The Credit Channel Through the Lens of a Semi-Structural Model*

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Abstract

In this paper, we estimate a semi-structural model with a banking sector for the Chilean economy. Our innovation consists of incorporating a system of equations that reflects the dynamics of credit, interest rate spreads and loan-loss provisions to the Central Bank of Chile's semi-structural model "MSEP". We estimate the model and analyze the macroeconomic effects of incorporating this sector. We find that the banking sector plays a role in accelerating the business cycle through lower spreads and procyclical credit supply, in contrast to the counter-cyclical role it has had in COVID-19 crisis. Additionally, we decompose the effects of this sector's variables in the historical business cycle. We find that credit growth can explain on average about 0.3 pp of total output gap variation. Moreover, we find that in episodes of severe stress, this role can grow to 1.9 pp, as has been the case of the COVID-19 pandemic. This last fact is important, given that in many cases, monetary policy is faced with the challenge of implementing non-conventional measures, many of them through the commercial banking sector. We find that this specification allows the model to better quantify the impact of measures that have favored the flow of credit specially in periods of stress.

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1 Introduction

The global financial crisis of 2008-09 highlighted the serious impact that credit supply disruptions can have on macroeconomic performance. Of course, this is not a new phenomenon, but it attracted renewed attention after this event. Therefore, under certain circumstances it can be important to understand the role credit dynamics for business cycles and macroeconomic policy. This necessity to understand the role of this part of the economy can increase in times of distress, since it is possible that credit crunches take place and exacerbate a downfall.

In this document we present a macroeconomic model that incorporates the dynamics of the banking sector. We part from the the semi-structural model used at the Central Bank of Chile (MSEP) for macroeconomic projections, and incorporate a set of equations that reflect the dynamics of this sector. The MSEP consists of a series of general equilibrium equations derived from New Keynesian models, as explained in Arroyo-Marioli et al. (2020). We incorporate a block of interrelated equations for commercial loans, interest rate spreads, and provision of funds for loan defaults. These equations impact directly on aggregate demand through loan quantities and have effects on GDP. Impacts on inflation and exchange rate fluctuations are indirect through the original model's channels. We use 2000 to 2020 Chilean data to estimate the model, simulate it, and analyze the results. First, we introduce the standard MSEP parameter values as priors, and then re-estimate them with the new block of banking system equations. We then simulate impulse function responses (IRFs) to contrast the impact of shocks with and without this new mechanism. Finally, we perform a historical decomposition of the Chilean cycle and quantify the role of credit.

We find that the banking sector acts as a relevant part of the cycle, accelerating it in expansion periods and further contracting it in recessions. We also find that this channel is more significant during large events, such as the 2008 financial crisis and the 2020 coronavirus pandemic. The mechanism through which this takes place is one in which a positive demand shock results in higher output, which in turn increases credit supply and reduces bank's default provisions. This then impacts positively on output, providing an acceleration effect. We find that this channel can accelerate growth up to 0.13% after a 1% demand shock takes place, within the first year. Additionally, we decompose the effects of this sector's variables in the historical business cycle. We find that credit growth can explain on average about 0.3 pp of total output gap variation. Moreover, we find that in episodes of severe stress, this role can grow to 1.9 pp, as has been the case of the 2020 COVID-19 pandemic. This last fact is important, given that in many cases, monetary policy is faced with the challenge of implementing non-conventional measures, many of them through the commercial banking sector. This specification allows the model to better quantify the impact of measures that have favored the flow of credit in periods of stress

We contrast our results to those of other countries, finding that this relevant role of the banking sector is similar to what happens in other countries. Some authors suggest that there could be non-linearities in the effects of credit, implying that in times of distress parameters could change and magnify the standard effect. We believe this could be an interesting venue to explore for future versions of this model.

The remainder of the article is organized as follows. Section 2 presents the literature, section 3 presents the model, section 4 describes the data used, section 5 shows the model estimation, section 6 presents the results, and section 7 offers the conclusions.

2 Literature

A growing literature emphasizes the role of macro-financial links in the analysis of monetary policy. Vlcek and Roger (2012) compile a long list of Central Banks that have models that include either financial frictions or financial intermediation. The most part of these models include just endogenous financial frictions, as in Bernanke et al. (1999) and Iacoviello (2005). In general, these models focus on understanding the factors that affect credit demand and tend to propagate and amplify the transmission of shocks through an accelerator mechanism, leaving no role for financial intermediaries.

We can divide this field of research in two groups. The first and more numerous group comprises of structural equilibrium models (DSGE models); this includes, for example, Gerali et al. (2010), Angeloni and Faia (2013), Angelini et al. (2014), or Gertler and Karadi (2011). For Chile we have Medina and Soto (2005) and García-Cicco et al. (2014).

On the other hand, another stream of macroeconomic models emphasize, for example, the role of credit supply factors, the structure of the banking system, and the role of the composition of the bank balance sheet in the transmission of macroeconomic and financial shocks (Curdia and Woodford, 2010; Gertler and Karadi, 2011). Despite these contributions, there is still no established framework to study the relationship between financial friction and macroeconomic activity and its implications for both monetary and macroprudential policies. Nevertheless the models can be useful to inform monetary policy.

We use a model that accounts for the interaction between a standard macroeconomic configuration and some key financial variables. We focus on a standard Neo-Keynesian model for a small and open economy as the basis for the macroeconomic block (Laxton et al., 2006). Although this type of model has been useful in guiding central banks in setting their interest rates, it does not incorporate financial variables that may be relevant for the authority. In order to have a simple framework in which financial variables are relevant, we include a financial block. Thus, the base model is extended to account for the interaction of the main macroeconomic variables with the financial sector.[1] Specifically, we follow the approach adopted by Samano (2011) and Nuguer et al. (2016) and we apply that into the base-line model by Arroyo-Marioli et al. (2020)[2].

The model consists of four equations for the macroeconomic block and three equations for the financial block. In the macro block we model an IS curve, a Tradable Phillips curve and a Non-Tradable one, an equation for the exchange rate and a Taylor rule. It is important to note that the equations (4), (7) and (9) can be obtained as log-linear approximations of the first-order conditions by consumers and firms based on an optimization problem with monopolistic competition where the price adjustment is slow, as suggested by Aguirre and Blanco (2015). As it is common in these types of specifications, lowercase variables represent

[1]The model has limitations. First, the lack of microfundaments, which makes the model sensitive to Lucas's criticism and inadequate for welfare analysis. Second, it is based on a representative agent configuration, leaving aside the heterogeneity among the agents.

[2]A similar idea is proposed by Alfaro and Sagner (2011), Becerra et al. (2017) the elaboration of stress scenarios. However, their approach is based on VAR type econometric models and not models with macroeconomic structure.

gaps (deviations in logarithms) of their respective steady states.

Finally, to capture the risk of the banking sector, we use the relationships found by Ehrenbergerová and Malovaná (2019). Using the quarterly projection model (QPM; gap model used by the Czech National Bank) they extend it by incorporating total credit, credit risk, and credit interest rates, highlighting the feedback from both sectors.

3 Model

The Central Bank of Chile (CBoC) regularly uses two main models for medium-term forecasting: the XMAS (Extended Model for Analysis and Simulation, García et al. (2019)), a big-scale DSGE model, and the MSEP (Modelo Semi-Estructural de Proyección), a semi-structural model, Arroyo-Marioli et al. (2020). MSEP is based on the basic structure of New-Keynesian (NK) models. The simplest NK model contains four equations: an *IS Curve*, a *Phillips Curve*, an equation for the exchange rate, and the Central Bank's reaction function.

Here we rely on MSEP and add a credit block following Becerra et al. (2020) and Ehrenbergerová and Malovaná (2019). This block consists of a series of equations that represent the dynamics of commercial credit, impacting the model through aggregate demand.

The model presented here can be summarized in two parts: the macroeconomic block and the financial block. The first one captures the typical dynamics seen in New Keynesian models: an IS curve, a Phillips curve, a Taylor rule, and a UIP condition, among other specifications. These will all come from the MSEP. The financial block is the innovation of this paper: it captures the role of the credit sector. The financial block feeds the macroeconomic block through the IS curve. At the same time, the macroeconomic block feeds back into the financial block through income and interest rates, generating an acceleration effect. As it is common in these types of specifications, lowercase variables represent gaps (deviations in logarithms) of their respective steady states.

3.a Macroeconomic block

The output gap is defined as the difference between the log of Non-Mining GDP (NMGDP) (Y) and the log of potential NMGDP ($\bar{Y}$):

$$y_t = Y_t - \bar{Y}_t \tag{1}$$

Output is determined by the following equations.

Quarter on quarter (QoQ) variation of potential NMGDP

$$\Delta \bar{Y}_t = G_t + \xi_t^{\bar{Y}}, \qquad \xi_t^{\bar{Y}} \overset{\text{iid}}{\sim} \mathcal{N}(0, \sigma^2_{\xi^{\bar{Y}}}) \tag{2}$$

Potential NMGDP growth (Blagrave et al., 2015)

$$G_t = \theta_G G^{ss} + (1 - \theta_G) G_{t-1} + \xi_t^G, \qquad \xi_t^G \overset{\text{iid}}{\sim} \mathcal{N}(0, \sigma^2_{\xi^G}) \tag{3}$$

IS Curve

$$\begin{aligned}\Delta y_t = & - a_1(y_{t-1} + y_{t-2}) - a_2(y_{t-1} - y_{t-2}) - a_3(r_t - rn_t + r_{t-1} - rn_{t-1}) \\ & + a_4(y_t^{em} + y_{t-1}^{em}) + a_5(y_t^{ad} + y_{t-1}^{ad}) + a_6 rer_{t-1} + a_7 tot_t + a_8 \hat{cr}_t - a_9 LLP_t + \nu_t^y.\end{aligned} \tag{4}$$

Demand shock ν^y

$$\nu_t^y = \rho^{\nu y} \nu_{t-1}^y + \xi_t^y, \qquad \xi_t^y \overset{\text{iid}}{\sim} \mathcal{N}(0, \sigma^2_{\xi^y}) \tag{5}$$

This specification follows closely Blagrave et al. (2015) and Blagrave and Santoro (2016), but with an important difference. We do not model the output gap as an AR(1) process, but rather as an error correction process as in Central Bank of Chile (2003). Equation (2) specifies the level of potential output in terms of its growth rate (G) and a shock to the level ($\xi^{\bar{Y}}$). In turn, potential growth follows an AR(1) process and converges to a long-run constant rate G^{ss}.

A semi-structural IS curve describes the change in the output gap, following an error correction setting, including additional controls. The real interest rate (r), net of the neutral level, has a negative impact on the output gap. The trading partners' output gaps, as a proxy for the external demand, have a positive effect. Finally, the shock ν^y follows an AR(1) with persistence $\rho^{\nu y}$, and shocks $\xi^{\bar{Y}}$, ξ^G, and ξ^y follow an iid process with zero mean and constant variance.

In addition to the baseline model, the IS curve contains two elements from the financial block. First, credit growth ($\hat{cr}_t$) affects positively economic activity, while the second element is credit risk (LLP_t). The idea is to capture that a strong credit expansion would be an indicator of possible banking problems.

Inflationary dynamics are similar to those presented in Arroyo-Marioli et al. (2020) with the innovation of using as CORE inflation the CPI excluding volatile iterms[3].

Core CPI^a

$$\pi_t^{Core} = \alpha_2 \pi_t^{NT} + (1-\alpha_2)\pi^T, \qquad \alpha_2 \in (0,1) \tag{6}$$

Non-tradable Core CPI

$$\pi_t^{NT} = bnt_1 \mathbb{E}_t \left[\pi_{t+1}^{NT}\right] + bnt_2(\pi_{t-1}^{NT} - \epsilon_{t-1}^{NT}) + bnt_3 y_t + \epsilon_t^{NT} + \nu_t^{NT} \tag{7}$$

$$\nu_t^{NT} = \rho^{\nu NT} \nu_{t-1}^{NT} + \xi_t^{NT}, \qquad \xi_t^{NT} \overset{\text{iid}}{\sim} \mathcal{N}(0, \sigma^2_{\xi^{NT}}), \qquad \epsilon_t^{NT} \overset{\text{iid}}{\sim} \mathcal{N}(0, \sigma^2_{\epsilon^{NT}}) \tag{8}$$

Tradable Core CPI

$$\pi_t^T = bt_2(\pi_{t-1}^T - \epsilon_{t-1}^T) + bt_3 y_t + bt_4(deus_t + deus_{t-1}) + bt_5 rer_{t-1} + \epsilon_t^T + \nu_t^T, \tag{9}$$

$$\nu_t^T = \rho^{\nu T} \nu_{t-1}^T + \xi_t^T, \qquad \xi_t^T \overset{\text{iid}}{\sim} \mathcal{N}(0, \sigma^2_{\xi T}), \qquad \epsilon_t^T \overset{\text{iid}}{\sim} \mathcal{N}(0, \sigma^2_{\epsilon^T}) \tag{10}$$

Food Non-Core CPI

$$\pi_t^F = \rho^{F1} \pi_{t-1}^F + \rho^{F2} y_t + \xi_t^F, \tag{11}$$

[3]For more details see Monetary Policy Report December 2019.

$$\nu_t^F = \rho^{vF}\nu_{t-1}^F + \xi_t^F, \qquad \xi_t^E \overset{\text{iid}}{\sim} \mathcal{N}(0, \sigma^2_{\xi^F}) \tag{12}$$

Energy Non-Core CPI

$$\pi_t^E = \alpha_3 poil_t^{MEPCO} + (1-\alpha_3)\nu_t^E, \tag{13}$$

$$\nu_t^E = \rho^{vE}\nu_{t-1}^E + \xi_t^E, \qquad \xi_t^E \overset{\text{iid}}{\sim} \mathcal{N}(0, \sigma^2_{\xi^E}) \tag{14}$$

Rest of Non-Core CPI

$$\pi_t^{nCore} = bv_1(\pi_{t-1}^{nCore} - \epsilon_{t-1}^{nCore}) + bv_2 deus_t + bv_3 rer_{t-1} + \epsilon_t^{nCore} + \nu_t^{nCore}, \tag{15}$$

$$\nu_t^{nCore} = \rho^{\nu nCore}\nu_{t-1}^{nCore} + \xi_t^{nCore}, \qquad \xi_t^{nCore} \overset{\text{iid}}{\sim} \mathcal{N}(0, \sigma^2_{\xi^{nCore}}), \qquad \epsilon_t^{nCore} \overset{\text{iid}}{\sim} \mathcal{N}(0, \sigma^2_{\epsilon^{nCore}}) \tag{16}$$

Consumer Price Index (CPI)[a]

$$\pi_t^{CPI} = \alpha_4\pi_t^{CORE} + \alpha_5\pi^F + \alpha_6\pi^E(1-\alpha_4-\alpha_5-\alpha_6)\nu_t^{nCore}, \qquad \alpha_4, \alpha_5, \alpha_6 \in (0,1) \tag{17}$$

We measure total inflation using the CPI. However, we do not model the behavior of this index directly. Instead, we use a *divide-and-conquer* kind of strategy: we split the aggregate index into distinct components that behave similarly. Equations (6) to (17) reflect these divisions. First, we divide total CPI into food CPI, energy CPI, rest-volatile CPI and CORE CPI. The CORE CPI comprises 65 percent of total CPI. Then, we separate the CORE into two distinct components: CPI excluding volatile items and non-core CPI (35 percent). Such separation follows the method of Carlomagno and Sansone (2019), who use econometric tools to isolate the most volatile components of consumer prices. Lastly, we divide CORE CPI into tradable (27 percent of total CPI) and non-tradable (38 percent) CPI. Tradable prices respond not only to the domestic business cycle, but also to exchange rates. On the other hand, non-tradable prices correlate more with domestic activity, past prices (via indexation), and inflation expectations.

For each CPICORE's sub-component, we allow for two kinds of cost-push shocks: temporary and more persistent. Specifically, persistent shocks are the following ν^{NT} and ν^{T} and one-period-lived shocks are ϵ_t^{NT} and ϵ_t^{T}.

Equation (11) specifies that food inflation depends on its own lag and the output gap. Equation (13) shows that energy inflation depends on the MEPCO-smoothed price of oil[4] and the QoQ nominal depreciation ($deus_t$). We use the nominal (instead of the real) depreciation because we assume that prices are rigid in the short-term. Finally, equation (17) reconstructs total inflation from its sub-components.

The bilateral nominal depreciation of the peso against the dollar, $deus$, is not observed by the model, but deduced from the following identity:

Nominal depreciation

$$deus_t = rer_t - rer_{t-1} - \pi_t^* + \pi_t^{CPI}. \tag{18}$$

The UIP allows us to deduce the expected bilateral depreciation in the short-run, $\mathbb{E}_t[deus_{t+1}]$, by equating the yield of domestic risk-free financial assets, i_t, and the yield of external assets, i_t^* plus the sovereign risk premium, ρ_t^{embi}. On the other hand, empirical evidence shows that exchange rate expectations depend on fundamentals such as the terms of trade. Therefore, the spot exchange rate depends on the difference between domestic and international interest rates, risk premiums, and the terms of trade. This relation is expressed in equation (20):

ToT UIP modification

$$\mathbb{E}_t rer_{t+1} = \theta tot_t + \nu_t^{UIP}, \tag{19}$$

$$rer_t = \mathbb{E}_t rer_{t+1} - \frac{i_t - in_t}{4} + \frac{i_t^*}{4} + \frac{\rho_t^{embi}}{4}, \tag{20}$$

[4]The MEPCO is a device designed to smooth oil price variations, and implemented by the National Petroleum Enterprise.

AR(1) structure for *UIP* shock

$$\nu_t^{UIP} = \rho^{\nu UIP}\nu_{t-1}^{UIP} + \xi_t^{UIP}, \qquad \xi_t^{UIP} \overset{\text{iid}}{\sim} \mathcal{N}(0, \sigma^2_{\xi^{UIP}}) \tag{21}$$

To close the macroeconomic block, there is a Taylor rule that describes the behavior of the Central Bank. This equation includes three terms. First, a persistence term to account for the Central Bank's reaction to changes in its macroeconomic outlook. Then, the expected inflation plays a significant role. Its associated coefficient satisfies the Taylor principle ($c_2 > 1$), implying that the Central Bank moves the nominal interest rate beyond the change in inflation, in order to accommodate the real interest rate, thus stabilizing prices. Finally, this rule also depends on the output gap. It is worth noticing that the Taylor rule does not operate on the interest rate directly but on its deviation from the neutral interest rate (in, equation (24)).

Taylor rule

$$i_t - in_t = c_1(i_{t-1} - in_{t-1}) + (1 - c_1)\left(c_2\mathbb{E}_t\left[\pi_{t+1}^{XFE,annual}\right] + c_3 y_t\right) + \nu_t^i \tag{22}$$

$$\nu_t^i = \rho^{\nu i}\nu_{t-1}^i + \xi_t^i, \qquad \xi_t^i \overset{\text{iid}}{\sim} \mathcal{N}(0, \sigma^2_{\xi^i}) \tag{23}$$

The Fisher equation (25) establishes the relationship between real and nominal interest rates.

The neutral nominal rate

$$in_t = rn_t + Target \tag{24}$$

Fisher Equation

$$r_t - rn_t = i_t - in_t - 4\mathbb{E}_t\pi_{t+1}^{CPI}. \tag{25}$$

The real neutral interest rate (rn) is determined by potential GDP growth according to equation (26). This definition follows Laubach and Williams (2016). We calibrate the parameter c_{rn_pot} using the long-term growth rate (G^{ss}) and the long-term real neutral interest rate (rn^{SS}), which we assume as given.

The Neutral Real Rate

$$rn_t = c_{rn\_pot}\mathbb{E}_t[G_{t+1}] + \xi_t^{rn}, \qquad c_{rn\_pot} = \frac{rn^{SS}}{G^{SS}}, \qquad \xi_t^{rn} \overset{\text{iid}}{\sim} \mathcal{N}(0, \sigma^2_{\xi^{rn}}) \tag{26}$$

We assume that international variables are exogenous. In consequence, we model them as auto-regressive processes as shown in the Appendix.

3.b Financial Block

We add the financial block to the rest of the economy to capture the credit channel in a stylized way. Specifically, we consider a financial sector, characterized by the existence of banks, in charge of the intermediation of resources between borrowers and lenders. This intermediation is carried out at a cost, the spread (SPR) which is represented by the equation (27).[5]

$$SPR_t = i_t^{Loan} - i_t \tag{27}$$

Curdia and Woodford (2010) argue that given the frictions present in credit demand, it is possible to impose an additional premium on the rate faced by borrowers. In the same line Gerali et al. (2010) show that banks devote resources to the management of their balance sheet and/or to cover the costs associated with regulatory requirements. In this paper, we also assume that banks enjoy some market power due to the presence of monopolistic competition that allows them to charge a margin on the policy rate when they grant credit. Equation (28) describes the dynamics of the placement rate.

$$i_t^{Loan} = \eta_1(i_t - i_n) + \eta_2 LLP_t + \eta_3 CAR_t + \varepsilon_t^{i^{Loan}} \tag{28}$$

[5]It is important to note that (27) shows that the spread between the rate charged for loans and the monetary policy rate and not with the rate of deposits as traditionally found in the literature. Empirical evidence shows that there is no significant difference between both rates.

The credit rate is affected by the monetary policy rate (MPR) with an impact equal to (η_1) that captures the transfer of the policy rate to the credits. It is also affected by credit risk (LLP). That is, if the banking sector experiences complications to recover the payment of its credits, the rate at which the new credits will be made will be higher in order to compensate for losses. On the other hand, if the regulation becomes more severe - greater capital requirement on risk-weighted assets (CAR) —the banks will increase the interest rate at which they grant loans[6].

$$\hat{cr}_t = \theta_1 \hat{cr}_{t-1} + \theta_2 y - \theta_3 SPR_t + \varepsilon_t^{\hat{cr}} \tag{29}$$

Credit dynamics is represented in equation (29) where $\hat{cr}_t$ is credit growth.[7] A higher *Spread* reduces the demand for credit, while the term θ_2 captures the pro-cyclical behavior of credit. Thus, we can capture the accumulation of risks in the financial sector through the evolution of the credit gap, which will be positively related to the economic activity (that is, credit booms generally begin after periods of rapid economic growth) and negatively related to the spread. This last relationship accounts for the link between financial conditions and credit booms. This is in line with Drehmann and Tsatsaronis (2014) who suggest that a strong credit expansion would be an indicator of possible banking problems.

$$LLP_t = \vartheta_1 LLP_{t-1} - \vartheta_2 \left(\frac{\sum_{i=1}^{4} y_{t+i}}{4} \right) + \vartheta_3 \hat{cr}_{t-1} + \varepsilon_t^{LLP} \tag{30}$$

Equation (30) is a measure of credit risk for banks, reflected in Provisions Expenses. We assume that it depends on expected economic activity and credit. The intuition behind this specification is that periods of expansion in economic activity are accompanied by reductions in delinquency levels, as debtors can meet the payment of their obligations. On the other hand, an accelerated expansion of credit, which would be captured by a positive credit gap could result in vulnerabilities for banks, as there is a possibility that the new loans are of lower quality as a result of a relaxation in standards for grant credit during credit booms.

[6]Banks will seek to obtain a higher return their obligation to maintain a higher level of capital, in other words, will keep the return on capital constant.

[7]This is defined as $\hat{cr}_t = CR_t - \bar{CR}_t$.The equations make clear that changes on credit growth as deviation of its trend.

This translates into higher provisions.

$$CAR_t = \rho_{CAR} CAR_{t-1} + \varepsilon_t^{CAR} \tag{31}$$

Finally, the equation for the evolution of the Bank Capital Index is described by the equation (31). It is independent of the central bank and depends on its own dynamics.

4 Data

This section describes the data set that we use in the model's estimation. For the macroeconomic block, we use the output gap, inflation, core inflation, the monetary policy rate, the real and nominal exchange rate, and several external variables. For the financial block, we use the interest rate for new commercial loans, the expenditure on provisions for that kind of loans, the commercial credit gap, and the capital adequacy index (CAR). The data is in quarterly frequency with information from the first quarter of 2005 to the first quarter of 2019. The data comes from the CBoC, except for the expense in provisions and the capital adequacy index which is from the Financial Market Commission (FMC).

We specify the model in terms of gaps and assume that these converge to zero in the long run. In other words, once the gaps are closed, in the absence of perturbations, the variable dynamics are those of the trend variables. The MSEP extended with banking sector aims to explain the joint dynamics of these variables during the business cycle.

For the variables of the macroeconomic block, we follow the data of Arroyo-Marioli et al. (2020). While for the financial block, the interest rate charged corresponds to the placement rate of commercial loans, we restricted the analysis to this type of credit because we wanted to study the feedback from the banking sector to economic activity through firms. For the credit gap, we use the annual credit growth of commercial loans. Finally, the provision expense index corresponds to the sum of the provisions plus penalties of the previous 12 months divided by the total credit.

The use of the aforementioned indicator as a measure of credit risk is well-known. Jara et al. (2007) estimate a credit risk model for 16 chilean banks during the period 1989 to

2004 and relates the evolution of expenditure in total provisions with variables that characterize the economic cycle, also controlling for the heterogeneity of the banking industry. Alfaro and Sagner (2011) focus on the credit risk of consumer banks and relate spending on consumer provisions during the period 1992 to 2009 with macroeconomic variables such as the product gap, the credit rate between 1 to 3 years, and the unemployment rate. Additionally, Jara et al. (2007), Alfaro and Sagner (2011) and Becerra et al. (2017) point out that the Central Bank of Chile uses the provision expense broken down by type of portfolio as a measure of credit risk in preparation of stress tests. Figure 1 illustrates the variables.

We use the Hodrick-Prescott filter to determine the trend of interest rates on commercial loans. For the rest of the variables of the financial block, credit growth, CAR, and credit risk the long-trend are modeled as the sample mean.

4.a Observed Variables

We transform the variables to feed the gap-model. We specify these transformations below. The model observes: the output gap (y), potential GDP ($\Delta\bar{Y}$), total inflation rate, inflation excluding food and energy (XFE), core inflation (tradable y non-tradable), non-core inflation rate, food and energy inflation (π^{CPI}, π^{XFE}, π^{Core}, π^{T}, π^{NT}, π^{nCore}, π^{F} and π^{E} respectively), monetary policy rate (i), real exchange rate (rer), terms of trade (tot), the output gap of advanced and emerging trading partners (y^{ad} and y^{em} respectively), Chile's EMBI (ρ^{embi}), external interest rate (i^{*}), oil price ($poil$), copper price (pcu), external inflation (π^{*}), and the unemployment rate (u_t). The variables of the financial block are *detrended*.

We get these variables through the following relationships:

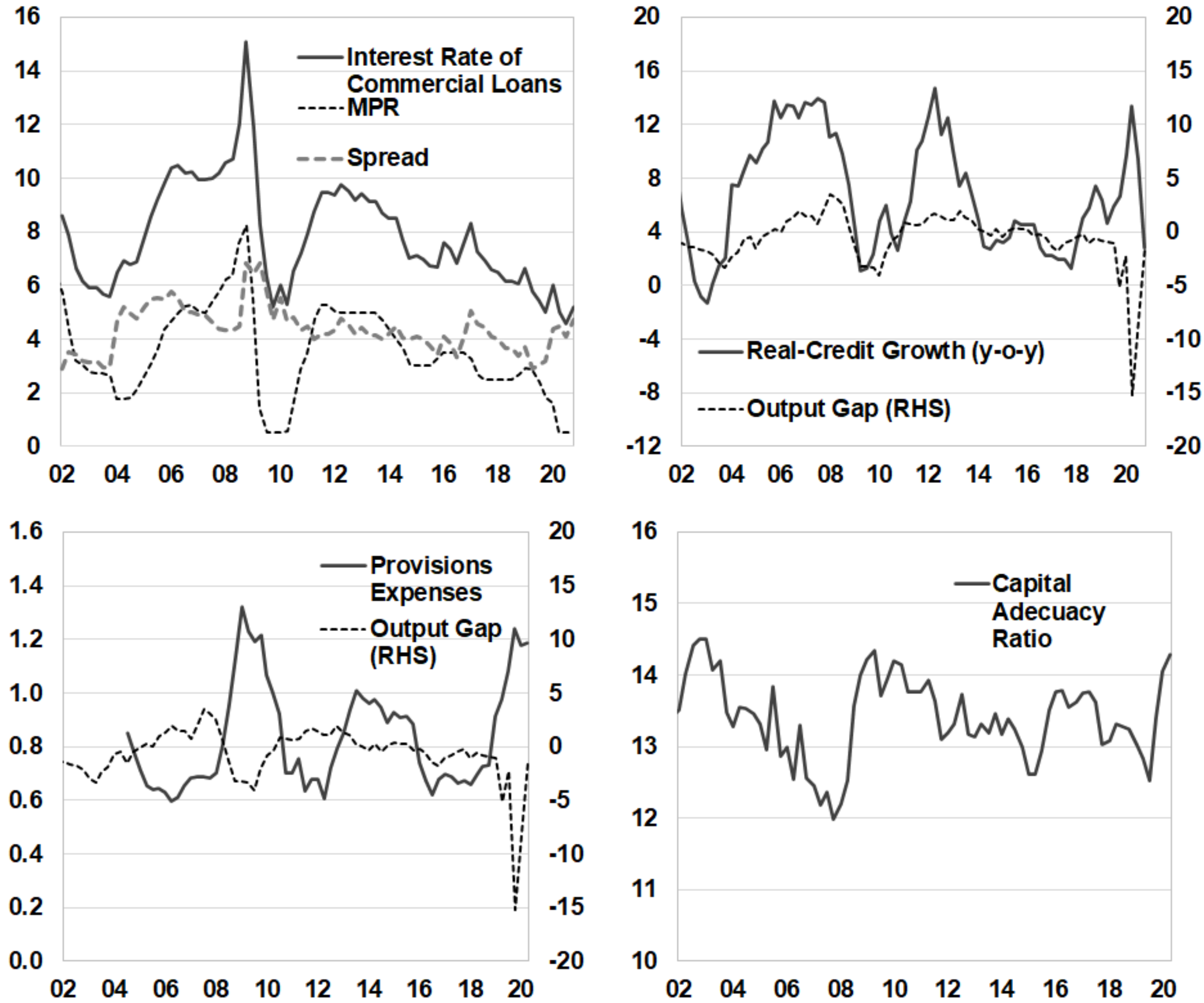


Figure 1: Observable variables from the financial block and Output Gap

Note: variables are shown in percentages. All are at level, except for credit growth, which is shown in annual variation.

$$\pi_t^{CPI} = \Delta \log\left(CPI_t^{sa}\right) - \bar{\pi}, \qquad \pi_t^{XFE} = \Delta \log\left(CPIXFE_t^{sa}\right) - \bar{\pi},$$

$$\pi_t^{Core} = \Delta \log\left(CoreCPI_t^{sa}\right) - \bar{\pi}, \qquad \pi_t^{nCore} = \Delta \log\left(NcoreCPI_t^{sa}\right) - \bar{\pi},$$

$$\pi_t^{NT} = \Delta \log\left(CoreCPI_{NT_t}^{sa}\right) - \bar{\pi}, \qquad \pi_t^{T} = \Delta \log\left(CoreCPI_{T_t}^{sa}\right) - \bar{\pi},$$

$$\pi_t^{F} = \Delta \log\left(FCPI_t^{sa}\right) - \bar{\pi}, \qquad \pi_t^{E} = \Delta \log\left(ECPI_t^{sa}\right) - \bar{\pi},$$

$$y_t = \log\left(\frac{NMGDP_t^{sa}}{NMGDP_t^{pot}}\right), \qquad \Delta\bar{Y}_t = \Delta \log\left(NMGDP_t^{pot}\right),$$

$$\Delta Y_t = \Delta \log\left(NMGDP_t\right), \qquad i_t = MPR_t,$$

$$rer_t = \log\left(\frac{RER_t}{RER^{eq}}\right), \qquad tot_t = \log\left(\frac{ToT_t}{ToT_t^{trend}}\right),$$

$$y_t^{em} = \log\left(\frac{EMGDP_t}{EMGDP_t^{trend}}\right), \qquad y_t^{ad} = \log\left(\frac{ADGDP_t}{ADGDP_t^{trend}}\right),$$

$$\rho_t^{embi} = \log\left(\frac{EMBI_t}{EMBI^{eq}}\right)/10000, \qquad pcu_t = \log\left(\frac{PCU_t}{PCU_t^{trend}}\right),$$

$$poil_t = \log\left(\frac{PWTI_t}{PWTI_t^{trend}}\right), \qquad \pi_t^{*} = \Delta \log\left(FPI_t\right) - \bar{\pi}^{*},$$

$$u_t = U_t - NAIRU_t, \qquad i_t^{*} = IUS_t - \bar{i}^{*},$$

$$il_t^{loan} = il_{obs_t}^{loan} - il_{trend}^{loan}, \qquad \hat{cr}_t = cr_t - cr^{trend},$$

$$LLP_t = LLP_t^{obs} - LLP^{trend}, \qquad CAR_t = capital_t^{obs} - capital^{trend},$$

where $NMGDP^{Pot}$ denotes potential GDP, estimated via multivariate filters. The following trends: $EMGDP^{trend}$, $ADGDP^{trend}$, $PWTI^{trend}$, PCU^{trend} and ToT^{trend} were calculated as in Arroyo-Marioli et al. (2020). While il_{trend}^{loan} is estimated through Hodrick-Prescott filter and cr^{trend}, LLP^{trend}, and $capital^{trend}$ are the means of the data.

5 Model estimation

We proceed to estimate the model with a Bayesian approach by taking the baseline values as priors and reestimating them with Chilean data. We use the following strategy: first, the set of parameters is divided between parameters associated with endogenous variables

(IS curve's, Phillips curve's, Taylor rule's parameters, and the Financial Block ones) and parameters associated with exogenous variables or variance restrictions (i.e., autoregressive coefficients and relative standard deviations between potential GDP shocks, unemployment, etc.). We calibrated the parameters from the second group as in Arroyo-Marioli et al. (2020). Second, the parameters associated with endogenous variables are jointly estimated using Bayesian methods. Priors distributions were informed both by univariate regressions using standardized econometric techniques (OLS and GMM), as well as priors used in Becerra et al. (2020).

Bayesian estimation was performed using *Dynare* software. We performed 200,000 iterations of *Metropolis-Hasting* algorithm to recover key moments of the posterior distribution. The data set goes from 2005Q1 to 2019Q1. We start from where the commercial credit data starts.

Table 1 reports assumed priors distribution as well as the mode mean and percentiles 10 and 90 of the estimated parameter's *posterior* distribution. Less relevant parameters are not reported.

6 Results

6.a Dynamic of the Chilean economy

Table 1 presents the results for the posterior. We find that the average estimated parameters for the macroeconomic block are in the range of estimates observed in the literature as well as presented in the base-line model in Arroyo-Marioli et al. (2020). Regarding the financial block, as expected from Figure 1, we find that the monetary policy rate (MPR) is an important factor for the determination of how much Banks will charge to their clients, η_1, followed by the credit risk, η_2, and the capital requirement η_3. Therefore, if the regulatory institutions require a higher capital level to banks, the cost will be transferred to the users through a higher interest rate. On the credit dynamics side, the parameter (θ_2) reflects its procyclical behavior.

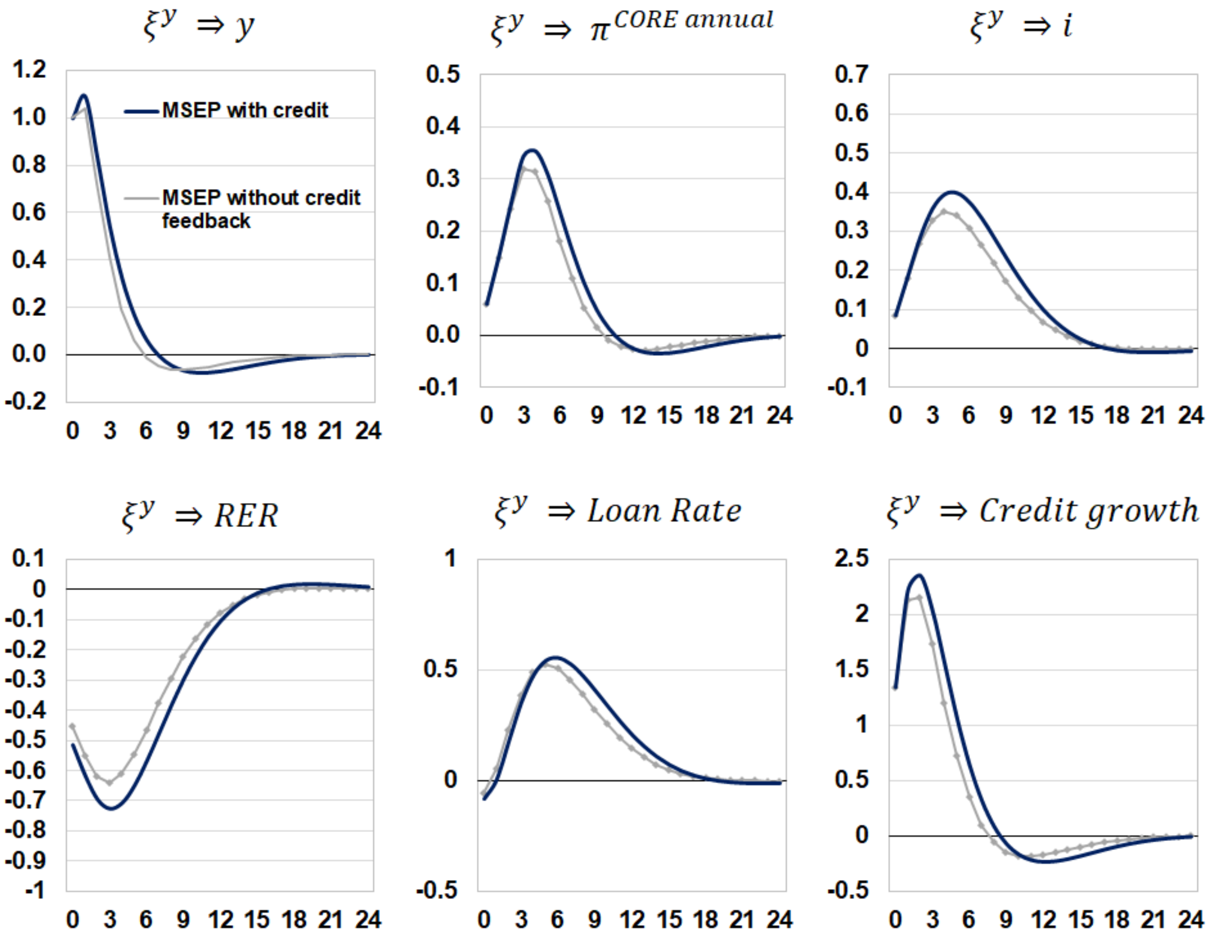
We then analyze the impulse response functions derived from to model to understand its basic

Table 1: Parameters, priors and posterior.

Equation	Parameter	Prior Dist.	Prior Media	Prior Std.	Posterior Mode	Posterior Int. 90 % prob
IS	α_1	Beta	0.15	0.04	0.19	0.15 / 0.26
	α_2	Beta	0.05	0.03	0.07	0.02 / 0.16
	α_3	Beta	0.07	0.02	0.05	0.03 / 0.07
	α_4	Beta	0.07	0.02	0.04	0.03 / 0.06
	α_5	Beta	0.06	0.02	0.03	0.02 / 0.06
	α_6	Beta	0.01	0.005	0.01	0.00 / 0.02
	α_7	Beta	0.02	0.005	0.01	0.01 / 0.02
	α_8	Beta	0.04	0.01	0.03	0.02 / 0.04
	α_9	Beta	0.04	0.01	0.04	0.02 / 0.05
Phillips's curve	bnt_1	Beta	0.20	0.05	0.16	0.10 / 0.23
	bnt_2	Beta	0.50	0.15	0.53	0.35 / 0.64
	bnt_3	Beta	0.10	0.03	0.07	0.05 / 0.10
	bt_2	Beta	0.70	0.08	0.70	0.60 / 0.79
	bt_3	Beta	0.02	0.005	0.02	0.01 / 0.03
	bt_4	Beta	0.05	0.01	0.03	0.02 / 0.04
	bt_5	Beta	0.02	0.005	0.02	0.01 / 0.02
	bv_1	Beta	0.20	0.01	0.20	0.18 / 0.21
	bv_2	Beta	0.10	0.025	0.10	0.07 / 0.13
	bv_3	Beta	0.05	0.01	0.04	0.03 / 0.06
ToT UIP	θ	Beta	0.25	0.07	0.17	0.11 / 0.25
Taylor rule	$c1$	Beta	0.80	0.05	0.81	0.76 / 0.86
	$c2$	Norm	1.70	0.10	1.59	1.42 / 1.76
	$c3$	Gamm	0.20	0.05	0.20	0.12 / 0.30
Lending rate	η_1	Norm	1.50	0.10	1.26	1.16 / 1.38
	η_2	Norm	2.50	0.10	2.47	2.31 / 2.63
	η_3	Beta	0.60	0.02	0.60	0.57 / 0.63
Credit	θ_1	Beta	0.70	0.10	0.56	0.44 / 0.67
	θ_2	Norm	1.50	0.10	1.31	1.17 / 1.48
	θ_3	Beta	0.2	0.05	0.17	0.11 / 0.26
Provision expenses	ϑ_1	Norm	0.9	0.10	0.81	0.68 / 0.95
	ϑ_2	Beta	0.20	0.03	0.11	0.08 / 0.14
	ϑ_3	Beta	0.027	0.01	0.01	0.01 / 0.02
Capital Adecuacy Ratio	ρ_{CAR}	Beta	0.30	0.10	0.65	0.53 / 0.74

dynamics, with emphasis on how the financial block interacts with the rest of the economy. Figure 2 shows the model's dynamics when a domestic demand shock increases the output level by 1 percent with respect to potential output. In this case, the MPR increases in response to the new level of the output gap and the increase in inflation. The MPR increase translates into an appreciation of the real exchange rate that helps to stabilize the economy. The loan rate increases as a response to a higher cost of funding. That effect dominates the improvement in the banks' portfolio reflected in the fall in provision expenses. Finally, real-credit growth follows a pro-cyclical behavior increasing around 2 percent over one year. The figure also reflects the accelerating effect of the feedback caused by the increase in credit depicted in both cases with and without feedback to activity through the IS curve. Overall, in the first year, this accelerating effect increases GDP up to 0.13%, inflation by 0.05%, interest rates by 0.04 basis points and appreciated the ER by an additional 0.1%.

Figure 2: Activity shock.



Note: IRFs use the posterior mode.

Figure 3 shows the response of the endogenous variables to an idiosyncratic shock that increases credit by 100 bp year on year. First, an increase in credit boosts activity and inflation, generating a monetary policy response. Because of the latter, the loan rate increases as well, since the cost of funding dominates.

Figure 3: Credit Growth shock.

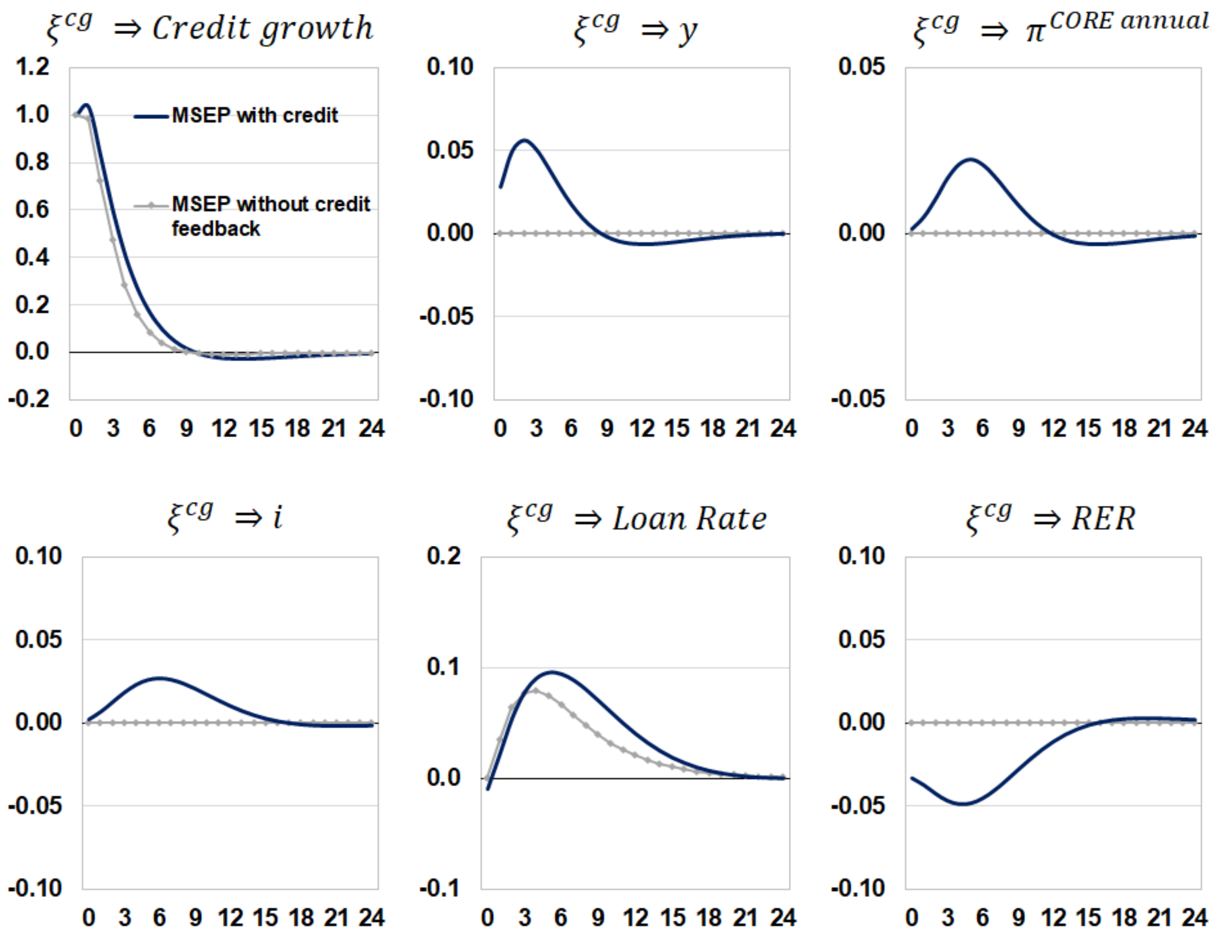
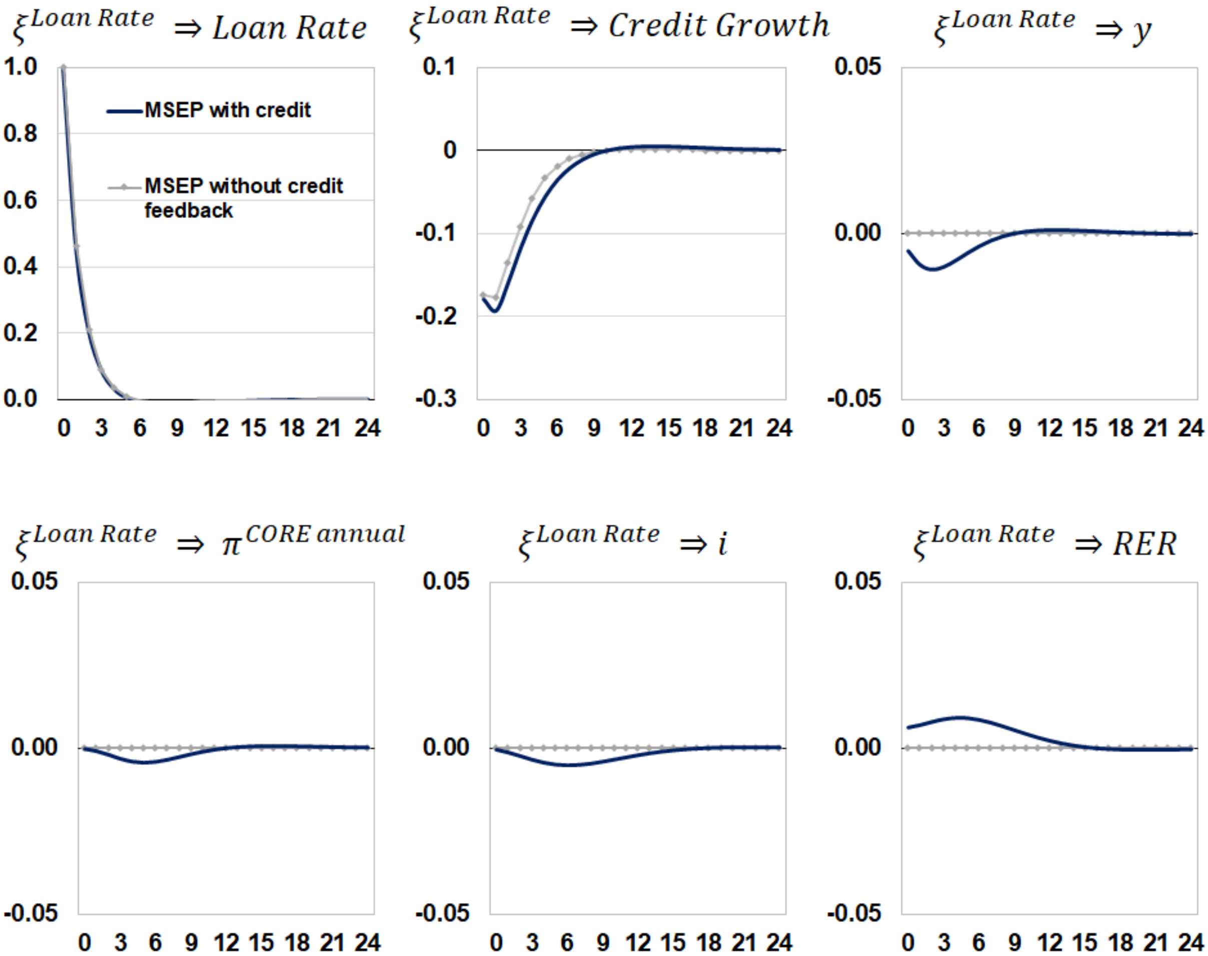


Figure 4 illustrates the impulse response function for a higher lending rate. A higher lending rate reduces credit since it is now relatively more expensive to borrow. There is also an impact on activity, worse financial conditions contract product and as a result, inflation also decreases.

Figure 4: Loan Rate shock.



The mechanism of a provision expenses shock is similar to the loan rate shock. A higher lending rate reduces credit since it is now relatively more expensive to borrow. There is also an impact on activity, since worse financial conditions reduce GDP. Given this, inflation also decreases. The main difference resides on the fact that the provisions expenses shock has a higher impact on activity. The reason is the presence of this term in the IS-curve.

Figure 5: Provisions Expenses shock.

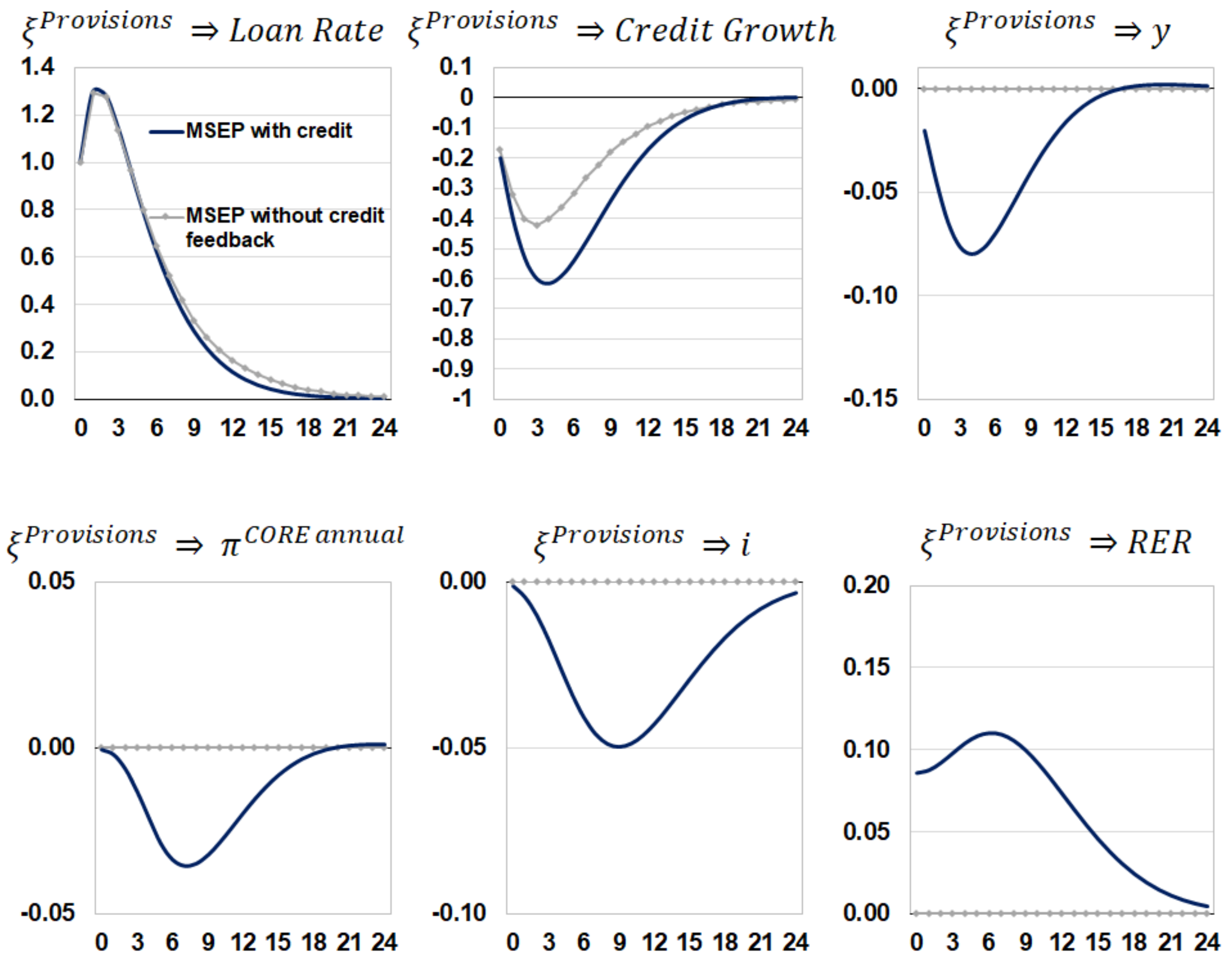
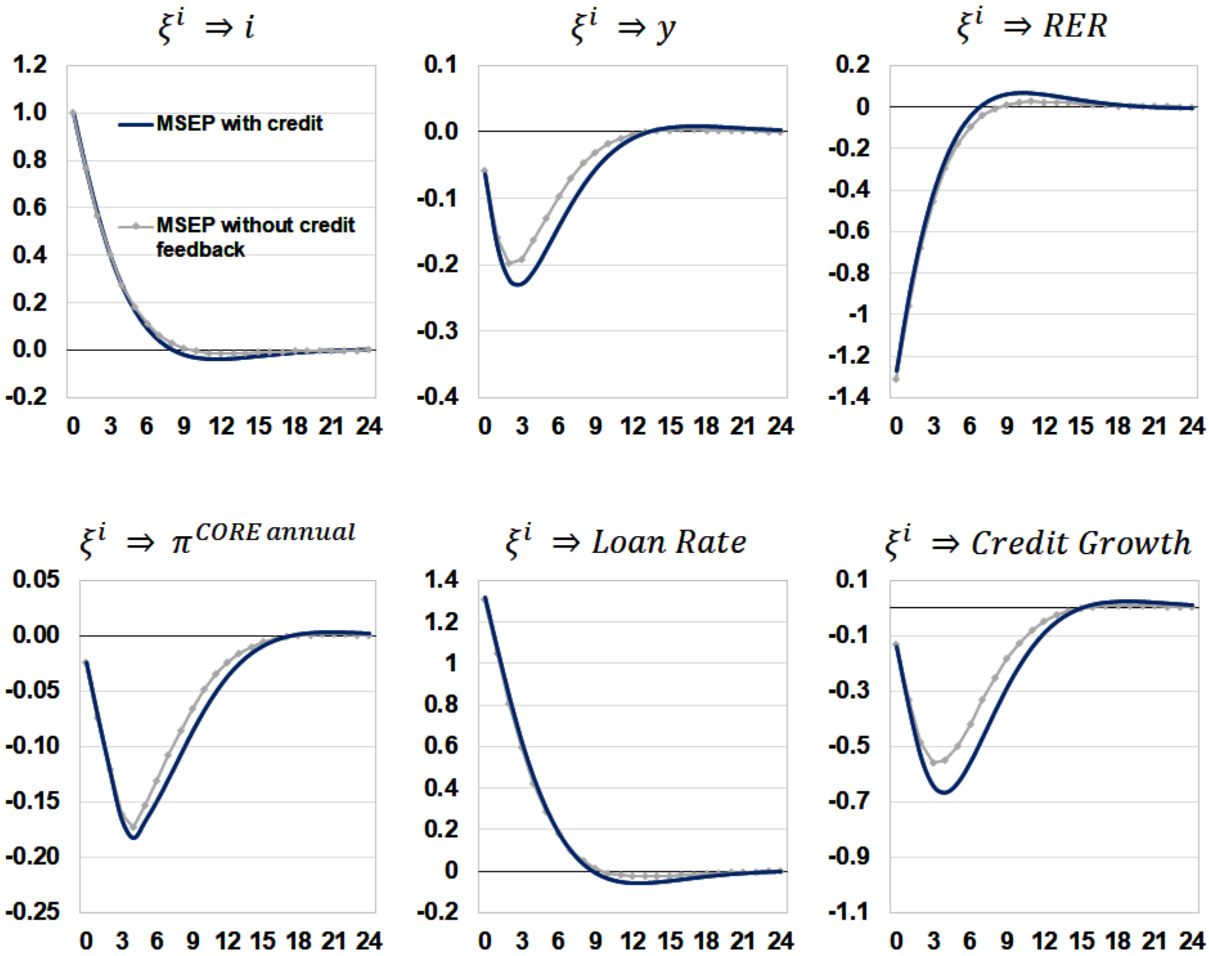


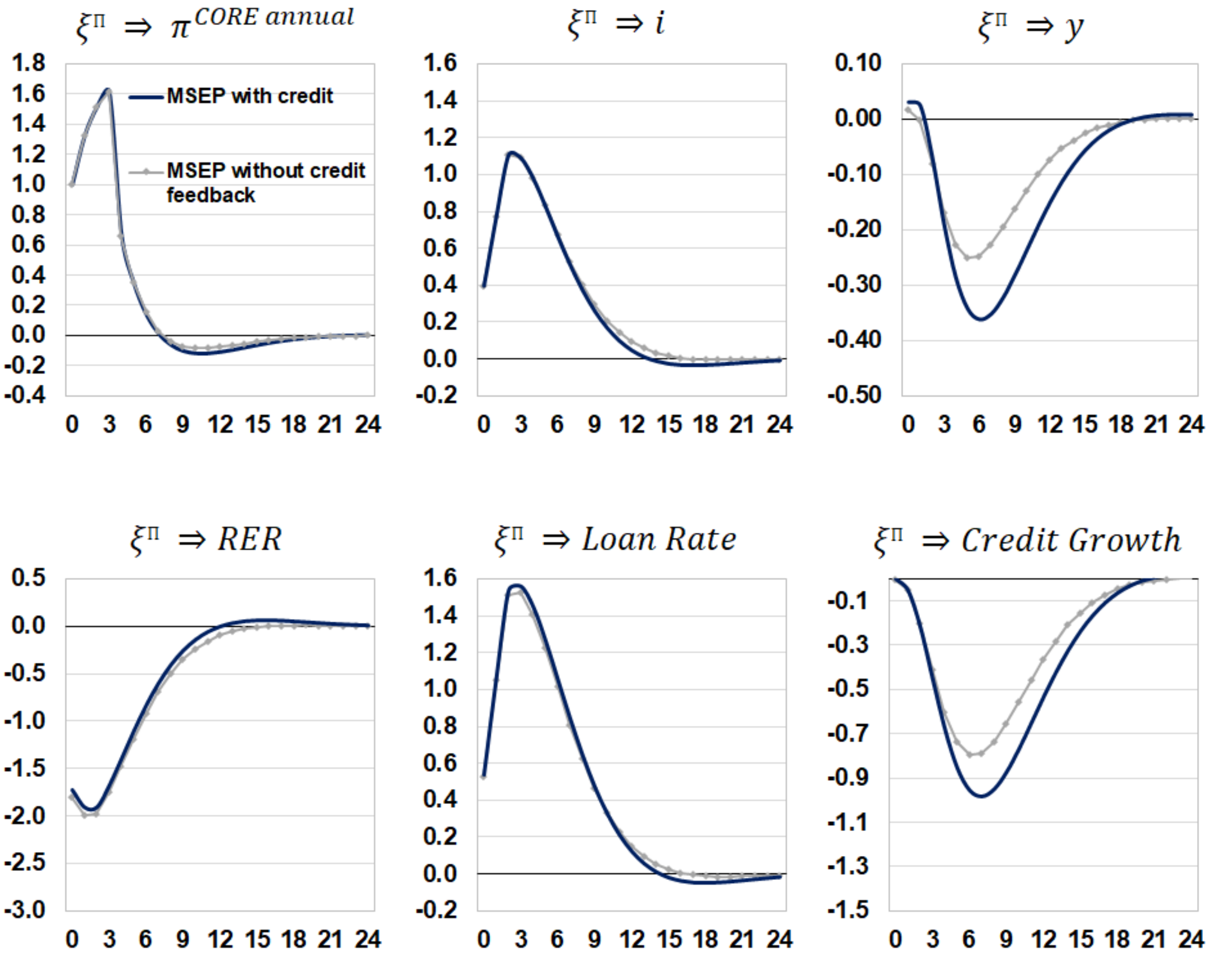
Figure 6 shows the model's response to a monetary policy shock that increases the MPR by 100 bp. First, a fall in the output gap is generated as well as an exchange rate appreciation due to domestic-foreign interest rate arbitrage. The combined effect of these last two variables translates into a fall in core inflation. The cumulative effect is a decrease of approximately 0.2 percent over one year. The response of the Loan Rate is relatively higher than the Monetary Policy Rate. The reason is the feedback from activity to the banking block due to provisions, interpreted as an increase in risk. Finally, credit contracts as a result of the decline in activity and higher loan rates.

Figure 6: Monetary Policy shock.



Finally, figure 7 illustrates the model's dynamics when a cost-push shock of size 1 percent hits the economy. First, the output gap becomes positive due to a decrease in the real rate due to Taylor's rule persistence. However, once it becomes positive, the output gap decreases, and, accompanied by an appreciation in the real exchange rate, inflation finally converges again to the equilibrium level. Communication with the banking block occurs through two channels. The first one is the increase in the Loan Rate following the MPR, and the second is the increase in provisions due to the fall in activity. Both effects go in the same direction.

Figure 7: Cost-push shock.



6.b Variance Decomposition

Table 2 shows the unconditional variance decomposition of forecast errors of the main model's endogenous variables. This measure indicates the contribution of each shock (columns) to the total variance of the forecast error of each variable (rows).

For activity, it is observed that output gap unconditional forecast error variance is explained in more than 60 percent by ξ^y shock, which is interpreted as a demand shock. Then, foreign demand (emerging and advanced business partners) explains almost 16 percent. The banking channel is not relevant on average.

Regarding core inflation, cost-push shocks explain roughly 70 percent of the unconditional core inflation forecast error variance, and that both the demand (domestic and foreign) and exchange rate channels explain about 10 and 17 percent, respectively.

When considering the total CPI, the unconditional forecast error variance is 11 percent explained by energy and food prices shocks and 16 percent by cost-push shocks. In addition, oil price shock (ToT) affects nearly 19 percent.

In the case of the nominal MPR, domestic demand (12 percent), cost-push (22 percent), monetary policy (40 percent) and foreign demand (6 percent) shocks explain most of its unconditional forecast error variance. Notice that foreign transitory shocks, such as UIP and oil price shocks, have relatively little impact. Regarding the RER, more than 11 percent of its unconditional forecast error variance is explained by ToT shocks, especially copper price shocks.

Until here, there are no major changes with respect to Arroyo-Marioli et al. (2020), now, within the scope of the bank-credit block, when considering Credit Growth, the unconditional forecast error variance is 41 percent explained by shocks from the banking sector. Also, demand shocks explained 33 percent, depicting the procyclical behavior of credit. The third element is the external sector, which affects credit through aggregate activity.

Regarding the loan rate, monetary policy shocks explain about a third of the variance, followed by cost shocks and shocks from the banking sector, which explain 20 percent each. The spread, being the difference between the MPR and the loan rate, is mainly explained by elements of the banking sector, around 60 percent.

Finally, spending on provisions is explained mostly by elements of the banking sector (about two-thirds of the variance), while the second most relevant shocks are demand and external demand shocks, which explain about 10 percent each.

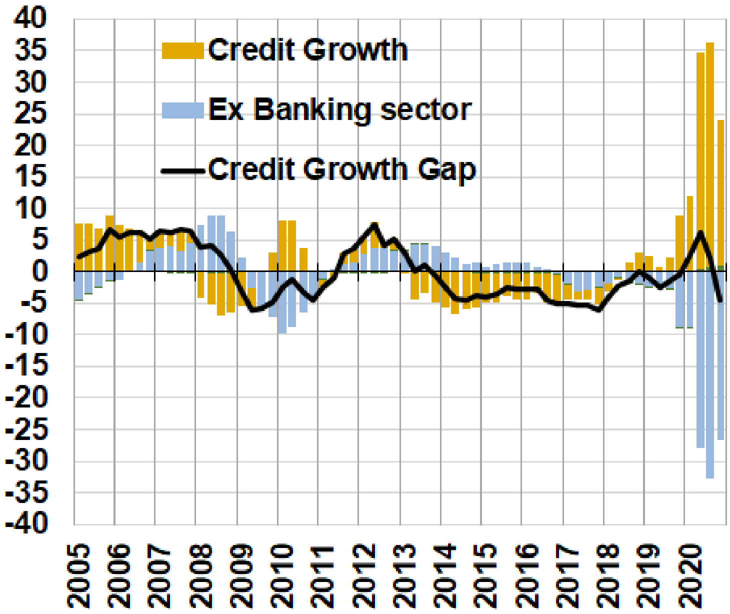
Table 2: Forecast Error Variance Decomposition (Percentage)

	Shock										
Variable	Demand	Cost	Monetary	UIP	F. fin.cond.	F. Demand	ToT	F&E	Banking	Others	Total
y	63.0	3.6	7.3	0.6	0.1	16.2	6.2	0.1	1.9	1.1	100
π^{CORE}	8.3	67.1	3.9	6.4	1.2	2.4	0.9	0.1	0.3	9.4	100
π^{CPI}	4.3	35.2	2.3	6.2	1.0	1.2	19.7	11.0	0.2	19.0	100
i	12.6	22.1	40.8	4.9	1.5	5.9	1.1	0.1	0.5	10.6	100
rer	5.0	8.3	6.8	49.1	9.4	4.7	11.9	0.0	0.2	4.6	100
Credit Growth	32.6	3.2	5.9	0.3	0.1	12.0	4.5	0.1	40.5	0.8	100
i_{loan}	10.6	20.9	35.2	3.8	1.1	2.2	0.9	0.1	18.8	6.4	100
$Spread$	6.2	8.1	11.0	1.0	0.2	4.3	1.7	0.0	65.1	2.4	100
LLP	8.4	3.8	4.0	0.4	0.1	12.2	3.6	0.0	66.5	1.1	100

6.c Historical Decomposition

We use the model to decompose historically the behavior of banking variables and their effects in the economy. Figure 8 shows the behavior of credit allocations from 2005 to 2020. The gray areas indicate endogenous behavior due to the cycle and the yellow the exogenous component. Allocations are clearly procyclical. This makes sense since in the model estimation we find that credit exacerbates the cycle. The innovations in credit during the global recession and, in particular, during the current pandemic, can potentially reflect the role of non-conventional monetary policy. We find this to be a very useful tool in times of distress, since our model allows to estimate the impact these non-conventional measures.

Figure 8: Credit Growth. (annual var. (%), demeaned)



A similar point can be made for provisions. Figure 9 shows also that the exogenous component of provisions acts counter-cyclically during the recent pandemic. Given the significant drop in GDP, provisions should have increased significantly. However, they have not. The model reads this as an exogenous impulse towards reducing provisions. This can also be capturing at least partially the effect of non-conventional monetary policy.

Finally and most important, the role of these shocks on the cycle are best seen in figure 10. During normal times, these innovations do not play a major role. However, during the pandemic, exogenous impulses form the credit sector have allowed to increase GDP counter-cyclically by almost 2 pp. This final result highlights the importance of non-conventional measures and provides a tool for the policymaker to measure the impact of these type of policies. In the case of Chile, the Central Bank of Chile implemented a lending program known as FCIC (Conditional Financing Facility for Increased Loans) in which commercial banks have access to a special funding program in exchange of reassuring that the funds are lent to the public. Effects of this measure should be reflected in our model.

Figure 9: Provision Expenses. (ratio (%), demeaned)

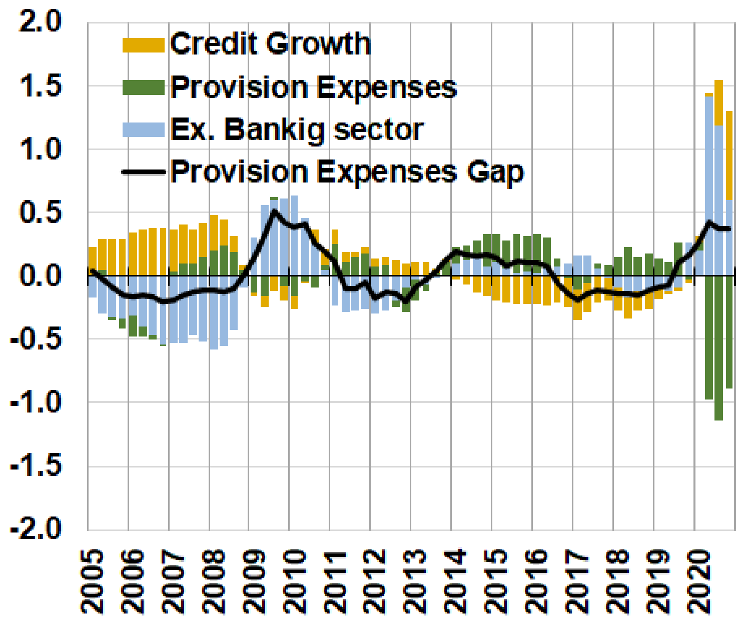
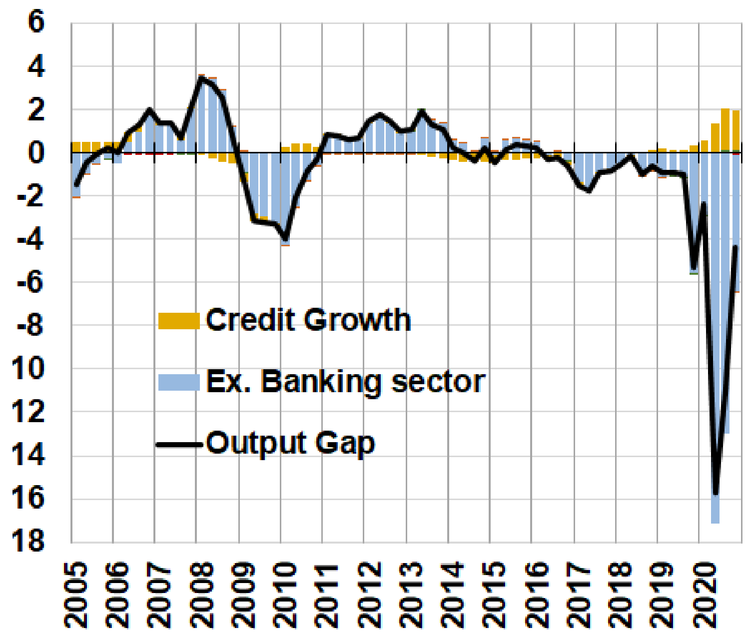


Figure 10: Output Gap. (%)



7 Conclusions

In this paper we incorporate the banking sector into the Central Bank of Chile's semi-structural model MSEP. We do this by incorporating a block of equations that describe dynamics for commercial loans, interest rate spreads and loan-loss provisions. The goal is understand the role that this sector plays in the macroeconomic cycle, with potential implications for monetary policy-making.

We estimate the model through a Bayesian approach for Chile from 2000 to 2019. We find that the banking sector plays an acceleration role in the business cycle: higher(lower) output gap level increases (reduces) credit loans and reduces (increases) loan-loss provisions. This is in turn increases (reduces) aggregate demand, accelerating the initial effect. We find that, under a 1% demand shock, this acceleration can add up to an additional 0.13% impulse to GDP and 0.05% to inflation in the first year. It also has a 0.04 basis point effect on interest rates in the first year and 0.07 basis points in the second one. The ER appreciates an additional 0.1% in both the first and second year. These latter two effects (interest rates and ER) occur through the Taylor rule and UIP condition.

Additionally, we decompose historically the effects of this sector's variables in the historical business cycle. We find that commercial loans can explain on average about 0.3 pp of total output gap variation. Moreover, we find that in episodes of severe stress, this role can grow to 1.9 pp, as has been the case of the 2020 COVID-19 pandemic. This last fact is important, given that in many cases, monetary policy is faced with the challenge of implementing non-conventional measures, many of them through the commercial banking sector. This specification allows the model to better quantify the impact of non-conventional measures.

As a conclusion, it is worth mentioning that the goal of this paper is to study the role of the banking sector in the economy by focusing on macro variables. The model was not designed to address the stability of the financial sector, but rather to see its effect in income and inflation. For a macroprudential analysis, please see Martínez et al. (2020).

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APPENDIX

A Full characterization of the model

We assume that international variables are exogenous. In consequence, we model them as auto-regressive processes as shown in equations (A32) to (A43). These variables include: the output gaps of emerging and advanced trading partners, the oil price, the copper price, the terms of trade, the external interest rate, external inflation, and the risk premium.

Emerging trading partners output gap

$$y_t^{em} = \rho^{em} y_{t-1}^{em} + \nu_t^{em}, \tag{A32}$$

$$\nu_t^{em} = \rho^{\nu em} \nu_{t-1}^{em} + \xi_t^{em}, \qquad \xi_t^{em} \overset{\text{iid}}{\sim} \mathcal{N}(0, \sigma^2_{\xi^{em}}) \tag{A33}$$

Advanced trading partners output gap

$$y_t^{ad} = \rho^{ad} y_{t-1}^{av} + \nu_t^{ad}, \tag{A34}$$

$$\nu_t^{ad} = \rho^{\nu ad} \nu_{t-1}^{ad} + \xi_t^{ad}, \qquad \xi_t^{ad} \overset{\text{iid}}{\sim} \mathcal{N}(0, \sigma^2_{\xi^{ad}}) \tag{A35}$$

Domestic oil price

$$poil_t^{mepco} = \alpha_{mepcomepco} poil_{t-1}^{mepco} + (1 - \alpha_{mepco})(deus_t + \pi_t^{ext} + poil_t + poil_{t-1}) + \xi_t^{mepco}, \tag{A36}$$

$$\xi_t^{mepco} \overset{\text{iid}}{\sim} \mathcal{N}(0, \sigma^2_{\xi^{mepco}})$$

ToT

$$tot_t = px_t - pm_t \tag{A37}$$

Foreign interest rate

$$i_t^* = \rho^{i*} i_{t-1}^* + \nu_t^{i*}, \tag{A38}$$

$$\nu_t^{i*} = \rho^{\nu i*} \nu_{t-1}^{i*} + \xi_t^{i*}, \qquad \xi_t^{i*} \overset{\text{iid}}{\sim} \mathcal{N}(0, \sigma^2_{\xi^{i*}}) \tag{A39}$$

Foreign inflation

$$\pi_t^* = \rho^{\pi*} \pi_{t-1}^* + \nu_t^{\pi*}, \tag{A40}$$

$$\nu_t^{\pi*} = \rho^{\nu\pi*} \nu_{t-1}^{\pi*} + \xi_t^{\pi*}, \qquad \xi_t^{\pi*} \overset{\text{iid}}{\sim} \mathcal{N}(0, \sigma^2_{\xi^{\pi*}}) \tag{A41}$$

Risk premium

$$\rho_t^{embi} = \rho^{embi} \rho_{t-1}^{embi} + \nu_t^{embi}, \tag{A42}$$

$$\nu_t^{embi} = \rho^{\nu\rho embi} \nu_t^{embi} + \xi_t^{embi}, \qquad \xi_t^{embi} \overset{\text{iid}}{\sim} \mathcal{N}(0, \sigma^2_{\xi^{embi}}) \tag{A43}$$