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Testing Real Business Cycle Models in an Emerging Economy

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Abstract

RBC models have been successful when applied to developed economies: their abilities in replicating the data of emerging countries remain largely unexplored. The rapid but unstable growth process in developing countries and their relatively less developed market structure pose a formidable challenge to neoclassical general equilibrium models. Using data of the Chilean economy, we explore the effects of market rigidities and macroeconomic policies on the dynamics of consumption, investment, inflation and factor markets. We find that business cycles models replicate much of the observed fluctuations of real and monetary variables in the Chilean economy, despite its idiosyncratic economic structure. Using a calibrated model we find that technology shocks, fiscal policies and labor market rigidities are the main sources of economic cycles, while monetary policies and wage indexation play a minor role. Econometric tests support the use of our calibrated model as an adequate representation of the Chilean data.

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1. Introduction

One of the most dynamic areas of macroeconomic research in the last decades is that of Real Business Cycle (RBC) models. Since the seminal work by Kydland and Prescott (1982), a number of papers have tested the ability of neoclassical general-equilibrium models to account for economic fluctuations. The original framework of Kydland and Prescott has been extended to include labor market rigidities (Hansen, 1985), taxes and government expenditures (McGrattan, 1994a), money and inflation (Cooley and Hansen, 1995), open economies (Backus et al, 1995), and increasing returns to scale in production (Weber, 2000). Each of these extensions has been successful in solving the limitations of calibrated models to replicate particularities of the data and can provide richer explanations of business cycles, although at the cost of increasing complexity.

Although RBC models have been successful when applied to developed economies, their ability in replicating the data of emerging countries remain largely unexplored. In the case of Chile, there are only a few noteworthy exceptions.[1] This paper provides the first systematic exploration of RBC models to the Chilean data, starting with the original Kydland and Prescott framework and introducing increasing degrees of complexity in the analysis. The purpose of this exercise is to test the capacities of RBC models to (1) replicate the salient characteristics of the observed aggregate fluctuations of the economy in the 1986-2000 period, and (2) provide insights regarding the contribution of fiscal and monetary policies to the cycle.

The challenge to RBC models posed by the Chilean experience is formidable. First, in the 1986-2000 period the economy experienced a rapid but unstable pace of growth. Although GDP grew at an average annual rate of 6.7%, it also experienced significant year to year fluctuations, from a high 10.1% growth in 1989 to only -1.0% in 1998. In contrast, in the same period GDP growth in the US was 2.6% and fluctuated within a narrower range of -1% to 4%. Second, in this period Chile experienced a remarkable reduction in inflation, from a high annual rate of 27% in 1989 to less than 3% in 1999, which suggests that the contribution of both nominal and real fluctuations might have played an important role during the period. Third, the economic structure of a developing country such as Chile differs markedly from that of industrial economies precisely in those underlying parameters that govern the mechanics of RBC models. Particularly different are the stock of capital and the capital-output ratio,

[1] Quiroz (1991) and Quiroz et al. (1991).

the size and composition of government expenditures, the composition of consumption and investment, and the size of technological shocks.

The structure of the paper is as follows. Section 2 provides a snapshot of the most salient features of economic cycles in Chile.[2] We use simple statistics to discuss the relative importance of the shocks to GDP and its components and to assess their temporal structure. Section 3 provides a brief description of the different general equilibrium models we use, stressing the role of technology shocks, the effect of real and monetary frictions (such as labor rigidities and cash-in-advance constraints), the impact of fiscal and monetary policy shocks, and the derived decision rules of optimizing agents. Section 4 of the paper describes the data –some of which has been collected especially for this study– and presents the parameterization of the different calibrated models. We also discuss the main difference between Chile´s key (deep) parameters and those of industrial economies, in particular the US. Section 5 presents the main empirical results, including the simulation of the models, the analysis of impulse-response functions. In section 6 we follow Canova et al. (1994) in viewing our artificial economies as restricted versions of more general VAR models. We, consequently, use econometric techniques to test these restrictions imposed by the structure of the model and the linearization process. Finally, section 7 collects the main conclusions and suggests future extensions of this work.

2. Characterizing the economic fluctuations of the Chilean economy

The stylized facts that characterize business cycles in Chile were obtained from the longest available database with consistent information on a quarterly basis, which covers the 1986-2000 period. As expected, economic fluctuations in Chile present important similarities when compared to the features of business cycles in industrialized countries (see, for example, Backus et al. 1995), but they also present interesting peculiarities.

We follow Lucas (1977) in defining business cycles as deviations from their long run trend. The definition and computation of this trend, nevertheless, are controversial. During the last years a rich debate ensued with respect to the abilities of different statistical methods to decompose time series into long and short term fluctuations (see Baxter and King, 1995; Guay and St-Amant, 1996). The relative advantages of competing techniques such as those of Beveridge and Nelson (1981), Watson (1986),

[2] For a complete description see Bergoeing and Suarez (2001).

Hodrick and Prescott (1997), and Baxter and King (1995) are, nevertheless, not established. Mechanical filters have been criticized by Harvey and Jaeger (1993) which show that the Hodrick-Prescott (HP) filter can induce spurious cyclicality when applied to integrated data. Guay and St-Amant (1996) found that the HP and Baxter-King (BK) filters perform poorly in identifying the cyclical component of time series that have a spectrum with the shape characteristic of most macroeconomic time series. Baxter and King (1995) note that two-sided filters such as the HP and BK filters become ill-defined at the beginning and the end of samples.

Notwithstanding this debate, we follow the standard practice of the business cycle literature of reporting all stylized facts using the deviations of the variables from their long-run trend obtained with the Hodrick and Prescott filter (HP). Since the purpose of our paper is to assess the capacities of this type of models in describing the regularities of Chile´s economic cycles, this choice allows us to compare our results to the evidence gathered for other countries. Canova (1998) illustrates his support of the use of the HP filter arguing that when comparing results among models we ought to be "looking through the same window".

We report several statistics for the HP filtered data.[3] In particular, we consider: (1) the amplitude of fluctuations (volatility), represented by the standard deviation of the cyclical component of each series, (2) the ratio of the standard deviations of the series to that of output (relative volatility); (3) the contemporaneous correlation of the cyclical components of a variable and that of output; and (4) the phase shift, represented by the correlation coefficients between leads and lags of each variable and output.[4] A variable leads output by *i* quarters if their cross correlation peaks *i* quarters before output. Since all variables are in logarithms, the change in the trend component represents the growth rate.

Figure 1 shows the evolution of the cyclical GDP in the period under analysis. Clearly, three cycles have occurred in the sample (measured from peak to peak), though they differ in magnitude and length. The size and volatility of GDP cycles are rather large; considering that the quarterly trend is 1.8% in the sample, the peak of the cycle would be equivalent to observing an annualized growth rate of 20%, while at the trough it would amount to growth rate of -15%.

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[3]All series are seasonally adjusted using the ARIMA X-12 procedure and expressed in natural logarithms before being filtered, with the exception of the percent variables, such as inflation and interest rates, which are in levels.

[4] As customary, if the contemporaneous correlation is close to one we label the variable as procyclical; if it is close to minus one, we called it countercyclical, and if it is close to zero, we say is acyclical.

Additional information is presented in Table 1 which reports numerical indicators of the amplitude and phase of the fluctuations of GDP and other key macroeconomic variables. In general terms this information points to several similarities in the Chilean business cycle with regards to that of industrialized countries, but it also highlights interesting differences. In the first place, volatility of GDP in Chile –which reaches 2.20– is much higher than in most industrialized economies.[5] In part, this higher volatility is a reflection of structural characteristics of the Chilean economy (relative absence of automatic stabilizers, shallow financial markets, less diversified production structure, etc.), but is also consistent with the pace of high growth sustained by Chile in the sample period.

Private consumption is procyclical in Chile as it is in most countries: as displayed in Figure 2, it moves in synchronicity with GDP, with a high correlation coefficient of 0.82. Consumption is highly volatile. This feature is one of the challenges that business cycle models have to face. Since RBC models are essentially neoclassical, consumption is usually modeled under the permanent income hypothesis. In this setting, consumption volatility should be smaller than that of output since agents that optimize intertemporaly tend to smooth out consumption. The apparent excess volatility of consumption is, in part, the result of using total consumption data. As a matter of fact, when consumption is separated into purchases of durable and nondurable goods, we find that their volatility is markedly different (see Figure 3). Volatility of durable goods is 8.5 times higher than that of non-durable goods.[6] In what follows, we restrict consumption to nondurable goods and include purchases of durable consumption goods as a component of investment. Although the volatility of the purchases of non-durable consumption goods is smaller than that of total consumption or GDP, it remains rather high (1.88). In part, this may be the result of the existence of liquidity constraints (credit restrictions), a characteristic that our business cycle models should also address.[7]

A second challenge posed by the Chilean data to business cycle models is the nature of shocks in labor markets. Unemployment displays wide fluctuations as it reduced from a high 15.4% in 1986 to a low 5.6% in the 1998 to rebound to 9.2% in 2000. It can be seen in Table 1 that total hours worked

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[5] Volatility in Europe in 1970 to mid 1990s period was only 1.01 on average (Backus et al., 1995). The US exhibits higher volatility (1.72) in the 1954-91 period (Cooley and Hansen, 1995).

[6] The higher volatility of the consumption of durable goods does not arise primarily from the changes in relative prices, as the price deflator of durable goods exhibit the same volatility of its counterpart for non-durable goods.

[7] A number of industrialized countries exhibit very high volatility in consumption of non durable goods (e.g., Germany, France or Japan). In the US, Switzerland, and Canada volatility relative to GDP is lower than in Chile.

Figure 1. Deviations from trend of GDP

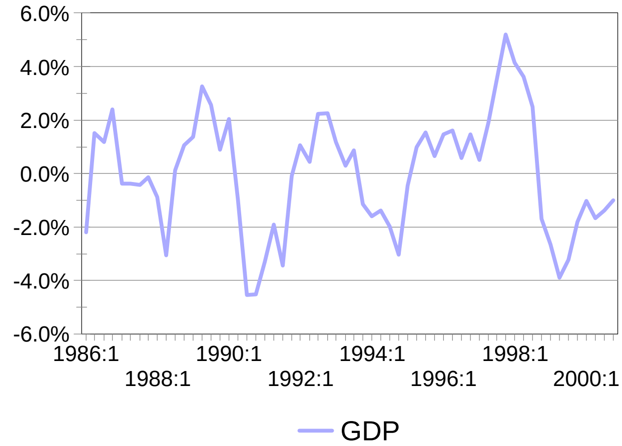


Figure 2. Deviations from trend of GDP and Total Consumption

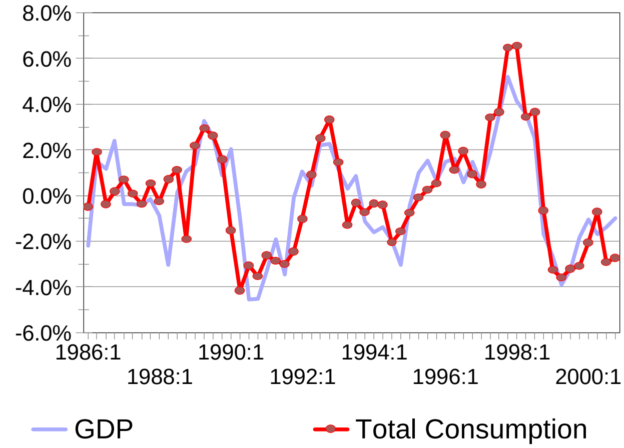


Figure 3. Deviations from trend of durable and non durable consumption

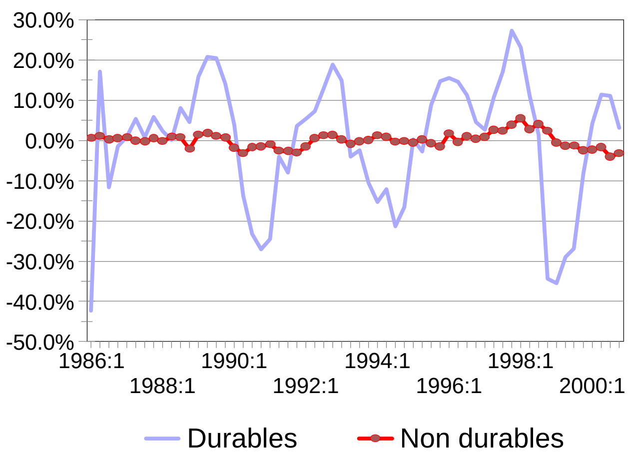


Figure 4. Deviations from trend of total and average hours worked

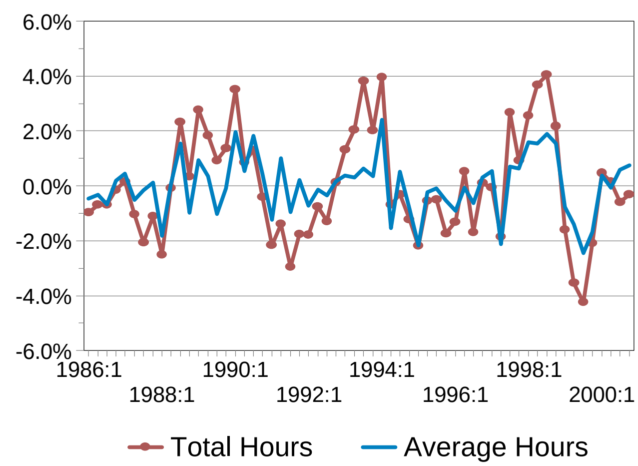


Figure 5. Deviations from trend of GDP and Prices

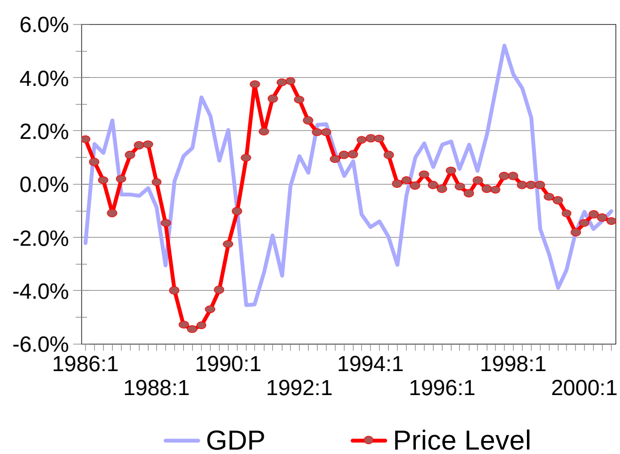
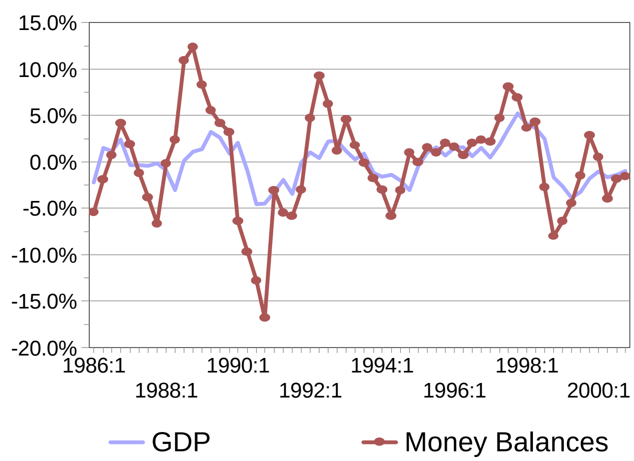


Figure 6. Cyclical components of GDP and Money Balances



are more volatile than real wages. In a neoclassical labor market total hours worked should display very low volatility because most of the adjustments should fall on wages and changes in total hours worked should be minimal. In Chile, on the contrary, the volatility of hours worked is quite high (1.92) and much higher than that of real wages (1.37), suggesting the existence of substantial rigidities or adjustment costs in the labor market. Additional evidence of such rigidities obtains when total hours worked is split into average hours worked per worker and the number of workers employed (employment). It can be seen in Figure 4 that average hours worked fluctuate less than total hours, suggesting that most of the adjustments correspond to the entry and exit of workers from the labor market rather than marginal adjustment in working schedules.[8]

An additional puzzle posed by the behavior of agents in labor markets are the fluctuations in real wages and their correlation with hours worked. In the Chilean case, the volatility of labor productivity is almost as high as that of GDP but it shows virtually no correlation with hours worked (estimated at 0.12). This is a worrisome feature for our business cycle models because one of the weaknesses of the original Kydland and Prescott specification is its inability to replicate the low correlation between hours worked and productivity levels or wages.

A third interesting feature of the business cycle in Chile is the presence of large fluctuations in investment. As a fraction of GDP, gross fixed capital formation increased from a low 15% in the mid 1980s to over 28% in the late 1990s. This important expansion of investment was also characterized by very high volatility levels, that reached 7.47 in the sample period, more than three times higher than that of GDP. When adding the purchases of durable goods to investment, volatility increases to 8.21.

As in most emerging economies, government expenditure in Chile displays some characteristics that are very different from developed economies. The size of the government measured by public consumption (as percent of GDP) is quite small in Chile reaching less than 10% in the 1986-2000 period. In addition, the government spends around 5% of GDP in capital formation (mostly in infrastructure) which we include in total investment. In addition, government consumption is quite unstable, with a volatility of 8.8, and is largely uncorrelated with fluctuations in GDP.[9] This high

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[8] As expected, the relative volatility of employment in Chile is higher than that in Japan (0.34) or Australia (0.34) and, surprisingly, similar to that in Europe (0.85), a continent characterized by sustained unemployment. Naturally, we grant that part of this heterogeneity in the performance of the labor market reflects differences in institutional arrangements.

[9] Government consumption in the US and Europe is around 18% of GDP (Backus et al, 1995). It is typically uncorrelated to GDP and displays lower volatility.

volatility suggests government expenditures might play an important role in causing economic fluctuations. A second important aspect of public consumption is that, for many groups of the society, these expenditures represent substantial transfers of goods and services (health and education, among others). Nevertheless, these groups also pay taxes, so that the net effect of changes in fiscal policies on economic activity and welfare may be ambiguous. Business cycles models developed below explicitly address this issue.

There are also significant differences between Chile and developed economies with regards to monetary shocks. As mentioned, inflation in Chile declined slowly from 27% in 1989 to around 3% in 2000, largely as a result of the gradualist monetary policy approach employed by the Central Bank (Morandé, 2002). The volatility of money, as measured by per capita real M1, is quite high (5.84) and money shocks are strongly correlated with GDP fluctuations (0.70). As a matter of fact, money cycles display a striking synchronicity with GDP fluctuations, as depicted in figure 6, and lead the cycle by one quarter. This certainly reflects the effects on the real side of the economy of the choice by the Central Bank of using real interest rate-based policy instruments –as opposed to targeting monetary aggregates– during the last ten years. Hence, it is not surprising to find that anti-inflationary policies have also induced marked volatility in the price level (2.12). Inflation has also been quite persistent, a direct result of the anti-inflationary policies implemented in the period that was compounded by the high degrees of price indexation of the Chilean economy.

Prices, on the other hand, display a negative correlation to GDP. This, compounded by the fact that real wages are procyclical, suggests that supply shocks are an important source of fluctuations in aggregate activity.

Table 1
Main Indicators of the Business Cycle in Chile
1986.1-2000.4

Variable	Volatility (std. dev. x100)	Volatility relative to that of output	Correlation with output: Contemporaneous	Correlation with output: Peak Quarter Lead(+), Lag(-)
Output	2.20	1.00	1.00	0
Consumption	2.43	1.11	0.83	0
• Non Durables	1.88	0.86	0.60	-1
• Durables*	15.94	7.25	0.80	0
Investment	7.47	3.23	0.83	0
Capital	1.32	0.60	0.41	-3
Avg. Hours Worked	1.07	0.74	0.21	-2
Total Hours Worked	1.92	0.87	0.44	-2
Employment	1.23	0.56	0.48	+2
Real Wages	1.37	0.62	0.38	-1
Government Cons.	1.55	4.04	-0.08	+2
Money	5.47	2.49	0.64	+1
Price Level	2.12	0.96	-0.26	0
Inflation	0.93	0.42	-0.06	+3
Exports	3.25	1.47	0.47	0
Imports	6.74	3.06	0.85	0

Note: (*) corresponds to the purchases of durable consumption goods.

Finally, in small open economies, such as Chile, one should expect an important effect of international business cycles on the domestic economy. In particular, when foreign trade is largely dependent on commodity prices. In our case, this dependence arises from the large share of copper on exports and also because Chile is dependent on oil imports. Commodity prices are very volatile. Hence, it is not surprising to find that the volatility of the terms of trade is more than two times higher than that of GDP. This is much larger than that of developed economies, which on average present a volatility of 3.7. Nevertheless, it is markedly smaller than most Latin American and African economies for which volatility in the 1950-1990 period hover around 12 (Mendoza, 1995). The correlation between terms of trade shocks and output fluctuations, however, is small and negative (-0.38), probably reflecting both the presence of commodity stabilization funds for copper and oil and the fact that the economy anticipates the effect of terms of trade shocks. Although the cycles of terms of trade are pronounced, exports and imports are not as volatile. The volatility of exports reaches 3.25, a value that is comparable to Europe (3.78) but much smaller than that of the US (5.65). Imports, on the other hand, are much more volatile than exports (6.74) but not significantly higher than the cases of Europe (5.12) and the US (5.65). Although the effect of the foreign sector might look as important, the share of net exports in GDP is less than 5% in the 1986-2000 period, considerably smaller than consumption, investment and government expenditures.

3. Business Cycles models

The original model by Kydland and Prescott has been extended to include, among other issues, household production (Benhabib et al. 1991); labor hoarding (Burnside et al. 1993); a limited version of open economies (Backus et al. 1995); money and inflation (Cooley and Hansen, 1995); incomplete markets and heterogenous agents (Rios-Rull, 1992); and increasing returns to scale (Devereux et al. 1996).

In this section we present a stylized business cycle model for the Chilean economy and discuss the rationale for the main extensions we later test. Based on the description of the salient characteristics of economic cycles in Chile presented in section 2 and with the purpose of evaluating the relative contribution of macroeconomic policies, we develop a model that focuses on government expenditures and monetary shocks and includes real-side shocks as captured by technological shocks. The main characteristic of our model is to encompass within the framework of a general equilibrium setup an important number of features of the economy, including productivity growth, fiscal expenditures and monetary policy, and labor market rigidities. The main drawback of the present version of the model is that it neglects some the real and financial aspects of international business cycles and their effect on the private sector.

In addition, in this section we present the algorithms to obtain analytical and numerical solutions to the general-equilibrium optimization problem. For the latter, our discussion only sketches the main issues and we refer the reader to Cooley (1995) for detailed discussions on the different techniques.

3.1 A Model with Monetary and Fiscal Policy, and Labor Rigidities

We analyze the importance of technological, fiscal and monetary shocks as the sources of aggregate fluctuations in Chile. The analysis emphasizes the role of real and monetary frictions, such as quantitative labor rigidities, a cash in advance constraint and wage contracts.

We develop a general model economy that considers a government, which engages in fiscal and monetary policy, a large number of identical firms, and a large number of identical consumers, all of them whom are infinitely-lived. Later, we simplify this general model in several dimensions to emphasize specific features of our model economy. In all models calibrated below, the production function is taken to be the same while the different specifications which we test are obtained by suitable changes in the utility function and the nature of government policies.

In our general model money is held because it is required to purchase consumption goods or some subset of consumption goods. We introduce this cash-in-advance motive for holding money into the basic indivisible labor real business cycle model. Money is created by the government according to an exogenous law of motion. In addition, government taxes consumption and collects the revenues of taxation in order to finance government consumption and lump sum transfers. Initially, there will be no money illusion; non neutralities will arise only because anticipated inflation acts as a distorting tax on activities involving the use of cash. The economy will be neutral with respect to unanticipated changes in the money supply. Later, we will incorporate wage contracts into the model, in order to analyze the properties of an economy where monetary policy is not neutral.

Each household's objective is to choose sequences of cash and credit goods consumption, represented respectively by $\{c_{1t}, c_{2t}\}_{t=0}^{\infty}$, hours of leisure $\{h_t\}_{t=0}^{\infty}$, investment $\{i_t\}_{t=0}^{\infty}$, and money to be carried into the next period $\{m_{t+1}\}_{t=0}^{\infty}$, that maximize expected discounted utility:

$$\max\ E_0 \sum_{t=0}^{\infty} \beta^t [\alpha \log c_{1t} + (1-\alpha)\log(c_{2t} + \pi g_t) - \gamma h_t] \qquad \textbf{(1)}$$

The households maximize utility subject to several constraints. The first is their budget constraint,

$$(1+\tau_t) P_t c_{2t} + p_t i_t + m_{t+1} \;=\; P_t\left[w_t h_t + r_t k_t\right] + m_t \qquad \textbf{(2)}$$

which states that expenditures in time period *t* on the cash good c_{1t}, on the credit good c_{2t}, on the investment goods i_t, and on money to be carried into the next period m_{t+1}, can not exceed their income. There are various sources of income. One is the income from renting capital to firms, $r_t k_t$, and from allocating part of their one unit of time to work, $w_t h_t$. Another source is from currency carried from the previous period m_t, plus a nominal transfer (or tax) paid at the beginning of period *t*, T_t, as is shown next in the cash-in-advance restriction.

$$(1+\tau_t) P_t c_{1t} = m_t + T_t \tag{3}$$

The government taxes both types of private consumption at the tax rate τ_t. P_t is the price level in period *t*.

Capital is assumed to be equal next period to new investment plus what remains after depreciation:

$$k_{t+1} - (1-\delta) k_t = i_t \tag{4}$$

The utility function specification follows Hansen (1985) by assuming that households can work a fixed number of hours h_t or none at al. At the aggregate level, the model predicts that a certain fraction of workers is employed *h* hours per period and a certain fraction is unemployed. This assumption, represented by the linearity of leisure in the utility function, allows greater substitution between leisure at different dates.[10] Finally, government consumption in period *t*, g_t, is assumed to be weighted in utility by π. This weight depends on the relative price of private consumption of the cash good and public consumption. If $\pi = 1$, then public consumption and private cash consumption goods are perfect substitutes. If $\pi = 0$, however, public consumption does not affect the utility of the households.

The per-capita money supply is assumed to grow at the rate $e^{\mu_t} - 1$ every period, i.e., ,

$$M_{t+1} = e^{\mu_t} M_t \tag{5}$$

[10]The standard specification, referred to as divisible labor, introduces leisure as $\gamma \log h$ into the utility function. For a detailed description of the indivisible labor setting, see Rogerson and Wright (1992).

where μ is revealed at the beginning of period *t*.

In this context, the government budget constraint is given by,

$$P_t g_t + T_t \;=\; \tau_t P_t\left[c_{1t} + c_{2t}\right] + M_{t+1} - M_t \qquad \textbf{(6)}$$

The representative firm seeks to maximize profit, which is equal to $Y_t - w_t H_t - r_t K_t$. Aggregate output, Y_t, is produced according to the following constant return to scale technology,

$$Y_t \;=\; e^{z_t} K_t^{\theta} H_t^{1-\theta} \qquad \textbf{(7)}$$

where K_t and H_t are the aggregate capital stock and labor input, respectively:

The technology shock, z_t, is assumed to be revealed at the beginning of period *t*. The fist order conditions for the firm's problem yield the following functions for the wage rate and rental rate of capital:

$$\begin{aligned} w_t &= (1-\theta) e^{z_t}\left(\frac{K_t}{H_t}\right)^{\theta} \\ r_t &= \theta e^{z_t}\left(\frac{H_t}{K_t}\right)^{1-\theta} \end{aligned} \qquad \textbf{(8)}$$

Finally, the following market clearing constraint is assumed to be satisfied,

$$c_{1t} + c_{2t} + i_t + g_t \;=\; e^{z_t} K_t^{\theta} H_t^{1-\theta} \qquad \textbf{(9)}$$

The stochastic shocks evolve according to the following laws of motion:

$$\begin{aligned} z_{t+1} &= (1-\rho_z)\bar{z} + \rho_z z_t + \varepsilon_{t+1}^{z} \\ \mu_{t+1} &= (1-\rho_\mu)\bar{\mu} + \rho_\mu \mu_t + \varepsilon_{t+1}^{\mu} \\ g_{t+1} &= (1-\rho_g)\bar{g} + \rho_g g_t + \varepsilon_{t+1}^{g} \\ t_{t+1} &= (1-\rho_t)\bar{t} + \rho_t t_t + \varepsilon_{t+1}^{t} \end{aligned} \qquad \textbf{(10)}$$

In order to guarantee a stationary solution in the limit, we transform variables so that all variables in the deterministic version of the household's problem converge to a steady state. In particular, we define $\hat{m}_t \equiv \frac{m_t}{P_t}$, $\hat{p}_t \equiv \frac{P_t}{M_{t+1}}$ and use this to eliminate m_t and P_t from the problem.

The Bellman's equation for the household's problem can now be written as follows:

$$v(z,\mu,\tau,g,K,k,\hat{m}) = \max\left[\alpha\log c_1 + (1-\alpha)\log\left(c_2+\pi g\right) - \gamma h + \beta E v(z',\mu',\tau',g',K',k',\hat{m}')\right]$$

subject to

$$\begin{aligned}
c_1 &= \frac{1}{1+\tau}\left[T + \frac{\hat{m}}{\hat{P}}\right] \\
c_2 &= (1-\theta)e^{z}\left(\frac{K}{H}\right)^{\theta} h + \theta e^{z}\left(\frac{H}{K}\right)^{1-\theta} k - i - \frac{\hat{m}'}{P} \\
T &= \frac{e^{\mu}-1}{\hat{P}} - \bar{g}y \\
I &= K' - (1-\delta)K \\
i &= k' - (1-\delta)k
\end{aligned} \tag{11}$$

and to the decision rules

$$\begin{aligned}
K' &= K(z,\mu,\tau,g,K) \\
H' &= H(z,\mu,\tau,g,K) \\
P' &= P(z,\mu,\tau,g,K)
\end{aligned} \tag{12}$$

The last line gives the perceived functional relationship between the aggregate state (z,μ,τ,g,K), and per capita investment, per capita hours , and the price level. In equilibrium, these functions must satisfy the requirements of the following definition:

A *recursive competitive equilibrium* consists of a set of decision rules for the household, $c_1(z,\mu,\tau,g,K,k,\hat{m})$, $c_2(z,\mu,\tau,g,K,k,\hat{m})$, $k'(z,\mu,\tau,g,K,k,\hat{m})$, $h(z,\mu,\tau,g,K,k,\hat{m})$ and $\hat{m}'(z,\mu,\tau,g,K,k,\hat{m})$; a set of per capita decision rules $K(z,\mu,\tau,g,K)$ and $H(z,\mu,\tau,g,K)$; pricing functions $P(z,\mu,\tau,g,K)$, $w(z,\mu,\tau,g,K)$ and $r(z,\mu,\tau,g,K)$; a government transfer function $T(z,\mu,\tau,g,K)$ and a value function $v(z,\mu,\tau,g,K,k,\hat{m})$ such that:

- Households optimize: Given the pricing functions and the per capita decision rules, solves the functional equation $v(z,\mu,\tau,g,K,k,\hat{m})$ from the previous Bellman problem, and c_1, c_2, k', h, and $\hat{m}'$ are the associated decision rules;
- The firm optimizes: The functions *w* and *r* are given by equation 8;
- The government satisfies its budget constraint, given by equation 6; and
- Individual decisions are consistent with aggregate outcomes:

$$\begin{aligned} k'(z,\mu,\tau,g,K,K,1) &= K(z,\mu,\tau,g,K) \\ h'(z,\mu,\tau,g,K,K,1) &= H(z,\mu,\tau,g,K) \\ \hat{m}'(z,\mu,\tau,g,K,K,1) &= 1 \end{aligned} \tag{13}$$

We solve for the linear per capita decision rules for a linear-quadratic approximation of this economy. The methods employed are described in detail in Hansen and Prescott (1995).

Finally, notice that, by introducing several simplifications, the previous general model can be trivially transformed into a standard real business cycle model (as in Prescott, 1986), or as a real business cycle model with fiscal policy as the only policy source of aggregate shocks (as in McGrattan, 1994). For example, by eliminating the cash-in-advance constraint, and by setting $m_t = g_t = \tau_t = 0$, for all *t* and $\alpha = 1$, the model converges to a standard real business cycle economy, where technology shocks are the sole source of fluctuations.

3.2 Introducing nominal wage rigidities

The empirical evidence, presented in section 2, shows that in Chile there is high persistency in both, prices and wages. Furthermore, as in most countries, a significant portion of the labor force (especially manufacturing) participate in long-term contracts and labor markets show evidence of rigidities, characterized by the fact that aggregate hours fluctuate more than wages do. A relevant question, within this context, is how relevant are, in practice, nominal contracts as a propagation mechanism of nominal shocks in Chile?

Several papers have studied the implications of nominal wage contracts in the US, within the equilibrium business cycles literature. See for example, Hansen and Cooley (1995). Here, we incorporate nominal wage contracts to evaluate the relevance of nominal rigidities to understand the main features of the Chilean business cycles.

We modify the cash-in-advance model studied in the previous section, following Cooley and Hansen (1995), we impose that the nominal wage rate for period *t* be agreed to one period in advance. In other words, at the end of period *t-1*, the nominal wage rate for period *t* is competitively determined on the basis of expectations about the technology, fiscal and monetary shocks. Then, in period *t*, after the shocks are revealed, households choose consumption and investment. In addition, firms unilaterally choose employment to equate the marginal product of labor to the realized real wage.

From the first-order condition for the firm's problem, we know that

$$w_t = (1-\theta)e^{z_t}\left(\frac{K_t}{H_t}\right)^{\theta} \quad \textbf{(14)}$$

In this setting, this implies that

$$\log W^c = \log(1-\theta) + \theta(\log K - \log\hat{H}) + E[z + \log P|\Omega]. \quad \textbf{(15)}$$

where W_t^c is the nominal wage rate, which is a function of $z_{t-1}, \mu_{t-1}, g_{t-1}$, and τ_{t-1}. Individual's consumption and investment choices are functions of the full state vector $(z_{t-1}, \mu_{t-1}, g_{t-1}, \tau_{t-1}, K_t, k_t, m_t)$ while per capita consumption, investment and employment are functions of the aggregate full state vector $(z_{t-1}, \mu_{t-1}, g_{t-1}, \tau_{t-1}, K_t)$. Furthermore, Ω is the aggregate information set, consisting of $(z_{t-1}, \mu_{t-1}, g_{t-1}, \tau_{t-1}, K_t)$. Finally, $\hat{H}$ is the expected labor input given Ω for which W_t^c is the market clearing wage. Taking W_t^c as given, households choose their desired labor supply, $\hat{H}$, as a function of $(z_{t-1}, \mu_{t-1}, g_{t-1}, \tau_{t-1}, K_t, k_t, m_t)$. In addition, the firm, also taking W_t^c as given, chooses its demand for the expected labor input by maximizing expected profits given the information set Ω.The resulting equilibrium contract wage will equate the conditional expected value of the marginal product of labor multiplied by the price level, given Ω.

Once the full state vector $(z_{t-1}, \mu_{t-1}, g_{t-1}, \tau_{t-1}, K_t)$ is revealed, actual hours worked, *H*, is chosen by the firm so that the marginal product of labor is equal to the realized real wage. Together with equation 14, we have that

$$H(z_{t-1}, \mu_{t-1}, g_{t-1}, \tau_{t-1}, K_t) = \left[\frac{(1-\theta)e^{z_t}P}{W^c(\Omega)}\right]^{\frac{1}{\theta}} K \quad \textbf{(16)}$$

Using equation 16 to eliminate W_t^c, we obtain

$$\log H \ = \ \log \hat{H} + \frac{1}{\theta}(\log P - E[\log P \,\Omega]) + \frac{1}{\theta}\varepsilon^z \qquad \textbf{(17)}$$

Equation 17 implies that $\log H - \log \hat{H}$ is an i.i.d. random variables with zero mean. Finally,

$$\log h \ = \ \log \hat{h} + \frac{1}{\theta}(\log P - E[\log P \,\Omega]) + \frac{1}{\theta}\varepsilon^z \qquad \textbf{(18)}$$

and, therefore, households understand that their choice for $\hat{h}(z_{t-1}, \mu_{t-1}, g_{t-1}, \tau_{t-1}, K_t, k_t, m_t)$ will differ from their actual hours worked, $h(z_{t-1}, \mu_{t-1}, g_{t-1}, \tau_{t-1}, K_t, k_t, m_t)$ by the realization of this random variable.

As before, in order to solve the representative household dynamic programming problem, we transform the price level and monetary stock so that all variables are stationary in the limit.

4. Parameterization of the Chilean economy

The models were parameterized using quarterly data for the 1986-2000 period. The data are expressed in real domestic currency of 1986 and were deseasonalized using the X-12 procedure (sources and detailed definitions of the data are described in the appendix). Most macroeconomic variables such as GDP, consumption, and investment were obtained from national accounts compiled by the Central Bank. The data were adjusted to match the variables in the model. We used Gallego and Soto's (2001) breakdown of private consumption into durable and non-durable goods. These series does not cover housing. Consequently, output series were adjusted to exclude the imputed services of housing and include the services provided by the stock of durable goods. Total consumption includes private consumption in nondurable goods and government consumption. Gross investment figures were also adjusted to exclude residential construction (housing) and include purchases of durable goods and public investment.

The capital stock series were obtained recursively using the perpetual inventory method, based on an estimate of the end-of-period capital stock in machinery and non-residential buildings for 1985 by Hofman (2000). We included also the stock of durable goods calculated by Gallego and Soto (2001).

We assumed a quarterly depreciation rate (δ) of 2%. The depreciation rate computed by regressing the depreciation series on the capital stock yields a similar estimate (1.9%). For the 1986-2000 period the capital-to-quarterly output ratio is 9.2.

The breakdown of time between work and leisure was obtained as follows. Total available hours per week were computed by multiplying the labor force by 100 hours per week. Total worked hours per week were computed using average hours worked and employment. We obtained an estimated share of leisure of 57%, substantially below the standard 70% of benchmark models for developed economies. Casual evidence suggests our estimate is likely to be accurate since part-time work is very uncommon in the formal labor market in Chile and occasional surveys tend to support the notion that work schedules are markedly longer than in developed economies. The complete set of parameters is displayed in Table 2.

Some of the parameters were obtained from the Euler conditions of the general equilibrium models described before. For example, the discount factor was obtained from the Euler condition for consumption, $\beta = (1 + r)^{-1}$. We used the 1986-2000 average of the real interest rate (annualized 9.1%) to obtain an estimated of β of 0.978. The share of capital in output, θ, was also obtained from the first-order conditions of the optimization problem, $\theta = \frac{[1-\beta(1-\delta)]}{\beta}\frac{k}{y}$. In models that exclude the government, the calibrated parameter is 0.40, while in models including the government, the calibrated parameter is 0.36. These values are much lower than the factor share of capital in GDP reported by the Chilean national accounts (0.59). We do not use this estimate for two reasons. First, measured labor compensation in countries like Chile fails to account for the income of most self-employed and family workers, who make up a large fraction of the labor force. Gollin (2001) shows that, for countries where there is sufficient data to adjust for this mismeasurement, the resulting capital shares tend to be close to 0.30. In fact the estimate for the Chilean economy is 0.367. Second, a high capital share implies implausibly high rates of return on capital in our numerical experiments. A capital share of 59% would imply an annual real interest rate of over 22%.

The parameter of leisure in the utility function (γ) also depends on the specification of the labor market and the presence of the government. For models that assume a frictionless labor market and no government, parameter γ was calibrated as

$$\gamma = \frac{(1-\theta)\, l}{n(1-\delta \frac{k}{y})} \tag{19}$$

while in models that consider both institutional rigidities in the labor market and the presence of the government, this parameter was calibrated as:

$$\gamma = \frac{(1-\theta) l}{(1+\tau) n \left(1-\delta\frac{k}{y} - g(1-\pi)\right)} \tag{20}$$

The calibrated γ parameters are in the range [1.05, 1.76], suggesting there is little curvature in the labor supply function.

In the absence of microeconomic studies of the Chilean case, the proportion of government expenditures that is valued by consumers, π, was estimated using the following Euler equation:

$$\frac{U^{\prime}(c_t)}{\beta U^{\prime}(c_{t+1})} = 1 + r_t - \delta = \frac{c_{t+1} + \pi g_{t+1}}{\beta (c_t + \pi g_t)} \tag{21}$$

From this first order condition we run the following non linear regression:

$$c_t = \frac{1}{\beta(1+r_t-\delta)} c_{t-1} + \pi \left(g_t - \frac{g_{t-1}}{\beta(1+r_t-\delta)} \right) + \varepsilon_t \tag{22}$$

the estimated parameter is π = 0.450 (std. dev.= 0.26), implying that less than half of government expenditures is valued by consumers as substitute of private consumption. We deem our value reasonable for the Chilean case since around 37% of government current expenditures in the 1974-1998 period were direct transfers to the population in terms of health, education, and housing subsidies (Banco Central de Chile, 2001).

In order to obtain an estimate of the proportion of the transactions made by consumers using cash, we use the Euler equations for consumption which implies:

$$\frac{C_t}{C_t^r} = \frac{1}{\alpha} + \frac{1-\alpha}{\alpha} R_t \quad \textbf{(23)}$$

where C_t/C_t^r is the inverse proportion of cash goods in total consumption. Note that, since cash-in-advance restrictions hold, $C_t/C_t^r = C_t/M_t$. Following Cooley and Hansen (1995), we regress the ratio non-durable consumption money (M1) on the nominal interest rate. The model was estimated using non-linear least squares and obtained a point-estimate value of 0.753 (std. dev.= 0.005). Arguably, the estimation is not necessarily an accurate measure of cash goods since M1 includes money held by firms. Nevertheless, the latter is a very small proportion of money balances in the Chilean case.

Table 2
Parameterization

Model	β	δ	γ	θ	π	μ	α
Frictionless labor No government	0.9787	0.02	1.0302	0.4	-	-	-
Labor rigidities No government	0.9787	0.02	1.8654	0.4	-	-	-
Labor rigidities Government	0.9787	0.02	1.7829	0.37	0.45	-	-
Labor rigidities Government and money	0.9787	0.02	1.7829	0.37	0.45	0.04	0.753

The dynamic stochastic general equilibrium models consider four forcing variables (technology shocks, government consumption, taxes, and money growth). Technology shocks were obtained directly from the data using the calibrated factor shares as $\lambda_t = y_t / k_t^{\theta} l_t^{1-\theta}$. As mentioned in section 2, the processes of the four shocks are parameterized estimating the following canonical regressions:

$$\Delta \log x_t = \bar{x}(1-\rho_x) + \rho_x \log x_{t-1} + \varepsilon_t^x \quad \textbf{(24)}$$

The values of $\bar{x}$ correspond to the average sample values of each variable. The average technology shock, $\bar{\lambda}$, was set at 1 since it is only a scale parameter. The average growth in the per-capita money supply is 4%, while government consumption amounts to 8.9% of GDP and taxes 14.8%. The AR(1) processes fitted to the detrended variables yield the coefficients in Table 3 and show no sign of residual correlation. We also computed the variance of the innovations of these shocks ($\sigma^2_{\varepsilon^x}$) as shown in table 3.

Table 3
Stochastic Processes of Innovations

Forcing variable	$\bar{x}$	ϱ_x	$\sigma^2_{\varepsilon^x}$
Technology shocks	1.000	0.981	0.0099
Money growth	0.040	0.506	0.0084
Gov. consumption	0.089	0.760	0.0094
Taxes	0.165	0.846	0.0124

5. Testing Real Business Cycles Models in an Emerging Economy

Before presenting the simulation results it is interesting to evaluate how different are the parameters of the Chilean economy when compared to those used in studies of the developed economies. Table 3 presents a summary of the key parameters. The Chilean economy, as well as other emerging economies, differ in fundamentals aspects from developed economies.

First and foremost, capital is more scarce in emerging economies than in developed economies. As presented in Table 4, the ratio of capital to annual output in Chile is significantly lower than in the US. Therefore, real interest rates are substantially higher, reaching 9.1% in the 1986-2000 period, almost twice as high as those considered in benchmark models for developed economies (McGrattan, 1994b; Cooley and Hansen, 1995 and Backus et al., 1995). This, in turn, implies that intertemporal effects are less important in Chile as the future is more heavily discounted.

A second important difference is the working of labor markets. The most significant difference is in the "curvature" of labor in the utility function. In the Chilean case; substitution is less than one half of that in the US (which is in the 2.33-3.22 range), a feature that does not depend on labor market rigidities. This reflects the smaller amount of leisure time allocated by Chilean workers, as well as the larger share of capital in factor incomes. It should be noted that increasing this parameter from 2.33 to 3.22 allowed Hansen (1985) to improve substantially the abilities of real business cycles models in replicating the US data on output and labor markets.

Table 4
Comparison of Key Parameters

	Chile (1986-00) this study	US (1947-1987) Mc Grattan (1994)	US (1954-1991) Cooley - Hansen (1995)
Capital-output ratio	9.25	10.70	13.30
Discount Rate	0.978	0.985	0.989
Leisure time	0.582	0.733	0.690
Labor Curvature			
• frictionless market	0.9922	2.330	2.530
• market rigidities	1.7042	3.220	-
Share of Gov. Expend. in Utility Function	0.467	0.000	-
Volatility of GDP	2.20	1.81	1.72
Variance of innovations			
• technology	0.0099	0.0096	0.0070
• money	0.0251	-	0.0089
• gov. expenditures	0.0094	0.0061	-

The third important difference between an emerging economy, such as Chile, and developed economies is in the volatility of shocks and their effect on output and its components. The volatility of output –measured as the variance of detrended log of GDP– is 30% higher than the US and as high as 20% of European economies (European data is taken from Backus et al, 1995). The volatility of technological shocks, however, seems to be very similar in Chile, the US, and European economies. Nevertheless, money shocks in Chile are three times larger. The volatilities of inflation and prices, consequently, are also twice as high in Chile than in the US. Likewise, government expenditures in Chile are also 50% more volatile than in the US and most European economies, reflecting the dependence of the Chilean fiscal account on a narrower tax base.

The last significant difference is in the consumers' valuation of the goods provided by the government. McGrattan (1994b) estimates an extreme case for the US economy: zero valuation. In the Chilean case, the estimated value is substantially larger, indicating that the consumers benefit from government expenditures but also need to smooth out and additional source of stochasticity.

5.1 Simulation Results

The first column in table 5 reproduces the main indicators of the Chilean business cycle we would like to replicate using our RBC models. The results for the simplest model are presented in column 1 and corresponds to the case in which we exclude the government, allow for divisible labor, and introduce only one source of stochasticity in the form of technological shocks (this is the simplest Kydland-Prescott type of model). It can be seen that the model is successful in replicating a number of the features of the data. In fact, it reproduces 75% of the volatility of output and investment, but falls short of matching that of consumption, labor supply and capital stock.[11] In addition, it produces a positive and significant correlation between hours worked and productivity, which is at odds with the data, being the latter negative. This simple model also replicates some of the correlation between the variables and output, but in general terms is unsatisfactory. For some variables it generates excessive contemporaneous correlation (e.g., consumption, investment, and labor productivity), while in others it fails to capture the true relationship, in particular in the case of capital and total hours worked. By construction the model does not replicate any nominal variable.

The second column considers extending the previous model to include labor market rigidities. It can be seen that the model is a better representation of the data in this dimension as it now replicates 80% of the volatility of the hours worked. Likewise, Output and investment fluctuations are now almost identical to the data, but consumption and labor productivity remains poorly represented. The model does not also replicate correctly the dynamics of the economy, as it attaches too much contemporaneous correlation between most variables and Output, and it fails particularly to replicate the correlation between hours worked and labor productivity.

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[11] The estimated volatility of the stock of capital (1.32) is distorted by having the 1999-2000 recession and the limitations of the HP filter. When computed with the 1986-1998 period we obtained a value (0.90) which is higher to those in the US and European (0.5).

Table 5 also presents the results of extending Model 2 to include the fiscal side of government activities. As displayed in column 3, the introduction of government expenditures improves significantly the abilities of the business cycle model to replicate the volatility of consumption. The model's capacity to reproduce the functioning of the labor market is still disappointing, as is apparent in the insufficient volatility of labor productivity and the positive –yet quite smaller– correlation between hours worked and productivity. On the other hand, it provides estimates of the correlation of Output to most variables within a narrow range (consumption, investment, labor productivity), although it falls short to replicate that of capital.[12]

In summary, these results suggest that (1) business cycles models are able to replicate a substantial fraction of the observed fluctuations of the real side of the economy, (2) in comparative terms, the introduction of government expenditures is a more promising way to model economic fluctuations than labor market rigidities, and (3) some dimensions of the working of the labor market are not correctly replicated by these models.

In addition to replicating real side fluctuations, for policy purposes one would like business cycle models to replicated nominal variables such as inflation and prices. Moreover, one should expect a further gain on the real side if the inability of these four initial models to replicate the volatility of consumption is linked to the existence of liquidity constraints.

Model 4 introduces cash-in-advance constraints to the previous model. The model successfully replicates the volatility of the price level and overestimates slightly that of inflation. It would seem that the model is able to replicate the volatility of consumption and its correlation with output and that liquidity constraints are irrelevant. However, when one split consumption into cash goods (i.e., liquidity constraint) and credit goods (unconstrained), the results are very different. The volatility of unrestricted consumption is 1.70, very similar to the data, and its correlation with Output cycles is 0.70, also very close to the data. In the case of restricted goods, the volatility of consumption is 2.30 while its correlation with output cycles is 0.34. Thus, the model provides a reasonable matching to data also along this dimension.

Nevertheless, the model continues to produce a labor market equilibrium solution which does not match the data and is unable to find a significant correlation between output and the price level and

[12] Again, when excluding the 1999-2000 recession, the correlation of output and capital stock is only 0.14.

inflation. As in all previous models that exclude government expenditures, the correlation between hours worked and average productivity levels is disappointingly high.

Table 5
Simulated Business Cycle Models for the Chilean Economy

Variables	Data 1986-2000	Model 1	Model 2	Model 3	Model 4	Model 5
Labor Rigidities		Excluded	Included	Included	Included	Included
Gov. Consump.		Excluded	Excluded	Included	Included	Included
Money		Excluded	Excluded	Excluded	Included	Included
Wage Indexation		Excluded	Excluded	Excluded	Excluded	Included
Volatility						
Output	2.20	1.65	2.12	2.14	2.22	2.51
Consumption	1.88	0.69	0.82	1.64	2.22	2.01
Investment	8.21	6.08	8.27	9.04	9.70	12.32
Capital	1.32	0.42	0.56	0.59	0.65	0.65
Hours Worked	1.92	0.59	1.38	1.54	1.52	2.54
Labor Product.	1.92	1.08	0.83	1.02	0.84	1.11
Prices	2.12	-	-	-	2.17	1.84
Inflation	0.93	-	-	-	1.29	0.96
Contemporaneous correlation to Output						
Output	1.00	1.00	1.00	1.00	1.00	1.00
Consumption	0.60	0.94	0.92	0.64	0.36	0.47
Investment	0.83	0.98	0.98	0.81	0.93	0.94
Capital	0.41	0.08	0.09	0.12	0.10	0.04
Hours Worked	0.49	0.98	0.98	0.90	0.97	0.90
Labor Product	0.72	0.99	0.93	0.74	0.90	0.19
Prices	-0.26	-	-	-	-0.54	-0.34
Inflation	-0.06	-	-	-	-0.32	0.13
Corr. Hours Wages	-0.38	0.94	0.83	0.37	0.76	-0.24

Finally, Model 5 attempts to overcome the inabilities of the RBC model to address the correlation between hours worked and productivity levels by introducing wage indexation. The logic of using wage rigidities is that the RBC model is allocating too much variation to labor supply and not enough to changes in labor demand, i.e., it allows nominal wages to match changes in relative prices.

It can be seen that once indexation is enabled, the negative correlation between hours worked and productivity is reproduced in general terms. In addition, most features of the nominal side of the data are adequately reproduced, including the volatilities of inflation and prices. However, this comes at the cost of inducing excess volatility in almost all real variables, including output, investment, and hours worked. In addition, the working of the labor market is not well captured since simulated labor productivity is not as volatile as in the data and, furthermore, exhibit little contemporaneous correlation with output.

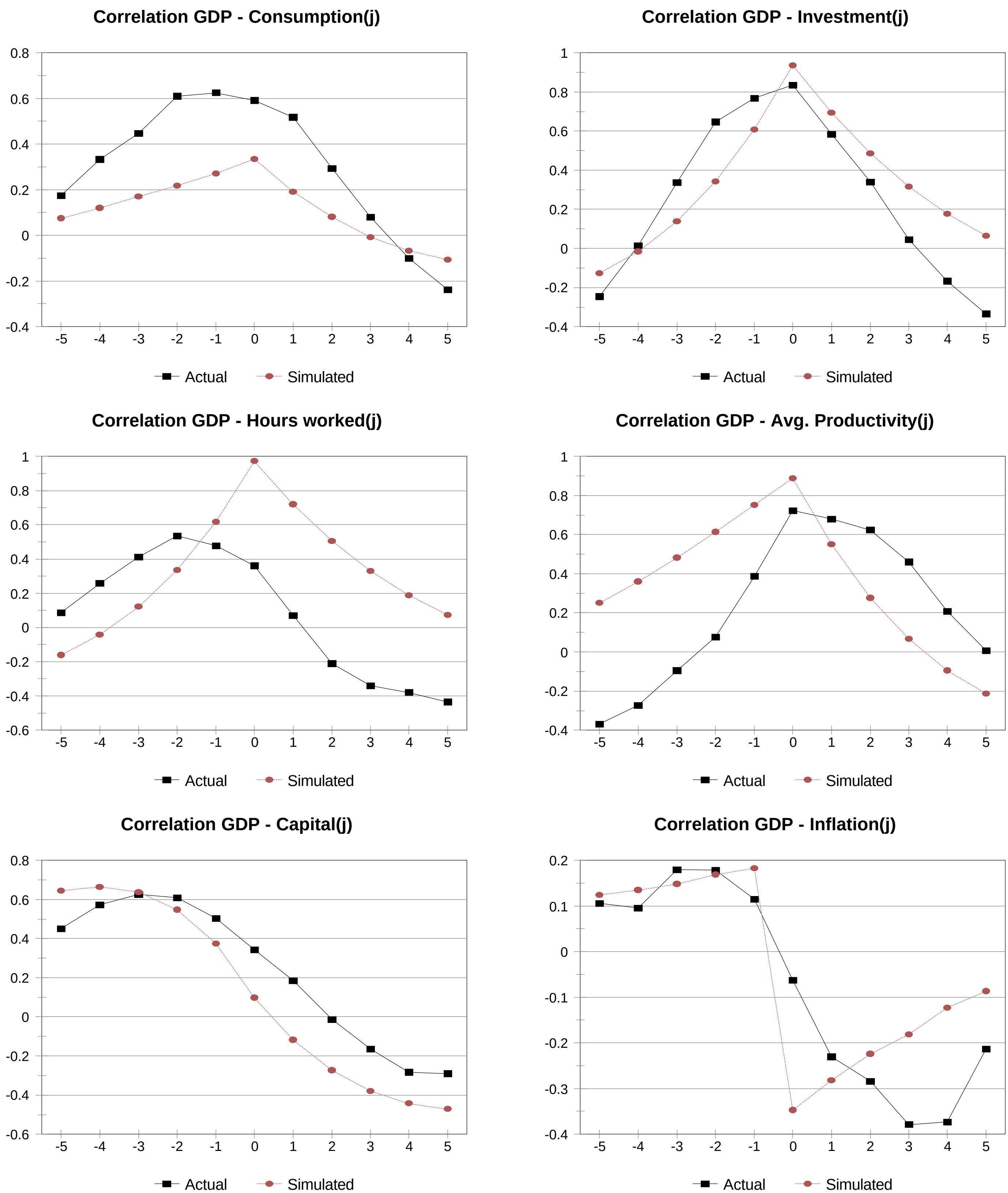
Our artificial economies should also be able to replicate the dynamics of the different variables in the cycle. We compute the correlations of the main endogenous variables and output arising from the simulated economies using Model 4, and compare them with the same correlations observed in the data. As can be seen in Figure 7, the model tracks quite closely the dynamics of investment, the capital stock and inflation, but performs less impressive with regards to consumption, hours worked and average productivity.

A second way to assess the capabilities of RBC models is to study their dynamic response to innovations in forcing variables. We selected Model 4 to study impulse-response functions because it is our better representation of the data and, also, because it allows us to discuss fiscal and monetary shocks.

Figure 8 shows the responses of output, consumption, investment and hours worked to a one-standard deviation shock to the technological process, money growth process, government expenditure process and tax process. The responses to temporary shocks, although quite short-lived, cause agents in the model to modify their consumption, investment and leisure decisions. By affecting prices, firms also modify their capital and labor hiring decisions.

- *Response to a Technology Shock*: A temporary technology shock increases total factor productivity. Since the return to work is temporarily high, individuals are encouraged to substitute intratemporally from leisure to consumption as well as intertemporally from current leisure into future leisure. Given the transitory nature of the shock, the positive wealth effect is likely to be

Figure 7
Actual and Simulated Cross Correlations



relatively weak, and the effect on leisure should be smaller so that employment is likely to respond positively to the transitory increase in productivity. With higher employment and higher productivity, current period output rises (the current period capital stock remains fixed). The consumption-smoothing motive suggests that a part of this increased output will take the form of additional new capital goods so that current period investment spending will rise together with current period consumption.

- *Response to a Money Growth Shock:* A temporary money growth shock has almost no effect on output and hours, but has a very large effect on consumption and investment. In fact, with a transitory increase in the growth rate of money, investment increases and, since output does not change, consumption decreases. Then, as the cash-in-advance restriction is less relevant, consumption increases and investment decreases.

- *Response to a Government Expenditure Shock*: A temporary government expenditure shock –when the budget is balanced every period– reduces consumption, since government expenditure partially substitutes it in utility. The impact on output and hours worked is initially negative, although very low. Then, investment increases and behaves in opposite ways with consumption through the recovery path towards the steady state.

- *Response to a Consumption Tax Shock*: The real response of the model to a transitory consumption tax shock is very similar to the response to a transitory government expenditure shock, since with balanced budget every period, increases in government expenditures are accompanied by reductions in the lump sum transfer to consumers. The main difference resides on the distortionary effect of the consumption tax, in opposition to the lump sum transfer. As a result, all variables respond much more than before.

5.2 How robust are RBC models?

The above parameterization imposes a number of restrictions on the structure of the economy that render the calibrated business cycle model a particular vision of the Chilean economy. A simple testing of these restrictions would be to change the structure of parameters and the dynamic nature of forcing variables and check whether the results do depend on these key parameters.

The sensitivity analysis is performed on the most ambitious specification (Model 4) and focuses basically on the two crucial policy parameters --the proportion of government expenditures valued by consumers, π, and the proportion of cash goods, α– and the imputed share of capital in output, θ. The results, presented in Table 6, suggest the following conclusions:

- Changing the share of capital and labor in Output does not induce significant changes in the computed volatilities and correlations with output. Since the capital stock is a very parsimonious series, the model exhibits less volatility in general (except for consumption).
- When parameter the valuation of public goods in the utility function is decreased from 0.45 to 0, the matching of variances and correlations is not affected in a significant manner for output, investment, employment, and the nominal variables. Consumption, on the other hand, reacts in the expected way, becoming less volatile as we eliminate one source of instability for the consumer.
- When liquidity constraints are made more stringent (i.e., when parameter α increases from 0.75 to 0.85) the general matching of variances and correlations for real variables becomes only marginally affected. Those for nominal variables improving slightly, suggesting that perhaps the value we used underestimates the true value.

In summary, changing the main parameters of this real business cycle of model does not produce significant changes in the qualitative conclusions reached above, although in some cases it modifies the numerical outcomes of the model and their distance from the actual data. Although this is not a formal test, the results suggest that the parameterization does in fact reflect the underlying structure of the Chilean economy and that the selection of crucial parameters is not too arbitrary.

Figure 8. Impulse Response Functions

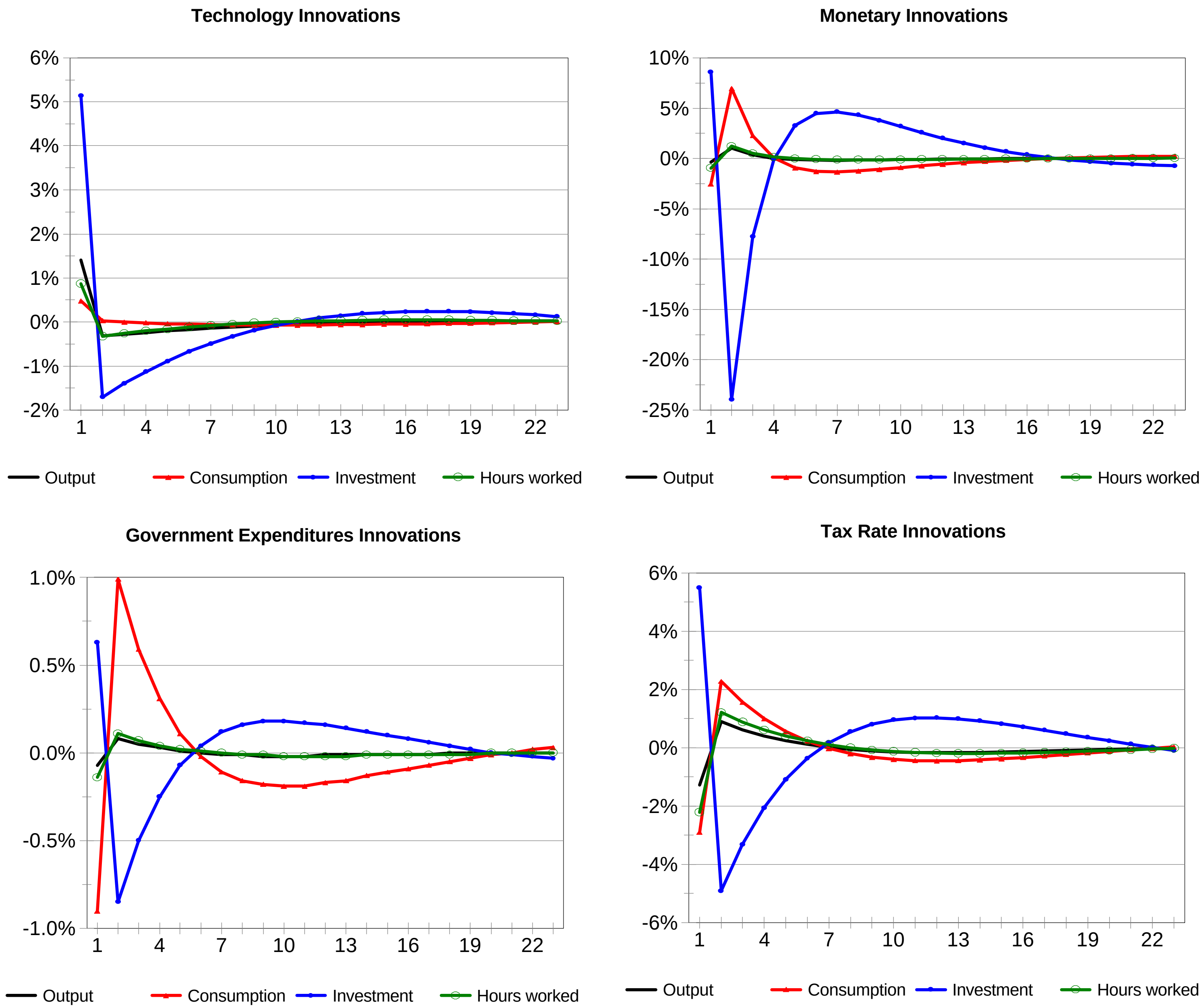


Table 6
Sensitivity Analysis of the Business Cycle Model of the Chilean Economy

Variables	Actual Data 1986-2000	Model 4 1	Increase θ from 0.37 to 0.45 2	Increase α from 0.75 to 0.85 3	Reduction π from 0.45 to 0 4
Volatility					
Output	2.20	2.22	2.08	2.26	2.16
Consumption	1.88	2.22	2.31	2.22	1.65
Investment	8.21	9.70	7.80	9.92	9.15
Capital	1.32	0.65	0.54	0.66	0.10
Hours worked	1.92	1.52	1.48	1.57	1.41
Labor Productivity	1.92	0.84	0.72	0.82	0.85
Prices	2.12	2.17	1.99	1.91	2.21
Inflation	0.93	1.29	1.13	1.03	1.33
Contemporaneous correlation to Output					
Output	1.00	1.00	1.00	1.00	1.00
Consumption	0.60	0.36	0.28	0.36	0.39
Investment	0.83	0.93	0.94	0.93	0.97
Capital	0.41	0.10	0.08	0.10	0.10
Hours Worked	0.49	0.97	0.97	0.97	0.97
Labor Productivity	0.72	0.90	0.89	0.89	0.93
Prices	-0.26	-0.54	-0.44	-0.40	-0.57
Inflation	-0.06	-0.32	-0.27	-0.26	-0.33
Corr. Hours - Wages	-0.38	0.76	0.76	0.76	0.82

5.3 Do RBC structures fit the data?

Business cycle models can be viewed as restricted versions of more general VAR models. These restrictions, imposed by the structure of the model and the linearization process, can be tested using relatively simple statistical procedures (see Canova et al, 1994). The debate among econometricians about the empirical evaluation of these models remains, nevertheless, controversial (Kydland and Prescott, 1996; Hansen and Heckman, 1996).

Following Canova et al. (1994), consider the following representation of Model 4 (including government expenditures, taxes, labor rigidities, and cash in advance restrictions) used before:

$$\begin{aligned} y_t &= A z_t \\ z_t &= F z_{t-1} + G \varepsilon_t \end{aligned} \qquad \textbf{(25)}$$

where y is the vector of variables of interest, z are the controlled and uncontrolled states (the latter labeled x), ε are the innovations, and A, F, and G are matrices of coefficients. These matrices are in general combinations of the "deep parameters" presented in Table 2; consequently Model 4 imposes particular structures to matrices A and F which can be tested directly against the sample data.

The first type of test arises from the long-run restrictions contained in matrix A. When the forcing variables (or uncontrolled states, x) are integrated variables, matrix F takes the following particular form:

$$\begin{bmatrix} \gamma & \delta \\ 0 & I_p \end{bmatrix}$$

where p of the eigenvalues of F are unity while the rest are the eigenvalues of γ. Since the latter are assumed to be less than one in business cycle models, there must be (n-p) cointegrating vectors among the states. This is the first testable hypothesis that can be confronted to the data. In our particular case, the z vector includes λ, g, μ, τ, and k.

The second testable implication of the RBC model as represented by equation 25 is that the residual of $y_t - A z_t$ ought to be stationary and the cointegrating vector must be A. Hence, a simple test of stationarity can be conducted to test this restriction.

Table 7 presents unit-root tests for the deseasonalized data. It can be seen that unit root tests do not reject the null of non-stationarity in the state variables k and n nor in the main variables of interest (output, consumption and investment), but the null is rejected in all forcing variables except tax rates. For technology shocks the evidence is less robust. It is widely accepted that unit root tests can be very misleading due to low power, structural breaks, etc. (Hamilton, 1994).

Treating forcing variables as integrated processes implies that, according to the business cycle model, there should be three cointegrating vectors (n=5, p=2). Table 8 presents the result of estimating cointegrating vectors within the sample data using Johansen's procedure. The RBC restrictions are weakly supported by the data in the sense that one cannot reject the null hypothesis of three cointegrating vectors.

Table 7
Unit Root Tests: Phillips-Perron Methodology
1986:1-2000:4

	Level		First Difference
	Without trend	With trend	
Money growth	-2.71	-4.00	-9.96*
Technology shocks	-0.87	-1.76	-5.78*
Government expenditures	-2.04	-3.39	-6.04*
Taxes	-2.34	-2.84	-6.61*
Capital Stock	-0.34	-2.34	-2.29
Output	-1.65	0.04	-4.54*
Consumption	-1.26	-0.58	-4.69*
Investment	-2.04	-1.08	-3.33*
Rejection Values 5%	-2.92	-3.50	-2.92
10%	-2.60	-3.18	-2.60

* denotes rejection of the null hypothesis at 1% significance level. All data seasonally adjusted, 3-lag truncation.

Table 8
Cointegration Tests: Johansen's methodology
Sample: 1986:1-2000:4 , 4 lags
Series: Capital, Hours worked, Technology shocks, Money growth, Government Expenditures

Eigenvalue	Trace Statistic	5 Percent Critical Value	1 Percent Critical Value	Number of cointegrating equations
0.63166	112.5845	76.07	84.45	None **
0.354944	58.65214	53.12	60.16	At most 1 *
0.277999	34.97756	34.91	41.07	At most 2 *
0.198612	17.38819	19.96	24.6	At most 3
0.095699	5.432024	9.24	12.97	At most 4

*(**) denotes rejection of the hypothesis at 5%(1%) significance level
Trace test indicates 3 cointegrating equation(s) at the 5% level.

Although the data suggest the existence of 3 cointegrating vectors, our RBC model does not necessarily produce exactly the same three vectors contained in the data. The second set of tests considers the implied reduced form of output, consumption, and investment, as described in equation 26, in terms of combination of the deep parameters of the model. Since, all endogenous variables are I(1), under cointegration η should be I(0).

$$\begin{aligned} y_t &= f_1(k_t, \tau_t, \lambda_t, g_t, \mu_t) + \eta_{y_t} \\ c_t &= f_2(k_t, \tau_t, \lambda_t, g_t, \mu_t) + \eta_{c_t} \\ i_t &= f_3(k_t, \tau_t, \lambda_t, g_t, \mu_t) + \eta_{i_t} \end{aligned} \qquad \textbf{(26)}$$

Cointegration tests are reported in Table 8 where it can be seen that the three equations cointegrate, thus providing econometric support to the RBC model, its implied decision rules, and the dynamics of endogenous variables.

Table 8

Cointegration Tests of the Reduced Form of the RBC model

1986:1-2000:4

	ADF test on ηs
Output	-3.85
Consumption	-5.43
Investment	-3.59

6. Summary and Conclusions

The goal of this paper was to test the capacity of various RBC type of models to (1) replicate the salient characteristics of the observed aggregate fluctuations of the Chilean economy in the 1986-2000 period, and (2) provide insights with regards to the contribution of fiscal and monetary policies as sources of business cycles. The Chilean economy provides an interesting case to study because, while it presents similarities with developed economies, it also displays important idiosyncratic features that challenge RBC theory.

The main findings of our paper can be summarized as follows. First, business cycles models are able to replicate much of the observed fluctuations of both, the real and monetary sides of the economy. Second, of the five models considered in this paper, an economy with government expenditures and labor indivisibility emerges as the best representation to account for short-term fluctuations in Chile. Although monetary shocks and nominal contracts improve the predictions of that model in some dimensions, they either generate excessive volatility or fail even further to account for the observed labor market behavior. Finally, replicating the fluctuations in consumption observed in the data may require placing additional constraints to the optimizing behavior of agents in our models.

This paper has provided strong evidence of the relevance of supply side shocks as sources of aggregate fluctuations in Chile. In the future, the main challenge consists in better understanding the connection between international business cycles and local markets dynamics, and the behavior of labor markets.

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Appendix
Data Sources and Definitions

The data are expressed in real domestic currency ($ of 1986) and were deseasonalized using the X-12 procedure. The following series were obtained from Indicadores Económicos y Sociales de Chile, 1960-2000 and its companion CD and correspond to national accounts definitions: GDP, total consumption, gross investment, and housing services. We also obtained money (M1A), interest rates, CPI, population, and labor force from the same source. GDP series were adjusted to include the services provided by the stock of durable goods and exclude the imputed services of housing. The breakdown of consumption into durable and non-durable goods, as well as the stock of durable goods and its imputed services, were obtained from Gallego and Soto (2001). Gross investment figures were adjusted to exclude housing (residential construction) and include purchases of durable goods. The capital stock series was obtained recursively using the end-of-period capital stock in machinery and non-residential buildings estimated for 1985 by Hofman (2000), the gross investment series including durable goods, and a quarterly depreciation rate of 2%. Quarterly tax revenues by category were obtained using annual revenue data from the tax authority's webpage (S.I.I.) and the standard related-series method. Labor force and average hours worked were obtained from the survey Encuesta de Ocupación y Desocupación released quarterly by the Departamento de Economía, Universidad de Chile. Total available time was fixed at 100 hours a week.