Public Expenditure Policy in Bolivia: Growth and Welfare*

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Abstract

It has been widely documented that public expenditure is important for economic growth, but little work has been done, in Bolivia, in relation to the macroeconomic impact of increasing public investment in infrastructure. This paper develops a Dynamic Stochastic General Equilibrium (DSGE) model for a small open economy that has four sectors: Non-tradable or services, importable or manufacturing, exportable intensive in capital or hydrocarbons, and exportable and less intensive in capital or mining. The model is parameterized and solved for the Bolivian economy and several interesting scenarios are performed by changing government expenditure, country risk, Total Factor Productivity and public capital elasticities. Actually, the government is retrieving fiscal policy as its main tool to attack poverty and aims to put government expenditure and investment as the foremost instruments to promote growth and welfare. The second-order approximation technique is used to solve the model. The benefit of using this technique is that it allows considering second-order effects (uncertainty) and in particular it allows measurement of welfare and growth effects more precisely.

Keywords: Fiscal Policy, Infrastructure, Multisector Growth Model

JEL classification: E62, H54, O41

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1 Introduction

Although infrastructure was incorporated in the theory of growth literature by Arrow and Kurz [1] and Weitzman [19], people began to study the theme seriously after the seminal work of Barro [5]. Barro’s model is well known, because he introduces government spending as a variable in the production function. The existence of constant returns to capital and government spending imply that the economy is capable of endogenous growth.

Coinciding with this new born of the growth literature, there is also the showing up of an empirical literature related to infrastructure. Infrastructure becomes an important source of growth as shown by Aschauer ([2], [3]). These works concentrated in the estimation of the production elasticities of government expenditure, using aggregated data for countries, mainly the U.S.¹ There are also cross-country studies that emphasize the role of infrastructure for a country’s growth.²

Papers in this literature have typically used regression analysis on either “growth accounting” or steady state equations. While these papers have been useful in pointing out the importance of infrastructure, their methodology does not allow for the analysis of important general equilibrium feedback effects among key macroeconomic variables and welfare.

In this sense, this paper examines the impact of public investment in infrastructure among output, consumption, private investment and foreign trade, using a Dynamic Stochastic General Equilibrium (DSGE) model for a small open economy with four sectors. These sectors which are the non-tradable sector (services), the importable sector (manufacturing), the exportable sector intensive in capital (hydrocarbons) and the exportable sector less intensive in capital (mining), are representative of the Bolivian economy. In particular the hydrocarbons sector which is conceived as the strategic and transformation sector, and the sector that will generate all the necessary resources to attack poverty and underdevelopment.

Therefore, the main objectives of the paper are to analyze the macroeconomic impact of public infrastructure on GDP, consumption, private investment and trade balance and to capture important dynamics involving public expenditure policy, external debt, performance of the exportable, non-tradable and importable sectors and the needed infrastructure expenditures improvement.

This type of new generation model allows us also to analyze and simulate numerous and interesting scenarios related to the dynamics of public spending policy, change in tax rates, change in import tariffs, fall in the relative price of exportable goods, increase in the country-risk premium together with its relationship with the debt that finances private investment, and variation in productivity in each or all sectors. In sum, we perform sensitivity analysis with the key parameters of the model combining them in different scenarios with


public investment in infrastructure.

The general equilibrium model is based on Chumacero, Fuentes and Schmidt-Hebbel [8] but modified to include public investment in infrastructure in a way similar to Rioja [17] and sector division for the exportable sector as in Estrada [10]. We calibrated the model for the Bolivian economy and solved it using the second-order-approximation technique developed by Schmitt-Grohe and Uribe [18]. The advantage in using this perturbation method is that it allows considering second-order effects, which arise as important features in an economy with high levels of uncertainty.

An important fact is that the model allows us to extract precise quantitative implications, because we examine the effects of a range of different scenarios on growth and welfare, as well as on the main macroeconomic variables (consumption and investment). Model simulation results are reported first, for steady-state effects and then for the dynamic effects on the composition of these variables.

In this regard, in this first version we display the accurately and exactly calibration of the model to the Bolivian economy. This allows us to be in a position to realistically assess the effects of public spending policy on growth and welfare.

2 Motivation (Fiscal Policy in Bolivia)

To be added.

3 The Basic Model

In this section we describe the main elements of the model, based on Chumacero, et.al. [8] and modified in order to address the issue of public investment in infrastructure as in Rioja [17] and expanded for a multisector economy as in Estrada [10]. The model is suitable to perform numerous and interesting scenarios related to fiscal policy (increase or decrease of taxes, current spending, public investment), shortage of external debt, fall in the price of energy-goods and commodities (minerals), variation in country-risk, among others, as will become clear from the following description.

3.1 The Households

The economy is inhabited by a representative agent who maximizes the expected value of lifetime utility as given by

$$E_t \sum_{t=0}^{\infty} \beta^t u(c_{m,t}, c_{n,t})$$

(1)

where $c_{m,t}$ represents consumption of importable goods $m$ and $c_{n,t}$ represents consumption of non tradable goods $n$ in period $t$. The other goods that are
produced in the economy are exportable goods which we denote \( x_h \) as the hydrocarbon good (natural gas) and \( x_a \) as the mineral good (zinc, gold, silver or tin).

Each household receives interest income \( r_k \), lump-sum transfers from the Government \( F \), profits from the importable, non-tradable and mineral firms \( \pi_m, \pi_n \) and \( \pi_{xa} \) respectively and can also contract foreign debt abroad, \( b \). So, the household’s budget constraint is

\[
(1 + \tau_{m,t})(1 + \tau_{cm,t})c_m + (1 + \tau_{cn,t})p_r c_n,t + (1 + \tau_{m,t})(1 + \tau_{cm,t})i_t + (1 + \bar{\eta})b_t \\
\leq (1 - \tau_{k,t})(1 + \tau_{m,t})(1 + \tau_{cm,t})r_t k_t + b_{t+1} + F_t + \pi_{xa,t} + \pi_m + \pi_n,t \tag{2}
\]

where \( \tau_m \) is an import tariff, \( \tau_k \) is the tax on capital income, \( \tau_{cm} \) and \( \tau_{cn} \) represent the tax rates on consumption of importables and non-tradables, \( p \) is the relative price on the non-tradable good in terms of the importable good (used as numeraire) and \( \bar{r} \) is the (net) interest rate paid on foreign debt. Private investment, which we denote by \( i_t \), follows the standard law of motion for private capital:

\[
k_{t+1} = i_t + (1 - \delta)k_t \tag{3}
\]

where \( \delta \) is the depreciation rate of private capital stock and \( k_t \) is the capital stock. As \( k_t \) is expressed in units of the importable good, it is also subject to the same taxes of the importable good destined to consumption (tariffs and the value added tax).

Then, the problem of the representative consumer can be summarized by the value function that satisfies:

\[
V(s_h) = \max_{c_m, c_n, k_{t+1}} \{ u(c_m, c_n) + \beta E[V(s_{h+1})] \} \tag{4}
\]

subject to (2) and (3), and the perceived laws of motion of the states \( s_h \).

The first-order optimality conditions are:

\[
p_t = \frac{u'_{cm,t}}{u'_{cm,t}} \frac{(1 + \tau_{m,t})(1 + \tau_{cm,t})}{(1 + \tau_{cn,t})} \tag{5}
\]

\[
1 = \beta E_t \left[ \frac{u'_{cm,t+1}}{u'_{cm,t}} \frac{(1 + \tau_{m,t})(1 + \tau_{cm,t})}{(1 + \tau_{m,t+1})(1 + \tau_{cm,t+1})} (1 + \bar{\eta}_{t+1}) \right]
\]

The first intratemporal optimality condition states that the relative price between importables and non-tradables must equate the ratio of marginal utilities.

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\(^3\)We define \( s_h = (\tau_m, \tau_{cm}, \tau_{cn}, p, \bar{r}, \tau_k, r, b, \pi_{xa}, \pi_m, \pi_n) \).
between both goods. The next two (intertemporal) conditions are the standard Euler equations that state that the marginal rate of substitution between consumption today and tomorrow, must equate their relative price, evaluated at the cost of foreign borrowing and the rate of return of capital investment, respectively.

3.2 The Firms

There are four sectors in the economy: importable (manufacturing), non-tradable (services), exportable intensive in capital (hydrocarbons) and exportable less intensive in capital (mining). In each sector there is an equal number of representative firms that require private capital \( k \) and public capital \( k^* \) to produce their goods. We assume that labor is sector specific. Next we state the problems faced by the firms.

3.2.1 Importable Goods’ Sector (Manufacturing)

The profits of the representative firm in the importable good’s sector are determined by

\[
\pi_{m,t} = (1 + \tau_{m,t})f(z_{m,t}, k_{m,t}, k_{m,t}^*) - (1 + \tau_{m,t})(1 + \tau_{cm,t})r_t k_{m,t} \tag{6}
\]

where \( z_{m} \) is a productive shock and \( k_m \) is the amount of private capital demanded. We can think as this sector represents the manufacturing sector.

The problem of the representative firm can then be summarized by the value function that satisfies:

\[
V(s_m) = \max_{k_m} \{ \pi_m + \beta E[V(s_{m+1})] \} \tag{7}
\]

subject to the perceived laws of motion of the states \( s_m \).

The first-order optimality conditions are:

\[
f'_{km}(z_{m,t}, k_{m,t}, k_{m,t}^*) = (1 + \tau_{cm,t})r_t \tag{8}
\]

which states that the marginal cost of new capital must equate its marginal value.

The output of this sector can either be consumed or used as capital in any of the four sectors.

3.2.2 Non-tradable Goods’ Sector (Services)

Profits for the non-tradable good’s sector are given by

\[
\pi_{n,t} = p_t f(z_{n,t}, k_{n,t}, k_{n,t}^*) - (1 + \tau_{m,t})(1 + \tau_{cm,t})r_t k_{n,t} \tag{9}
\]

where \( z_n \) is a productive shock, and \( k_n \) is the amount of (importable) capital demanded by the sector, which we can assume that it is the service’s sector.

\[\text{We define } s_m = (\tau_m, \tau_{cm}, r, z_m)\]
The problem of the representative firm can then be summarized by the value function that satisfies:

\[ V(s_n) = \max_k \{ \pi_n + \beta E [V(s_{n+1})] \} \]  (10)

subject to the perceived laws of motion of the states \( s_n \).

The first-order optimality conditions are:

\[ ptf'_{ktn}(z_{n,t}, k_{n,t}, k^*_t) = (1 + \tau_{m,t})(1 + \tau_{cm,t})r_t \]  (11)

3.2.3 Intensive in Capital Exportable Sector (Hydrocarbons)

There is a hydrocarbon’s sector which is intensive in capital and whose profits are given by:

\[ \pi_{xh,t} = q_{xh,t}f(z_{xh,t}, k_{xh,t}, k^*_t) - (1 + \tau_{m,t})(1 + \tau_{cm,t})r_t k_{xh,t} \]  (12)

where \( q_{xh} \) is the relative price of the exportable good intensive in capital in terms of the importable good, \( z_{xh} \) is a productive shock, and \( k_{xh} \) is the amount of (importable) capital demanded by this exportable sector.

The problem of the representative firm can then be summarized by the value function that satisfies:

\[ V(s_{xh}) = \max_{k_{xh}} \{ \pi_{xh} + \beta E [V(s_{xh+1})] \} \]  (13)

subject to the perceived laws of motion of the states \( s_{xh} \).

The first-order optimality conditions are:

\[ q_{xh,t}f'_{kxh}(z_{xh,t}, k_{xh,t}, k^*_t) = (1 + \tau_{m,t})(1 + \tau_{cm,t})r_t \]  (14)

3.2.4 Less Intensive in Capital Exportable Sector (Mining)

The other exportable sector (mining) is less intensive in capital and has a similar profit’s function given by

\[ \pi_{xa,t} = q_{xa,t}f(z_{xa,t}, k_{xa,t}, k^*_t) - (1 + \tau_{m,t})(1 + \tau_{cm,t})r_t k_{xa,t} \]  (15)

where again \( q_{xa} \) is the relative price of minerals in terms of importable goods, \( z_{xa} \) is a productive shock, and \( k_{xa} \) is the amount of (importable) capital demanded by this exportable sector.

The problem of the representative firm can then be summarized by the value function that satisfies:

\[ V(s_{xa}) = \max_{k_{xa}} \{ \pi_{xa} + \beta E [V(s_{xa+1})] \} \]  (16)

subject to the perceived laws of motion of the states \( s_{xa} \).

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5 We define \( s_n = (\tau_{m}, \tau_{cm}, p, z_n) \)
6 We define \( s_{xh} = (\tau_{xh}, \tau_{m}, \tau_{cm}, z_{xh}, q_{xh}) \)
7 We define \( s_{xa} = (\tau_{xa}, \tau_{m}, \tau_{cm}, z_{xa}, q_{xa}) \)
The first-order optimality conditions are:

\[ q_{xa,t} f'_{kxh}(z_{xa,t}, k_{xa,t}, k^*_{t}) = (1 + \tau_{m,t})(1 + \tau_{cm,t}) r_t \]  

(17)

3.3 The Government

The government invests in infrastructure \( I \), has current expenditure consumption \( g \) and provides lump-sum transfers to households \( F \). The Government satisfies the following constraint:

\[
g_t + F_t + I_t = \tau_{m,t}(c_{m,t} + i_t - y_{m,t}) + \tau_{cm,t}(c_{m,t} + i_t) \\
+ \tau_{cn,t}c_{n,t}p_t + (1 + \tau_{m,t})(1 + \tau_{cm,t}) r_t k_t + \pi_{xh,t} \]

(18)

Notice that in the right hand side of equation (18) we include all the taxes but also the profits from the hydrocarbons sector. This is in concordance with the nationalization of the hydrocarbon’s sector that took place in year 2007. Since then, the hydrocarbon’s sector is meant as the strategic sector for the Bolivian economy and the main source of resources for the State.

Public capital evolves according to

\[ k_{g,t+1} = I_t + (1 - \delta_g)k_{g,t} \]

(19)

where \( 0 \leq k_g \leq 1 \) is a constant depreciation rate of public capital.

As in Rioja [17] we assume that only the effective measure of the stock of public capital \( k_g \) is useful for private production. That is,

\[ k^*_{t} = \theta k_{g,t} \]

where \( 0 \leq \theta < 1 \) is an infrastructure effectiveness index. The closer \( \theta \) is to 1, the more effective the public capital stock, and the larger the benefit that firms get.

Typically the government does not optimize any explicit objective function but instead its current expenditure follow the rule:

\[ g_{t+1} = (1 - \rho)\overline{g} + \rho_g g_t + v_{g,t+1}, v_{g,t+1} \sim N(0, \sigma_{g}^2) \]

(20)

3.4 The Foreign Sector

The foreign sector determines the relative prices of the exportable goods in terms of the importables, i.e. the terms of trade. Terms of trade are assumed to follow the following law of motion:

\[ g_{xi,t+1} = (1 - \rho_{q_{xi}})\overline{g}_{xi} + \rho_{q_{xi}} g_{xi,t} + v_{q_{xi},t+1}, v_{q_{xi},t+1} \sim N(0, \sigma_{q_{xi}}^2) \]

(21)

where \( i = xh, xa \) respectively.
We assume also that the country faces an upward-sloping supply schedule for debt and model it as:

\[ r_{t+1} = (1 - \rho_r)\bar{r} + (1 - \rho_r)\varphi \frac{b_t}{y_t} + \rho_r \bar{r}_t + v_{r,t+1} \]  

(22)

where \( \bar{r} \) is the country risk premium. Notice that this debt schedule depends on the ratio of external debt \( b_t \) over output \( y_t \). This is to avoid having to model the world credit market.

3.5 Market-Clearing Conditions

Define the production functions of the exportables, importable and non-tradable goods by:

\[ y_{xh,t} = f(z_{xh,t}, k_{xh,t}, k^*_t) \]  

(23)

\[ y_{xa,t} = f(z_{xa,t}, k_{xa,t}, k^*_t) \]

\[ y_{m,t} = f(z_{m,t}, k_{m,t}, k^*_t) \]

\[ y_{n,t} = f(z_{n,t}, k_{n,t}, k^*_t) \]

The market clearing conditions are:

\[ CA = -(b_{t+1} - b_t) = q_{xh,t}y_{xh,t} + q_{xa,t}y_{xa,t} + y_{m,t} - c_{m,t} - g_t - i_t - I_t - \bar{r}_t b_t \]  

(24)

and

\[ p_t y_{n,t} = p_t c_{n,t} \]  

(25)

where equation (24) describes the equilibrium in the importable good market, which shows that the current account (CA) balance must be compensated by the capital account balance. Equation (25) is the typical equilibrium condition in the non-tradable good market.

3.6 Competitive Equilibrium

A competitive equilibrium is a set of allocation rules \( c_m = C_m(s), c_n = C_n(s), k_{t+1} = K(s), b_{t+1} = B(s), k^*_t = K^*(s), k_{xh,t+1} = K_{xh}(s), k_{xa,t+1} = K_{xa}(s), k_{m,t+1} = K_m(s), k_{n,t+1} = K_n(s) \); a set of pricing functions \( r = R(s) \), and \( p = P(s) \); and the laws of motion of the exogenous state variables \( s_{t+1} = S(s) \), such that:
• Households solve the problem (4) taking as given \( s \) and the form of the functions \( R(s) \), \( P(s) \), and \( S(s) \), with the equilibrium solution to this problem satisfying \( c_m = C_m(s) \), \( c_n = C_n(s) \), \( k_{+1} = K(s) \), and \( b_{+1} = B(s) \).

• Firms of the hydrocarbons, mining, importable and non-tradable sectors solve the problems (7), (10), (13), (16), taking as given \( s \) and the form of the functions \( R(s) \), \( P(s) \), and \( S(s) \), with the equilibrium solutions to these problems satisfying \( k_{xh,+1} = K_{xh}(s) \), \( k_{xa,+1} = K_{xa}(s) \), \( k_{m,+1} = K_{m}(s) \), \( k_{n,+1} = K_{n}(s) \).

• The economy-wide resource constraints (24) and (25) hold each period, and the factor market clears:

\[
K_{xh}(s) + K_{xa}(s) + K_{m}(s) + K_{n}(s) = K(s)
\]

4 Bolivian Model

The model which is clearly non-linear, is difficult to solve analytically. The alternative is to use numerical methods. Therefore, we adopt functional forms for the utility and productions functions and give values to the parameters of the model to match exactly real data of Bolivia. Failure to exactly match the National Account ratios and key indicators will result in the extraction of inadequate results and not precise policy implications.

4.1 Functional Forms and Calibration

With the generic model specified, next we present the functional forms and the criteria used to choose specific values of the parameters.

4.1.1 Functional Forms

For the preferences we are considering the following functional form:

\[
u(c_{m,t}, c_{n,t}) = \theta_m \ln c_{m,t} + \theta_n \ln c_{n,t}
\]

with \( \theta_m, \theta_n > 0 \) and \( \theta_m + \theta_n = 1 \).

For the production functions we employ the following specification:

\[
f(z_{i,t}, k_{i,t}, k_i^*) = e^{z_{i,t}k_i^*(k_i^*)^{\phi_i(\theta)}}
\]

where \( \alpha_i \) is the compensation for capital as a share of output of sector \( i = xh, xa, m, n \). Note that the coefficient of public capital in the production function \( \phi_i(\theta) \) is modeled as a function of effectiveness \( \theta \) (as in Hulten [14]). The rationale is that new public investment is more productive the higher the degree of effectiveness in the whole system. If \( \phi \) did not depend on \( \theta \), an increase in public investment would have the same impact whether effectiveness was low or high.
The productivity shocks $z_i$ are assumed to follow AR(1) processes:

$$z_{i,t+1} = (1 - \rho_i)z_i + \rho_i z_{i,t} + v_{i,t+1}, v_{i,t+1} \sim N(0, \sigma^2_{z_i})$$

### 4.1.2 Steady-State

The steady-state model is summarized by the following set of equations.

From the households’ first-order conditions we obtain the typical Euler equations:

$$p = \frac{\theta_n}{\theta_m} \frac{c_m(1 + \tau_m)(1 + \tau_{cm})}{c_n(1 + \tau_{cn})}$$  \hspace{1cm} (S1)

$$1 = \beta(1 + \bar{r})$$  \hspace{1cm} (S2)

$$1 = \beta((1 - \tau_k)r + 1 - \delta)$$  \hspace{1cm} (S3)

From the firms’ first order conditions we get:

$$e^{\tau_m} \alpha_k \kappa_m^{-1}(\theta k_g)^{\phi_m} = (1 + \tau_{cm})r$$  \hspace{1cm} (S4)

$$pe^{\tau_n} \alpha_k \kappa_n^{-1}(\theta k_g)^{\phi_n} = (1 + \tau_m)(1 + \tau_{cm})r$$  \hspace{1cm} (S5)

$$q_{xh}e^{\tau_{xh}} \alpha_{xh} \kappa_{xh}^{-1}(\theta k_{g})^{\phi_{xh}} = (1 + \tau_m)(1 + \tau_{cm})r$$  \hspace{1cm} (S6)

$$q_{xa}e^{\tau_{xa}} \alpha_{xa} \kappa_{xa}^{-1}(\theta k_{g})^{\phi_{xa}} = (1 + \tau_m)(1 + \tau_{cm})r$$  \hspace{1cm} (S7)

The government budget constraint (18) holds, as well as the laws of movement of private and public capital (3) and (19) respectively. By combining these equations we get:

$$g + F + \delta_k k_g = \tau_m(c_m + \delta k - y_m) + \tau_{cm}(1 + \tau_m)(c_m + \delta k) + \tau_{cn} c_n p + (1 + \tau_m)(1 + \tau_{cm})\tau_k r k + \pi_{xh}$$  \hspace{1cm} (S8)

The foreign interest rate is related to the ratio of debt over GDP as:

$$\bar{r} = \tau + \frac{b}{y}$$  \hspace{1cm} (S9)

Finally the equation for Aggregate Demand is given by:

$$0 = q_{xh} y_{xh} + q_{xa} y_{xa} + y_m - c_m - g - i - I - \bar{r} b$$  \hspace{1cm} (S10)
4.1.3 Calibration

Once the laws of motion are specified, we accurately calibrate the model so that it can display the main characteristics of the Bolivian economy. We are considering quarterly data for the period 1990-2007. In table 1, we display the parameters of the model, which we assume, for now, that are invariant to changes in economic policies.

<table>
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<th>Preferences</th>
<th>Production Functions</th>
<th>Technology Shocks</th>
<th>Fiscal Variables</th>
<th>Exogenous Prices</th>
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<td></td>
<td>$\sigma_{xca} = 0.001$</td>
<td>$\sigma_{xck} = 0.001$</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>$\sigma_{xcm} = 0.001$</td>
<td>$\sigma_{xck} = 0.001$</td>
<td></td>
</tr>
</tbody>
</table>

Table 1: Parameters

The first column of table 1 shows the deep parameters of preferences. The subjective discount factor $\beta$ was set to make it consistent with a 1.54 percent annual rate at which Bolivians can borrow ($\bar{r}$ in our model). Notice that $\beta = 1/(1 + \bar{r})$ from equation S2 and $\bar{r}$ is also related to the country risk. This parameter was calculated by computing the difference between the interest rate on treasury bonds from Bolivia and the U.S. The parameters $\theta_m$ and $\theta_n$ are chosen so as to reproduce the share of total consumption over GDP in steady state, where we define total consumption as consumption in importables plus consumption in non-tradables times its relative price.

The second column describes the deep parameters of the production functions. The depreciation rate of private capital $\delta$ is taken from Caselli [7] which founds an annual depreciation rate of 4 percent. The output-factor elasticities in each sector $\alpha$ were obtained in the following manner: The share of capital in
the hydrocarbons sector was extracted from the input-output matrix. It has the
highest value (0.69) showing that this is the sector that is intensive in capital.
The share of capital in mining (0.2) was obtained from Jordan [15] and the rest
of the shares were obtained from Estrada [10]. He adjusted these shares in a
way that match the share of private capital of 0.37 calculated by Gollin [13].
Therefore the following relation holds:

\[ \alpha = \frac{\alpha_n y_n}{y} + \frac{\alpha_m y_m}{y} + \frac{\alpha_{xh} y_{xh}}{y} + \frac{\alpha_{xa} y_{xa}}{y} \]

where \( \alpha_{xh} > \alpha_{xa} \) showing that indeed the hydrocarbons sector is more in-
tensive in capital than the mining sector.

The third column contains the TFP parameters that will be moved to analyze
impulse responses and dynamic effects to technology shocks in the economy.
These parameters have been calibrated to match the closer as possible the share
of each sector over GDP. These results are shown in table 4 below.

The forth column shows the government parameters and fiscal variables. The
parameters of the government expenditure AR(1) process have been obtained
by performing a simple OLS regression, although the parameter \( \tilde{g} \) has been
calibrated in order to match the government expenditure over GDP. The rate
of depreciation of public capital \( \delta_g \) has been estimated by the World Bank
to be about twice as high as the rate of depreciation of private capital. The
benchmark effectiveness parameter \( \theta \) is estimated here based on data from table
2 which corresponds to the so called "Loss Indicators" of the World Bank. These
loss indicators have been taken from the World Development Indicators (WDI)
and the National Institute of Statistics (INE). The Bolivian loss index across
infrastructure types is calculated by taking a weighted loss and comparing it
with the weighted average of industrialized countries.\(^8\)

<table>
<thead>
<tr>
<th>Year</th>
<th>Power(^a)</th>
<th>Telecom(^b)</th>
<th>Paved roads(^c)</th>
<th>Water(^d)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1995</td>
<td>11.56</td>
<td>96.60</td>
<td>94.50</td>
<td>n.a.</td>
</tr>
<tr>
<td>1996</td>
<td>11.49</td>
<td>95.01</td>
<td>94.50</td>
<td>42.52</td>
</tr>
<tr>
<td>1997</td>
<td>11.61</td>
<td>93.56</td>
<td>94.30</td>
<td>40.85</td>
</tr>
<tr>
<td>1998</td>
<td>11.99</td>
<td>91.33</td>
<td>94.00</td>
<td>35.03</td>
</tr>
<tr>
<td>1999</td>
<td>11.41</td>
<td>88.67</td>
<td>93.60</td>
<td>33.32</td>
</tr>
<tr>
<td>2000</td>
<td>10.18</td>
<td>86.85</td>
<td>93.40</td>
<td>31.02</td>
</tr>
<tr>
<td>2001</td>
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<td>84.63</td>
<td>93.30</td>
<td>31.86</td>
</tr>
<tr>
<td>2002</td>
<td>13.07</td>
<td>81.37</td>
<td>93.30</td>
<td>33.00</td>
</tr>
<tr>
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<td>78.62</td>
<td>93.00</td>
<td>31.50</td>
</tr>
<tr>
<td>2004</td>
<td>13.61</td>
<td>73.07</td>
<td>93.00</td>
<td>27.96</td>
</tr>
<tr>
<td>2005</td>
<td>13.95</td>
<td>66.59</td>
<td>n.a.</td>
<td>27.96</td>
</tr>
<tr>
<td>2006</td>
<td>14.36</td>
<td>62.13</td>
<td>n.a.</td>
<td>28.57</td>
</tr>
<tr>
<td>2007</td>
<td>n.a.</td>
<td>58.68</td>
<td>n.a.</td>
<td>28.94</td>
</tr>
</tbody>
</table>

Table 2: Infrastructure Loss Indicators

\(^8\)We use the same weights as in Rioja [17], this means 0.40, 0.10, 0.25, 0.25 for the Latin
American countries and 0.50, 0.09, 0.30, 0.11 for industrialized countries, for power, telecom,
paved roads and water systems respectively.
a. Electric power transmission and distribution losses (% of output)  
b. Mobile and fixed-line telephone unsubscribed people (per 100 people)  
c. Roads not paved (% of total roads)  
d. Households without water and sanitation services (% of total households)  

According to these calculations, Bolivia has a level of effectiveness of 55.25 percent which means that infrastructure in Bolivia is 45 percent less effective than in the developing countries.9

The infrastructure share parameters $\phi$ must be related to $\theta$. Unfortunately, there is no specific regression for Bolivia that estimates this parameter, nor at the aggregate level and neither at the sectorial level. So, we have calibrated this parameter using as benchmark, the computations performed by Rioja [17]. According to table 3 in Rioja’s paper for a value of $\theta$ equal to 0.5525, it corresponds a value for $\phi$ equal to 0.075. Note, that this is the value for infrastructure share in the aggregate production function of the economy. To compute the $\phi_i$ for each sector $i$, we decomposed the aggregate $\phi$ using as weights the share of public investment in infrastructure in each sector in total public investment. Similar to the $\alpha$’s the following relation must hold.

$$\phi = \phi_n \frac{I_n}{T} + \phi_m \frac{I_m}{T} + \phi_{xh} \frac{I_{xh}}{T} + \phi_x \frac{I_x}{T}$$

As Chumacero et.al.[8] and Estrada [10] we are assuming that all taxes follow AR(1) processes of the form

$$\log(\tau_{i,t+1}) = (1 - \rho_{\tau_i})\tau_i + \rho_{\tau_i} \log(\tau_{i,t}) + \epsilon_{\tau_{i,t+1}}, \epsilon_{\tau_{i,t+1}} \sim N(0, \sigma^2_{\tau_i})$$

where $\tau_i$ can be the tax on importables ($\tau_m$), a tax on consumption of importables ($\tau_{cm}$), a tax on non-tradables ($\tau_{cn}$) or a tax on capital ($\tau_k$).

The constants $\tau_i$ which are reported in table 1 are the steady state tax rates that are invariant along the analysis. The consumption taxes ($\tau_{cm}$ and $\tau_{cn}$) are approximated by the value added tax (IVA) which is 0.13 percent. The tax on capital income $\tau_k$ corresponds to the tax on benefits which has a rate of 0.25 percent. The import tariff $\tau_m$ has been extracted from Estrada [10] and has an average value of 9 percent without considering the tariff preferences.

Finally in column 5 of table 1 we display the so called exogenous prices. All of them follow standard laws of motion and most of their parameters were estimated using OLS regressions. We calibrated only the terms of trade of hydrocarbons ($\bar{q}_{xh}$) and mining ($\bar{q}_{xa}$) so that these sectors match their shares in GDP. To compute both prices we have used the unitary value index of exports for hydrocarbons and mining respectively. The value of $\bar{p}$ was calculated using equation S9 and taking $\bar{e}$ equal to 1.54 percent and a debt to GDP ratio of 81 percent10. Thus $\bar{p}$ is equal to -0.64 percent.

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9In developing countries the effectiveness index $\theta$ is normalized to 1, which means that infrastructure is highly effective.
10We used public and private external debt.
The following tables show the calibrated values for the National Account ratios. This time we are considering the GDP by expenditure type and also the GDP by economic activity. The ratios of the model do not match exactly the ratios of the data, but are close enough to say that our model is accurately calibrated for the Bolivian economy.\textsuperscript{11}

\begin{table}[h!]
\centering
\begin{tabular}{|c|c|c|c|}
\hline
Variable & Ratios & Data & Model \\
\hline
\textit{Consumption} \hspace{1cm} \textit{GDP} & $c/y$ & 0.7413 & 0.7215 \\
\textit{Private Investment} \hspace{1cm} \textit{GDP} & $i/y$ & 0.0929 & 0.0932 \\
\textit{Public Investment} \hspace{1cm} \textit{GDP} & $f/y$ & 0.0620 & 0.0620 \\
\textit{Government Current Consumption} \hspace{1cm} \textit{GDP} & $g/y$ & 0.1147 & 0.1107 \\
\textit{Trade Balance} \hspace{1cm} \textit{GDP} & $X + (M - F)/y$ & -0.0125 & -0.0125 \\
\hline
\end{tabular}
\caption{Calibrated Values (GDP by Expenditure Type)}
\end{table}

The calibrated values for each sector as a share of GDP for the average period (1990-2008) is shown in the following table.

\begin{table}[h!]
\centering
\begin{tabular}{|c|c|c|c|}
\hline
Variable & Ratios & Data & Model \\
\hline
\textit{NonTradables} \hspace{1cm} \textit{GDP} & $y_n/y$ & 0.5542 & 0.4884 \\
\textit{Importables} \hspace{1cm} \textit{GDP} & $y_m/y$ & 0.3339 & 0.3789 \\
\textit{Hydrocarbons} \hspace{1cm} \textit{GDP} & $y_xh/y$ & 0.0607 & 0.0707 \\
\textit{Mining} \hspace{1cm} \textit{GDP} & $y_xa/y$ & 0.0512 & 0.0617 \\
\hline
\end{tabular}
\caption{Calibrated Values (GDP by Economic Activity)}
\end{table}

We have to admit that the matching is not so good for the non tradable and importable sectors. But in part this is explained by the fact that it is difficult to classify the sectors in importables and non tradables using the disaggregation of GDP by economic activity. We computed the same ratios, but using the classification suggested by Barja [4] and the sectorial disaggregation of the input-output matrix and found ratios very similar to the ones reported in table 4 by our model.

\section{5 Results}

To be added.

\subsection*{5.1 Long Run Effects}

To be added.

\textsuperscript{11}A detailed explanation of how we handled our equations to fit the data can be found in the appendix.
5.2 Impact and Dynamic Transition Effects

To be added.

6 Conclusions

The model has been calibrated accurately to the Bolivian economy and the policy functions for each variable can be computed using the second-order approximation technique derived by Schmitt-Grohé and Uribe [?]. We have already designed the Matlab and Gauss computer codes to implement the second-order approximation to the policy rules. So our next step will be to analyze the log run and dynamic effects of different fiscal policy scenarios.\textsuperscript{12}

References


\textsuperscript{12}The Matlab codes are available upon request.
Appendix

Aggregate Demand Equation from our model:

\[ CA \equiv -(b_{t+1} - b_t) = q_{xh,t}y_{xh,t} + q_{xa,t}y_{xa,t} + y_{m,t} - c_{m,t} - g_t - \bar{r}_t - I_t - e \]

or

\[ q_{xh,t}y_{xh,t} + q_{xa,t}y_{xa,t} + y_{m,t} = c_{m,t} + g_t + \bar{r}_t + I_t + e + (b_{t+1} - b_t) \]

The equilibrium condition in the non-tradable sector is
\[ p_t y_{n,t} = p_t c_{n,t} \]

So we can add this equation to the aggregate demand

\[ q_{xh,t} y_{xh,t} + q_{xa,t} y_{xa,t} + y_{m,t} + p_t y_{n,t} = c_{m,t} + p_t c_{n,t} + g_t + i_t + I_t + \bar{r}_t b_t - (b_{t+1} - b_t) \]

Now we define GDP as

\[ GDP = y_t = q_{xh,t} y_{xh,t} + q_{xa,t} y_{xa,t} + y_{m,t} + p_t y_{n,t} \]

Total consumption is defined as

\[ C = c_t = c_{m,t} + p_t c_{n,t} \]

Investment is the addition of private investment plus public investment:

\[ INV = inv_t = i_t + I_t \]

Finally from the current account (CA) we have:

\[ X - M = \bar{r}_t b_t - (b_{t+1} - b_t) \]

\[ X - M - \bar{r}_t b_t = -(b_{t+1} - b_t) \]

\[ X - (M + F) = -(b_{t+1} - b_t) \]

where \( F = \bar{r}_t b_t \) represents the interest payment over external debt (service of debt or net factor payment).

So we have to calibrate:

\[ GDP = C + INV + G + X - (M + F) \]

or

\[ y_t = c_t + g_t + i_t + I_t + X_t - (M_t + F_t) \]

\[ 1 = \frac{c_t}{y_t} + \frac{g_t}{y_t} + \frac{i_t}{y_t} + \frac{I_t}{y_t} + \frac{X_t}{y_t} - \left( \frac{M_t}{y_t} + \frac{F_t}{y_t} \right) \]

The equation that is represented in table 3 is

\[ 1 = \frac{c_t}{y_t} + \frac{g_t}{y_t} + \frac{i_t}{y_t} + \frac{I_t}{y_t} + \frac{TB_t}{y_t} \]

We have also calibrated the parameters to match the ratios of each sector as a share of GDP. Then it is true that

\[ y_t = y_{n,t} + y_{m,t} + y_{xh,t} + y_{xa,t} \]
or

\[ 1 = \frac{y_{n.t}}{y_t} + \frac{y_{m.t}}{y_t} + \frac{y_{xh.t}}{y_t} + \frac{y_{xa.t}}{y_t} \]

In importables we considered the manufacturing sector and agriculture. For non tradables we considered energy, construction, commerce, transport and communications, financing establishments, public administration services and other services. In hydrocarbons we considered petroleum and natural gas and finally for mining we considered metallic and non-metallic minerals.