The Art and Science of Monetary and Fiscal Policies in Chile

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The Art and Science of Monetary and Fiscal Policies in Chile*

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Abstract

There is consensus that Chile has made substantial progress in its macroeconomic policies during the last 30 years. However, there is no comprehensive and formal quantification of the macroeconomic stabilization gains in terms of the critical dimensions in the conduct of monetary and fiscal policies. In this work, we make an effort to quantify these gains using a structural model that incorporates essential features of the Chilean economy, disentangling the role of changes in policies and shocks in shaping the business cycles. We pay particular attention to two simultaneous and significant policy regime changes. In 2000, Chile moved from a managed exchange rate regime to a floating one coupled with flexible inflation targeting. On fiscal, policy shifted to a more countercyclical budget, changing a the-facto nominal target for a structural one. Policies also deviated from their implicit rules in the old and the new regimes—the "art" policy component. Fitting the model to the Chilean data through Bayesian techniques in the period 1990-2015, we find that a flexible exchange rate regime and a countercyclical fiscal rule enhance each other in terms of lowering macroeconomic volatility, especially those arising from commodity prices and other critical economic shocks. Together, the monetary and budgetary reforms attenuated both GDP and inflation's volatility considerably in 2000-2015 (compared to the counterfactual based on the 90's policies). The art part also contributed substantially to lowering macro volatility, especially fiscal policy deviations on GDP volatility. For the 90s, the counterfactuals using the new policy framework also show lower volatility and an even more relevant role for policy deviations.

Keywords: DSGE Model, Fiscal and Monetary Policies, Macroeconomic stabilization, Chile.
JEL codes: C54, E32, E37, E52, E62, F41.

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1 Introduction

It is widely acknowledged that Chile has made significant progress in its macroeconomic policies over the past 30 years. In 1990, Chile was struggling with soaring inflation of 25% and a debt-to-GDP ratio of 50%, but by 2008, it had brought debt-to-GDP ratio down to less than 5% and, during 2001-2019, inflation averaged 3.2% with minor deviations. This achievement is particularly impressive considering that Chile is a small, open, and Latin American economy, which makes it more susceptible to external market forces, especially if it heavily relies on commodity exports. What institutional changes could have accounted for this "economic miracle"? We believe that significant contributions came from the macroeconomic reforms implemented at the turn of the millennium. In 2000, Chile moved from a managed exchange rate regime to a floating one with flexible inflation targeting. On the fiscal side, the policy shifted towards a more countercyclical budget, replacing the *de facto* nominal target with a structural one.

As far as our literature review indicates, there is no comprehensive and formal quantification of the macroeconomic stabilization gains in terms of the critical dimensions in the conduct of monetary and fiscal policies. In this work, we make an effort to quantify these gains. Our novel framework allows us to distinguish three main components to assess the effectiveness of the reforms in reducing macroeconomic volatility. To analyze the contribution of the reforms, it is necessary to identify and pinpoint the impact of i) external shocks, ii) the systematic behavior of macroeconomic policies, and iii) deviations from implicit policy rules. We denote the systematic behavior as the *science* of policies, whereas the deviations from these systematic rules as the *art* of policies. In this study, we strive to quantify these gains using a structural model that incorporates critical features of the Chilean economy, isolating the role of policy changes and shocks in shaping business cycles. By fitting the model to Chilean data through Bayesian techniques between 1990 and 2015, we find that a flexible exchange rate regime and a countercyclical fiscal rule complement each other in reducing macroeconomic volatility, particularly those stemming from commodity prices and other critical economic shocks. Together, monetary and fiscal reforms significantly reduced both GDP and inflation volatility between 2000 and 2015 (compared to the counterfactual based on the policies of the 1990s). The art component also contributed significantly to reducing macroeconomic volatility, particularly the effect of fiscal policy deviations on GDP volatility. When using the new policy framework, the counterfactuals for the 1990s show lower volatility and an even more substantial role for policy deviations.

The rest of this manuscript is organized as follows. The next section provides a literature review of the main research that is related to our work. Section 3 makes a brief description of the main aspects of fiscal and monetary policy in Chile since 1990. Section 4 presents a DSGE model to characterize business cycle in Chile and with special focus on the evolution on the fiscal and monetary policies. The procedure to select the value of the parameters of the model is discussed in section 5. Section 6 shows the macroeconomic responses to several key shocks under the different policy rules in place during the 1990s and 2000s in Chile in order to understand the role of policies in these responses. The main quantification of the changes in macroeconomic volatility attributed to changes in policy rules and policy shocks is presented in section 7. In that section, we also perform several robustness checks of this quantification. Finally, section 8 concludes.

2 Literature Review

When considering the stabilization of the business cycle in response to external shocks, macroeconomists typically consider a combination of monetary and fiscal policies. However, there is an ongoing debate as to which type of policy is more effective, particularly in countries with higher levels of volatility. This is especially relevant for small and open economies, which are often more vulnerable to external market forces, especially if they rely heavily on commodity exports. As a result, it can be challenging to differentiate between whether high inflation or GDP volatility is due to external factors, such as commodity shocks, or the systematic effects of national economic policies, such as poor fiscal or monetary policy.

Several authors (Bernanke et al. (1997), Stock and Watson (2002), Blanchard and Gali (2009) and Benati and Surico (2009)) have examined the impact of monetary policy on the stabilization of business cycles. Using a Structural Vector Autoregressive (SVAR) approach, they have shown that monetary policy can be an effective tool for countries to attenuate external shocks. However, the SVAR methodology has some limitations. It cannot analyze simultaneous changes in main macroeconomic policies or provide external validity in counterfactual scenarios due to the Lucas critique. Therefore, some researchers have turned to Structural Dynamic Stochastic General Equilibrium (DSGE) models to evaluate policy contributions. This approach coincided with the "Great Moderation" of the first decade of the 21st century, during which macroeconomists questioned whether reduced macroeconomic cycle volatility was due to "good luck" or better economic policies. Giannone et al. (2008) and Nakov and Pescatori (2010) found that changes in the propagation mechanism and better monetary policy were key factors in the reduction of GDP growth volatility in the U.S. Additionally, attenuation of Total Factor Productivity shocks explained about 57% of the reduced volatility in GDP growth.

On the fiscal side authors such as Pieschacón (2012), used a DSGE model to study the effectiveness of fiscal discipline in countries exposed to oil price shocks. The author found that a fiscal rules, precisely acyclical ones, can significantly help isolate exogenous shocks. Similarly, Garcia et al. (2011) analyzed the impact of a counter-cyclical fiscal rule on different types of consumers facing external shocks. They found that the rule benefits unconstrained consumers, or those with full access to financial markets, but not non-Ricardian consumers, who spend their entire income within a specific time period. Other studies, such as Ojeda-Joya et al. (2016) and Kumhof and Laxton (2010), highlight the importance of counter-cyclical fiscal rules, especially in commodity-dependent emerging economies. Using a DSGE approach, these authors show that such rules can be particularly effective in stabilizing the business cycle in countries that are sensitive to commodity price shocks.

Additionally, authors like Frankel et al. (2013) and Céspedes and Velasco (2014) argue that, recently, developing economies and specially latinamerican ones have, *de facto*, improved their conduct on monetary and fiscal policies. Nonetheless there is still some strong preoccupation on the way countries should react to commodity boom-bust cycles and there is also a vast debate on how can these countries improve both fiscal and monetary rules.

Finally, it is important to acknowledge that several authors, such as Medina and Soto (2016), Fornero and Kirchner (2018), García et al. (2019) and Kumhof and Laxton (2010), have extensively worked with DSGE models tailored to the Chilean economy. However, to the best of our knowledge, none of them have investigated the following contribution.

Based on the previous review, we believe that our research makes three major contributions to the current state of the art literature. First, we use the Chilean case as a natural experiment for applying a well-established structural DSGE model, tailored to the Chilean economy. The above allow us to disentangle and identify the economic shocks ("luck"), systematic behavior of macroeconomic authorities (science) and deviations from implicit policy rules (art). This allows us not only to successfully estimate the contributions of the policy reforms but, more importantly, it also sheds light on the central debate surrounding the "great moderation" topic that tries to separate role of shocks and policies in affecting macroeconomic volatility. Second, we extend and complement the work in Medina and Soto (2016), Fornero and Kirchner (2018) and García et al. (2019) by explicitly modelling both monetary and fiscal policy behaviour before the adoption of a full inflation targeting regime and structural balance rule at the begining of 2000. This represents a significant contribution as it provides a robust benchmark for quantifying the role of policy rules and shocks in shaping the business cycle. Thirdly, we offer clear policy lessons for emerging that are pursuing macroeconomic stabilization policies, particularly those similar to the case of Chile.

3 A Brief History of Fiscal and Monetary Policy in Chile since 1990

Since 1990 Chile has had two distinct macroeconomic policy regimes. During the first decade, fiscal policy was tight on average but not especially countercyclical. Later, it followed a rule based on a structural result, becoming more countercyclical. During the nineties, monetary policy significantly lowered inflation using declining annual short run targets and a managed exchange rate to maintain a weak real exchange rate. In 2000, monetary authorities adopted a fully-fledged inflation-targeting regime and a floating exchange rate system. In this section we revisit what were the considerations and operations behind these decisions as well as a few key results. As it will become clear, the set of implicit policy functions were quite different between the two regimes.

Following a deep economic crisis in 1982-83, Chile had two consecutive and successful IMF-supported programs in 1984-89, with standard international reserves and domestic credit targets. After abandoning a fixed exchange rate regime in 1982, the new policy framework included a heavily managed exchange rate aim to keep a depreciated currency (to gain competitiveness and pay for substantial external liabilities). Fiscal policy was relatively tight until 1988 when the dictatorship expanded spending and cut taxes significantly in a failed attempt to win a referendum. Inflation, to some extent, was residual.

The first democratic government after the Pinochet regime took office in 1990 with enormous macroeconomic challenges. Inflation had accelerated from 11% in mid-1988 to 25% in early 1990. Although the debt-to-GDP ratio had declined in the previous three years, it stood above an uncomfortable 50%. Perhaps, more importantly, the government confronted a severe lack of confidence from the private sector. With several countries in the region suffering from populism and hyperinflation, the new center-left authorities needed to signal their commitment to a market economy and macroeconomic rectitude.

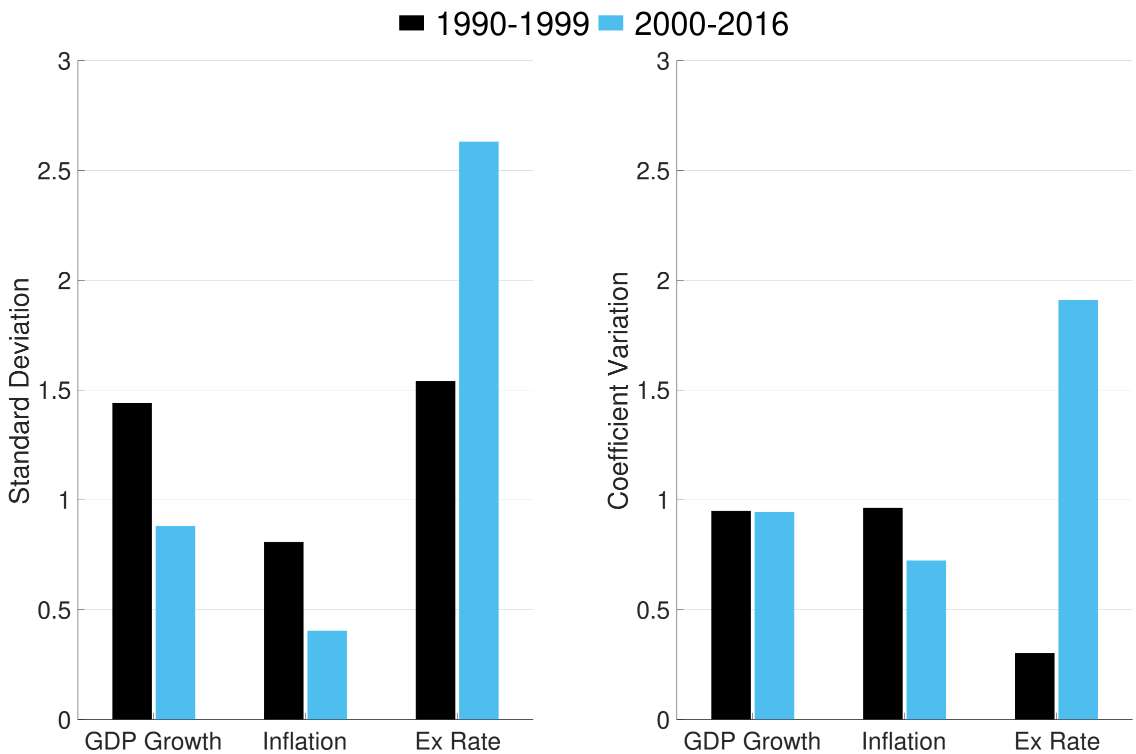

Figure 1: Standard Deviation and coefficient of variation for selected variables (1990-2016). Data source: Central Bank of Chile.

In this context, the government decided to continue opening up the economy to international trade, cutting import tariffs unilaterally. It also agreed with the opposition on tax increases to fund more social spending and with social partners to lower the indexation component of wage adjustments. Initially, the government also implemented a sizeable macroeconomic adjustment to contain double-digit economic growth in 1989. Macroeconomic performance in the first years of the transition to democracy was excellent, with high growth, lower inflation, and more robust fiscal accounts. In short, Chile continued firmly embracing the Washington Consensus, and the results were stellar in comparative terms. (Goldfajn et al. (2021)). Figure 1 illustrates the overall volatility from 1990-2016.

3.1 Fiscal policy

In the nineties, authorities did not offer an explicit fiscal rule but were clear that lowering sovereign debt was necessary for a stable macroeconomy. In practice, they spent a relatively stable share of annual revenues, thus acting similar to what a nominal fiscal rule would have accomplished. For eight years (1990-1997), the budget surplus fluctuated around 2% of GDP (see figure 2).

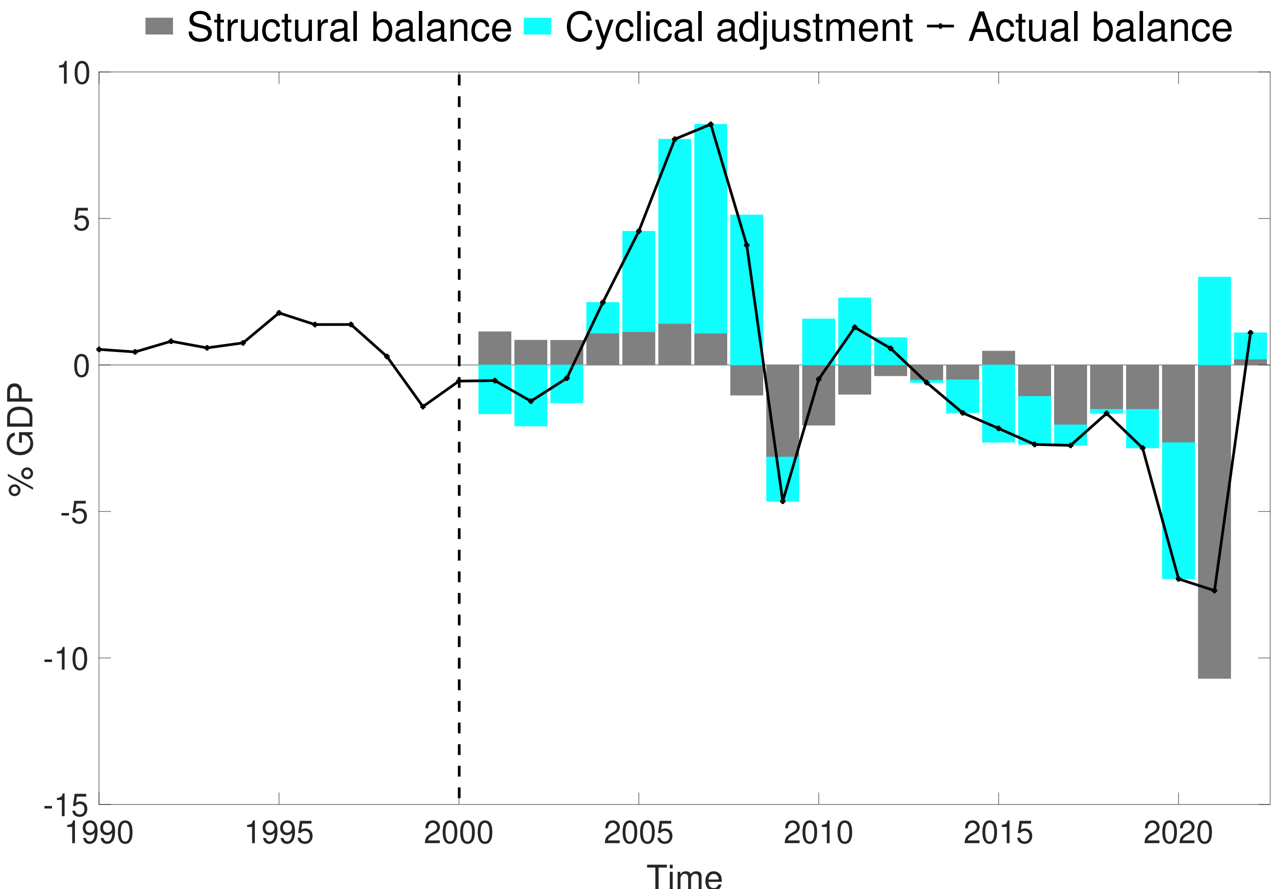

Figure 2: Fiscal Result - 1990/2022 - Chile. Source: DIPRES, Central Bank of Chile, Consejo Fiscal Autónomo (CFA, *Independent Fiscal Council*).

Although fiscal policy promoted macroeconomic stability —together with high economic growth, it implied a substantial decline of public debt to less than 30% of GDP in 1994— the implicit fiscal rule was not immune to amplify business cycle fluctuations. Subsequent economic accelerations pushed revenues and spending, and it was challenging to implement a clear countercyclical stance. The discussion between the Central Bank and the Treasury on how to rein-in domestic demand became apparent after terms of trade deteriorated amid the Asian Crisis in 1998-99 and was a clear example of the challenge; the fiscal authorities considered that having a budget surplus was enough and wanted tighter capital inflows controls to curb capital inflows. The monetary authorities, in turn, worried about the level of government spending. Ultimately, as revenues declined with lower copper prices and falling activity, authorities ceased to chase a nominal result and allowed for a large fiscal deficit.[1]

Having Chile suffered a larger-than-expected recession in 1999, there was a complete overhaul of the macroeconomic policy regime. On fiscal, a new government that took office in 2000 inaugurated a formal rule based on a structural balance surplus equivalent to 1%

[1]See Valdés (2009) for a description on the timing of the policy decisions.

of GDP (though it was just an announcement, not legislated). The objective was to have a less procyclical policy based on an easy-to-explain simple indicator. A structural measure would separate the effects of the economic cycle and "abnormal" copper prices (which is by far the main Chilean export and a relevant part of government revenues) and thus allow automatic stabilizers to work. Changes in the indicator would signal a proper change in the fiscal stance. In each budget, total spending would have to match projected structural revenues plus 1% of potential GDP.[2]

Operationally, the structural balance calculation needs long-term copper price and trend (level) GDP estimates. With these inputs, one can calculate the cyclical component of copper prices and economic output, which, together with proper elasticities, allows one to strip out the cyclical component of government income. Figure 2 describes the official structural result since 2000.

Throughout the next decade and a half, fiscal authorities followed this rule with minor changes in 2002 (mainly formalities around how to calculate structural parameters) and in 2008, when the government decided to cut the numerical target to a balanced structural budget. In 2009, after the global crisis, policy was de facto abandoned for a year. The results of implementing the new rule were impressive in the first few years: policy was in line with the 1% surplus target and public savings increased significantly with the copper price boom of 2005-2008 (with sizeable nominal budget surpluses). Later, in the years following the great global crisis of 2009, the fiscal result was on average in deficit (with an important increase in public debt, though less than the global average) and the fiscal stance was generally acyclical. There have been several proposals on how to improve the fiscal framework (e.g., Larraín et al. (2019)), but broadly continues to operate in the same way.

3.2 Monetary and Exchange Rate Policies

The Central Bank of Chile became independent at the end of 1989 when the ending dictatorship enacted its charter following an explicit mandate in the 1980 Constitution[3]. Its primary objective was achieving price stability while receiving strong protection against political pressures. In coordination with the Finance Ministry, the Bank adopted annual inflation targets announced every September for the following December's year-on-year inflation, initially as a broad range and then as a narrower one. Authorities progressively lowered these targets until 1999. Figure 3 illustrates the decline of targets and inflation itself. Three factors explain this achievement: robust productivity growth that lowered unit

[2]See Marcel et al. (2001) for the rationale and calculations of the structural result.

[3]Organic Constitutional Law (LOC). October 10, 1989 (Law No. 18,840).

labor costs, an effort to use targets instead of past inflation in the wage-setting process, and a gradual increase in Central Bank credibility (see De Gregorio (2003)).

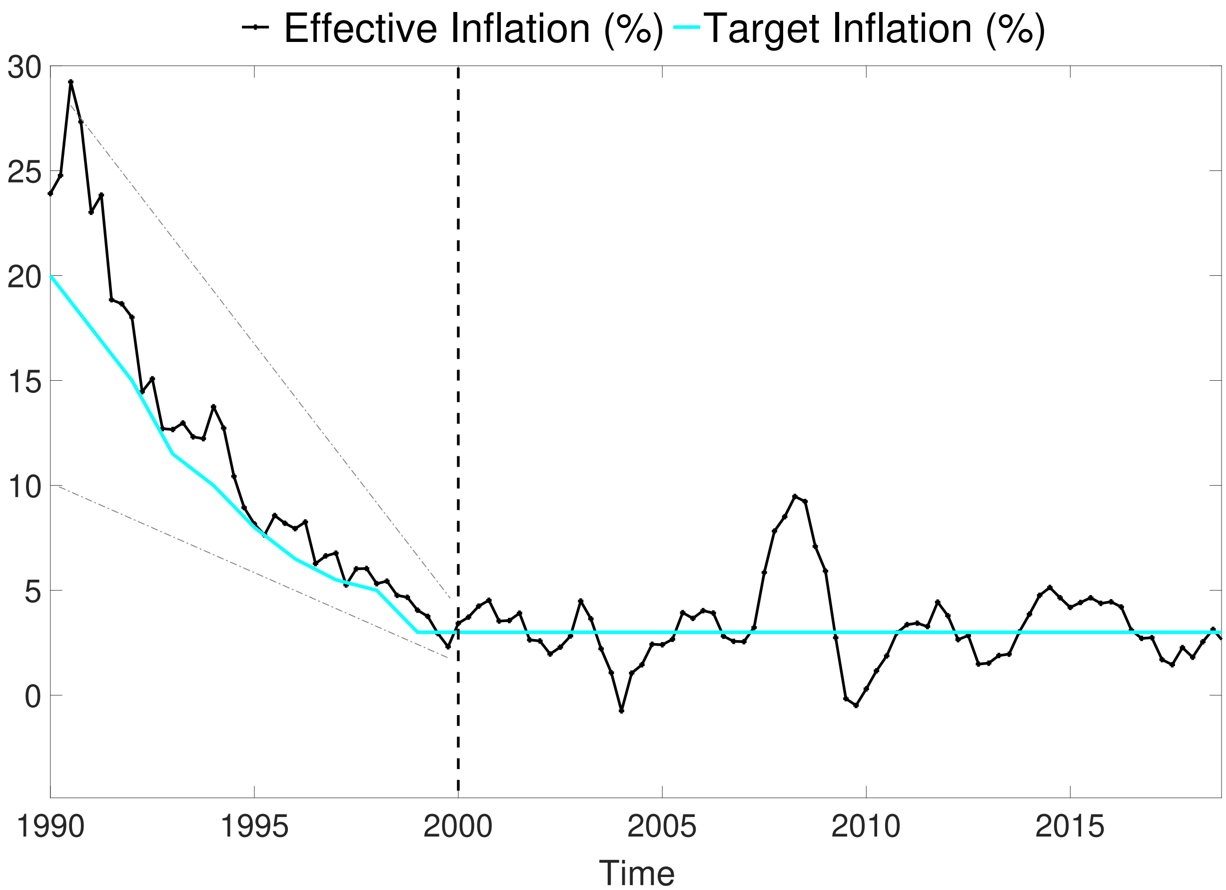

Figure 3: Inflation Target vs Effective - 1990Q1/2018Q4 - Chile. Source: Central Bank of Chile.

In contrast to the adoption of public targets for inflation, exchange rate policy (entirely in the hands of the Central Bank) continued based on a crawling band, as in the previous years with the IMF programs. The center of the band ("Dólar Acuerdo") crawled at a rate that compensated internal and external inflation differentials. Throughout the nineties, authorities modified the crawling band occasionally, including broadening it and adding an appreciation trend coefficient to reflect productivity gains. Figure 4 clearly illustrates the concern and effectiveness of the Central Bank on stabilizing the exchange rate around the crawling reference exchange rate. High domestic interest rates (to rein in domestic demand) and the exchange rate band produced arbitrage opportunities and pulled significant capital inflows. Authorities reacted by implementing capital controls of different sorts, but they were not particularly effective (De Gregorio et al. (2000)). Policy contradictions became increasingly apparent.

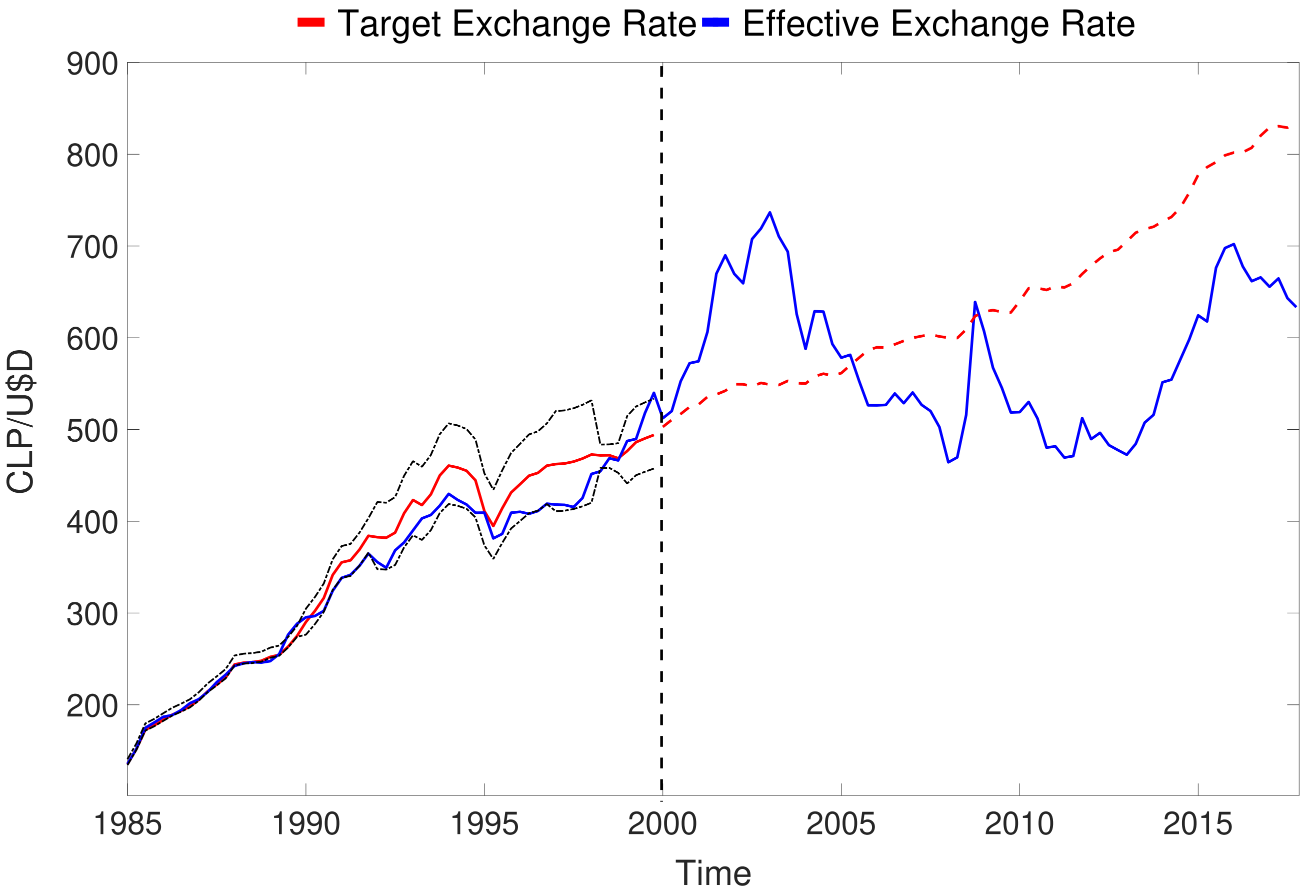

Figure 4: Target vs Effective Exchange Rate –1985Q1/2017Q4– Chile. Source: Central Bank of Chile.

As with Fiscal Policy, Monetary and Exchange Rate policies suffered a profound overhaul in 2000. Again, the policy reaction to the Asian crisis uncovered several problems: First, fear of floating pushed the Central Bank to an overly tight monetary policy. Although the exchange rate band was supposed to allow for some currency depreciation, authorities heavily intervened within the band, even with non-sterilized operations, producing a severe liquidity squeeze. Behind this fear, there were two elements. The Central Bank was concerned with private sector FX mismatches that could trigger financial problems. The view was that the managed exchange rate contained volatility and produced excess risk-taking. Also, there was an (incorrect) view that the FX pass-through to inflation was relatively high (see Valdés (2009)). Second, it became apparent that annual inflation targets were too rigid as a policy proposal, leaving little space to accommodate large external shocks. Thus, the policy framework changed significantly: In 2000, the Central Bank announced a permanent 2 to 4% inflation target and a fully floating exchange rate. In 2001 it also scrapped all the tools that allowed it to implement capital controls. This framework has been in place up to now. Figure 3 illustrates the effectiveness of the reform: average inflation was

3.2% between 2001 and 2019.

Operationally, the Central Bank chooses its policy instrument —a target for the overnight interbank interest rate— such that regardless of the current level of inflation, projected inflation over a two-year horizon is at 3%. In principle, this commitment guides the expectations of economic agents and transforms the inflation target at the nominal anchor of the economy. Authorities use standard monetary operations to achieve the desired interest rate level (see Central Bank of Chile, 2020 for further details).

4 The Model

The model is constructed upon previous studies such as Medina and Soto (2016), Adolfson et al. (2007), Altig et al. (2011), Christiano et al. (2005), and Smets and Wouters (2007). The main framework of the model is that it has two domestic sectors. The fist one creates differentiated goods that are both consumed nationally and exported internationally. The second one produces a commodity, in this specific case, copper and its output is completely exported to the international markets. The reason for developing this two-sector model is mainly due to the particularities of Chile as an small, open economy and significant commodity exporter of the world. This multi-sectorial model considers Fornero and Kirchner (2018) observations, where the mining investment (copper) has significant importance in the economy. In this model both sectors are characterized by having an endogenous decision of investment in (copper and non copper) capital, that is, capital is specific to each sector, which could also imply that the rental rate of capital is different in each sector. It is important to highlight such endogenous nature of the copper sector because it incorporates more transmission mechanisms in the economy. For example, in an endogenous mining sector, if a copper price shock occurred, there would be an increase on demand for resources from the home economy, channels that do not exist when the copper production is completely exogenous, thus affecting variables such as employment, wages, consumption and GDP. A share of the proceedings from copper production is owned by the government; the rest is owned by foreign investors. The model also considers several real and nominal rigidity's in addition to shock processes tailored to the Chilean economy. Moreover, in order to replicate an accurate representation of monetary and fiscal authorities behaviour over time, we characterize the specific monetary and fiscal rules to both periods we are analyzing. We now describe the different agents and markets that compound the model economy.

4.1 Households

The domestic economy is inhabited by a continuum of households indexed by $j \in [0,1]$. The expected present value of the utility of household j is given by

$$U_t(j) = E_t \left\{ \sum_{i=0}^{\infty} \beta^i \varphi_{C,t} \left(\frac{\left[C_{t+i}(j) - hH_{t+i}\right]^{\frac{\sigma_C - 1}{\sigma_C}}}{1 - 1/\sigma_C} - \zeta_L \frac{l_{t+i}(j)^{1+\sigma_L}}{1+\sigma_L} + \frac{\zeta_{\mathcal{M}}}{\mu} \left(\frac{\mathcal{M}_{t+i}(j)}{P_{C,t+i}} \right)^{\mu} \right) \right\}, \tag{1}$$

where $C_t(j)$ is a consumption of household j, and $l_t(j)$ is her/his labor effort. Additionally $\mathcal{M}_t(j)$ corresponds to nominal money balances held at the beginning of period t by household j.[4] β is the subjective discount factor and $\varphi_{C,t}$ is preference shock that is included to model a demand shock in consumption. This preference shock follows an autoregressive process of order one, with persistence given by $\rho_{\varphi_C} \in (0,1)$ and identical and identically distributed (i.i.d.) innovations $\varepsilon_{\varphi_C,t}$ with zero mean and variance equal to $\sigma^2_{\varphi_C}$. Parameters σ_C and σ_L are the intertemporal elasticity of substitution for consumption and the inverse elasticity of labor supply with respect to real wages, respectively. Parameter ζ_L controls the disutility of working. We also consider that the preferences display habit formation, where the external habit is presented as $H_t = C_{t-1}$ and the parameter h controls the intensity of habit formation. C_t is the aggregate per capita consumption in period t.

The consumption bundle for each household is a CES aggregator that includes domestically produced goods (home goods) and imported goods (foreign goods):

$$C_t(j) = \left[\gamma_C^{\frac{1}{\eta_C}} C_{H,t}(j)^{\frac{\eta_C - 1}{\eta_C}} + (1-\gamma_C)^{\frac{1}{\eta_C}} C_{F,t}(j)^{\frac{\eta_C - 1}{\eta_C}} \right]^{\frac{\eta_C}{\eta_C - 1}}, \tag{2}$$

$C_H(j)$ and $C_F(j)$ represent the domestic and imported goods consumed by household j, respectively. Parameters γ_C and η_C are the share of domestic goods in the consumption basket and the elasticity of substitution between domestic and foreign consumption goods, respectively. Each household purchases a composite of domestic and imported goods in period t in order to minimize the total cost of its consumption basket. Therefore, each household minimizes $P_{H,t}C_{H,t}(j) + P_{F,t}C_{F,t}(j)$, subject to (2), where $P_{H,t}$ and $P_{F,t}$ are the prices of domestic and imported goods sold domestically, respectively. Hence, the demand for domestic and imported goods for household j is given by:

$$C_{H,t}(j) = \gamma_C \left(\frac{P_{H,t}}{P_{C,t}} \right)^{-\eta_C} C_t(j), \; C_{F,t}(j) = (1-\gamma_C) \left(\frac{P_{F,t}}{P_{C,t}} \right)^{-\eta_C} C_t(j)$$

[4]The separability of money balance and having the short-term interest rate as the monetary policy instrument imply that in the equilibrium conditions we can abstract of the money supply.

4.2 Budget constraint and consumption-savings decisions

In order to include the possibility of amplification effects of fiscal impulse we assume there are two type of households: (1) Ricardian and (2) non-Ricardian households. This approach is similar to Galí et al (2007) who incorporate this possibility in order to generate a rise in aggregate consumption in response to an increase in government spending as the empirical evidence suggests. This possibility is captured for the presence of Non-Ricardian Households, who cannot smooth consumption intertemporally since they are unable to have access to the capital markets, implying that a change in their labor income induces more closely a change in consumption. In contrast, Ricardian households do have full access to capital markets, thus hey are able to smooth their consumption interteporally. Formally, we assume that households $j \in [0, \lambda]$ are non-Ricardian households and households $j \in (\lambda, 1]$ are Ricardian households in the economy.

Ricardian households. These households have access to three different types of assets: (1) money $\mathcal{M}_t(j)$, (2) one-period non-contingent foreign bonds (denominated in foreign currency) $B^*_{P,t}(j)$ and (3) one-period domestic contingent bonds $d_{t+1}(j)$ which pays out one unit of domestic currency in a particular state. We assume that there are no adjustment costs in the portfolio composition of domestic assets. Nonetheless, each time a domestic household borrows from abroad it must pay a premium over the international price of external bonds. This premium is introduced in the model to obtain a well defined dynamics around the steady state of the economy. Therefore, the household budget constraint is given by:

$$P_{C,t}C_t(j) + E_t[q_{t,t+1}d_{t+1}(j)] + \frac{\mathcal{E}_t B^*_{P,t}(j)}{(1+i^*_t)\Theta\left(\frac{\mathcal{E}_t B^*_t}{P_{Y,t}Y_t}\right)} + \mathcal{M}_t(j) = W_t(j)l_t(j) + \Pi_t(j) - T_{P,t} + d_t(j) + \mathcal{E}_t B^*_{P,t-1}(j) + \mathcal{M}_{t-1}(j), \quad (3)$$

where $\Theta(.)$ represents the premium domestic households have to pay each time they borrow from abroad which, in equilibrium, depends on the ratio of net foreign asset position of the country to GDP, where B^*_t is the aggregate net foreign asset position of the economy and $P_{Y,t}Y_t$ is the nominal GDP. Moreover, $\mathcal{E}_t$ is the nominal exchange rate, $T_{P,t}$ are per capita net taxes, $W_t(j)$ is the nominal wage set by household j and $\Pi_t(j)$ are profits received from domestic firms. Finally, variable $q_{t,t+1}$ is the period t price of domestic contingent bonds normalized by the probability of the occurrence of a particular state. The relevant foreign interest rate is given by:

$$1 + i^*_t = R^{FED}_t \varsigma^{EMBI}_t \xi_t,$$

where R_t^{FED} is the gross interest rate from the Federal Reserve Bank in US, ς_t^{EMBI} is the sovereign country spread (EMBI), and ξ_t^* is an additional unobservable exchange rate shock. Theses three variables are modelled as exogenous AR(1) processes:

$$\log\left(R_t^{FED}/\bar{R}^{FED}\right) = \rho_{r^*}\log\left(R_{t-1}^{FED}/\bar{R}^{FED}\right) + \varepsilon_{r^*,t} \tag{4}$$

$$\log\left(\xi_t/\bar{\xi}\right) = \rho_{\xi}\log\left(\xi_{t-1}/\bar{\xi}\right) + \varepsilon_{\xi,t} \tag{5}$$

$$\log\left(\varsigma_t^{EMBI}/\bar{\varsigma}^{EMBI}\right) = \rho_{embi}\log\left(\varsigma_{t-1}^{EMBI}/\bar{\varsigma}^{EMBI}\right) + \varepsilon_{embi,t} \tag{6}$$

where $\bar{x}$ denotes the steady state value for variables x, and $\varepsilon_{x,t}$ is an i.i.d. shock with zero mean and variance σ_x^2. Ricardian households choose consumption and the composition of their portfolios by maximizing equation (1) subject to (3). Due to the fact that we are assuming the existence of a complete set of contingent claims, consumption is equalized across Ricardian households.

Non-Ricardian households. As stated previously, these households are characterized by having no access to the capital market and own no share in domestic firms. Hence, they must consume completely their disposable labor income, period by period:

$$P_{C,t}C_t\left(j\right) = W_t(j)l_t\left(j\right) - T_{P,t}, \tag{7}$$

where $j \in [0, \lambda]$.

4.3 Labor supply and wage setting

Each household j is a monopolistic supplier of a differentiated labor service. There is a set of perfect competitive labor service assemblers that hire labor from each household and combine it into an aggregate labor service unit, l_t, that is then used by the intermediate goods producer. The labor service unit is defined as:

$$l_t = \left(\int_0^1 l_t(j)^{\frac{\epsilon_L - 1}{\epsilon_L}} dj\right)^{\frac{\epsilon_L}{\epsilon_L - 1}} \tag{8}$$

where $l_t(j)$ corresponds to the labor supply of household and and ϵ_L is the elasticity of substitution of the household labor supply. Minimizing costs (given the different wages set by different households) we can find the optimal composition of this labor service unit. Thus, the demand for the labor service provided by household j is:

$$l_t(j) = \left(\frac{W_t\left(j\right)}{W_t}\right)^{-\epsilon_L} l_t, \tag{9}$$

where $W_t(j)$ is the wage rate set by household j and W_t is an aggregate wage index defined as $W_t = \left(\int_0^1 W_t(j)^{1-\epsilon_L} dj\right)^{\frac{1}{1-\epsilon_L}}$.

As in Erceg *et al* (2000), we assume that wage setting is subject to a nominal rigidity à la Calvo (1983). The previous means that, in each period, each type of household faces a constant probability $(1-\phi_L)$ of being able to re-optimize its nominal wage. Moreover, we assume there is an "passive" updating rule for all those households that cannot re-optimize their wages. This "passive" updating rule states that: workers who do not optimally reset their wages update them by considering a geometric weighted average of past CPI inflation and the inflation target set by the authority, $\overline{\pi}_t$, where ξ_L is the weight to past inflation. Also, this "passive" rule considers the productivity growth rate in order to avoid a divergent real wage dispersion along the steady state growth path. Once a household has decided a wage, it must supply any quantity of labor service that is demanded at that wage.

For simplicity we assume that non-Ricardian households set wages equal to the average wage set by Ricardian households. Given the labor demand for each type of labor, this assumption implies that labor effort of non-Ricardian households coincides with the average labor effort by Ricardian households.

4.4 Investment and capital goods

Capital used for the production of non-commodities domestic goods and commodities goods is sector specific. This assumption is meant to capture some realism regarding that infrastructures and equipment used in one sector are hard to re-allocate in the other sector. Accordingly, the evolution of capital in each sector is given by:

$$K_{t+1}^J = (1-\delta) K_t^J + S\left(\frac{I_t^J}{I_{t-1}^J}\right) I_t^J. \tag{10}$$

where K_t^J is the capital stock in sector J and I_t^J is investment in new capital goods in sector J, with $J = H$ for the non-commodity sector and $J = CO$ for the commodity sector. δ is the capital depreciation rate, which we assume is the same in both sectors. We also consider costs of adjustment of the investment such that one unit of investment generates $S\left(\frac{I_t^J}{I_{t-1}^J}\right) I_t^J$ units of capital in the sector J. The presence of a delay in this function of costs captures inertia in investment decisions and is an approximation of the time to build the phenomenon observed for the investment decisions.

There is a representative capital producer in each sector that maximizes the present value of renting specific capital in each sector net of the cost of investment in new capital goods:

$$\max_{K_{t+i}^J, I_{t+i}^J} E_t \left\{ \sum_{i=0}^{\infty} \Lambda_{t,t+i} \frac{\left[Z_{t+i}^J K_{t+i}^J - P_{I,t+i} I_{t+i}^J\right]}{P_{C,t+i}} \right\}, \tag{11}$$

subject to (10) and where $\Lambda_{t,t+i}$ is the stochastic discount factor between periods t and $t+i$, Z_t^J is the rental rate of capital in sector $J = H, CO$ and $P_{I,t}$ is the price of investment goods. The investment good in each sector is a composition of domestic non-commodity goods and foreign goods, following a typical CES aggregator:

$$I_t^J = \left[\gamma_I^{\frac{1}{\eta_I}} (I_{H,t}^J)^{\frac{\eta_I - 1}{\eta_I}} + (1-\gamma_I)^{\frac{1}{\eta_I}} (I_{F,t}^J)^{\frac{\eta_I - 1}{\eta_I}} \right]^{\frac{\eta_I}{\eta_I - 1}}, \tag{12}$$

where η_I represents the elasticity of substitution between non-commodity domestic and foreign goods, and γ_I is the share of domestic non-commodity domestic goods in investment. Minimizing the cost of the investment basket in sector J, $P_{H,t} I_{H,t}^J + P_{F,t} I_{F,t}^J$, subject to (12), we obtain the investment demand functions for $I_{H,t}^J$ and $I_{F,t}^J$.

4.5 Domestic production of non-commodities

This sector consists basically of two types of firms. One type of firms are producers of differentiated intermediate goods while the second type of firms assemble the differentiated intermediate goods to sell them in the domestic and foreign markets. The first type of firm produces differentiated goods with capital and labor. These firms have monopoly power and face a nominal rigidity that prevents them to adjust optimally prices every period. The second type of firms that assembles differentiated take prices as given and behaves competitively.

4.5.1 Assembly of intermediate goods

Considering first the assemblers of intermediate goods. These firms sell different final goods both in the domestic and foreign markets. Formally, in order to produce $Y_{H,t}$ units of non-commodity home goods, they combine domestically produced intermediate varieties by using the following aggregation:

$$Y_{H,t} = \left[\int_0^1 Y_{H,t}(z_H)^{\frac{\epsilon_H - 1}{\epsilon_H}} dz_H \right]^{\frac{\epsilon_H}{\epsilon_H - 1}}, \tag{13}$$

where $Y_{H,t}(z_H)$ represents the of intermediate variety (z_H) and ϵ_H is the elasticity of substitution among varieties.

4.5.2 Producers of intermediate goods

As stated previously, the production of intermediate goods is characterized by firms that act as a monopoly in the production of a single variety. It is in the nature of the previous to differentiate their production to be used by assemblers. Therefore, each firm maximizes profits by choosing the price of its variety subject to the available technology for production. The technology available to produce the variety z_H of non-commodity home goods is given by

$$Y_{H,t}(z_H) = A_{H,t} \left(l_t(z_H)\right)^{\alpha_H} \left(K_t(z_H)\right)^{1-\alpha_H}, \tag{14}$$

where $A_{H,t}$ represents a productivity shock (which is common to all firms in this sector) and follows an autoregressive process in log-linear form:

$$\log\left(A_{H,t}/\bar{A}_H\right) = \rho_{A_H} \log\left(A_{H,t-1}/\bar{A}_H\right) + \varepsilon_{A_H,t}, \tag{15}$$

where $\bar{A}_H$ is the steady state value for the productivity $A_{H,t}$, ρ_{A_H} is the persistence of the productivity shock in this sector and $\varepsilon_{A_H,t}$ is independent and identically distributed (iid) innovation with zero mean and variance equal to $\sigma^2_{A_H}$. In the production function above, endogenous variables $K_t(z_H)$ and $l_t(z_H)$ represent the amount of physical capital rented and the amount of labor used, respectively. Finally, parameter α_H represents the share of labor services in production. Since the technology has constant return to scale, firms determine the optimal mix of factors by minimizing total cost of production, subject to the constraint imposed by the technology.

We assume that price has nominal rigidities following the approach proposed by Calvo (1983). Thus, firms adjust their prices infrequently and they do so when receiving a signal. The previous works as it follows: In every period the probability of receiving a signal and adjusting optimally their prices is $1-\phi_H$ for all firms, independently of their history. Hence, the chance of receiving this signal is equal for all firms, and independent of their history and from the event of adjusting optimally prices in the domestic market. Moreover, we also assume that a firm that does not receive any type of signal will update its prices following a simple "passive" updating rules based on a weighting average between past inflation and the inflation target. In this passive rule, the weight of past inflation is $\chi_H \in (0,1)$ and the weight of the inflation target is $1-\chi_H$. In order to consider internal inflationary shocks, we assume an exogenous mark-up shock $\zeta_{\pi,t}$ with persistence ρ_{ζ_π} and i.i.d. innovations with zero mean and variance equal to $\sigma^2_{\zeta_\pi}$.

4.6 Import goods retailers

Considering now the import sector. The previous consists of a continuum of firms that buy a homogeneous good in the foreign market. These firms operate by turning the importer good into a differentiated import.[5] Later on, the competitive assemblers combine this (continuum of differentiated) imports in a final import good $Y_{F,t}$. The technology of importing assemblers, similar to the ones describer earlier, is given by:

[5]This differentiating technology can be interpreted as brand naming.

$$Y_{F,t} = \left[\int_0^1 Y_{F,t}(z_F)^{\frac{\epsilon_F - 1}{\epsilon_F}} dz_F \right]^{\frac{\epsilon_F}{\epsilon_F - 1}}, \tag{16}$$

where $Y_{F,t}(z_F)$ is the quantity of a differentiated import z_F used by the assemblers and ϵ_F is the elasticity of substitution among differentiated imported goods.

It is important to state that each different importing firm posses monopoly power over the domestic retailing of that variety. Also, the different importing firms buy the homogeneous foreign good at price P_t^* abroad in foreign currency. Moreover, we assume local currency price stickiness. The latter is done in order to allow for incomplete exchange rate pass-through to the import prices. Analogously as the previous subsection, a different importing firm adjusts the domestic price of its variety infrequently, when receiving a signal. The signal arrives with probability $1 - \phi_F$ each period. As in the case of domestically produced goods, if a firm does not receive a signal, it updates its price following a "passive" rule based on a weighting average between past inflation with a weight χ_F and the inflation target with weight $1 - \chi_F$. Equivalent to the non-commodity domestic sector, we assume the presence of the same exogenous mark-up shock $\zeta_{\pi,t}$.

4.7 Commodity production and the foreign sector

In the case of Chile, the commodity sector consists of the copper production. The firms in this sector takes the international price of the commodity as given. All production is completely exported to the rest of the world at the given international price. The production of copper uses capital as its only endogenous factor[6]. Assuming an endogenous commodity production is different to Medina and Soto (2016), who consider an exogenous endowment for commodity (copper) production for Chile. Having capital and investment is this sector enables the model to better capture the some aspects of the investment boom experienced in Chile after 2010, which it was attributed partially to the copper price boom 2010-2014 (see Fornero and Kirchner (2018)). Formally, total copper production has the following technology:

$$Y_{CO,t} = (A_{CO,t})^{1-\alpha_{CO}} (K_{CO,t-1})^{\alpha_{CO}}, \tag{17}$$

where parameter α_{CO} corresponds to the share of capital in the commodity production, $A_{CO,t}$ captures a transitory (although very persistent) productivity of the sector in terms of technology and quality of the available natural resources. We will assume that the productivity follows a stochastic autoregressive process of order 1 (in log-linear form):

$$\log\left(A_{CO,t}/\bar{A}_{CO}\right) = \rho A_{CO} \log\left(A_{CO,t-1}/\bar{A}_{CO}\right) + \varepsilon_{CO,t} \tag{18}$$

[6]The labor used in the copper sector is very small thus, for simplicity, we omit it in the model.

where $barA_{CO}$ is the long-run value for the productivity $A_{CO,t}$, ρ_{CO} is the persistence of this productivity in the commodity sector, and $\varepsilon_{CO,t}$ is iid shock with zero mean and variance $\sigma_{A_{CO}}$. Profits of copper sector firms can be written as:

$$\Pi_{CO,t} = P_{CO,t} Y_{CO,t} - Z_t^{CO} K_{CO,t-1} \tag{19}$$

Foreign agents demand the commodity good and domestic goods assembled by the intermediaries. The demand for the commodity good is completely elastic at the price $P^*_{CO,t}$. Thus, the law of one price holds for this good. Therefore, the domestic currency price of the commodity is given by,

$$P_{CO,t} = \mathcal{E}_t P^*_{CO,t}, \tag{20}$$

We assumed that the log-deviation of the real price copper (price of copper deflated by the foreign price level) can be represented as an AR(1) process,

$$\log\left(P^*_{CO,t}/P^*_t\right) = \rho_{P_{CO}} \log\left(P^*_{CO,t-1}/P^*_{t-1}\right) + \varepsilon_{P_{CO},t} \tag{21}$$

where ρ_{P_CO} is the persistence of the copper price shock and $\varepsilon_{P_{CO},t}$ is an i.i.d. innovation with zero mean and variance of $\sigma^2_{P_{CO}}$. The foreign inflation also follows an autoregressive process of order 1 (in log-linear form):

$$\log\left(P^*_t/P^*_{t-1}\right) = (1-\rho_{\pi^*})\log\left(1+\bar{\pi}^*\right) + \rho_{\pi^*}\log\left(P^*_{t-1}/P^*_{t-2}\right) + \varepsilon_{\pi^*,t} \tag{22}$$

where ρ_{π^*} corresponds to the persistence of the foreign inflation shocks, $\bar{\pi}^*$ is the steady state value of foreign inflation, and $\varepsilon_{\pi^*,t}$ is an i.i.d. innovation with zero mean and variance of $\sigma^2_{\pi^*}$.

The real exchange rate is defined as the relative price of a foreign price level and the price of a consumption basket in the domestic economy:

$$RER_t = \frac{\mathcal{E}_t P^*_t}{P_{C,t}}. \tag{23}$$

The demand for the rest of world for non-commodity Home goods:

$$C^*_{H,t} = \left(C^*_{H,t-1}\right)^{h^*} \left(Y^*_t \left(\frac{P_{H,t}}{\mathcal{E}_t P^*_t}\right)^{-\eta^*}\right)^{(1-h^*)} \tag{24}$$

where Y^*_t is the relevant foreign demand for Chile (e.g. GDP of the trading partners), α^* is a constant, h^* is an inertia coefficient for the external demand for non-commodity goods, and η^* is the elasticity of substitution between non-commodity Home goods and foreign goods in external demand. The foreign demand for Chile also follows an autoregressive process:

$$\log\left(Y_t^*\right) = (1-\rho_{Y^*})\log\left(\bar{Y}^*\right) + \rho_{Y^*}\log\left(Y_{t-1}^*\right) + \varepsilon_{Y^*,t}. \tag{25}$$

As in previous external shocks, $\bar{Y}^*$ is the steady state value for foreign demand, ρ_{Y^*} is the persistence of foreign demand shocks, and $\varepsilon_{Y^*,t}$ is an i.i.d. innovation with zero mean and variance given by $\sigma_{Y^*}^2$.

4.8 Monetary and Fiscal Policies

As described previously, Chile experienced a substantial change in its frameworks to conduct monetary and fiscal policies around 2000. In order to characterize the systematic behavior of monetary and fiscal policies, we model them as rules, which would represent the "science" dimension. Deviations with respect to these rules will be considered as the discretionary part of the policies and we denominate as "art" component of policies when we take the model to the Chilean data. We first describe the case of the monetary policy and then the case of fiscal policy.

Monetary Policy. Recalling what is detailed in section 3, the monetary policy in Chile was modified at the end 1999. In synthesis, monetary policy during the 1990s was characterized by a partial inflation targeting regime with a manage exchange rate. At the end of 1999, the central bank allow the exchange rate to float and implement a full-fledged inflation targeting regime. Typically, an inflation targeting regime is described by a Taylor-type rule that uses the short-term interest rate as the policy variable that aims to stabilize the inflation around its target and the GDP around its trend growth path. Hence, we use a Taylor-type rule to characterize the monetary policy during 1990s and since 2000[7]

In consequence, for the period 1990-1999 the monetary policy rule is characterized by a Taylor rule augmented for the presence of a role for the stabilization of the exchange rate. Importantly, the monetary policy instrument was the short-term real interest rate during the 1990s.[8] Formally, the monetary policy rule for the 1990s is given by:

$$\frac{1+r_t}{1+\bar{r}} = \left(\frac{1+r_{t-1}}{1+\bar{r}}\right)^{\varphi_i}\left(\frac{P_{C,t}}{P_{C,t-1}}\frac{1}{1+\bar{\pi}_t}\right)^{(1-\varphi_i)(\varphi_\pi-1)}\left(\frac{Y_t/Y_{t-4}}{\overline{Y}_t/\overline{Y}_{t-4}}\right)^{(1-\varphi_i)\varphi_{dy}}\left(\frac{\mathcal{E}_t/\mathcal{E}_t^a}{\mathcal{E}_{t-1}/\mathcal{E}_{t-1}^a}\right)^{(1-\varphi_i)\tau_m}\exp\left(\varepsilon_{m,t}\right), \tag{26}$$

where r_t is the short-term interest rate indexed to the past inflation (interest rate in UF), $\bar{\pi}_t$ is the time-varying inflation target during the 1990s, Y_t is total GDP, $\overline{Y}_t$ is the trend

[7]See, for example, Cespedes and Soto (2007) for an estimation of Taylor-type rules for Chile since 1990.

[8]For details of the use of the short-term interest rate indexed to the inflation during the 1990s in Chile see, for example, Valdés (1998).

for total GDP, and $\mathcal{E}_t^a$ is the center of the exchange rate band that operated during the 1990s. $\bar{r}$ is the steady state value for short-term real interest rate and $\varepsilon_{m,t}$ is iid deviation of the monetary policy with respect to the rule with zero mean and variance σ_m^2. This rule implies that interest rate adjusts in response to deviations inflation from the inflation target and GDP annual growth with respect to its trend with a degree of smoothing (coefficient φ_i), which it is standard in inflation targeting regime. However, this rule also includes a stabilization of the exchange rate, which captures the presence of exchange rate band during the 1990s that affects setting the short-term interest rate. Coefficients $\varphi_\pi - 1$, φ_{dy}, τ_m are the weights in the rule of the stabilization for inflation, GDP growth, and the exchange rate, respectively. Notice that the reaction to inflation is $\varphi_\pi - 1$ since the interest rate is expressed in real terms, so that with a nominal interest rate the weight for the stabilization of inflation will be approximately φ_π.

The monetary policy abandoned the exchange rate band at the end of 1999 and allowed the exchange rate to float freely combined with a full inflation targeting regime. At the same time, in 2001 the monetary policy "nominalized" the interest rate. Accordingly, the monetary policy rule since 2000 is modelled as:

$$\frac{1+i_t}{1+\bar{i}} = \left(\frac{1+i_{t-1}}{1+\bar{i}}\right)^{\varphi_i} \left(\frac{P_{C,t}}{P_{C,t-1}}\frac{1}{1+\overline{\pi}_t}\right)^{(1-\varphi_i)\varphi_\pi} \left(\frac{Y_t/Y_{t-4}}{\overline{Y}_t/\overline{Y}_{t-4}}\right)^{(1-\varphi_i)\varphi_{dy}} \exp\left(\varepsilon_{m,t}\right), \tag{27}$$

where the same definitions apply as in the case of the monetary policy of the 1990s, with the difference that there is no exchange rate stabilization and the interest rate is expressed in nominal terms, i_t. It is worth noting that the inflation target since 2000 is constant at 3% and, therefore $\bar{i}$ is the steady state value for the real interest rate plus the constant inflation target. Following Blinder (1997) and Gertler et al. (1999), we interpret the monetary policy rules (26) and (27) without the shocks $\varepsilon_{m,t}$ as the *science* of monetary policy. Also, we will denote shocks $\varepsilon_{m,t}$ as the *art* of monetary policy.

Fiscal Policy Rule. Analogously to the monetary policy, we need to specify as well the fiscal rules for 1990s and for 2000s. In order to characterize the fiscal rule, it is important to start showing the budget constraint of the government. This budget constraint is the same in both periods. Formally, the net position of the government measured in foreign currency, $B_{G,t}^*$, evolves according to:

$$\frac{\mathcal{E}_t B_{G,t}^*}{(1+i_t^*)\,\Theta\left(\frac{\mathcal{E}_t B_t^*}{P_{Y,t}Y_t}\right)} = \mathcal{E}_t B_{G,t-1}^* + T_t - P_{G,t}G_t, \tag{28}$$

where $(1+i_t^*)\,\Theta\,(.)$ is the relevant gross interest rate for government debt, G_t is government expenditure and T_t are total net fiscal nominal revenues (fiscal revenues minus transfers to the private sector). By simplicity, we assume that the basket consumed by the government is only in domestically produced goods, implying that the price deflator of government consumption is $P_{G,t} = P_{H,t}$. Total net fiscal revenues are given by:

$$T_t = T_{P,t} + T_{CO,t}, \tag{29}$$

Hence, fiscal revenues come from two sources: tax income to the private sector (net of fiscal transfers), which is a function of GDP, $T_{P,t} = \tau_t P_{Y,t} Y_t$; and revenues from copper which are given by $T_{CO,t} = \chi \Pi_{CO,t}$. Parameter χ defines the share of the fiscal sector in total copper profits and variable τ_t corresponds to the average net income tax as percentage of GDP.[9]

The fiscal policy is defined by the three variables: $B_{G,t}$, τ_t, and G_t. Therefore, given the budget constraint of the government, it is necessary to define behavior rules for two of these three variables. Tax policy is predetermined by the prevalent taxes to the private sector, which is assumed to follow an autoregressive process:

$$\tau_t = (1 - \rho_\tau)\,\bar{\tau} + \rho_\tau \tau_{t-1} + \varepsilon_{\tau,t}, \tag{30}$$

where $\bar{\tau}$ is the steady state net tax, ρ_τ is the persistence of the tax shocks, and $\varepsilon_{\tau,t}$ is an i.i.d. innovation with zero mean and variance equal to σ_τ^2. Therefore, the fiscal policy rule will determine the level of government expenditure, $P_{G,t} G_t$.

When all agents are Ricardian, defining a trajectory for the primary deficit is irrelevant for the households decisions, as long as the budget constraint of the government is satisfied. On the contrary, when a fraction of the agents are non-Ricardian, then the precise trajectory of the government debt and the primary deficit are relevant. Additionally, the path of the government expenditure may be relevant on its own as long as its composition differs from the composition of private consumption.

The *structural balance* fiscal rule implemented in Chile since 2001 has the explicit objective to smooth the path of government expenditure in order to avoid a procyclicality in the fiscal policy.[10] As it will be clear, this rule allows for a change in the net asset position of the government together with an endogenous adjustment in government expenditure and/or transfers. Consider the overall balance of the government:

$$BA_t = T_t - P_{G,t} G_t + \left(1 - \frac{1}{\left(1 + i^*_{t-1}\right)\Theta_{t-1}}\right)\mathcal{E}_t B^*_{G,t-1}, \tag{31}$$

Equation (31) implies that the balance of the government includes interest payments of net asset position (the last term on the RHS). The structural balance, $B_{S,t}$, is defined as

[9] Seignorage from the Central Bank is rebated to the private sector as a lump-sum transfer.

[10] The description of the structural balance fiscal rule in Chile is an adaptation of the rule presented in Marcel et al. (2001).

the effective balance minus cyclical fiscal revenues:

$$B_{S,t} \equiv BA_t - \widetilde{T}_t = T_t - \widetilde{T}_t - P_{G,t}G_t + \left(1 - \frac{1}{\left(1+i^*_{t-1}\right)\Theta_{t-1}}\right)\mathcal{E}_t B^*_{G,t-1} \qquad (32)$$

where $\widetilde{T}_t = \left(\widetilde{\tau}_{P,t} + \widetilde{\tau}_{CO,t} + \widehat{g}_t\right) P_{Y,t}Y_t$ corresponds to cyclical revenues coming from taxes and copper price plus an exogenous shock to structural revenues ($\widehat{g}_t$) not attributed to these two factors. This exogenous shock is modelled as an i.i.d. innovations with zero mean and variance equal to σ^2_g. The two components of the cyclical revenues are endogenously determined as:

$$\widetilde{\tau}_{P,t} = \psi_y \left(\widetilde{y}_t + \widetilde{y}_{t-1} + \widetilde{y}_{t-2} + \widetilde{y}_{t-3}\right)/4 \qquad \widetilde{\tau}_{CO,t} = \psi_{P_{CO}}\left(\chi\right)\left(y_{CO}\right)\log\left(\frac{P^*_{CO,t}}{P^*_{ref,t}}\right) \qquad (33)$$

where $\widetilde{y}_t$ is the output gap (in log form) used by the fiscal policy to determine the cyclical position of the economy, $P^*_{ref,t}$ is a reference price of copper used by the fiscal policy to define the long-run price to infer the structural revenues coming from the copper sector and y_{CO} is the steady state share of copper production in total GDP. Parameters ψ_y is the degree of sensitivity of the cyclical component of non-copper revenues to the annual moving average output gap and and $\psi_{P_{CO}}$ is the sensitivity of the cyclical component of copper revenues to the log deviation between current and reference price of copper after controlling for the average size of copper in the total economy and the share of the government in copper production. It worth noting that since 2002 there are two external committees that compute the trend GDP for estimating the output gap, $\widetilde{y}_t$, the reference for copper, $P^*_{ref,t}$. Previous to 2002, we use the information for these variables contained in Marcel et al. (2001), who made a computation of the structural fiscal balance for the 1990s based on estimations for the trend GDP and long-run copper price. In the empirical estimation below, we use econometric equations that connects the output gap, $\widetilde{y}_t$, with cyclical component of total GDP in the model, $\log\left(Y_t/\bar{Y}_t\right)$, and the reference copper price, $P^*_{ref,t}$, with the current price, $P^*_{CO,t}$. In order to include explicitly the dynamics of the output gap and the reference copper price we assume the following equations for these variables:

$$\widetilde{y}_t = \rho_{\widetilde{y}}\widetilde{y}_{t-1} + \alpha_{bpib}\left(y_t + y_{t-1} + y_{t-2} + y_{t-3}\right)/4 + \varepsilon_{\widetilde{y},t} \qquad (34)$$

$$\log\left(P^*_{ref,t}/P^*_t\right) = \rho_{ref}\log\left(P^*_{ref,t-1}/P^*_{t-1}\right) + \alpha_{ref}\log\left(P^*_{CO,t}/P^*_t\right) + \varepsilon_{ref,t} \qquad (35)$$

where $y_t = \log(Y_t/\bar{Y}_t)$ is the detrended GDP in the model whereas innovations $\varepsilon_{\widetilde{y},t}$ and $\varepsilon_{ref,t}$ are i.i.d. with zero mean and variance $\sigma^2_{\widetilde{y}}$ and σ^2_{ref}, respectively.

The fiscal rule since 2000 states an objective for the overall fiscal balance as percentage of GDP to determine the level of government spending coherent with that objective. Formally, using (32) as percentage of GDP we obtain that:

$$
\begin{aligned}
\frac{P_{G,t}G_t}{P_{Y,t}Y_t} &= \left(1-\frac{1}{\left(1+i^*_{t-1}\right)\Theta_{t-1}}\right)\frac{\mathcal{E}_t}{\mathcal{E}_{t-1}}\frac{\mathcal{E}_{t-1}B^*_{G,t-1}}{P_{Y,t-1}Y_{t-1}}\frac{P_{Y,t-1}Y_{t-1}}{P_{Y,t}Y_t}+ \\
&\quad \frac{T_t}{P_{Y,t}Y_t}-\frac{\widetilde{T}_t}{P_{Y,t}Y_t}-\varepsilon_{S,t}
\end{aligned} \tag{36}
$$

According to the *structural balance* fiscal rule, the objective of the fiscal policy is to keep the structural balance close to zero in the long-run, but deviations from this is captured by shock $\varepsilon_{S,t}$ with standard deviation equal to σ_S.[11] We model fiscal policy during the 2000s as setting the government expenditure with equation (36).

For 1990 period we keep the same source of fiscal revenues, but we assume that a fraction $\tau_f > 0$ of cyclical components of revenues are spent instead of being saved every period. Hence, we model government expenditure as percentage of GDP as:

$$
\begin{aligned}
\frac{P_{G,t}G_t}{P_{Y,t}Y_t} &= \left(1-\frac{1}{\left(1+i^*_{t-1}\right)\Theta_{t-1}}\right)\frac{\mathcal{E}_t}{\mathcal{E}_{t-1}}\frac{\mathcal{E}_{t-1}B^*_{G,t-1}}{P_{Y,t-1}Y_{t-1}}\frac{P_{Y,t-1}Y_{t-1}}{P_{Y,t}Y_t}+ \\
&\quad \frac{T_t}{P_{Y,t}Y_t}-(1-\tau_f)\frac{\widetilde{T}_t}{P_{Y,t}Y_t}-\varepsilon_{S,t}
\end{aligned} \tag{37}
$$

As with the case of monetary policy, we denote the fiscal rule in either (36) or (37) as the *science* of fiscal policy and the shocks $\hat{g}_t$ and $\varepsilon_{S,t}$ as the *art* of fiscal policy.

4.9 Aggregate Equilibrium

It is necessary to specify the equilibrium in the different market described. The equilibrium condition in the market of non-commodity Home goods is:

$$
Y_{H,t} = C_{H,t} + I^H_{H,t} + I^{CO}_{H,t} + C^*_{H,t} + G_t \tag{38}
$$

where $C^*_{H,t}$ external demand for non-commodity Home goods described previously, and G_t is government expenditure.

The value of the net exports are given by:

$$
NX_t = \mathcal{E}_t P^*_{CO,t} Y_{CO,t} + P_{H,t} C^*_{H,t} - \mathcal{E}_t P^*_t Y_{F,t} \tag{39}
$$

where the imports of foreign goods are:

$$
Y_{F,t} = C_{F,t} + I^H_{F,t} + I^{CO}_{F,t} \tag{40}
$$

[11] As mentioned above, originally the target for the structural surplus was 2% of GDP. This target was reduced in May 2007 to 0.5%. In 2009, the structural balance was set at 0% of GDP.

Finally, it is convenient to define the economy's total nominal GDP as:

$$P_{Y,t}Y_t = P_{CO,t}Y_{CO,t} + P_{H,t}Y_{H,t} \tag{41}$$

and the real GDP as:

$$Y_t = \overline{P}_{CO}Y_{CO,t} + \overline{P}_H Y_{H,t} \tag{42}$$

where $\overline{P}_{CO}$ and $\overline{P}_H$ are the long-term (detrended) prices of commodities (copper) and Home goods. Combining the the budget constraints from households and government together with the market clearing conditions we obtain the balance of payment identity:

$$NX_t + \mathcal{E}_t B^*_{t-1} = \frac{\mathcal{E}_t B^*_t}{(1+i^*_t)\Theta\left(\frac{\mathcal{E}_t B^*_t}{P_{Y,t}Y_t}\right)} \tag{43}$$

5 Parametrization

In order to implement the model to describe and analyze the business cycles in Chile during the period 1990-2015, we need to define the value of parameters. Having the value of the parameters allow us to compute the steady state and obtain the fluctuations using standard perturbation methods (e.g. Uhlig (1998)). We separate the parameters in two groups: calibrated parameters and estimated parameters. The value of the calibrated parameters are based on related literature, whereas estimated parameters are specific to the model considered here and we estimate them. The value of all the parameters can be found in Table 1. In the following subsections (5.1 and 5.2) we present separately the detail of the calibrated and estimated parameters, respectively.

5.1 Calibrated Parameters

Most of the parameters were calibrated based on standard recent literature for Chile as in García et al. (2019), Medina and Soto (2016) and Fornero and Kirchner (2018). The model uses a quarterly frequency throughout all its setup. To be consistent with Chilean data, the share of the commodity export sector over total GDP (G/Y) is 15% and net exports to GDP ratio (NX/Y) 1%. Moreover, the copper share in total GDP (Y_{CO}/Y) is calibrated to 10%.

Following the estimations of Duncan (2003) for Chile, we use an intertemporal elasticity of substitution (σ_C) fixed in 1.0, same value for inverse of the labor supply elasticity (σ_L).[12] Based on the neutral interest rate in Chile, Fuentes et al. (2008), of around 3%, the household discount factor (β) is chosen to imply a steady state real interest rate around 3% (annual basis) as well.

[12]This calibration is in line with Fornero and Kirchner (2018) based on microeconomic data from Chile.

In line with Fornero and Kirchner (2018), we set the elasticity of substitution between domestic and imported consumption goods (η_C) to 0.5. Considering the average fraction of domestic goods in the CPI basket since 2001, we determined that the share of domestic produced goods in consumption (γ_C) is 70%. Later on the habit formation coefficient is calibrated in line with Medina and Soto (2016) and Fornero and Kirchner (2018) with a value of $h = 0.70$. For the production function of the capital goods, we set the elasticity of substitution in investment between domestic and imported goods (η_I) at 0.5 (consistent with Fornero and Kirchner (2018)) and the share of domestic produced goods in investment (γ_I) to 70%. Moreover, considering the the quarterly depreciation rate of this type of capital (δ), we can set it to 2.5% (6% annual) and the investment adjustment cost is set at $\mu_S = 2.5$, in line with Adolfson et al. (2007), Medina and Soto (2016), Smets and Wouters (2007) and Fornero and Kirchner (2018).

To be consistent with the average fiscal income associated with the copper sector we calibrated, in the commodity export sector, the commodity tax or government ownership in the commodity profits $(1-\varphi)$ to 50%. Later on, considering a AR(1) process, we calibrated the persistence of the copper price shocks at $\rho_{P_{CO}} = 0.95$, which is approximately the value obtained from a quarterly estimation. The previous is also in line with García et al. (2019).

In the intermediate goods sector, the share of labor in the production function in the home economy sector (α_H) is around 70% in production. On the commodity sector, the capital share in the production function (α_{CO}) is calibrated to 30%. The above is congruent with Medina and Soto (2016), Monfort (2008) and Fornero and Kirchner (2018).

In line with Medina and Soto (2016), we calibrate foreign sector features as following. The inertia in foreign demand (h^*) is equal to 0.7. The price elasticity of foreign demand for domestically produced goods (η^*) is 0.5. Finally, the elasticity of the external supply of debt ϱ is equal to 0.001.

Nominal rigidities were calibrated based on Medina and Soto (2016) and Fornero and Kirchner (2018). For instance, the á la Calvo type of rigidities were calibrated as the following: probability of adjusting wages $\phi_L = 0.875$, probability of adjusting domestic prices (P_H) is set to $\phi_H = 0.750$, same as probability of adjusting foreign prices ($P_{F,t}$) $\phi_F = 0.750$. We also consider wage indexation in the labor market of the home economy $\epsilon_L = 0.5$, domestic goods $\chi_H = 0.5$ and imported goods indexation $\chi_F = 0.5$.

Based on our TANK type of model, we set the fraction of non-Ricardian households in Chile to $\lambda = 50\%$. The literature in this topic is extensive. For instance, Fornero and Kirchner (2018) determined that value at $\lambda = 50\%$. Authors like Schmidt-Hebbel and Servén (1996) uses a value of 0.45 for the period 1963-1991. Others like Corbo and Schmidt-Hebbel (1991) estimated λ equal to 0.60 for the period 1968-88.

Finally, when it comes to the calibrated shock processes, we based our parameters, persistence's' (ρ_i) and standard deviations (σ_i), on García et al. (2019).

Table 1: Complete Parametrization

Parameter	Value	Description
Household Preferences		
β	0.995	subjective discount factor
σ_C	1.0	elasticity of intertemporal substitution in consumption
σ_L	1.0	inverse of the labor supply elasticity
h	0.70	habit formation coefficient
λ	0.5	fraction of Non Ricardian Households
ϵ_L	11	elasticity of substitution of the household labor supply
Consumption and Investment Baskets		
γ_C	0.70	share of domestic goods in consumption
η_C	0.5	elasticity of substitution domestic and imported goods
γ_I	0.70	share of domestic goods in investment
η_I	0.5	elasticity of substitution domestic and imported goods
Nominal Rigidities		
ϕ_L	0.875	prob. adjusting wages
ξ_L	0.5	wage indexation
ϕ_H	0.75	prob adjusting P_H
χ_H	0.5	domestic goods indexation (home)
ϕ_F	0.75	prob adjusting P_F
χ_F	0.5	imported goods indexation

Capital Accumulation		
μ_S	2.5	investment adjustment cost coefficient
δ	0.025	depreciation rate
Production Technologies		
α_H	0.70	labor share in domestic production
α_{CO}	0.30	capital share in the commodity sector
χ	0.50	Govt ownership in the commodity profits
Foreign Sector		
NX/Y	1%	steady state net exports to GDP ratio
h^*	0.70	inertia in foreign demand
η^*	0.5	price elasticity of foreign demand for domestically produced goods
ϱ	0.001	elasticity of the external supply of debt
Y_{CO}/Y	10%	copper share in total GDP
Monetary Policy		
φ_i	0.840	interest rate smoothing (estimated)
φ_π	1.50	reaction to inflation
φ_{dy}	1.0	reaction to output (estimated)
τ_m	1.57	reaction to exchange rate (estimated)
Fiscal Sector		
G/Y	15%	government expenditure to GDP ratio
ψ_y	1.87	sensitivity of Non-comm. rev to output gap (estimated)
$\psi_{P_{CO}}$	1.59	sensitivity of Comm. rev to dev copper price-ref price (estimated)
τ_f	0.52	cyclical aggressiveness (estimated)

Exogenous Processes		
ρ_{A_H}	0.898	persistence of technological shocks sector H
$\rho_{A_{CO}}$	0.990	persistence of technological shocks sector CO
ρ_{τ}	0.872	persistence of tax shocks
ρ_{r^*}	0.980	persistence of foreign interest rate shocks
ρ_{embi}	0.889	persistence of domestic risk premium (EMBI) shocks
ρ_{π^*}	0.549	persistence of foreign inflation shocks
ρ_{y^*}	0.991	persistence of foreign GDP shocks
ρ_{ξ}	0.480	persistence of exchange rate shocks
ρ_{ref}	0.943	persistence of reference copper price shocks (estimated)
α_{ref}	0.057	reaction of reference copper price to spot price (estimated)
$\rho_{\widetilde{y}}$	0.975	persistence of output gap
α_{bpib}	-0.118	output gap reaction to m.a. GDP (estimated)
ρ_{φ_C}	0.220	persistence of preference shocks
ρ_{ζ_π}	0.900	persistence of core inflation shocks
$\rho_{P_{CO}}$	0.950	persistence of copper price shocks
σ_{A_H}	2.085%	SD of technological shocks sector H
σ_{τ}	1.042%	SD of tax shocks
σ_{g}	0.90%	SD of structural fiscal revenues shock ($\hat{g}_t$)
σ_{embi}	0.083%	SD of domestic risk premium (EMBI) shocks
σ_{π^*}	0.125%	SD of foreign inflation shocks
$\sigma_{A_{CO}}$	4.00%	SD of technological shocks sector CO
σ_{y^*}	4.142%	SD of foreign GDP shocks
σ_{ξ}	2.932%	SD of exchange rate shocks
σ_{ref}	2.55%	SD of reference copper price shocks

$\sigma_{\widetilde{y}}$	0.560%	SD of output gap shocks
σ_{φ_C}	0.230%	SD of preference shocks
σ_{ζ_π}	0.140%	SD of core inflation shocks
σ_m	0.250%	SD Taylor rule shock at $\varepsilon_{m,t}$
σ_{r^*}	0.116%	SD of foreign interest rate shocks
$\sigma_{P_{CO}}$	10%	SD of copper price shocks
σ_S	0.9%	SD in the structural balance shock ($\varepsilon_{S,t}$)

5.2 Estimated Parameters

In this subsection we present the *estimated* parameters of the model (summarized in table 2). First, we estimate equations (26) and (27) simultaneously, calibrating $\varphi_\pi = 1.5$ in line with Medina and Soto (2016) and Fornero and Kirchner (2018).[13] As mentioned previously, from 2000 and on, monetary policy interest rate is nominal and the exchange rate is allow to be fully flexible. In constrast, during the 90's the monetary policy rule was real interest rate indexed to unit account in Chile that is readjusted daily based on previous inflation.[14] After controlling for the change in the policy instrument for real to nominal, we keep the same reaction coefficients for output and inflation stabilization and interest rate smoothing in the two period analyzed: 1990-1999 and 2000-2015. A key difference is that to represent the exchange rate band in the 90's, we considered that the real term interest rate reacts to smooth the exchange rate around its band as shown in equation (26) with a coefficient τ_m. Formally, our estimation uses a short-term real interest rate, known as PRBC90[15] time series for the 90's and the standard overnight inter-bank nominal rate for the period starting in 2000. Our estimations indicate that φ_i, φ_{dy} and τ_m are equal to 0.840, 1.0 and 1.57, respectively. Moreover, our estimation indicates that monetary policy innovations has a standard deviation around 1 percent ($\sigma_m = 0.95\%$).

For the fiscal side, we estimate the cyclical component of fiscal revenues as percentage of GDP as functions of the log-deviation of the GDP ($\tilde{y}_t$) and the copper price ($\log(P^*_{CO,t}/P^*_{ref,t})$) with respect their trends as given by expressions in (33). During the 2000s, we use the expert committees that provide the GDP trend and the reference price

[13] A similar effort to estimating a monetary policy rule before and after the flexibility of the exchange rate is found in Céspedes and Soto (2007).

[14] This unit of account is known as "Unidad de Fomento" (UF) in spanish.

[15] PRBC90 stands for the inflation indexed bonds (UF) tendered by the Central Bank of Chile during the 1990's with maturity of 90 days. The above was the main monetary policy instrument at the time.

as trend for the copper price. For the 1990s, we use the estimated value for these two variables contained in Marcel et al. (2001). We also take the estimated value of the structural balance for the 90s from Marcel et al. (2001). We use that, on average, the ratio of copper production to total GDP is 10 percent ($y_{CO} = 0.1$) and the participation of the government in copper revenues is 35 percent (χ). The estimation indicates that ψ_y and $\psi_{P_{CO}}$ are equal to 1.59 and 1.87, respectively.

For the cyclical aggressiveness coefficient in the fiscal rule (τ_f) during the 90s we estimate how sensitive was government expenditure to the log-deviation in output and copper price with respect their trends ($\widehat{y}_t$ and $\log(P^*_{CO,t}/P^*_{ref,t})$). The above is due to the ex-post fiscal balance estimation for the 90's. In practice, fiscal expenditure was higher than the one determined by the cyclical adjustment by the fiscal rule of the 2000s. Our estimation indicates that $\tau_f = 0.52$.[16]

Finally, we estimate equations (34) and (35). For equation (34), We find that α_{bpib} is equal to -0.118 with $\sigma_{\widetilde{y}} = 0.6\%$. Estimating equation (35) deliver a point estimate for ρ_{ref}, α_{ref} and σ_{ref} are equal to 0.943, 0.057 and 2.55%, respectively. The standard errors of the estimated equations provide point estimates for σ_{ref}, σ_m, $\sigma_{\tilde{y}}$, σ_g, and σ_S.

6 Comparison of the policy frameworks

Using the parameters values described in the last section, we analyze the difference in the transmission of key economic shocks attributed to the change in the monetary and fiscal rules from 90s and 2000s.

Overall, we find that the setup of the 90s leads to a more reactive nominal interest rate response, lower exchange rate depreciation and a more procyclical fiscal balance path. This is mainly due to the exchange rate flexibility acting as a shock absorber and the less procyclicality of the rules in the 2000s setup.

For instance, Figure 5 illustrates the impulse response function (IRF) to a 1 standard deviation demand (preference) shock. We observe a larger exchange rate depreciation in the 2000s rules due to FX flexibility and a larger response of the fiscal balance due to the structural balance fiscal rule. A similar pattern can be found in Figure 6, where a 1 s.d. Federal Reserve rate shock leads to a higher exchange rate depreciation, lower nominal interest rate, and a larger correction of the fiscal balance over time.

[16] We explore alternative forms to estimate the two critical parameters for the monetary and fiscal rules during the 90s, namely, τ_m and τ_f. In fact, we use simultaneous simulated methods of moments for the estimation of parameters τ_m and τ_f arriving to similar values. This alternative estimation is available in section 9.1 of the appendix.

Table 2: Estimated Parameters

Parameter	Value	Std. Error	Description
φ_i	0.840^{***}	0.048	interest rate smoothing
φ_{dy}	1.0^{**}	0.315	reaction to output
τ_m	1.57^{*}	0.840	reaction to exchange rate in the 1990s
ψ_y	1.87^{**}	0.570	sensitivity of Non-comm. rev to output gap
$\psi_{P_{CO}}$	1.59^{***}	0.075	sensitivity of Comm. rev to dev copper price-ref price
τ_f	0.52^{***}	0.110	sensitivity of govt spending to cyclical revenues
ρ_{ref}	0.943^{***}	0.006	persistence of reference copper price shocks
α_{bpib}	-0.118^{**}	0.035	output gap reaction to m.a. GDP
α_{ref}	0.057^{***}	0.007	reaction of reference copper price to spot price
σ_{ref}	2.55%		SD of reference copper price shocks
σ_m	0.95%		SD of monetary policy shocks
$\sigma_{\tilde{y}}$	0.60%		SD of output gap shocks
σ_g	0.90%		SD of structural fiscal revenue shocks ($\hat{g}_t$)
σ_S	0.90%		SD of the target in the structural balance ($\varepsilon_{S,t}$)

Note: Significance P-Value * $p < 10\%$; ** $p < 5\%$; *** $p < 1\%$

Consistent with the above, Figure 7 shows that a 1 s.d. inflation (mark-up) shock leads to a smoother nominal interest rate reaction in the 2000s setup, and the responsiveness of the fiscal balance is larger, illustrating the fiscal balance rule acyclicality in action. The same pattern can be seen in Figure 8, where an exchange rate shock leads to a significantly less aggressive nominal interest rate response in the 2000s while the 90s present a less procyclical fiscal response.

Finally, one of the significant shocks that play a critical role in the overall volatility of the economy is the copper price shock. As mentioned previously, given the nature of the Chilean economy as a small, open economy and a significant commodity exporter, a commodity shock is central. Figure 9 shows a sharper exchange rate depreciation and a higher responsiveness of the fiscal balance in the 2000s setup. Additionally, in contrast to the 90s setup, the real interest rate responsiveness is also higher, leading to real effects on GDP, trade flows, and interest rates. The final message of the *modus operandi* of the rules is that the 90s setup would lead to a higher volatility scenario, whereas the 2000s rules would attenuate this shocks.

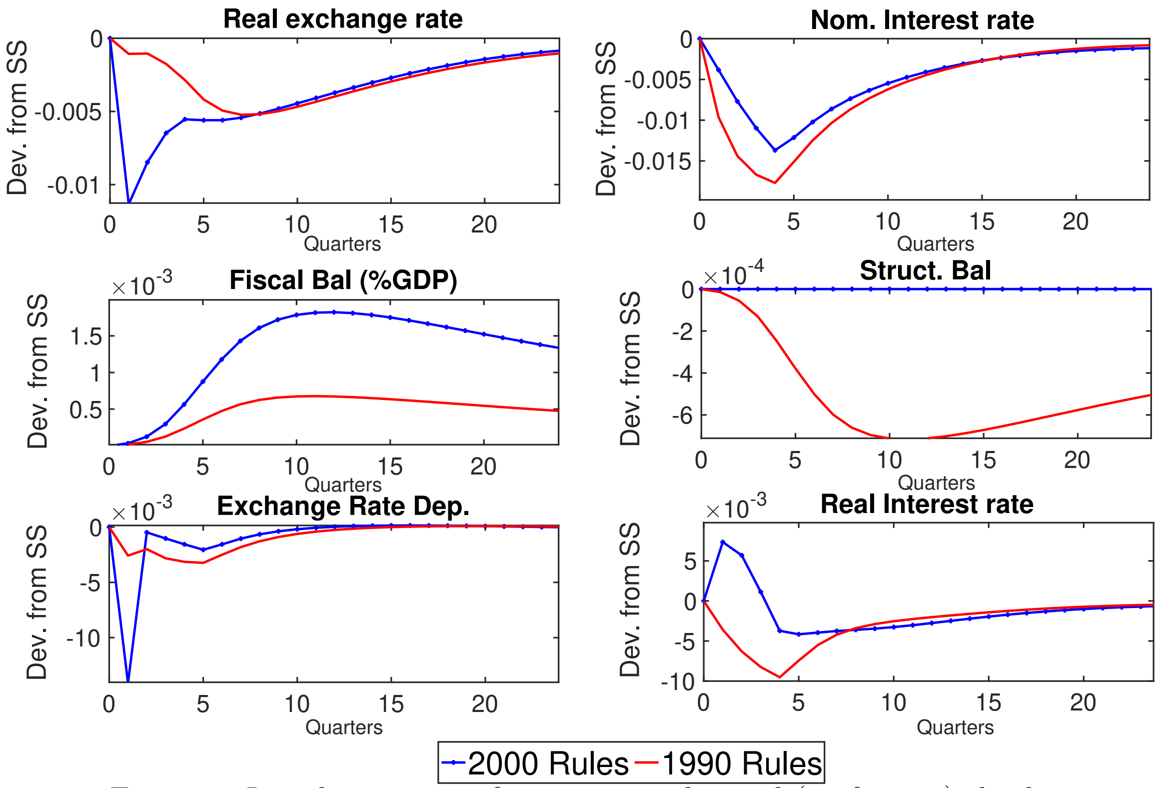

Figure 5: Impulse response function to a demand (preference) shock , $\varphi_{C,t}$

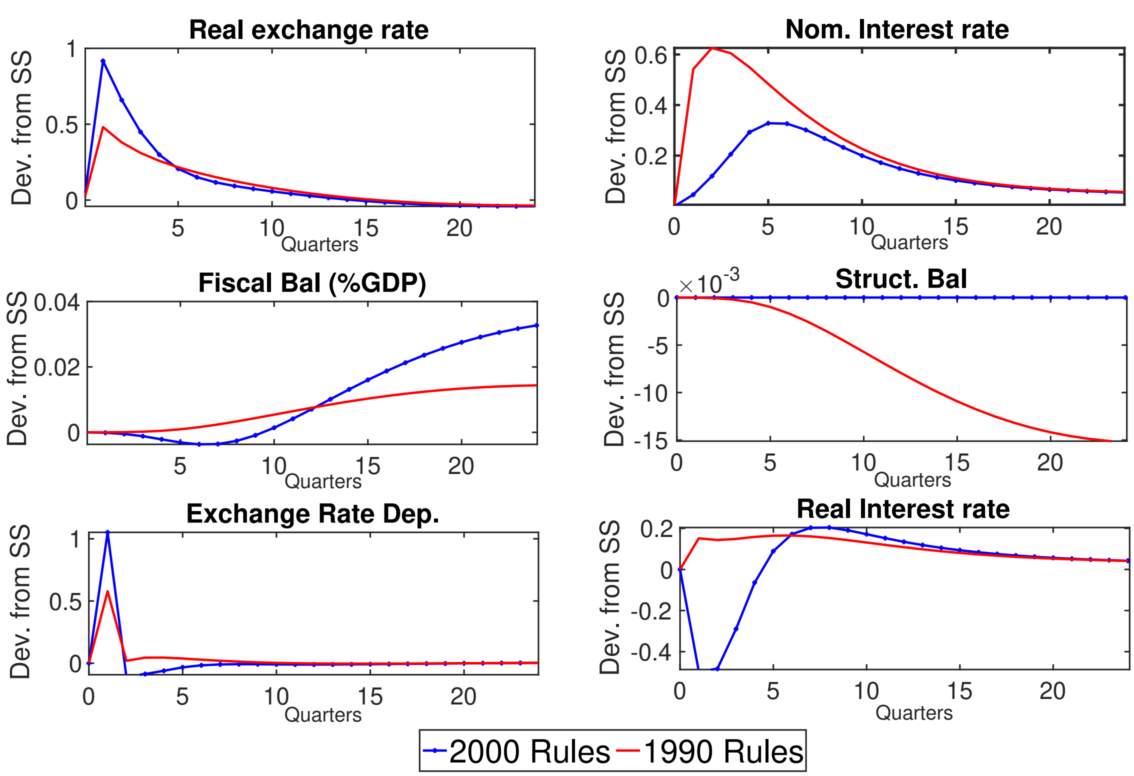

Figure 6: Impulse response function to a Federal reserve rate shock, R_t^{FED}

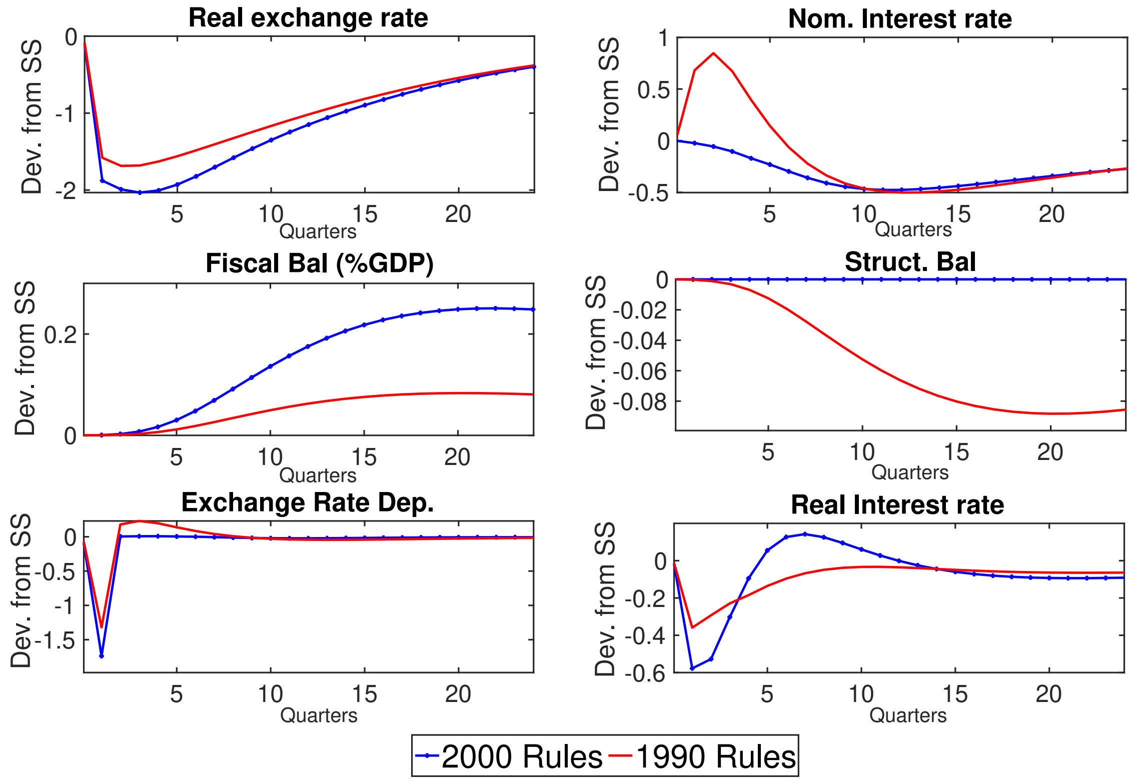

Figure 7: Impulse response function to inflation (mark-up) shock, $\zeta_{\pi,t}$

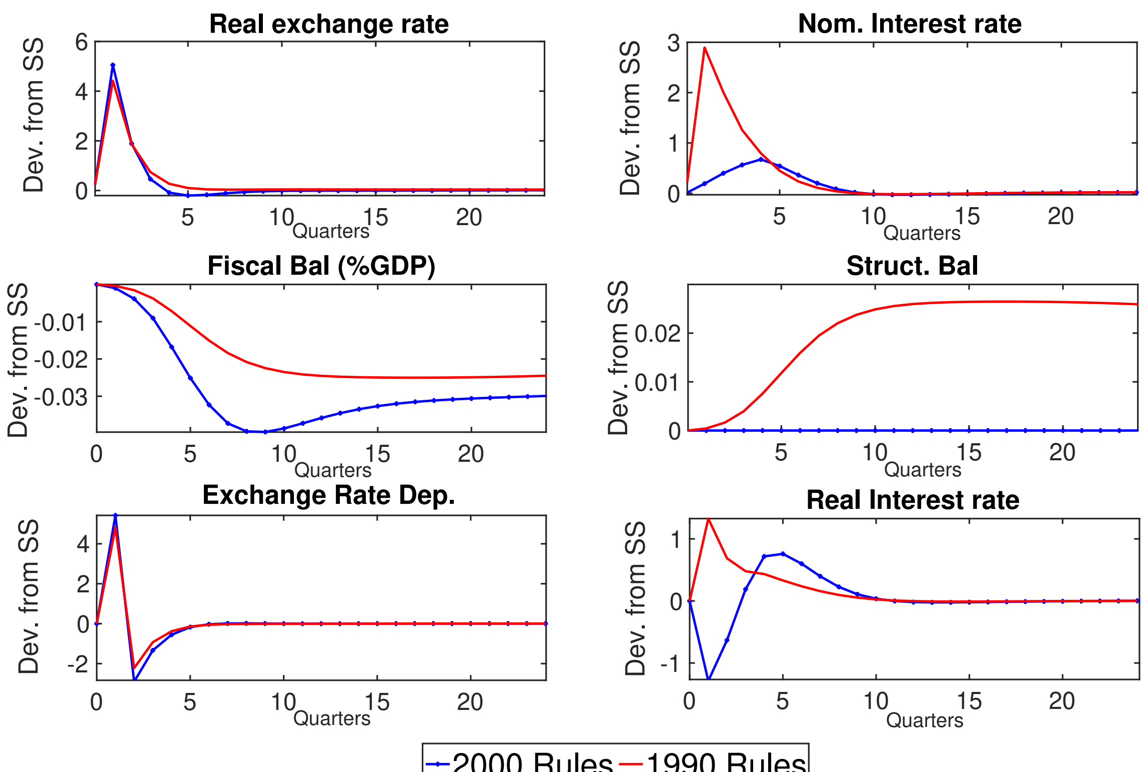

Figure 8: Impulse response function to an exchange rate shock, ξ_t

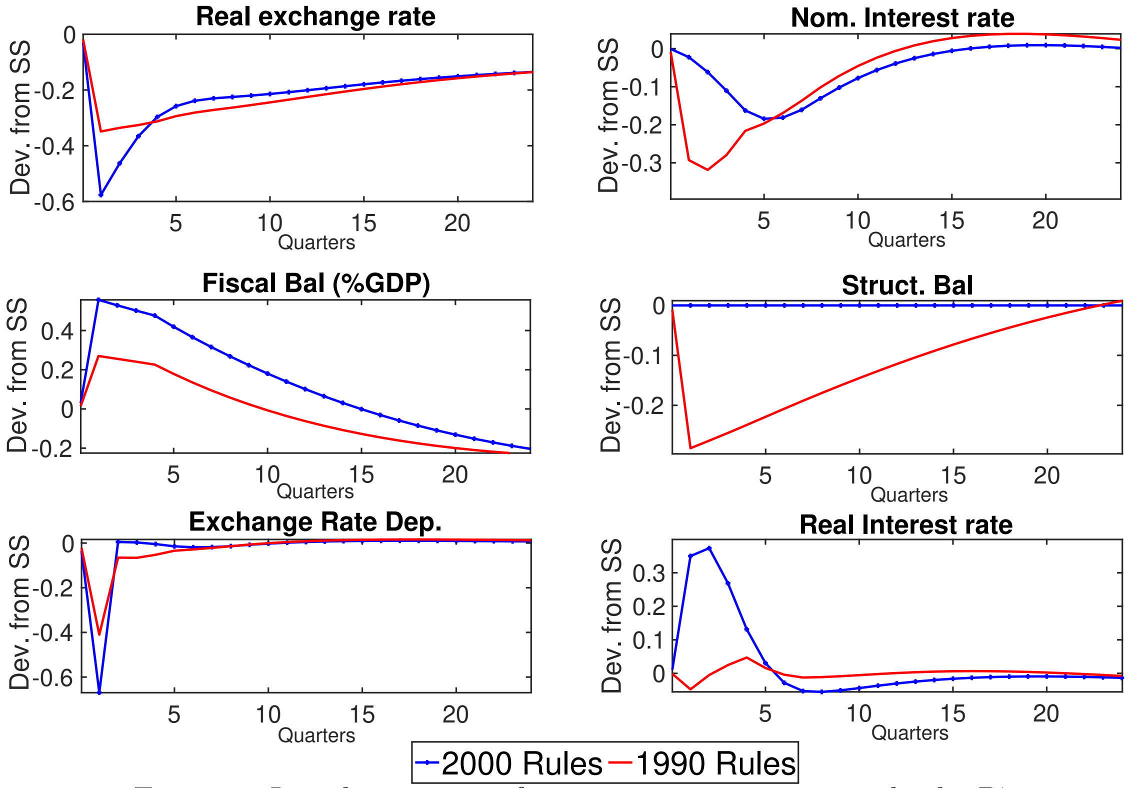

Figure 9: Impulse response function to a copper price shock, $P^*_{CO,t}$

7 Model-based analysis of the business cycle

In this section, we take the model formally to the data to analyze the business cycles in Chile during the period 1990-2015 with a special emphasis on the role of the monetary and fiscal rules in affecting the macroeconomic fluctuations. In the first subsection, we briefly describe the macroeconomic data used. The second subsection present the methodology to disentangle the role of shocks and policy rules in the Chilean business cycles. The third subsection presents the results obtained and several contrafactual scenarios that quantify the contributions of policy rules and policy shocks in macroeconomic stability in Chile. Finally, the last subsection perform several robustness check in order to evaluate how the quantification of the previous subsection are sensitive to several key assumptions.

7.1 Data

We build our database using official sources such as Central Bank of Chile, National Statistics Institute (INE), Budget Department (DIPRES), Autonomous Fiscal Council (CFA) and Ministry of Finance. The dataset uses quarterly frequency from 1990Q1 to 2015Q4. The vast majority of the time series were detrended using a standard Hodrick-Prescott filter ($\lambda = 1600$). Other specific variables were detrended using alternative, more suitable, options.

The list of all observable variables declared in the model are: total GDP, core inflation, real exchange rate, monetary policy rate, output gap according to DIPRES, international copper price, growth rate of the foreign GDP based on the main trading partners, federal reserve rate, overall fiscal balance as percentage of GDP, structural fiscal balance as percentage of GDP and reference price of copper from DIPRES.

All time series variables, with the following exception, were detrended using a standard Hodrick-Prescott (HP) filter ($\lambda = 1600$)[17]. Variable "inflation" was detrended using the target inflation rate of the Central Bank of Chile as trend. Moreover, variable "monetary policy rate" need it to be constructed in real terms (due to the nature of the instrument –real monetary policy rate (PRBC90)– during the 90s described in section 3). In order to do that we subtracted the inflation target of the period from 2002 and on, therefore providing a full monetary policy time series in real terms. Consequently, we applied the standard HP filter in order to achieve the cyclical component. Finally, variable "exchange rate depreciation" was detrended using the center of FX band ("dolar acuerdo", detailed in section 3) as the trend.

7.2 Inference of shocks and contrafactual scenarios

The perturbation method to describe the dynamics of the variables in the model are combined with the observable variables:

$$\begin{aligned} \mathbf{X}_t &= \mathbf{P}X_{t-1} + \mathbf{Q}\varepsilon_t \\ \mathbf{X}_t^{obs} &= \mathbf{H}\mathbf{X}_t \end{aligned} \tag{44}$$

where $\mathbf{X}_t$ is a vector with all variables in the model at t, $\mathbf{X}_t^{obs}$ is a vector with observables at t, and ε_t is a vector with all innovations in the exogenous shocks of the model at t. These variables are expressed as deviations of their steady states. Matrices $\mathbf{P}$ and $\mathbf{Q}$ depend on all parameters of the model and matrix $\mathbf{H}$ makes the correspondence between observable variable and model variables. It is important to note that the value of coefficients in matrices $\mathbf{P}$ and $\mathbf{Q}$ depend among other things on the policy rules in place. We have imposed that all parameters except the one related to the policy rules are kept constant over the whole sample. Hence, the matrices $\mathbf{P}$ and $\mathbf{Q}$ will be different across periods 1990-1999 and 2000-2015.[18]

[17] Mainly using the log difference between the variable and it's HP trend, i.e $\ln(x) - \ln(x_{HP-TREND})$

[18] In the subsection 7.4 we will perform a robustness check where in addition to changes in the policy rule there are other key parameters that change before and after 2000.

Applying the Kalman filter to the system (44), we can obtain an inference of the shocks contained in ε_t conditional on the information up to t and also conditional on information up to the last observation in each sample (1990Q1-1999Q4 and 2000Q1-2015Q4). This last case is denominated the smoothed inference. In fact, we can decompose each variable according the contribution of each shock using the smoothed Kalman filter:

$$\mathbf{X}_{t|T} = \mathbf{P}^t \mathbf{X}_{0|T} + \sum_{j=0}^{T} \mathbf{P}^j \mathbf{Q} \widehat{\varepsilon}_{t-j|T} \tag{45}$$

where $\mathbf{X}_{0|T}$ denotes the inference of the initial value for all variables of the model and $\widehat{\varepsilon}_{t-j|T}$ corresponds to the inference of the shocks in period $t-j$, both conditional on all observable variables from $t=1$ to $t=T$.

The inferred shocks are separate in two main groups: (i) standard shocks related to the supply, demand and external forces; and (ii) policy shocks related to deviations: $\varepsilon_{m,t}$, $\hat{g}_t$, $\varepsilon_{S,t}$. Recall that $\varepsilon_{m,t}$ corresponds to the monetary policy shock. Also, $\hat{g}_t$ and $\varepsilon_{S,t}$ are respectively shocks to the structural fiscal revenues and to the target for the structural fiscal balance, which are interpreted as fiscal policy shocks.

To construct contrafactual scenarios we proceed as follows and we require to define some notation. First, Denote $\widetilde{\varepsilon}_{t-j|T}$ the inferred shocks in $\widehat{\varepsilon}_{t-j|T}$ excluding the policy shocks. Second, define $\widetilde{\varepsilon}_{m,t-j|T}$ as sequence of vector of zeroes, but with the inference of the monetary policy shocks contained in $\widehat{\varepsilon}_{t-j|T}$ in the respective position of that vector. Third, similarly, define $\widetilde{\varepsilon}_{f,t-j|T}$ as sequence of vector of zeroes, but with the inference of the fiscal policy shocks contained in $\widehat{\varepsilon}_{t-j|T}$ in in the respective position of that vector. Fourth, let consider $\widetilde{\mathbf{P}}$ and $\widetilde{\mathbf{Q}}$ as the corresponding matrices that result of changing one or both policy rules.

Hence, the part of the evolution on all variables of the model with base rule from period $t=1$ to $t=T$ due to the standard shocks (no policy) can be computed as:

$$\mathbf{X}^B_{t|T} = \sum_{j=0}^{T} \mathbf{P}^j \mathbf{Q} \widetilde{\varepsilon}_{t-j|T} \tag{46}$$

In contrast, the part of the evolution due to standard shocks derived under the alternative policy rules would be:

$$\mathbf{X}^C_{t|T} = \sum_{j=0}^{T} \widetilde{\mathbf{P}}^j \widetilde{\mathbf{Q}} \widetilde{\varepsilon}_{t-j|T} \tag{47}$$

In consequence, the comparison between the evolution of $\mathbf{X}^B_{t|T}$ and $\mathbf{X}^C_{t|T}$ provides a metric to assess the role of policy rules in affecting business cycle fluctuations due to standard shocks.[19] This quantitative comparison emphasizes the importance of the *science* of macroeconomic policies in Chile to modify the transmission of economic fluctuations.

Analogously, we can express the part of the evolution of the variables attributed to the policy shocks under the base policy rules as:

$$\mathbf{X}_{t|T}^{M} = \sum_{j=0}^{T} \mathbf{P}^{j}\mathbf{Q}\widetilde{\varepsilon}_{m,t-j|T} \tag{48}$$

$$\mathbf{X}_{t|T}^{F} = \sum_{j=0}^{T} \mathbf{P}^{j}\mathbf{Q}\widetilde{\varepsilon}_{f,t-j|T} \tag{49}$$

Hence, the contractual scenarios during $t = 1$ to $t = T$ without policy shocks can be written as:

$$\widehat{\mathbf{X}}_{t|T}^{M} = \mathbf{X}_{t|T} - \mathbf{X}_{t|T}^{M} \tag{50}$$

$$\widehat{\mathbf{X}}_{t|T}^{F} = \mathbf{X}_{t|T} - \mathbf{X}_{t|T}^{F} \tag{51}$$

$$\widehat{\mathbf{X}}_{t|T}^{MF} = \mathbf{X}_{t|T} - \mathbf{X}_{t|T}^{M} - \mathbf{X}_{t|T}^{F} \tag{52}$$

where $\widehat{\mathbf{X}}_{t|T}^{M}$, $\widehat{\mathbf{X}}_{t|T}^{F}$, and $\widehat{\mathbf{X}}_{t|T}^{MF}$ are respectively the contracfactual scenario without monetary policy shocks, without fiscal policy shocks, and without both monetary and fiscal policy shocks. These alternative scenarios allow us to quantify the relevance of policy shocks in shaping business cycle fluctuations and we interpreted these policy shocks as the *art* of macroeconomic policies. For instance, the comparison between $\mathbf{X}_{t|T}$ and $\widehat{\mathbf{X}}_{t|T}^{M}$ provides a quantification of the role of the *art* of monetary policy in macroeconomic fluctuations.

To summarize the macroeconomic volatility in the base case and under the alternative scenarios we compute the root-mean-square deviation of GDP and core inflation with respect their trends:

$$RMSD(y) = \sqrt{\frac{1}{T}\sum_{t=1}^{T}(\Delta^{a} y_t)^2} \tag{53}$$

$$RMSD(\pi) = \sqrt{\frac{1}{T}\sum_{t=1}^{T}(\pi_t^{a})^2} \tag{54}$$

where $\Delta^{a} y_t$ and π_t^{a} are the cyclical deviations of the GDP annual growth and core inflation annual rate obtained from the base case and the alternative scenarios.

[19]In order to focus in the fluctuations attributed to standard shocks, we omits the initial conditions in the comparison of policy rules. The inference of initial condition corresponds to a transition effect that for first years in each subsamples.

7.3 Results

In this section we on focus how the business cycle evolution of GDP and inflation depend on the policy rule and the policy shocks. We analyze separately the evolution of these variables during 2000s and 1990s.

Figure 10 shows the computed root mean square of the quadratic deviation of GDP and core inflation during the 2000 attributed to the standard shocks ($SD(y)$ and $SD(\pi)$). These two computations can be used to summarize the macroeconomic volatility. There are four dots in that figure. The red dot corresponds to the case under the monetary and fiscal rules during 2000-2015. The other dots are based on the contrafactual scenarios changing one or both policy rules by the one used in the 1990s. The main message that emerges is that the policy rules applied during the 2000s clearly provide the lower macroeconomic volatility in comparison in response to standard shocks inferred in that period. Analogously, figure 11 present the same computation, but this time based on the standard shocks inferred during the 1990s. Again, using monetary and fiscal policy rules of the 2000s in responses to the standard shocks inferred in the 1990s has lower macroeconomic volatility than using the 1990s rule. In contrast to shocks in the 2000s, the shocks in the 1990s shows a small trade-off between using fiscal policy rule estimated in the 1990s and the structural balance rule considered for the 2000s. In responses to the inferred shocks in the 1990s, having the fiscal policy rule of the 1990s reduces sligthly volatility of core inflation and increases volatility of GDP in comparison of having the structural balance rule of the 2000s.

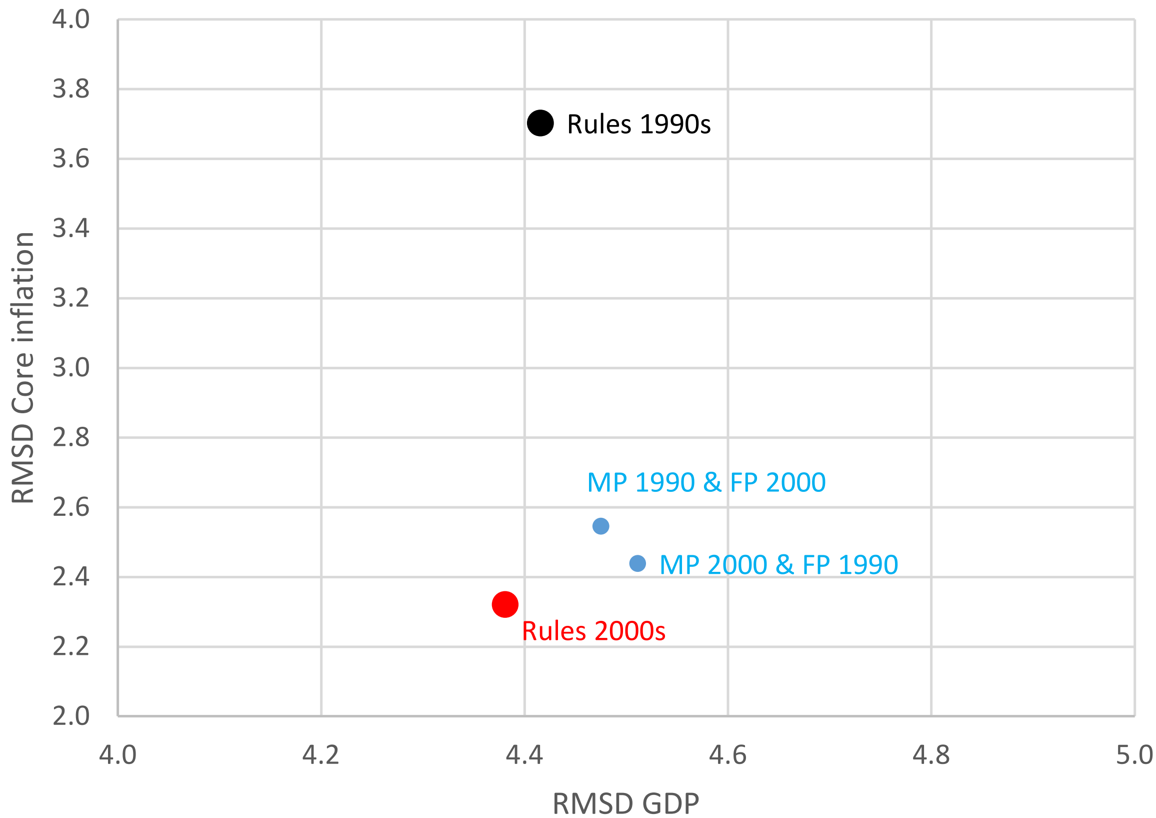

Figure 10: Role of the policy rules (*science*) for standard shocks in the 2000s

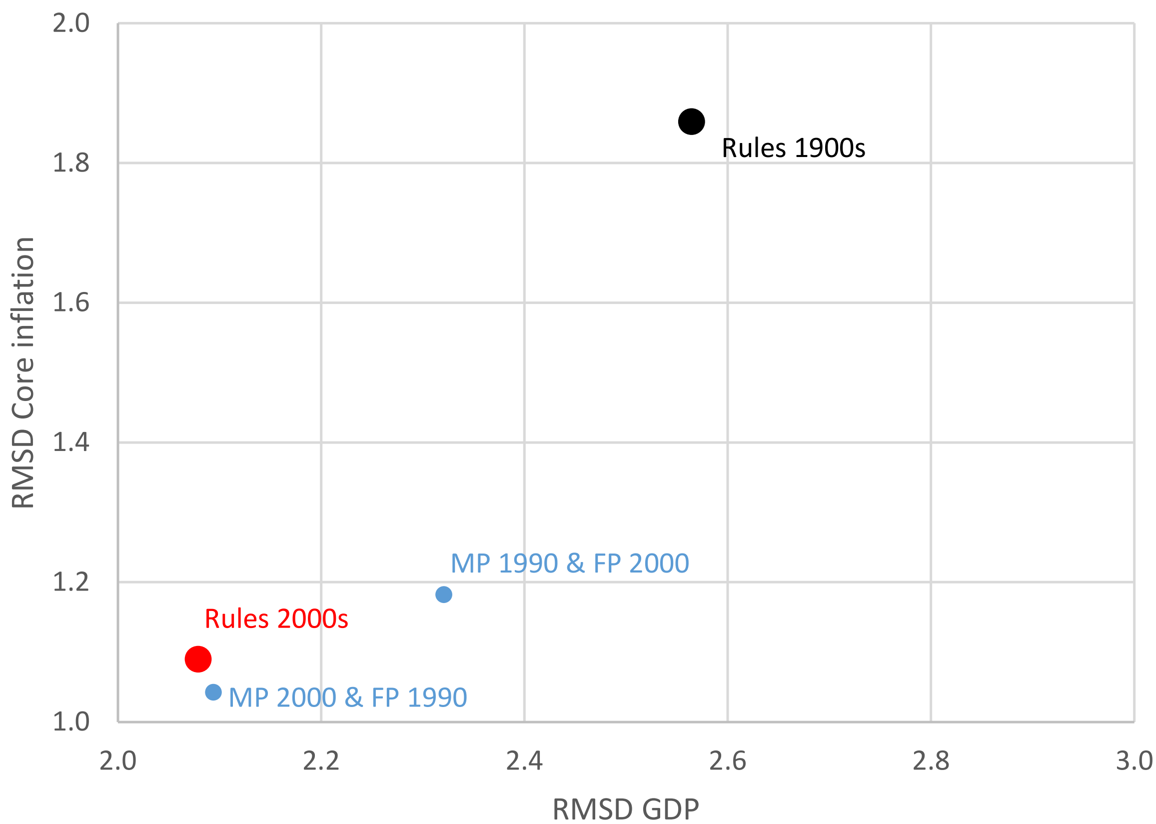

Figure 11: Role of the policy rules (*science*) for standard shocks in the 1990s

We now turn to the analyze of the role of policy shocks. Figures12 and 13 show the macroeconomic volatility in each period considering the policy shocks and excluding them. In figure 12, the red dot marks the level of GDP and core inflation volatility when the inferred policy shocks during 2000s with the policy rule of that period. We can see that for the 2000s the policy shocks contributed to reduce unambiguously the macroeconomic volatility as removing either monetary and fiscal policy shocks tends to rise the volatility of GDP and core inflation. For the 1990, the conclusion is less unambiguous since removing fiscal policy shocks clearly increase macroeconomic volatility whereas monetary policy shocks tend to rise core inflation volatility with a small reduction in GDP volatility.

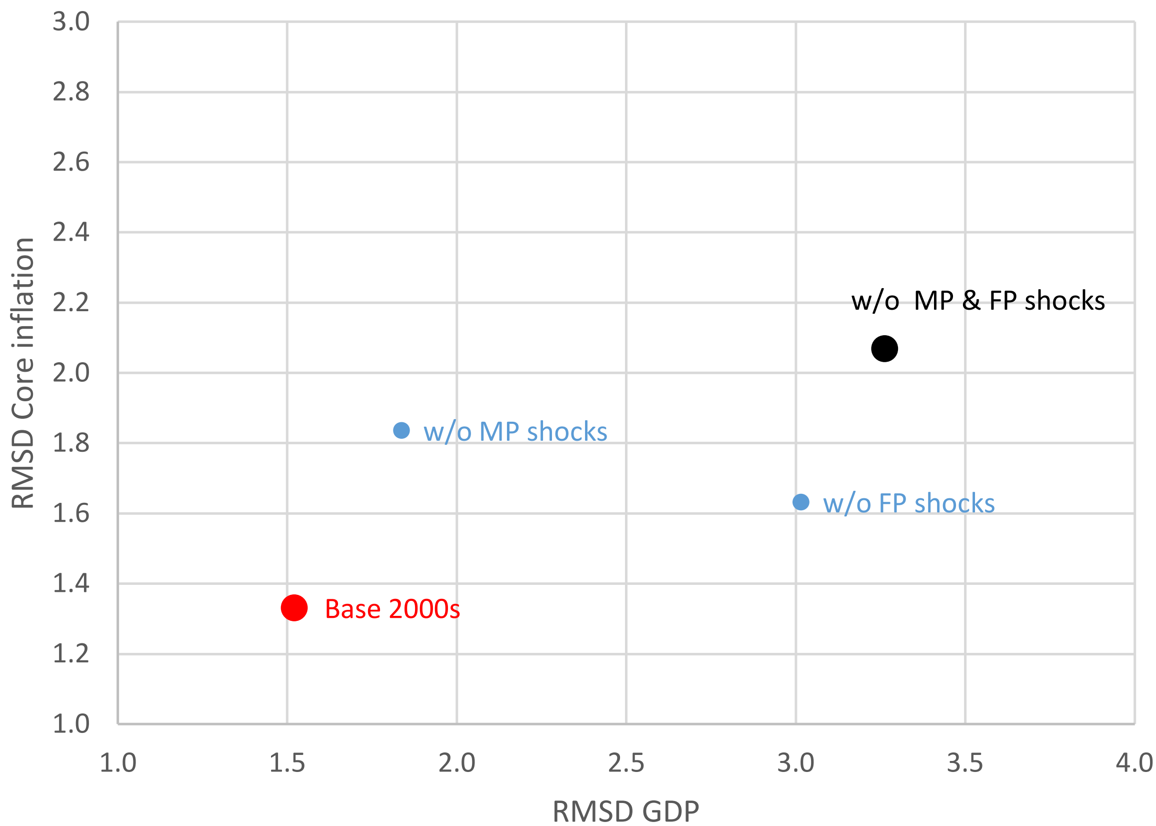

Figure 12: Role of policy shocks (*art*) during the 2000s

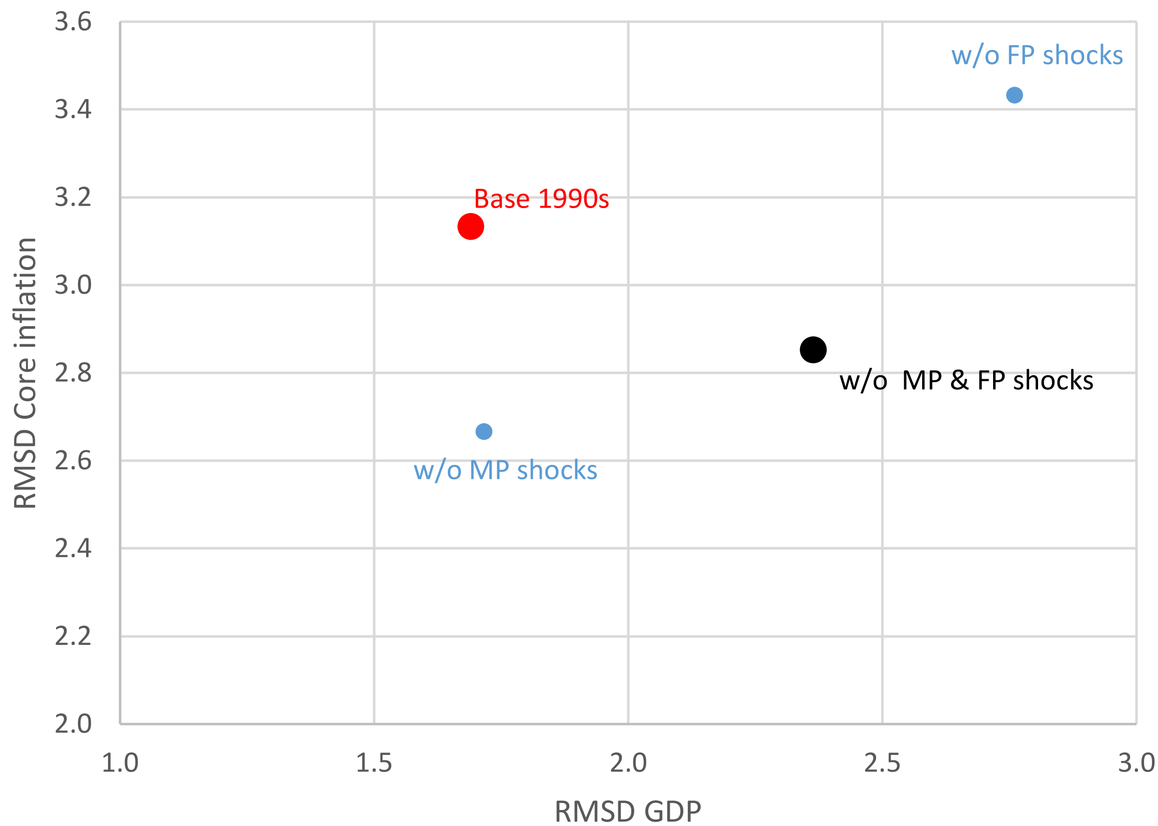

Figure 13: Role of policy shocks (*art*) during the 1990s

To sum up the main results, we can stress that both the *science* and *art* of macroeconomic policy evolution have contributed to reduce macroeconomic volatility in Chile. This is clearly evident with the inferred shocks in 2000s with the monetary and fiscal policy implemented during the 2000s in comparison with the policies in the 1990s or when removing the policy shocks of the 2000s. For the 1990s, we see that this conclusion is less strong and some tradeoff emerges. However, it still true that the policy rules of 2000s provide lower macroeconomic volatility with the inferred shocks of the 1990s. Also, fiscal policy shocks of the 1990, on average, tended to reduce macroeconomic volatility, which is not necessarily true in the case of monetary policy shocks of the 1990s.

7.4 Robustness analysis of results

In this subsection we explore how the previous quantification of volatilities change under alternative parametrizations. First, we consider the possibility of having the parameters that control price and wage rigidities different in each subsample. Changes in the degree of price and wage rigidities can also affect the macroeconomic volatility beyond the role of policy rules and policy shocks. Second, we analyze a case where all coefficients in the monetary policy rules in (26) and (27) are completely different across subsamples. Hence, the change in the monetary policy between the 1990s vis-a-vis the 2000s is not only about the exchange rate stabilization, but it also to modifications to inflation and GDP stabilization and interest rate smoothing. Third, the monetary policy rule can depends on the Federal Reserve rate and, therefore, the level of this FED rate affects systematically the conduct of monetary policy in Chile.[20]

In order to implement each alternative parametrization, we use Bayesian techniques to estimate in each subsample the considered parameters. This methodology assumes a prior distribution for the estimating parameters, which it is the same in both subsamples. We then computes the posterior distribution based on the data in each subsample.[21] We will use the posterior mode of the estimated parameters as the value to compute the same volatilities explained in subsection 7.2 under the base case and the contrafactual scenario.

Table 3: Bayesian estimation of parameters of price and wage rigidities

Parameter	Prior shape	Prior mean	Prior SD	Post mode 1990-1999	Post mode 2000-2015
ϕ_H	Beta	0.75	0.10	0.32	0.62
χ_H	Beta	0.50	0.10	0.56	0.40
ϕ_L	Beta	0.88	0.10	0.83	0.29
ξ_L	Beta	0.50	0.10	0.50	0.54
ϕ_F	Beta	0.75	0.10	0.81	0.83
χ_F	Beta	0.50	0.10	0.57	0.73

Table 3 present the Bayesian estimation of the parameters that controls the degree of price and wage rigidities. We center the prior estimation in the value used in the calibration explained in section 5. The last two column shows the posterior mode of each parameter

[20] Caputo and Herrera (2017) uses a panel of countries finding evidence of this reaction of the monetary policy rate to the FED rate.

[21] More details on the implementation of the Bayesian Estimation in DSGE models can be found, for instance, in Schorfheide (2000) and Fernández-Villaverde and Rubio-Ramírez (2007).

estimated with the data from the 1990s and from the 2000s. The posterior modes suggest that frequency of price changes in domestic goods has reduced from 1990s to 2000s, whereas nominal wages has turned less rigid in 2000s in comparison to the 1990s. Imported goods has increased its indexation to past inflation from the 1990s to 2000s. For the rest of parameters related to price and wage rigidities we see no big difference across subsamples.

Table 4: Bayesian estimation of monetary policy rules

Parameter	Prior shape	Prior mean	Prior SD	Post mode 1990-1999	Post mode 2000-2015
φ_i	Beta	0.84	0.05	0.94	0.66
φ_π	Normal	1.50	0.10	1.37	1.62
φ_{dy}	Normal	1.00	0.30	1.36	0.79
τ_m	Normal	1.57	0.84	1.01	0.04

The results of the policy rule estimated completely different across subsamples are shown in table 4. As in the previous case, we center the priors of each parameters in the value considered in section 5 in each subsample. Importantly, the prior mean of the exchange rate stabilization (τ_m) is 1.57 in the 1990s and 0 in the 2000s. We estimation points out that monetary policy was more inertial in the 1990s than in the 200s, with a higher stabilization of inflation in 2000s relative to the 1990s. The posterior mode also confirms a much higher stabilization of the exchange rate in the 1990s with an almost nonexistent role for that in the 2000s.

Table 5: Bayesian estimation of reaction of FED rate in MP rules

Parameter	Prior shape	Prior mean	Prior SD	Post mode 1990-1999	Post mode 2000-2015
φ_{FED}	Normal	0.00	1.00	0.00	0.00

The third alternative estimation considered the possibility of including a reaction of the monetary policy rate in each subsample to the Federal reserve rate. In particular, we include the term $\left(\frac{R_t^{FED}}{\bar{R}^{FED}}\right)^{(1-\varphi_i)\varphi_{FED}}$ in the monetary policy rules (26) and (27) in each subsample. The priors and posterior mode in each period is presented in table 5. We find no systematic role of the FED rate in setting the short-term interest rate both subsamples.

Table 6: Macroeconomic volatilities 2000s. Base and alternative cases

	Role of policy rules (*science*)					
	Base estimation		P and W rigidities 1990s		MP rules est. separately	
	1990 rules	2000 rules	1990 rules	2000 rules	1990 rules	2000 rules
$RMSD(y)$	4.42	4.38	3.58	3.45	4.05	3.71
$RMSD(\pi)$	3.70	2.32	3.24	2.26	2.61	1.89
	Role of Policy shocks (*art*)					
	Base estimation		P and W rigidities 1990s		MP rules est. separatedly	
	w/ pol. sh.	w/o pol. sh.	w/ pol. sh.	w/o pol. sh.	w/ pol. sh.	w/o pol. sh.
$RMSD(y)$	1.52	3.26	1.52	3.10	1.52	3.10
$RMSD(\pi)$	1.33	2.07	1.33	2.07	1.33	1.71

Tables 6 and 7 reproduce the macroeconomic volatilities presented in subsection 7.3 (base estimation) together with the one obtained based on the estimation provided in tables 3 and 4. Since the last alternative estimation (including the FED rate in the monetary policy rule) does not deliver any relevant changes, we do not include them of the computation of the macroeconomic volatilities under these robustness exercises. To isolate the role of policy rules, we compute again the macroeconomic volatilities changing the policy rules but keeping the price and wage rigidities estimated in the 1990s. This is shown in columns fourth and fifth of table 6 for the shocks inferred in 2000-2015. The case when the monetary policy rule is estimated separately in each subsample is presented in columns sixth and seventh of table 6. Our main conclusions during the 2000s remained as in the base estimation: policy rules implemented in the 2000s and policy shocks in that period contributed to attenuate macroeconomic volatility.

Table 7: Macroeconomic volatilities 1990s. Base and alternative cases

	Role of policy rules (*science*)					
	Base estimation		P and W rigidities 1990s		MP rules est. separately	
	1990 rules	2000 rules	1990 rules	2000 rules	1990 rules	2000 rules
$RMSD(y)$	2.56	2.08	2.12	2.30	2.13	2.13
$RMSD(\pi)$	1.86	1.09	1.98	1.30	2.26	1.40
	Role of Policy shocks (*art*)					
	Base estimation		P and W rigidities 1990s		MP rules est. separately	
	w/ pol. sh.	w/o pol. sh.	w/ pol. shocks	w/o pol. sh.	w/ pol. sh.	w/o pol. sh.
$RMSD(y)$	1.69	2.36	1.69	2.32	1.69	2.29
$RMSD(\pi)$	3.13	2.85	3.13	3.00	3.13	2.80

Table 7 shows the computation of macroeconomic volatility in the 1990s in the same two robustness exercises: using the price and wage rigidities of the 1900s; and with completely separated estimation of monetary policy rule in each subsample. As in the base estimation, the conclusions of the role of policy rules for the 2000s and policy shocks is less unambiguous in reducing macroeconomic volatility when faces with the macroeconomic conditions that the economy experience during the 1990s.

8 Conclusions

Chile is an emerging economy that has progressed in its macroeconomic frameworks in the last thirty years. Several institutional arrangements and specific policy rules have cemented this evolution. At the end of the 1990s decade, Central Bank abandoned the exchange rate band and started to implement a full-fledged inflation targeting regime with a flexible exchange rate. Later in 2001, the government of that time announced the implementation of a fiscal policy rule oriented to finance public expenditure based on an estimation of structural or long-run revenues. These modifications were oriented to avoid pro-cyclicality in fiscal and monetary policy rules. At the same time, both policies kept some degree of discretion to accommodate deviations from the intended rules.

Methodologically, it is not trivial to decompose the part of the fluctuations that is attributed to policy rules changes and the part attributed to different shocks affecting the economy. Clearly, the shocks affecting Chile, like any other emerging economy, has evolved, being potentially different over time.

In this manuscript, we have made an effort to quantify the gains in terms of reducing macroeconomic volatility that the modifications in policy rules and discretionary policy deviations in the case Chile. In doing so, we have fitted a well-established DSGE model for Chile with a special treatment of the monetary and fiscal rules implemented in the distinguished periods and estimating the different shocks that affect the Chilean economy.

As expected, the policy rules implemented in the 2000s are better equipped to isolate the economy from traditional shocks such as prices, demand and external factors. Moreover, using the model to infer the shocks hitting the economy during the 2000s, we find that policy rule modifications around 2000 clearly reduce macroeconomic volatility. We also find that policy shocks in the 2000s have contributed to attenuate macroeconomic volatility. For that reason, we conclude that in 2000s the *science* and *art* of monetary and fiscal policy helped macroeconomic stabilization overall. The results for the shocks inferred during the 1990s are less strong in the previous conclusion. However, it is shown that the policy rules of the 2000s would have been able to reduce inflation fluctuations in the 1990s and policy shocks in that period contribute to reduce GDP volatility.

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9 Appendix

9.1 Simulated Methods of Moments – Robustness Check

An alternative estimation for the key parameters that govern the monetary and fiscal policy rule in the model can be achieved by using a Simulated Methods of Moments (SMM) approach. The above consists in a simulation-based approach that involves comparing moments from the model data with moments from the actual data to estimate the value of the parameters of the model. This procedure is in line with authors such as Ruge-Murcia (2007), McFadden (1989) and Lee and Ingram (1991). A crucial dimension of our estimation, that departs from traditional SMM estimations, is that it needs to be a joint determination estimation due to the nature of the Chilean case. Therefore, we perform a joint determination (or simultaneous estimation) of two changes in theoretical moments to match two changes in data moments. The above will become clearer through the following section.

In order to really test the robustness of our model, the choice of such moments, and the economic interpretation, is crucial. We provide two (second) moments that, to our knowledge, fulfill as best as possible both the characteristics of the model and the economic interpretation.

The first moment consists in analyzing the absolute change in the correlation between exchange rate depreciation ($\mathcal{E}_{dep}$) and real copper price ($P^*_{CO,t}$) from 90's to 00's. Analyzing the data, it is observed that the $corr(\mathcal{E}_{dep}; P^*_{CO,t})_{90s}$ in the 90s is equal to -0.376, while in the 00s $corr(\mathcal{E}_{dep}; P^*_{CO,t})_{00s} = -0.097$, a clear result for exchange rate flexibility facing external shocks. Therefore, the first moment for the model to match would be the following

$$|\Delta corr(\mathcal{E}_{dep}; P^*_{CO,t})|_{DATA} = 0.28 = |\Delta corr(\mathcal{E}_{dep}; P^*_{CO,t})|_{MODEL} \tag{55}$$

Analogously, the second moment of choice was the absolute change, from 90's to 00's, in the correlation between government revenues ($\mathcal{G}_{rev}$) and government expenditure ($\mathcal{G}_{exp}$). Examining the data, it is observed that the $corr(\mathcal{G}_{rev}; \mathcal{G}_{exp})_{90s}$ in the 90s is equal to 0.976, while in the 00s $corr(\mathcal{G}_{rev}; \mathcal{G}_{exp})_{00s} = 0.780$, a clear result for the procyclicality of the fiscal rule in the 90s (alternatively, a less procyclical fiscal behaviour for the 00s). Therefore, the second moment for the model to match would be the following

$$|\Delta corr(\mathcal{G}_{rev}; \mathcal{G}_{exp})|_{DATA} = 0.20 = |\Delta corr(\mathcal{G}_{rev}; \mathcal{G}_{exp})|_{MODEL} \tag{56}$$

Evidently, the choice of each moment was done in order to characterize the most important parameters governing the monetary and fiscal rules of the model. The simultaneous estimation of both equations, would give us a value for τ_m and τ_f (see equations 26 and

37). Our SMM estimation indicates that parameters τ_m and τ_f, which represent the weight of the exchange rate deviation in the monetary policy rule and the aggressiveness of the cyclical fiscal rule are equal to 1.476 and 0.750, respectively. This estimation does not differ significantly from the one detailed in section 5.2, where τ_m and τ_f are equal to 1.57 and 0.52, respectively. The main takeaway remains the same, during the 90s both the monetary and fiscal policies were more aggressive, the monetary by stabilizing FX and the fiscal by being more procyclical.