v^{E} (Adj cost for firm dividends)	0.5	[0.24;2.92]
v^{D} (Adj cost for bank dividends)	0.5	[0.14;1.18]

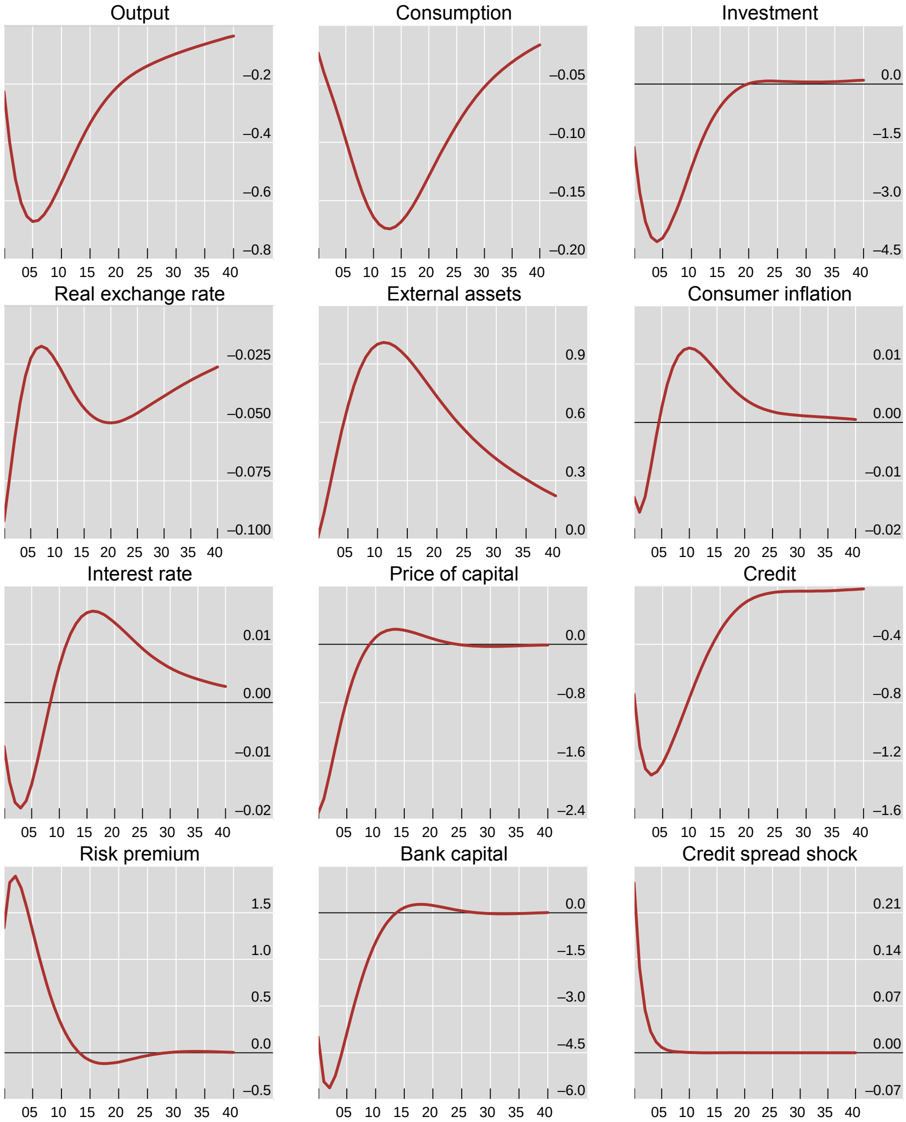
Figure 1 shows the results. The exogenous increase in bank monitoring costs increases the bank intermediation spread, leads to a higher cost of credit for entrepreneurs and a lower amount of credit extended. As a result, new investment and output declines. Lower output reduces consumption in the medium term and the demand for imported goods also declines.

The lower domestic demand leads to a decline in domestic inflation, which, together with lower output, in turn translate into a lower monetary policy interest rate in the short run.

On the financial side, lower demand for investment decreases the price of capital. This creates an amplification mechanism, as a lower price of capital, negatively affects net worth and bank capitalisation, which further increases the bank intermediation spread and amplifies the effects previously described for macroeconomic variables.

Impulse response to a credit spread shock, CTW model with domestic financial sector

Figure 1



Source: Author's estimates.

2.2 The commodity sector[11]

Another important feature of the countries in this project is that they are all commodity exporters, although the relevance of commodity exports in total trade varies. To account for this, we extend the model by including a commodity sector in the spirit of Medina and Soto (2007), Medina et al (2007), Hevia and Nicolini (2013), Catao and Chang (2013), and Garcia-Cicco et al (2014). In this sector, there is a set of competitive firms that produce a homogeneous commodity good that is entirely exported abroad. Commodity producers take prices as given and demand is also

[11] This section was prepared by Markus Kirchner and Javier García-Cicco (Central Bank of Chile).

exogenous. Therefore, commodity production has a pure income effect on domestic aggregate demand. Also, we assume that a fraction of commodity income is transferred abroad to foreign owners of commodity producing firms, which reduces its impact on the current account.

More precisely, a firm in the commodity export sector is endowed with a quantity Y_t^{CO} of exports, assumed to grow exogenously along the balanced growth path of the economy. The entire production is sold abroad at a given foreign price P_t^{CO*}. The associated real price, $p_t^{CO*} = P_t^{CO*} / P_t^*$, is assumed to evolve exogenously. In terms of domestic currency, the income generated in the commodity sector is given by $S_t P_t^{CO*} Y_t^{CO}$, where S_t is the nominal exchange rate. We assume that domestic agents receive a share $\chi \in [0,\ 1]$ of this income and the remaining goes to foreign investors. The household's budget constraint now becomes:

$$\begin{aligned} & c_{h,\tau} + \left(1 + \Upsilon_\tau^D\right)\frac{L_{h,\tau}^D}{P_\tau} + \frac{B_{h,\tau}}{P_\tau R_\tau} + \frac{S_\tau B_{h,\tau}^*}{P_\tau \Phi_\tau R_\tau^*} \\ & \leq \frac{W_{h,\tau}}{P_\tau} H_{h,\tau} + R_{D,\tau-1}\frac{L_{h,\tau-1}^D}{P_\tau} + \frac{B_{h,\tau-1}}{P_\tau} + \frac{S_\tau B_{h,\tau-1}^*}{P_\tau} + \frac{\Lambda_{h,\tau}}{P_\tau} + \frac{\chi S_\tau P_\tau^{CO*} Y_\tau^{CO}}{P_\tau} \end{aligned} \tag{8}$$

Commodity prices and quantities are given by:

$$lny_t^{CO} = \left(1 - \rho_{y^{co}}\right) lny^{CO} + \rho_{y^{co}} lny_{t-1}^{CO} + \varepsilon_t^{y^{co}} / 100, \tag{9a}$$

$$lnp_t^{CO*} = \left(1 - \rho_{p^{CO*}}\right) lnp^{CO*} + \rho_{p^{CO*}} lnp_{t-1}^{CO*} + \varepsilon_t^{p^{CO*}} / 100, \tag{9b}$$

where $\varepsilon_t^{y^{co}} \sim NID\left(0, \sigma_{y^{co}}^2\right)$ and $\varepsilon_t^{p^{CO*}} \sim NID\left(0, \sigma_{p^{CO*}}^2\right)$, $y_t^{CO} = Y_t^{CO} / z_t^+$ denotes real scaled commodity output ($y_t^{CO} = \frac{Y_t^{CO}}{z_t^+}$, with z_t^+ an appropriate trend term).

The introduction of the commodity sector affects the evolution of net foreign assets, as shown by the link between net exports and the current account. From the definition of the current account, expenses on new purchases of net foreign assets, A_{t+1}^*, plus factor payments of commodity income to foreign agents and expenses on imports must equal income from exports and from previously purchased net foreign assets:

$$\begin{aligned} & S_t A_{t+1}^* + factor\ payments\ of\ commodity\ income_t + expenses\ on\ imports_t = \\ & receipts\ from\ exports_t + R_{t-1}^* \Phi_{t-1} S_t A_t^* \end{aligned} \tag{10}$$

Factor payments of commodity income equal the share $1 - \chi$ of the income generated in the commodity sector that goes to foreign agents:

$$factor\ payments\ of\ commodity\ income_t = \left(1 - \chi\right) S_t P_t^{CO*} Y_t^{CO} \tag{11}$$

and the receipts from exports equal exports of the homogenous domestic good plus exports of the commodity good:

$$receipts\ from\ exports_t = S_t P_t^x X_t + S_t P_t^{CO*} Y_t^{CO} \tag{12}$$

In net, only the share of income from commodity exports received by domestic agents affects the accumulation of net foreign assets.

Also, the production of the commodity sector affects the evolution of the gross domestic product (GDP) and the GDP deflator. By definition GDP equals the production of the domestic homogeneous good minus capital utilisation costs plus commodity production:

$$GDP_t = Y_t - a(u_t)K_t + Y_t^{CO} \tag{13}$$

Similarly, nominal GDP is defined by:

$$p_t^{gdp}\, GDP_t = Y_t - a(u_t)\bar{K}_t + q_t p_t^C p_t^{CO*} Y_t^{CO} \tag{14}$$

where p_t^{gdp} and p_t^C are the relative price of the gdp deflator and the consumption basket with respect to the price of the homogeneous final good, and q_t is the real exchange rate.

We first analyse the effect of incorporating the commodity sector only. We simulate the response to a 10% commodity price shock with persistence parameter $\rho_{p^{CO*}} = 0.95$. The additional parameters are $\chi = 0.61$, $\eta_{y^{co}} = 0.1$ and $\delta = 0.015$.[12]

The blue lines in Figure 2 show the results for the case with a commodity sector but no domestic financial sector. The unexpected increase in the commodity price generates a positive income effect for domestic agents, so consumption, investment and output increase. The shock also generates a real exchange rate appreciation, and an associated increase in all types of imports (for consumption and investment) and a decrease in non-commodity exports. Due to the real appreciation, inflation decreases under the given calibration and the associated response of the short-term interest rate through the Taylor rule is negative.

Finally, note that the impulse response dynamics due to the commodity price shock depend on the values of the structural parameters of the model. For example, under some other combination of parameters (substitution elasticities, Calvo probabilities, etc), the response of inflation could be positive and not negative as in Figure 2. For this particular calibration, the pass-through effect of the exchange rate appreciation dominates the effect of higher domestic demand on inflation.

2.3 Amplification effects of commodity price shocks and interaction with the domestic financial sector

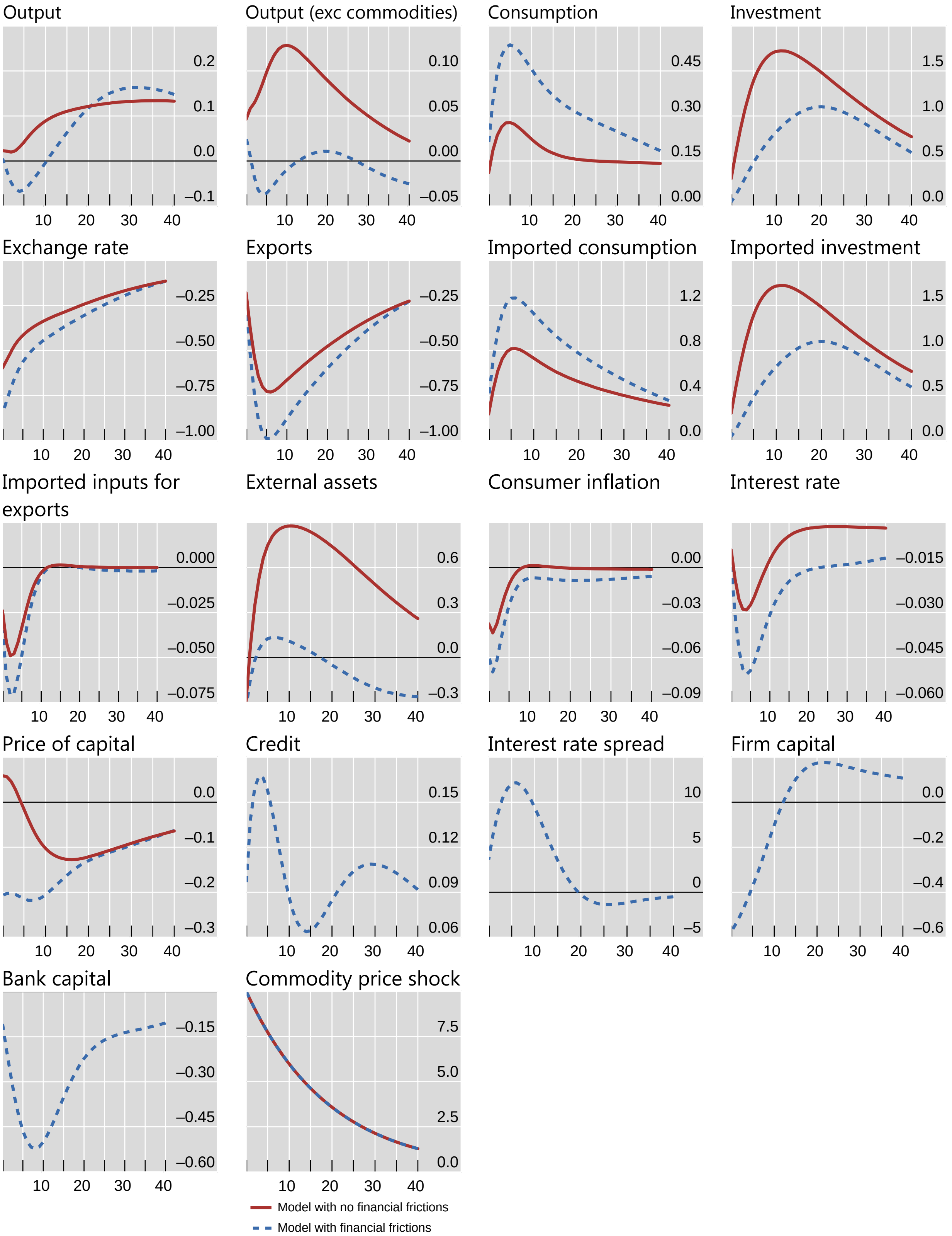
We now consider the model with both the commodity and the domestic financial sector and compare the effect of an increase in commodity prices to the ones described in section 2.2. In general, the domestic financial sector creates an amplification mechanism for the effect of commodity price shocks, as shown in Figure 2. The blue line depicts the case where financial frictions are absent, while the dashed red line shows the case where financial frictions are present.

In the scenario with no financial frictions and financial shocks, a positive commodity price shock generates a real appreciation that lowers inflation and the monetary policy rate. Also, the positive income effect generates an increase in

[12] These are taken from García-Cicco et al (2014). Notice that we do not match the ratio of investment to GDP as in CTW, but instead set $\eta_{y^{co}}$ and take $\eta_i = 0.18$ from CTW.

Impulse response to a commodity price shock, CTW model with commodity sector and domestic financial sector

Figure 2



consumption, investment and output. However, the real appreciation increases imports and reduces exports, leading to a worsening of the trade balance.

As for the price of capital, it increases on impact due to higher demand for investment goods, but then we observe a reduction given a higher proportion of imported investment goods which have become cheaper due to the real appreciation.

In contrast, the model with financial frictions amplifies real effects. A lower price of capital deteriorates the balance sheets of all agents in the economy, leading to an initial reduction in net worth and to a tightening of credit conditions. As a result, the price of capital falls, which amplifies further the effect of financial frictions. Consumption increases more in this scenario because less investment translates into lower returns for savings and thus a lower gain from postponing consumption.

In the case with financial frictions (with the current calibration), GDP first declines but eventually rises above GDP under the no financial frictions scenario. The initial fall reflects higher imports and lower increase in investment, whereas the later increase reflects the increase in consumption in the medium term.[13]

3. Estimation: Cross-country results

We estimate the model parameters using data for the four countries in the sample and present the key results from the estimation exercise. The model parameters are estimated using Bayesian methods with Dynare 4.4.2, with 25 observable variables for each country and considers 21 structural shocks, which include the 16 structural shocks from CTW, plus the observed country premium shock, shocks to commodity production and prices and financial shocks to banks' and entrepreneurs'' interest rate spreads.

The method used is a standard Bayesian MCMC to estimate a linear approximation of the model, following CTW. An advantage of this solution method is that it can be easily implemented using a standard Kalman filter for the likelihood evaluation.[14]

The sample comprises quarterly data from 2001 to 2014.[15] Estimation is implemented including the 2008 financial crisis episode, and it is assumed there is a stable single steady state for the whole sample and therefore a single regime with constant parameter values.

A number of transformations are made to the time series for the estimation. All growth rates are quarterly log differences. The inflation and interest rates are

13 It may be noted that the fall in entrepreneurs' net worth could be moderated (or even reversed) if entrepreneurs would receive a proportion of the extra revenue generated by the commodity sector.

14 However, this method might not capture completely the mechanism described in the model, as pointed out by Fernandez-Villaverde et al (2016). Nevertheless, using richer solution algorithms such as global methods with non-linear models have the problem known as curse of dimensionality.

15 Except for Mexico, which starts in 2004 due to data constraints regarding credit rates, and Peru, which ends in 2013.

annualised quarterly rates. To account for the trends in the data, the growth rates and interest rates are demeaned.[16] All transformed series are multiplied by 100.

3.1 Calibration details

Table 3 presents the calibrated parameters for the commodity sector.[17] For each country, we consider the most important commodities in their exports structure. Also, we target the ratio of commodity exports to GDP in the steady state by comparing it to the historical average.[18] Finally, we consider the percentage of domestic ownership of firms in the commodity producing sector to analyse the proceeds that stay as income for the country's current account.

Calibrated parameters: Commodity sector

In per cent — Table 3

	Chile	Colombia	Mexico	Peru
Main commodity	Copper	Oil	Oil	Copper/Gold
Commodity exports to GDP	15%	7%	4%	18%
Domestic ownership share	56%	64%	100%	60%

For Chile, the commodity exports to GDP ratio is set to match the average share of mining exports in nominal GDP since 1996 and the domestic ownership share (χ) is set to 56%, the average share of exports by Codelco in total copper exports from 2001–13.[19] The parameters for Colombia are obtained from estimates of Rincon et al (2014).

For Mexico, oil production is owned by PEMEX and oil exports to GDP are calculated using INEGI's data. In Peru, domestic ownership of mining companies is set to 60% and commodity exports to GDP to 18%, the averages for the sample period.

Table 4 presents the calibrated parameters for the financial sector extension. These are set to match historical averages for interest rate spreads, loan to value ratios and bank capital requirements. For all countries, we target a bank capital requirement of 8% and a loan to value (LTV) ceiling of 6%, except in Chile, where the bank capital

16 Some exceptions are hours and commodity production for Chile, which were detrended by fitting log-linear trends, and commodity price and production, real stock price and bank's leverage for Colombia, by fitting linear trends.

17 Other calibrated parameters for the real sector follow the values from CTW and some parameters are set according to targets related to historical averages or to existing literature for each country.

18 This assumption considers that commodity stocks are still far from depletion and that there is no trend of declining production, although this might be an issue in some countries.

19 According to data from Cochilco (the Chilean copper commission), Codelco copper exports represent 33% of total copper exports plus fiscal income from taxes applying the general tax on foreign companies in Chile $(\tau=0.35)$ Note that private mining companies are mainly foreign-owned, such that all domestic income is attributed to the government.

requirement and the LTV target are set to match leverage ratios of 13 for banks and 2.05 for entrepreneurs.[20]

Calibrated parameters: Financial sector

In percentage points or per cent Table 4

	Chile	Colombia	Mexico	Peru
Loan to deposit spread	3.25	3.00	3.09	18.92
Deposit to target rate spread	0.52	1.00	0.00	0.00
Loan to value ratio	51%	65%	65%	65%
Bank capital requirement	8%	8%	8%	8%

3.2 Estimated parameters

The parameters that are not calibrated are estimated using Bayesian methods, in most cases using priors following CTW.[21] The priors of parameters for the financial sector equations are centred on OLS estimates. The posterior distributions are estimated based on 1,000,000 draws from the Metropolis-Hastings (MH) algorithm, discarding the first 500,000 draws. The mean and covariance matrix of the proposal density for the MH algorithm were the maximum of the posterior distribution and the negative inverse Hessian around that maximum. Following CTW, the parameters were scaled to obtain the same order of magnitude of the calibrated parameters. The inverse Hessian was scaled to obtain an average acceptance rate from the MH algorithm of approximately 23.4%.[22]

Table 5 reports some key results for the financial sector. First, lending spreads are highly persistent in Colombia and Mexico but much less so in Chile and Peru. In addition, for Chile, the credit rate is more volatile than the deposit rate, but the deposit rate is somehow more persistent than the credit rate. High persistence in the lending spread in Mexico might reflect the high concentration of monopolistic power in the banking sector.

We also observe low elasticities of financial spreads to leverage, for both deposit and credit spreads. The exceptions are the higher elasticities for Chile's credit spread and Colombia's deposit spread. In Chile, the correlation of GDP with the credit rate is more negative than that with the deposit rate, which may partly explain why the elasticity of the credit spread is larger than that for the deposit spread.

20 Both are computed using the average since 2001, where the data for bank leverage is calculated from consolidated data from the banking system in Chile compiled by the Chilean Superintendence of Banks and Financial Institutions (SBIF), while the data for firm leverage is obtained from is computed by consolidating balance sheet data by the Chilean stock market authority (SVS). On average, the latter includes the largest 300 firms in the country.

21 For a detailed discussion of the priors used for each country, refer to the annex (available upon request) with estimation details for each country.

22 In the case of Peru the acceptance rate was calibrated to 20%.

Estimated parameters: Financial sector

Posterior mean (Metropolis – Hastings) Table 5

	Chile	Colombia	Mexico	Peru
Elasticity				
Credit spread (*100)	1.58	0.86	0.64	0.45
Deposit spread (*100)	0.69	1.63	0.48	0.57
Persistence lending spread	0.43	0.84	0.87	0.45
Persistence				
Credit spread shock	0.42	0.56	0.82	0.57
Deposit spread shock	0.52	0.82	0.65	0.69
Standard deviation				
Credit spread shock	0.19	0.15	0.11	0.25
Deposit spread shock	0.09	0.28	0.16	0.14

Source: Author's estimations.

In Table 6 we report the most relevant estimated parameters in the commodity block. Both commodity prices and quantities are highly persistent in all countries. In the case of prices, similar persistence is observed first in Chile and Peru, and then in Colombia and Mexico, possibly because commodity exports are dominated by copper in the first group and by oil in the second. As for volatility, commodity prices are much more volatile than quantities.

Estimated parameters: Commodity sector

Posterior mean (Metropolis – Hastings) Table 6

	Chile	Colombia	Mexico	Peru
Commodity price shock				
Persistence	0.88	0.62	0.68	0.85
Standard deviation	14.8%	10.0%	14.1%	6.1%
Commodity production shock	0.43	0.84	0.87	0.45
Persistence	0.77	0.74	0.83	0.78
Standard deviation	3.0%	2.5%	9.2%	2.1%

Source: Author's estimations.

Finally, Table 7 presents the estimated parameters for the Taylor rule for each country. An interesting result to point out is that the coefficients in the Taylor rule are very similar among countries. In general, all countries place large weights on inflation when setting monetary policy rates. This explains why the negative commodity price shock leads to a tightening of monetary policy, as the effect of the exchange rate depreciation on higher inflation prevails over the effect of a fall in output growth.

Estimated parameters: Monetary Policy – Taylor rule

Posterior mean (Metropolis – Hastings) Table 7

	Chile	Colombia	Mexico	Peru
Persistence	0.783	0.808	0.849	0.928
Inflation	1.686	1.730	1.845	1.753
Output growth	0.125	0.162	0.126	0.202

Source: Authors' estimates.

3.3 Model moments

We check the ability of the estimated model to replicate data moments, focusing on volatility and contemporaneous correlations with output of real and financial variables. Tables 8 and 9 summarise the type of variables that are better replicated by the model for each indicator separately.[23] The exercise consists of simulating 1000 draws of the model at the posterior means of the estimated parameters where each draw features 41 observations, as in the original sample, with 200 burning periods. The simulations generate a distribution of model-based moments that are compared to the same moment in the data.

Standard deviations: The model can replicate with 95% confidence

Table 8

	Macroeconomic Variables	Financial Variables	Prices and Policy Variables	All Variables
Chile	6/9	4/6	8/10	18/25
Colombia	6/9	2/5	9/11	17/25
Mexico	5/9	2/6	8/10	15/25
Peru	4/9	2/6	2/10	8/25

Source: Authors' estimates.

Correlations with Output: The model can replicate with 95% confidence

Table 9

	Macroeconomic Variables	Financial Variables	Prices and Policy Variables	All Variables
Chile	6/9	3/6	9/10	18/25
Colombia	7/9	5/5	11/11	23/25
Mexico	3/9	2/6	9/10	14/25
Peru	7/9	5/6	6/10	18/25

Source: Authors' estimates.

The model is able to capture the behaviour of macroeconomic and prices and policy variables quite well, with respective averages of 58% and 65% of moments. However, one of the main shortcomings is to match financial variables, especially in

[23] A detailed description of which data moments have a better fit for each country is available upon request.

the case of volatility, where the model only captures 43% of the data's moments, on average, and most of the model's financial variables are more volatile than in the data.

With respect to correlations with output, the model shows a better capacity to replicate this statistic overall (71% on average), even though the behaviour of financial variables are only partially captured (65% on average).

3.4 Variance Decomposition

First, we analyse the importance of financial shocks in the behaviour of real macroeconomic variables such as output and investment. For this, we present a conditional variance decomposition analysis for 1.5 years, given that financial shocks are expected to affect real variables at business cycle frequencies, but their effect tends to dissipate in the long run.

Table 10 shows the results of the conditional variance decomposition at a horizon of 1.5 years. Financial shocks are important in the short run behaviour of investment and output in most countries except for Chile. Financial shocks, both to credit and deposit interest rate spreads, explain more than 25% of output volatility in Colombia and Peru and more than 40% of investment volatility in Mexico and Peru. Therefore, it is highly relevant in those countries to consider the financial sector in order to analyse the impact of financial shocks into the real economy and the effectiveness of policies in addressing these issues.

Another important feature is the importance of external shocks, given that all countries are commodity exporters. This are especially important in explaining fluctuations in external variables such as the exchange rate, but are also important in explaining fluctuations in other real variables, especially in the case of Chile.

The contribution of external shocks do not differ much when analysing long-run effects, although the relative importance of external versus domestic shocks varies across countries. External shocks are most important in Chile and Peru, not only for external variables such as the real exchange rate and the current account, but also for real variables such as output, inflation and the monetary policy rate.

Among these, commodity price shocks are especially important in Chile for consumption, the real exchange rate and the monetary policy rate, whereas country risk premium shocks are significant for the monetary policy rate and external variables. Foreign inflation shocks are important in Peru for output and inflation. External shocks also explain financial variables in Chile, especially the mark-up shock to imported investment.

Even though external shocks are important drivers of external variables in Colombia, they have a smaller effect on real variables, which are mostly explained by investment efficiency shocks and, to a lesser extent, by financial shocks, especially in the case of output and investment. These results are similar to Christiano et al's (2011) results, as including financial shocks into the model are key to account for the variance of investment and output, and to reduce the importance of investment efficiency shocks.

However, in the case of Mexico, external shocks have a negligible contribution to the long run variance because the impact of those shocks tend to be small. This is true even for external variables such as the real exchange rate and the current account, in line with Justiniano and Preston (2010).[24] In our exercise, fluctuations in real variables are mainly associated with investment efficiency shocks, similar to results obtained by CTW in models without financial shocks.

Contribution of shocks to the six-quarter conditional variance of the forecast error

In percentage points

Table 10

	Chile	Colombia	Mexico	Peru
External shocks[1]				
Output	57	1	19	14
Investment	62	1	5	10
Inflation	47	3	20	66
Real exchange rate	91	94	30	91
Policy rate	54	3	13	59
Credit	42	11	9	23
Interest rate spread	45	26	0	0
Investment efficiency shock[2]				
Output	2	34	11	38
Investment	15	59	33	40
Inflation	0	18	39	2
Real exchange rate	0	2	65	1
Policy rate	0	30	47	0
Credit	0	17	15	5
Interest rate spread	0	41	0	0
Financial shocks[3]				
Output	0	26	9	26
Investment	0	34	41	47
Inflation	0	9	2	0
Real exchange rate	0	0	2	0
Policy rate	0	15	2	0
Credit	0	51	55	15
Interest rate spread	1	4	99	99

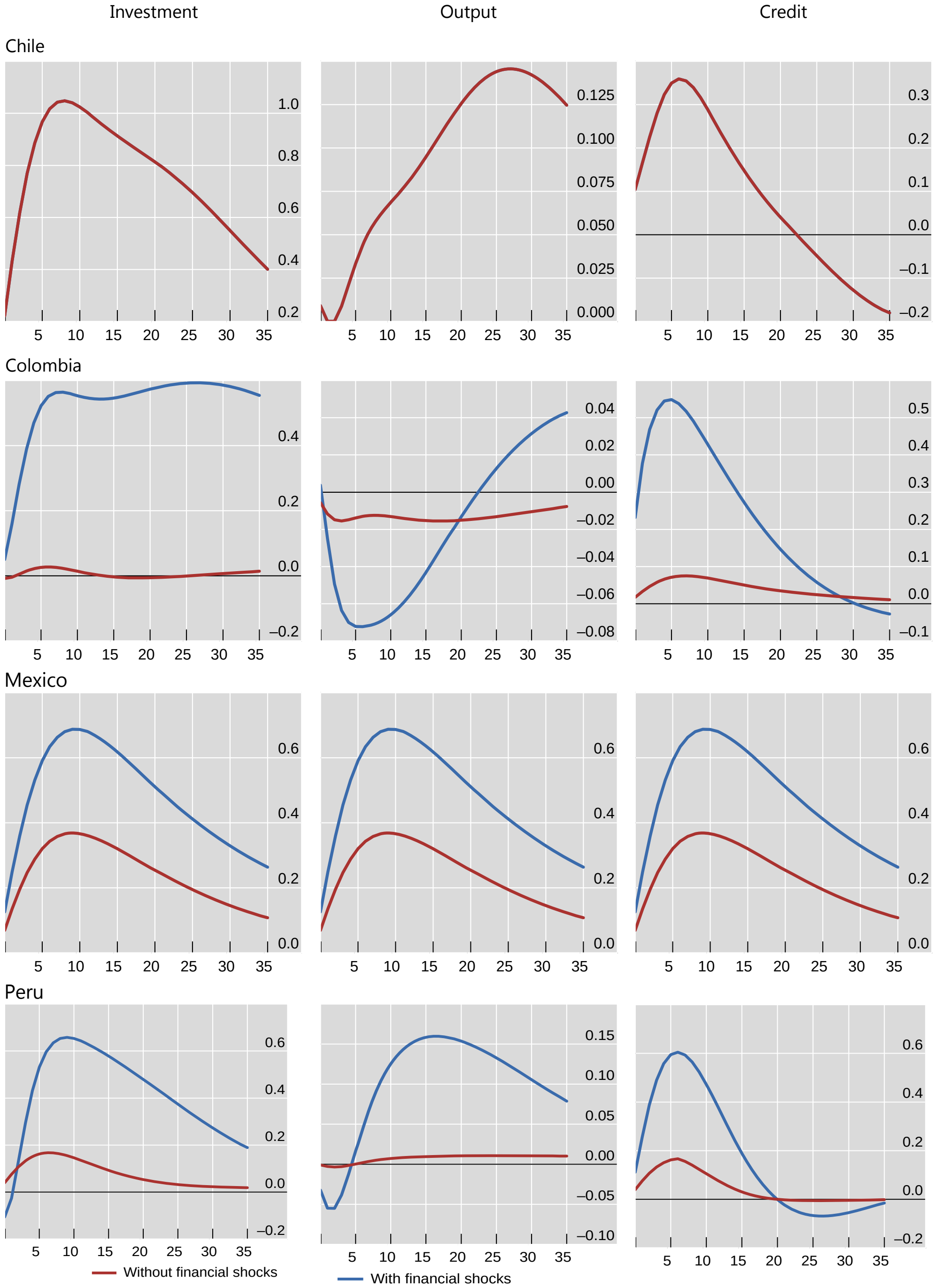
[1] External shocks include shocks to country risk premium, commodity price, mark-up on export and import prices, foreign GDP, foreign inflation and foreign interest rate. However, other shocks such as the big collapse in world trade in 2008-09 have been omitted. [2] Investment efficiency shock is part of the domestic shocks group. Other domestic shocks include the ones to technology, preferences, government expenditure, commodity production and mark-up on domestic prices. [3] Financial shocks are described in Table 1.

Source: Author's estimations.

[24] However, new evidence extracted from SVAR points that the effect of foreign shocks in Mexico is higher than estimated by a DSGE model, with almost 50 % of output fluctuations explained by shocks occurring in the US in a similar horizon. See Carrillo, Elizondo and Hernández-Román (2016), who use a SVAR methodology, and Hernández and Leblebicioglu (2015) for an enhanced DSGE model for small open economies.

Responses to a sudden increase in commodity prices. Estimated models with and without financial shocks

Figure 3



Source: Authors' estimates

In order to analyse the importance of the financial amplification mechanism, we also estimate an alternative version of the model, without the exogenous shocks to the financial sector (but leaving the endogenous financial amplification mechanism). Figure 3 reports the results for the reaction of output, investment and credit to a sudden increase in commodity prices for each country. These results show that financial channels account for a large proportion of the amplification in the response of real variables generated by the interaction with the financial sector.

Also, the results suggest that the model is consistent with other linearised approximations of New-Keynesian models with financial frictions, where the endogenous financial accelerator mechanism does not create a quantitatively large amplification. However, the data does reflect that the financial sector is an important non-linear source of the amplified impact of shocks on real macroeconomic variables. Thus, this effect is reflected in the large volatility of the financial shocks in the model, as they capture the deviations of the behaviour of real variables from a model with no financial frictions.

4. Credit cycles, effectiveness of macroprudential policies and interaction with monetary policy

Now, we proceed to analyse the effect of using financial stabilisation policies in the type of macroeconomic model traditionally used in monetary policymaking, extended by incorporating a banking sector. For instance, consider a scenario of increasing credit spreads where only using monetary policy is not enough to compensate a tightening in credit conditions. An increase in credit spreads leads to lower credit supply which translates into lower investment and output growth. A decrease in aggregate demand reduces inflation, so monetary policy reacts by reducing the policy rate, but is not enough as the cost of bank borrowing is still higher than before the financial shock. In this context, macroprudential policies may be useful as they can directly affect financial sector decisions and thereby complement monetary policy in smoothing business cycle fluctuations.

We first analyse the impact of macroprudential policies on financial conditions. We focus on bank capital requirements and LTV ceilings to illustrate the impact of financial policy tools. These are introduced in the model as instruments that affect either the credit or the deposit spread. Both respond to the deviation of real credit from its steady state.

In order to compare across countries, we calculate the accumulated effect of a 10% tightening in bank capital to loans ratio ($capb_t / L_t^E$) and in LTV (m_t) after five years. The results in Table 11 show a significant tightening in credit growth for both Colombia and Mexico, whereas the effect is milder in Chile and Peru. This result is consistent with previous evidence on the importance of financial shocks on the behaviour of credit shown in the variance decomposition in Table 10.

Macroprudential policies: Impact on credit growth

Response to a 10 per cent change in macroprudential tool — Table 11

	Bank capital requirement	Loan to value
Chile	0.16	0.50
Colombia	1.23	2.17
Mexico	1.28	3.49
Peru	0.91	0.80

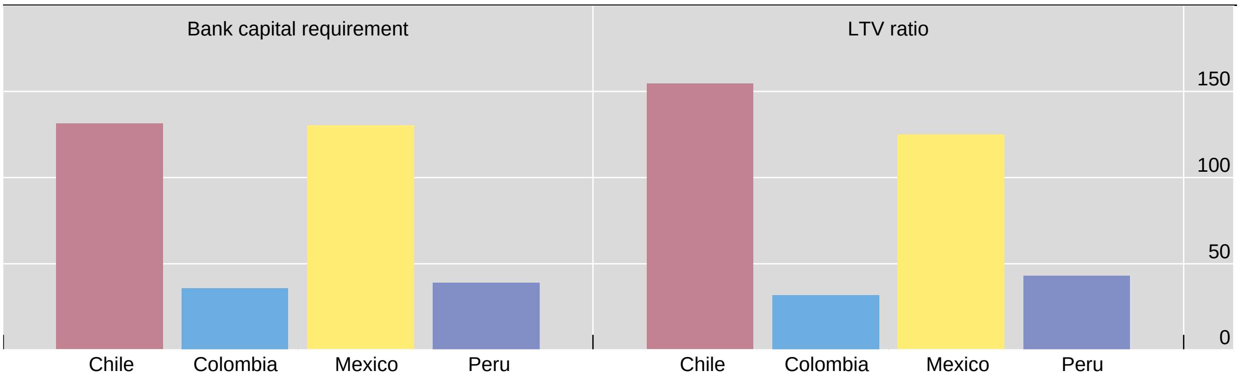
For the indirect effect of using macroprudential policies on the real sector, we use an indicator which we call the "macroprudential sacrifice ratio". Macroprudential instruments can affect economic and financial conditions by influencing the supply of credit. During credit booms, higher capital requirements or lower LTV ceilings can be used to raise net interest margins, lowering the supply of credit, investment and output growth.

The "macroprudential sacrifice ratio" is constructed by assessing how each macroprudential tool affects credit growth and GDP growth. Intuitively, it shows how much GDP one gives up if one tightens macroprudential policy in order to contain a credit boom. Alternatively, it shows the expansionary impact on GDP (which may or may not be inflationary) when (macroprudential) policy is relaxed to boost credit growth in bad times.

To build this indicator, we first calculate how a change in the policy tool by one percentage point would reduce credit and output growth. The ratio between these measures captures to what extent lower credit growth translates into lower output growth (or the reverse). Figure 4 shows that the impact of changes in credit conditions on GDP is significant for most countries (high sacrifice ratio).

Even with a model to account for normal times, the result shows that the cost of containing credit booms is significant. This should be compared to the benefits of avoiding financial crises, which often follow credit booms. While financial crises are relatively infrequent, the cumulative costs can be quite large.

GDP/Credit macroprudential sacrifice ratio — Figure 4



Calculated as $100^*\sum_{t=0}^{20}\left(Y_{MPP+MP}-Y_{MP}\right)/\sum_{t=0}^{20}\left(Credit_{MPP+MP}-Credit_{MP}\right)$

Source: authors' calculations.

5. Policy analysis

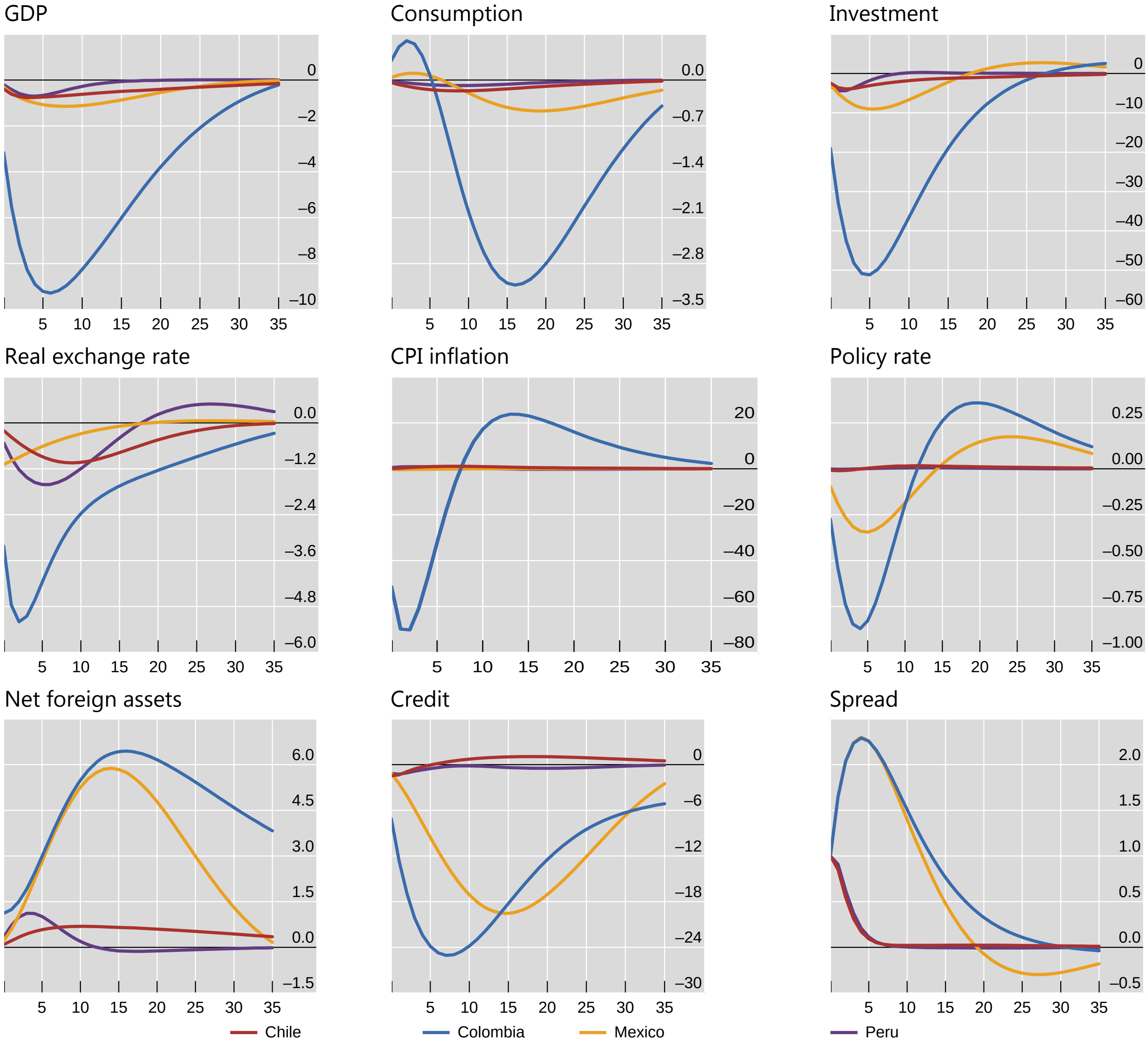
In this section we analyse monetary and macroprudential policy reactions to both financial and real shocks. In particular, we consider an increase in the credit spread for the financial shock and a fall in commodity prices for the real shock. These exercises are aimed to shed light on how macroprudential policies can complement monetary policy actions under those two scenarios. The results show that the ability of restoring credit conditions with macroprudential policies is much larger when the economy is hit by a financial shock. However, they can also be useful to restore credit conditions affected by a negative real shock because monetary policy mainly reacts by increasing interest rates to contain inflationary pressures, further constraining credit conditions.

5.1 Reaction to an increase in credit spreads

5.1.1 Monetary policy only

First, we analyse how each country is affected by an exogenous tightening in credit conditions and the reaction of monetary policy under this scenario. Although results are quite similar in qualitative terms, the size of these effects differs across countries. Figure 5 shows the reaction of each country to an annual 100 basis point increase in the spread between the interest rate that entrepreneurs pay to borrow from banks and the monetary policy rate.[25]

Responses to a sudden increase in credit spreads. No MPP case Figure 5



Source: Author's estimates.

[25] For a related discussion, see section 2.1 above.

The increase in credit spreads leads to a higher cost of lending, which reduces credit supply, prompting a reduction in investment, affecting both current and future output growth. Banks leverage increases immediately given the effect on their net worth, and need to deleverage given lower supply of funds. Consumption is negatively affected by the reduction in output growth. The real exchange rate appreciates, given the reduction in the demand for imports of both investment and consumption goods.

In quantitative terms, the real effects of the increase in credit spreads is larger in Colombia. However, in the case of Peru, a one standard deviation shock to the credit spread is one order of magnitude larger than for other countries, given the higher average credit rates in the banking sector.[26]

In terms of prices and monetary policy, consumer inflation falls because of a decrease in the price of imported consumption goods (due to the real appreciation). Both lower inflationary pressures and weaker output lead to a quantitatively small monetary policy loosening.

On the financial side, an increase in credit spreads lowers the supply of loans provided by the banking sector and increases the interest rate spreads faced both by entrepreneurs (between the lending and the policy rate) and banks (between the deposit and the policy rate). The reduction in the policy rate partially offsets the effect of credit spreads on the cost of financing, but it is smaller than the increase in spreads, so that the cost of funding investment is higher.

Consistent with the results from the conditional variance decomposition analysis, the quantitative impact of a financial shock on real variables is significant for most countries except for Chile. Monetary policy reacts by lowering the policy rate, but this effect is quantitatively limited.

5.1.2 Monetary and macroprudential policies

Given that monetary policy does not react significantly to a financial shock and that macroprudential policies directly target the cost of borrowing and lending in the financial sector, it is worth exploring the ability of these measures to restore credit conditions and, through that, to contain the effects on real variables.

Macroprudential tools, particularly lower capital requirements and LTV ceilings in this model, are aimed at restoring financial conditions by lowering interest rate spreads. This leads to an increase in the supply of credit, which impacts investment and output growth.

As a result, we observe restored credit conditions. Figure 6 shows that complementing monetary policy with a loosening of bank capital requirements[27] would allow to relax credit conditions and delivers about a 50% reduction in the size of the original effects with monetary policy only. These results complement those of

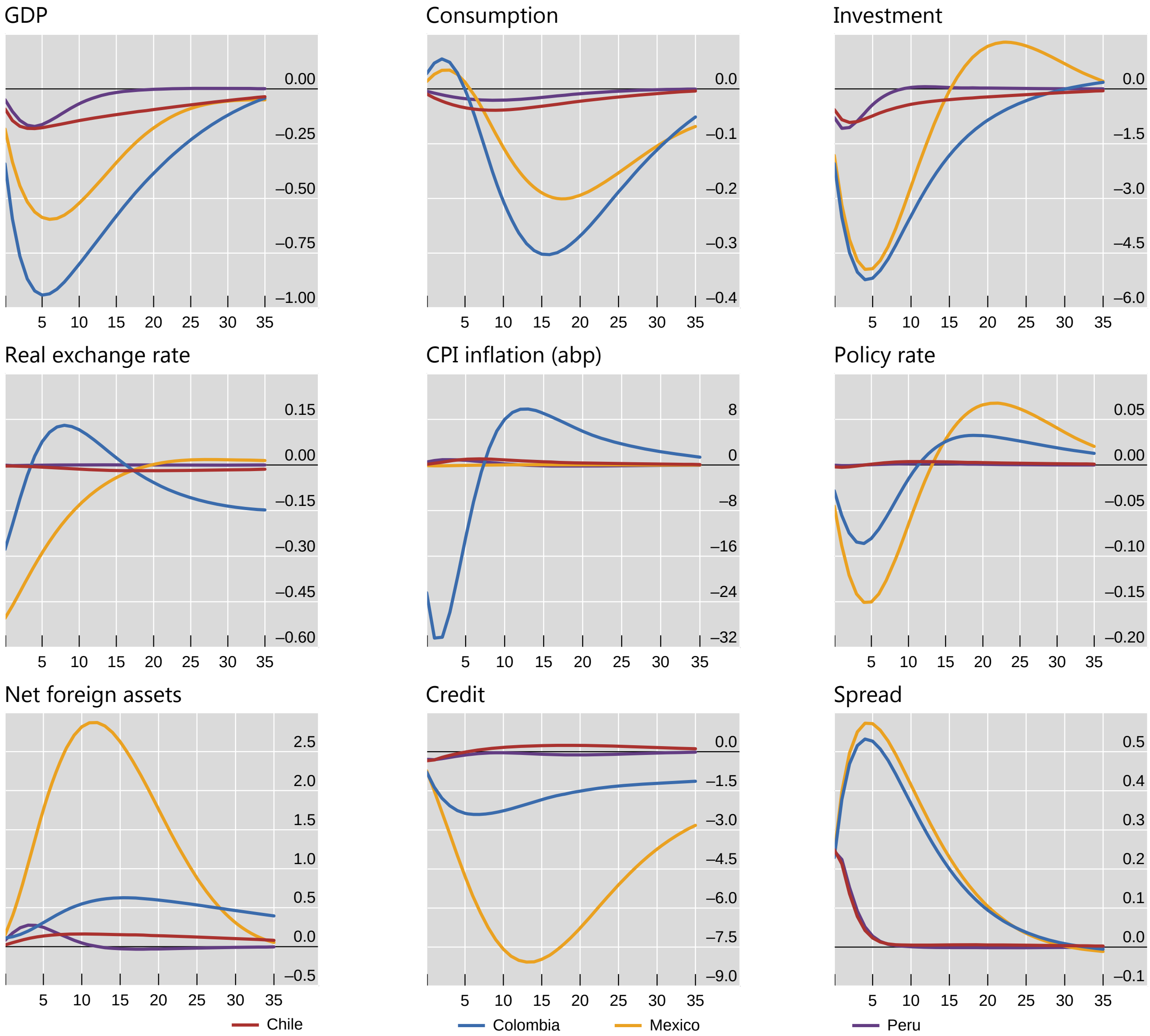
[26] A one standard deviation shock for Peru of 2.4 %, relative to values between 0.1 and 0.2 for the other countries in the sample. Therefore, financial shocks are still relevant for short run dynamics, as shown in the conditional variance decomposition analysis.

[27] We standardised the impulse response function to a 100 basis point increase in the credit spread shock as in the original exercise. The loosening of bank capital requirements follows a rule that depends on the deviation of credit from its steady state value. For reference, this exercise considers a 10% reduction in bank capital requirements for Chile and Peru and a 30% reduction for Colombia and Mexico, respectively.

the "macroprudential sacrifice ratio" presented in Figure 4. Therefore, in the case of a financial shock, macroprudential tools are highly effective in restoring credit conditions as well as macroeconomic variables such as output, investment, inflation and exchange rates.

Responses to a sudden increase in credit spreads. Loosening of bank capital requirement

Figure 6



Source: Authors' estimates.

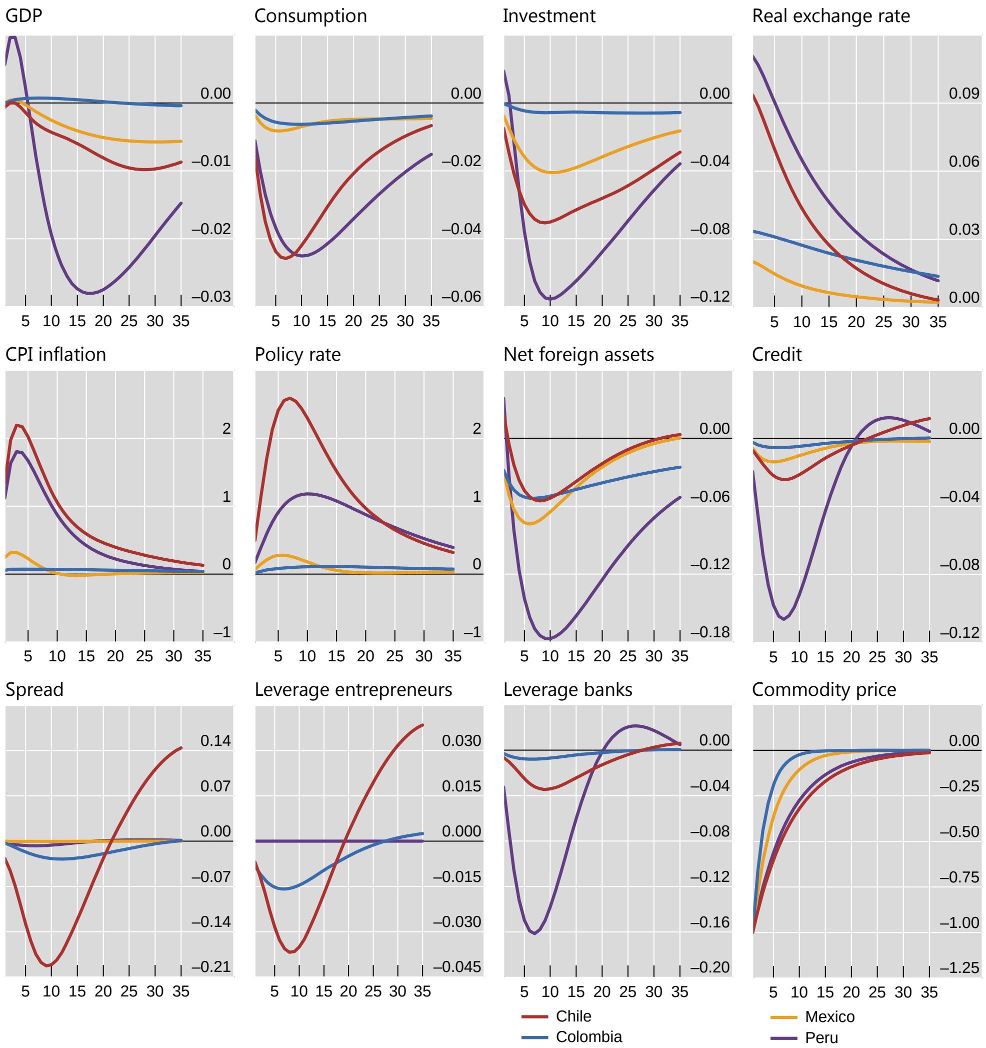
5.2 Reaction to a fall in commodity prices

This exercise illustrates the ability of macroprudential policies to complement monetary policy even when the shock is not originated in the financial sector. We consider a fall in commodity prices, which is relevant in these countries as they are commodity exporters.

5.2.1 Monetary policy only

Although results are quite similar in qualitative terms, the size of these effects differs across countries. Figure 7 shows the reaction of each country to a 1% reduction in its own commodity price index. The decrease in commodity prices generates a real depreciation, which feeds into higher inflation, prompting increases in the monetary policy rate. Chile and Peru show higher persistence in commodity prices and a larger real exchange rate depreciation, whereas the effect is smaller in Colombia and Mexico. This inflation outcome reflects the passthrough from the exchange rate to import prices and then to inflation, and the increase in the monetary policy rate, which reacts to counteract inflationary pressures.

Responses to a sudden decrease in commodity prices. No MPP case — Figure 7



Source: Authors' estimates.

On the financial side, financial frictions amplify the contractionary impact of a commodity price shock, given that not only the policy rate increases, but credit spreads become larger. This in turn reduces firms leverage and credit obtained through the banking sector, which amplifies the negative effect on domestic demand.

There is only a small contraction in bank leverage and thus in credit in all countries except for Peru. Given that Colombia and Mexico show smaller effects on the real exchange rate and on the monetary policy rate, the cost of financing does not react as much and the final effect on credit is small.

On the real side, a reduction in commodity prices generates a negative income effect that affects consumption, investment and output. The presence of financial frictions amplifies the size of these responses. Real exchange rate depreciation increases demand for non-commodity exports, but reduces consumption and investment of imported goods. The income effect on consumption is larger in Chile and Peru than in Colombia and Mexico. This is partly explained by the milder real depreciation in the latter set of countries, which increases the price of imported goods and reduces their demand. Also, monitoring costs on deposits, and thus the impact of financial frictions on deposit spreads, are lower, facilitating consumption smoothing by households.

The contraction in credit amplifies the negative effect on investment. A fall in commodity prices reduces entrepreneurs' net worth which tightens credit conditions and lowers funding for new investment. In addition, Chile and Peru show larger drops due to a higher share of imported goods in investment which are affected by the real depreciation.

5.2.2 Monetary and financial policies

Now we analyse whether financial policy tools can complement monetary policy to mitigate the negative impact of a commodity price decline. In principle, one of the effects of a commodity price bust is a worsening of credit conditions which amplify the negative effects on the real sector. Therefore, financial stabilisation measures could be viewed as a policy instrument to restore credit conditions, which impacts investment and output growth. Lower capital requirements and LTV ceilings are used in the policy experiment to counteract the effect of the commodity price bust on credit growth.

Figure 8 shows the GDP to credit sacrifice ratio calculated using a scenario with a negative commodity price shock. The impact of changes in credit conditions on GDP is small in Mexico and Peru[28] (low sacrifice ratio), but is much larger in Chile and Colombia (high sacrifice ratio).

Even with a model to account for normal times and in the scenario where credit constraints are triggered by a real shock, some countries like Chile and Colombia show that the cost of containing credit booms is significant. This should be compared to the benefits of avoiding financial crises, which often follow credit booms. While financial crises are relatively infrequent, the cumulative costs can be quite large.

We observe that using macroprudential policy to restore credit conditions lead to higher non-commodity exports due to the real depreciation lead to higher GDP growth. However, restored credit conditions not only lead to higher investment and output growth, but also generate inflationary pressures, which are particularly significant in the case of Chile and Colombia.[29] In this scenario, monetary policy

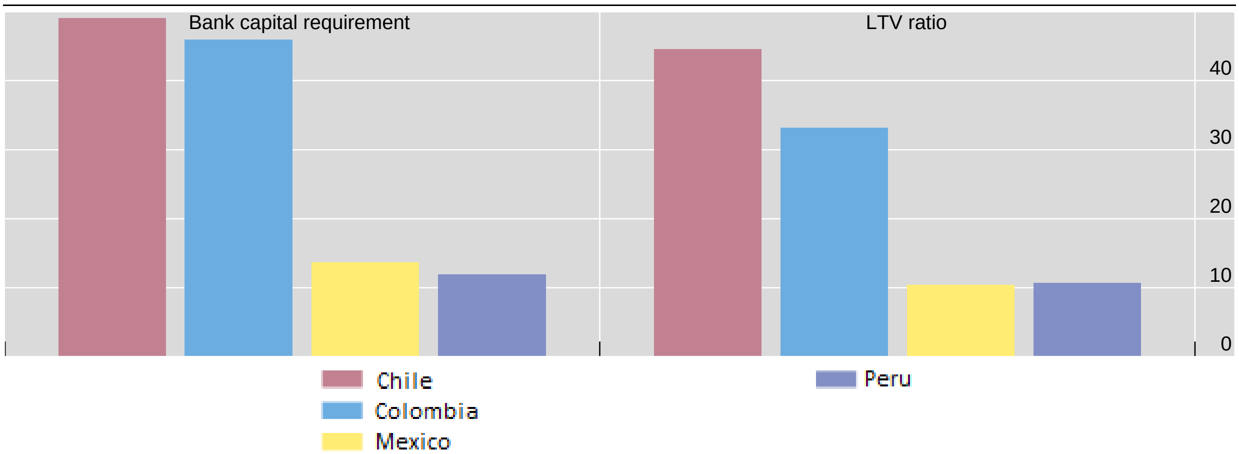
[28] This result is similar to Perez and Vega (2014), who also find mild effects of reserve requirements in Peru.

[29] A 1% increase in credit growth due to macroprudential tools leads to higher inflation by 3.0 and 1.4 basis points in Chile and Colombia, respectively.

responds to higher inflation by increasing the policy interest rate even more than in the scenario with monetary policy only. Therefore, there is a trade-off of the impact of macro- prudential policies in the real sector between boosting GDP growth and generating higher inflation.

GDP/Credit macroprudential sacrifice ratio under a negative commodity price shock

Figure 8



[1] Calculated as $100 = \sum_{t=0}^{20}\left(Y_{MPP+MP} - Y_{MP}\right) / \sum_{t=0}^{20}\left(Credit_{MPP-MP} - Credit_{MP}\right)$.

Sources: Authors' estimates, BIS calculations.

5.3 Exchange rate passthrough

This section presents the ability of the model to capture the exchange rate passthrough to inflation. This has become especially relevant for monetary policy in these countries, given that the fall in commodity prices translated into exchange rate depreciation and passthrough to inflation has become a challenge for inflation targeting countries to meet their targets.

In the model, a fall in commodity prices affects inflation in two ways. As mentioned in section 2.2, the passthrough effect of exchange rate depreciation on the price of imported goods dominates the negative effect of lower domestic demand.

We calculate the coefficients of exchange rate passthrough to consumer prices delivered by the model and compare them to other empirical studies. In our case, we report the conditional passthrough coefficients for a commodity price shock. Table 12 shows the calculated coefficients. The results show a significant impact of exchange rate depreciation on higher inflation, especially in the case of Chile and Colombia, and a lower coefficient in Mexico.

These results are in line with empirical studies for emerging economies. For instance, our results are consistent with estimates obtained by Albagli et al (2015) using calculated passthrough coefficients from impulse response functions of VAR models, both in quantitative terms as well as by capturing that Mexico has a much lower passthrough coefficient than the rest of countries. For country-specific results, Rincon and Rodriguez (2016) estimate a passthrough to CPI inflation in Colombia between 4 and 30%, consistent with the result obtained by our model. For Mexico, Capistran et al (2012) find a passthrough below 20%.

Model estimated pass-through coefficients

Table 12

Chile	0.246
Colombia	0.255
Mexico	0.077
Peru	0.120

Source: Authors' estimates.

6. Conclusions

In this work we provide a general framework for policy analysis for commodity-exporting countries that face important financial frictions and are subject to fluctuations in international financial conditions. We evaluate the impact of lower commodity prices and the effects of monetary and macroprudential policies to counter this impact with the following results.

First, financial frictions are relevant for our sample economies, although to a lesser extent for Chile. These frictions amplify the effects of a sudden fall in commodity prices since the latter entails a negative income effect that spills into the financial sector and tightens domestic credit conditions.

Second, an analysis of the importance for economic and financial activity of domestic, foreign and financial shocks shows that foreign factors are the main drivers in the case of Chile and Peru, whereas in Colombia and, to a much greater extent, in Mexico, investment efficiency shocks are important as well.[30] In these models, financial shocks are also significant in explaining the short-run dynamics of output and investment for most countries.

Third, an increase in credit spreads create a reduction in the supply of credit, leading to lower output, consumption and investment growth and to a real appreciation. Under this scenario, macroprudential policies in most countries are highly effective in counteracting the negative real macroeconomic effects created by a tightening in credit conditions.

Fourth, a fall in commodity prices generates a negative income effect that translates into drops in consumption, investment and output, which are amplified in the presence of financial frictions. Even though all countries are commodity exporters, the impact on the real sector varies considerably across countries.

An analysis of the GDP to credit "sacrifice ratio" indicates that policymakers would have to give up a much larger amount of GDP in order to dampen credit growth via macroprudential policies (increase in capital adequacy requirements, reductions in LTV ceilings) in Chile and Colombia. The impact on GDP would be

30 However, these results should be taken with reserve, since the estimated DSGE model is subject to the well-known Justiniano and Preston (2010) critique, which shows that DSGEs of this class may bias downwards the effects of foreign shocks on the domestic economy.

smaller in Mexico and Peru. On the other hand, if macroprudential policy tools were used to counteract the impact of a fall in commodity prices by increasing credit growth the expansionary impact on output would be larger on Chile and Colombia.

A number of issues need to be considered in interpreting the preceding results. The model tracks well the behaviour of real variables, but a shortcoming is that financial variables show excessive volatility. Furthermore, the model accounts for the impact of macroprudential tools only in periods of relative financial stability, given that the solution method uses a local approximation with financial markets working smoothly. Periods of financial distress cannot be modelled using these methods.

Another important issue is that external datasets are not completely comparable, since each country uses a weighted average for its main trade partners. Future research could consider estimating a panel VAR model to take into account common external shocks such as commodity prices.

An additional caveat of our analysis is that we do not link the commodity sector to the fiscal sector, so a sudden fall in the price of commodities does not directly affect government finances and public debt. This transmission mechanism seems to be relevant and it would be thus interesting to study it in future work.

Finally, this paper captures the impact of financial policies to address real and financial shocks during business cycles. However, the local solution method used in conventional New Keynesian models does not allow large imbalances to build up, so these models do not completely consider the effect of the accumulation of risks in the financial sector. An extension using non-linear solution methods could allow for larger deviations of financial variables from their steady state and to describe episodes of financial distress. However, such nonlinear solution methods may involve increasing computational costs, known as the curse of dimensionality.[31]

[31] See, for instance, Bianchi (2011) and Akinci and Chahrour (2015) for non-linear macroeconomic models with financial risk build-up and financial crisis events.

References

Agénor, PR and L Pereira da Silva (2014): "Macroprudential regulation and the monetary transmission mechanism", *Journal of Financial Stability*, Elsevier, vol 13(C), pp 44-63.

Akinci, O and R Chahrour (2015): "Good news is bad news: leverage cycles and sudden stops," *Staff Reports* 738, Federal Reserve Bank of New York

Albagli, E, A Naudon and R Vergara (2015): "Inflation dynamics in LATAM: a comparison with global trends and implications for monetary policy", *Economic Policy Papers, Central Bank of Chile*, 58.

Alpanda, S, G Cateau and C Meh (2014): "A policy model to analyze macroprudential regulations and monetary policy", *Bank of Canada Working Paper*, no 2014-6.

Bianchi, J (2011): "Overborrowing and systemic externalities in the business cycle", *American Economic Review*, American Economic Association, vol 101(7), pp 3400-3426, December.

Canova, F (2005): "The transmission of US shocks to Latin America", *Journal of Applied Econometrics*, John Wiley and Sons, Ltd, vol 20(2), pp 229-251.

Capistran, C, R Ibarra and M Ramos-Francia (2012): "El Traspaso de Movimientos del Tipo de Cambio a los Precios. Un Análisis para la Economía Mexicana", *El Trimestre Económico*, vol LXXIX (4), no 316, pp 813-838.

Carrillo, JA, V Nuguer and J Roldan (2015): "Monetary and macroprudential policy mix: an institution-design approach", paper presented at the BIS CCA Research Network closing conference on "Incorporating financial stability considerations into central bank policy models", Mexico City, 29-30 January 2015.

Carrillo, JA, R Elizondo and LG Hernández-Román (2016): "An inquiry on the transmission of US shocks into Mexico", mimeo.

Castillo, P, C Carrera, M Ortiz and H Vega (2014): "Spillovers: the role of prudential regulation and monetary policy in small open economies", *BIS Working Papers,* no 459, September 2014.

Catao, L and R Chang (2013): "Monetary Rules for Commodity Traders", *IMF Economic Review*, 61, pp 52-91.

Cespedes, L, R Chang and A Velasco (2014): "Is inflation target still on target?", *International Finance*, 17, 2 , pp 185-207.

Cespedes, L, R. Chang, and A Velasco (2017): "Financial intermediation, exchange rates, and unconventional policy in an open economy," *Journal of International Economics,* forthcoming.

Christiano, L, M Trabandt and K Walentin (2011): "Introducing financial frictions and unemployment into a small open economy model", *Journal of Economic Dynamics and Control*, 35, pp 1999-2041.

Cook, D and M Devereux (2006): "Accounting for the East Asian crisis: a quantitative model of capital outflows in small open economies", *Journal of Money, Credit and Banking*, Blackwell Publishing, vol 38(3), pp 721-749, April.

Fernandez-Villaverde, J, J Rubio Ramirez and F Schorfheide (2016): "Solution and estimation methods for DSGE models", *NBER Working Papers*, 21862, National Bureau of Economic Research, Inc.

Fornero, J, M Kirchner and A Yany (2015): "Terms of trade shocks and investment in commodity-exporting economies", Central Banking, Analysis, and Economic Policies Book Series in R Caputo and R Chang (eds), *Commodity Prices and Macroeconomic Policy*, Central Bank of Chile, ed 1, vol 22, chap 5, pp 135-193.

Garcia-Cicco, J and M Kirchner (2015): "Macroeconomic and financial interactions in Chile: an estimated DSGE approach", paper presented at the BIS CCA Research Network closing conference on "Incorporating financial stability considerations into central bank policy models", Mexico City, 29-30 January 2015.

García-Cicco, J, M Kirchner and S Justel (2014): "Financial frictions and the transmission of foreign shocks in Chile", *Working Papers*, *Central Bank of Chile*, no 722.

Gertler, M, S Gilchrist and F Natalucci (2007): "External constraint on monetary policy and the financial accelerator", *Journal of Money, Credit and Banking*.

González, Andres, Franz Hamann and Diego Rodríguez (2015): "Macroprudential Policies in a Commodity Exporting Economy", *BIS Working Paper*, 506.

Gruss, Bertrand (2014): "After the boom: commodity prices and economic growth in Latin America and the Caribbean", *IMF Working Paper*, WP/14/154, Washington, International Monetary Fund.

Hernández, K and A Leblebicioglu (2015): "The transmission of US shocks to emerging markets", Manuscript.

Hevia, C and JP Nicolini (2013): "Optimal devaluations", *IMF Economic Review*, 61.

Jermann, U and V Quadrini (2012): "Macroeconomic effects of a financial shock", *American Economic Review*, vol 102, no 1, pp 238-271.

Justiniano, A and B Preston (2010): "Can structural small open-economy models account for the influence of foreign disturbances?", *Journal of International Economics*, Elsevier, vol 81(1), pp 61-74, May.

Medina, J P and C Soto (2007): "The Chilean business cycles through the lens of a stochastic general equilibrium model", *Working Papers, Central Bank of Chile*, no 457.

Medina, J P, A Munro, and C Soto (2007): "What drives the current account in commodity-exporting countries? The cases of Chile and New Zealand", *Economía Chilena*, 10 (3), pp 67-114.

Perez, F and M Vega (2014): "The dynamic effects of interest rates and reserve requirements", no 2014-18.

Rincón, H, D Rodríguez, J Toro and S Téllez (2014): "FISCO: Modelo Fiscal para Colombia", *Borradores de Economia*, 855, Banco de la Republica de Colombia.

Rincón, H and N Rodríguez (2016): "Pass-through of exchange rate shocks on inflation: a Bayesian smooth transition VAR approach", *Borradores de Economia*, 930, Banco de la Republica de Colombia.

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