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July 2014

Online at <https://mpra.ub.uni-muenchen.de/75702/>

MPRA Paper No. 75702, posted 22 December 2016 05:58 UTC

**DIMINISHING COMMODITY PRICES AND CAPITAL FLIGHT IN A
DUTCH DISEASE AND RESOURCE CURSE ENVIRONMENT:
THE CASE OF BOLIVIA**

by

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2014

Abstract¹

Diminishing commodity prices and increasing world interest rates are the two main expected outcomes from slowdown of emerging economies and growth recovery of advanced economies in the post financial crisis. A CGE model is used to analyze commodity shocks in a natural resource country framework with two export oriented resource sectors (gas & oil and minerals) and mainly two emerging tradable sectors (food and manufacturing) with dominant import substitution orientation. Positive shocks of unusual magnitude in the pre-crisis generate strong Dutch disease (DD) effects but also unusual levels of government income, savings and investment, giving rise to a growth opportunity. A negative shock to the mineral sector in the post-crisis does not reverse the growth opportunity as long as the gas & oil sector remains strong. However, policy would be required to help absorb the labor released and in the long-run structural reforms are needed to significantly diminish built-in DD effects in this sector. If in addition a significant negative shock hits the gas & oil sector, the economy can experience negative growth. Having a stabilization fund would help in this scenario, but to avoid it altogether sector policy is more important. Additionally, a DSGE model with tradable/non-tradable sectors and skilled/unskilled savers/not savers workers is calibrated to analyze the conditions under which capital flight might occur under increasing world interest rates in the post-crisis. These conditions require a significant degree of macroeconomic deterioration which is not being observed, but point to some key variables to follow, such as the level of net external assets held by the country.

JEL classification: C68, Q30, F40, F60

Keywords: Natural resources, External shocks, Real exchange rate, Dutch disease, Commodity prices, Capital flight, Resource curse, Bolivia, CGE, DSGE

¹ This paper was written for the IDB research project “Macroeconomic and Financial Challenges Facing Latin America and the Caribbean after the Crisis.” The authors would like to thank the IDB for their funding after the research proposal was selected in a competitive process. The paper was originally concluded in July 2014 and revised in December 2014.

1. Introduction

There is a vast literature on Dutch Disease (DD) generally about an external shock (price increase of main exports, capital inflows, foreign aid, remittances) that results in large foreign exchange inflows to a country, which generates a wealth effect but also appreciation of the real exchange rate, resulting in de-industrialization (Magud and Sosa, 2010). A broader treatment of issues related to commodity exporters is the more recent Natural Resource Curse (NRC) literature (Frankel, 2010 is a review), based on the observed long-term negative relationship between natural resource exports as proportion of GDP and economic growth. Others have questioned this relationship (Lederman and Maloney, 2007; Sinnott, Nash and De la Torre, 2010). Nevertheless, the NRC literature is broader in that it contains DD as only one possible explanation of the phenomenon among others, including short and medium-term price volatility, long-term decline of prices and, above all, poor institutional development. In addition to the problems of a small open economy, however, Bolivia suffers from low productivity, widespread poverty and a precarious political economy. Much more recent literature introduces the concept of a Resource-Rich Developing Country (RRDC), recognizing the needs and constraints of such countries, in addition to the problems of resource exhaustibility and price volatility, and argues for a more optimistic view that natural resources are a development opportunity when properly managed (Davis, Ossowski and Fedelino, 2003; IMF, 2012a; Humphreys, Sachs and Stiglitz, 2007; Lederman and Maloney, 2007). Consistent with that view, this literature also makes practical proposals for ensuring the proper management of a natural resource: countercyclical monetary and fiscal policies,² stabilization funds, *inter alia*, all of which require institutional development. Going back to the DD literature, the idea of properly managing a natural resource could also be extended to the idea of managing an external shock, positive or negative, in the sense that a country that experiences a natural resource-based external shock will typically not stay idle but implement policy responses of different sorts with different effects over time.

This paper analyzes these issues for the Bolivian case in an integral way (DD+NRC+RRDC) in order to better understand the nature and implications of shocks, evaluate their impact and make policy suggestions. The analysis is done with the international financial crisis of 2008-09 as its background event: pre-crisis, crisis and current post-crisis. Policy recommendations concentrate on the latter. While the pre-crisis boom benefitted emerging and

² Contractionary in booms and expansionary in recessions in order to moderate the boom-bust cycle.

developing countries thanks to Asian growth (China and India) even during most of the post-crisis period, this prolonged era might be coming to an end. Post-crisis shocks are expected to come from normalization of monetary policy in the United States as economic growth returns. This might increase international interest rates and volatility and therefore have the effect of capital flight from emerging market and developing economies. A slowdown of Asian growth (particularly that of China), together with low growth in the Euro Area, would lower commodity prices,³ which would in turn affect export revenues of resource exporters.

From the perspective of the Bolivian economy, lower mineral prices compared to 2011 levels are already being observed and are affecting exports, although natural gas prices remain high due to still-high international oil prices at the time of writing.⁴ Regarding increases in international interest rates, once perceived as a medium-term event, in a low-growth context some capital flight might also be observed in the form of bank deposits abroad.⁵ Although these events are expected to have macroeconomic effects, the strong buffers based on international reserves, government savings and policy response should allow for stabilization, somewhat similar to what was experienced in the 2008-09 international financial crisis. The difference this time would be the perception of permanent shocks as international interest rates stabilize at their new levels, together with a new lower level of Chinese economic growth. Therefore, while on the surface the Bolivian macro economy might still appear to be in a boom and under control, in practice the negative shocks will put the current growth model and macro equilibrium to a test.

Methodologically, the study begins with a literature review that includes relevant DD, NRC and RRDC literature with the objective of identifying Bolivian macroeconomic stylized facts from 2000 to 2013. The study continues with a Computable General Equilibrium model to simulate shocks and study the characteristics of sector DD effects among other macroeconomic effects in a natural resource developing country framework. Next, a Dynamic Stochastic General Equilibrium Model is used to simulate shocks and DD dynamics in a skilled/unskilled savers/not saver workers framework, with the objective of understanding the conditions under which capital flight might occur in a developing country like Bolivia. Finally, both instruments are used to anticipate shocks and derive policy options in the post crisis.

³ Risks for the Latin American region were identified by the Latin American Shadow Financial Regulatory Committee in their Statements #28, #30 and #31 (2013 and 2014).

⁴ Gas export prices are connected to international oil prices by export contracts.

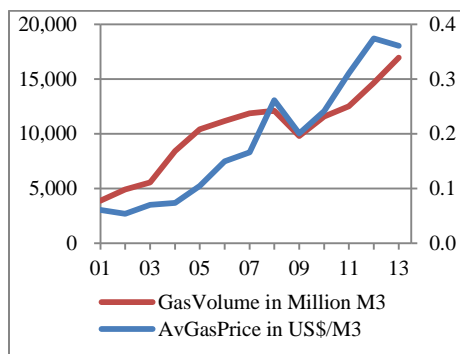
⁵ Capital flight in the form of foreign investment reversals are not expected given that Bolivia did not experience that source of capital inflow in a significant way during the post-crisis, at least up to 2012.

2. The Evidence of Dutch Disease and the Natural Resource “Curse”

2.1 Shocks to the Economy

In the 2003-2013 period the Bolivian macro economy experienced external shocks through several sources, which combined have produced a surprising set of macro results with no parallel in Bolivian economic history. By far the most important shock has been the combined quantity and price effects from natural gas exports to Brazil and Argentina (Figure 1), the first from demand increase and the second from booming international prices of oil.⁶ As a result the value of hydrocarbon⁷ exports in billion US\$ increased from 0.5 in 2003 to 6.5 in 2013.⁸ In addition, the increase in the international price of minerals and agricultural commodities exported by Bolivia also generated an important inflow of export revenues. For instance, the value of mineral exports in billion US\$ increased from 0.4 in 2003/04 to 2.8 in 2013, while the value of soybean exports in billion US\$ increased from 0.3 in 2003 to 0.9 in 2013. Equally surprising has been the inflow of remittances, which have increased from an average of 0.06 billion US\$ in 1997-2003 to an average of 1 billion US\$ in 2007-12.

Figure 1. Gas Export Price and Volume



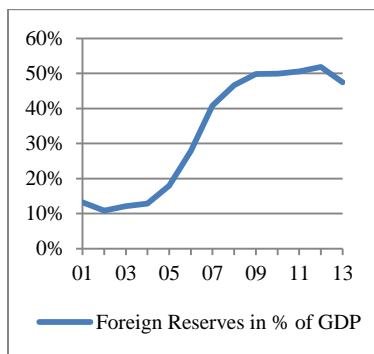
Source: Bolivian Central Bank.

⁶ Natural gas export prices are tied to international oil prices by contract.

⁷ Hydrocarbon exports include natural gas, crude oil and oil derivatives. By far natural gas is the most important.

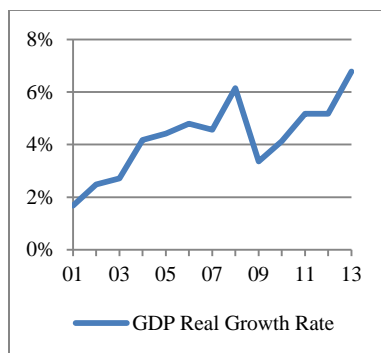
⁸ The main investments in oil and gas exploration and construction of a pipeline to Brazil happened during the second half of the 1990s. The pipeline to Argentina already existed.

Figure 2. Foreign Reserves as a Percentage of GDP



Source: Bolivian Central Bank.

Figure 3. Real GDP Growth



Source: Bolivian Central Bank.

In addition, all of the above happened together with a large debt cancellation in 2006-07 by the World Bank and the Inter-American Development Bank, reducing Bolivian foreign public debt from 50 percent to 17 percent of GDP (from 5 to 2.2 billion US\$) after a 20-year period of debt overhang, low international export prices and low growth. Figure 2 shows the most visible result of the resource boom: growth in foreign reserves from 10 percent to 50 percent of GDP.⁹

Even though these favorable shocks reversed quite rapidly during the 2008-09 international financial crisis,¹⁰ in the immediate post-crisis immediate years they came back as rapidly and with greater strength, as is captured by the behavior of gas export prices and volumes (Figure 1) and the behavior of the real GDP growth rate (Figure 3).

⁹ Valencia (2010) computed an optimal level of net foreign assets for the Bolivian economy as a whole between 29 to 37 percent of GDP. He believes the excess reserve accumulation has a basic precautionary motive but could have other objectives. Cerezo (2010) computes an adjusted optimal level of 27 percent of GDP for 2009 but warns that this optimum can increase rapidly in adverse macroeconomic conditions.

¹⁰ Except for debt cancellation.

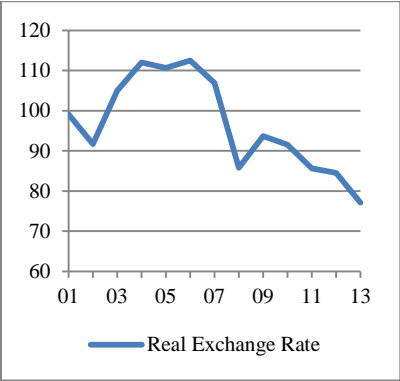
The rest of this section presents descriptive information about the economic impact of these shocks in the process of identifying potential evidence of DD and NRC.

2.2 Effects on the Real Exchange Rate

Theory predicts that real exchange rate appreciation is key evidence of DD. The multilateral real exchange rate data (Figure 4) show fluctuation from depreciation (2002-06) to appreciation (2007-08) to depreciation (2009) and back to appreciation (2010-13) in accordance with the international economic environment and degree of openness, although with a general tendency toward appreciation since 2006. Several authors (Frankel, 2010) argue that if the exchange rate is flexible the real appreciation should occur through a nominal appreciation (Figure 5), while if the exchange rate is fixed real appreciation should occur via money inflows and inflation (Figure 6). The Bolivian experience seems to have been a mix, with the latter predominant after 2009.

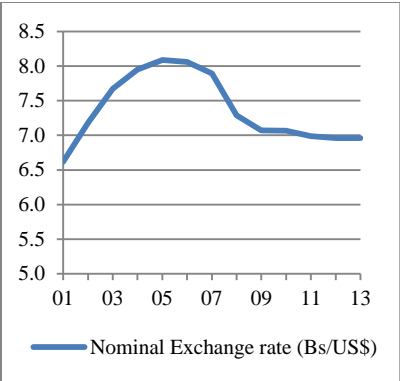
The managed nominal exchange rate appreciated in the pre-crisis but was kept approximately fixed most of the time, particularly since 2008. If allowed to float, it would have dropped in percent terms to levels similar to what were observed in other countries of the region and would have displayed their volatility as well. A de facto fixed exchange rate to contain appreciation had two main policy rationales: helping to de-dollarize the economy and defending the country's competitiveness. Regarding the first rationale, the fixed rate together with other incentives in effect (e.g., an increase in the required reserve ratio for local deposits in US\$ and establishment of a tax on financial transactions in US\$) resulted in a drop of financial dollarization from levels above 90 percent to levels below 30 percent in just a few years.

Figure 4. Real Exchange Rate



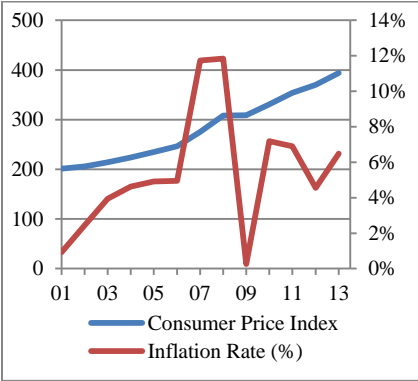
Source: Bolivian Central Bank.

Figure 5. Nominal Exchange Rate



Source: Bolivian Central Bank.

Figure 6. Consumer Price Index



Source: Bolivian Central Bank.

2.3 Effects on the Real and External Sectors

Beside the contribution to GDP growth of the tradable gas and oil sector and the mineral sector,¹¹ given their characteristics of being capital-intensive but low-value added sectors,¹² all other sectors of the economy also benefitted from the boom and contributed to grow.¹³ The non-tradable sectors grew more than the tradable sectors only after 2008 (Figures A1 and A2¹⁴), a basic characteristic of DD highlighted in the literature. The other two important tradable sectors are agriculture and manufacturing. In the Bolivian case it is important to note that, even though the manufacturing sector has the largest share of GDP (an average of 17 percent) and the agricultural sector the second largest (an average of 14 percent), both are incipient and operate in a dominant small-scale import-substitution labor-intensive informal economy with little and poor articulation with the few export-oriented larger-scale firms (PNUD/Bolivia, 2005). It is traditional to think of an economy where the tradable sector that will lose its competitiveness due to DD is a strong capital-intensive export-oriented manufacturing sector (de-industrialization). This is not the case in the Bolivian economy, where industrialization has not yet occurred and the export-oriented part of it is rather small and technologically simple. Nevertheless, the data show that the incipient agriculture and manufacturing sectors have been the adjustment sectors (Figures A3 and A4), consistent with DD but in a developing country context. The data also show a behavior difference between the two booming natural resource sectors and other sectors (Figures A5 and A6). The mineral sector experienced momentum from 2004 to 2009 (a temporary or medium-term shock), while the gas and oil sector's momentum started earlier and still continues, possibly qualifying as a permanent shock.

DD theory predicts that non-booming sector exports would be displaced. The fact that net exports remained positive can be explained in part by the highly favorable terms of trade experienced, leading to an export increase in real terms that doubled in the 2003-05 period and doubled again in the 2005-12 period (Figure A7). However, the increase in exports came with

¹¹ Together their average annual growth rate has been 7.3 percent, with a 12 percent average share in GDP during the boom years. However, these sectors have some pulling effect on other sectors of the economy.

¹² An exception is the mineral cooperatives that tend to be low-capital and labor-intensive but with low productivity, which can only survive at high international prices. This form of organization has become dominant in the Bolivian mining sector.

¹³ In the short to medium term there is an observed positive relationship between resource exports and GDP growth. The NRC literature suggests that the negative relationship occurs in the long run due to institutional failures.

¹⁴ These figures are in the Graph Appendix.

greater concentration in two commodities, natural gas and oil and mineral goods,¹⁵ which have increased in share of total exports from an average of 55 percent in 2000-05 to 76 percent in 2006-13, while exports of food products and manufactures decreased from an average of 45 percent in 2000-05 to 24 percent in 2006-2012 (Figure A8). This change in export structure is evidence of the DD effects in a developing country context like Bolivia.¹⁶ The most important innovation came from the expansion of natural gas exports.¹⁷

DD theory predicts that the windfall would promote overconsumption. Sachs (2007) argues that DD is a genuine concern mainly if the resource boom is used to finance consumption rather than investment, especially in public goods like infrastructure, which will increase the productivity of the non-traded and non-resource traded sectors, thus outweighing the negative consequences of real appreciation. The data show that consumption and investment on average have been 85 percent and 16 percent of GDP, respectively, since the 1990s, but a closer look at the changing behavior of the consumption/investment ratio shows a decreasing tendency after 2004 during the boom (Figures A9 and A10). Government investment was dominant over this period, also determining an increasing tendency in absorption since 2006. Analysts have frequently blamed low private investment (foreign and national) to property rights risks (also referred to as the “cost of nationalization”).

Furthermore, DD theory predicts the windfall would promote imports. The data show imports have increased in real terms by 143 percent in the 2004-13 period. However the structure of imports has remained the same on average: 50 percent materials and intermediate goods, 28 percent capital goods and 22 percent consumption goods (Figures A11 and A12). This reflects a structural characteristic of the Bolivian economy: imports of capital and intermediate goods have as their main destination the domestic production of basic consumption goods (import substitution). The rest of non-basic consumption goods are simply imported. The fact that global imports in real terms have increased can be thought of as evidence of the DD effects, but not necessarily if part of these imports were used in the expansion of the infrastructure sectors

¹⁵ Mineral exports are not concentrated in one commodity but rather have the following diversification ordered by their 2012 export value: silver, zinc, lead, tin, gold, wolfram, antimony and other.

¹⁶ Regarding the relationship between commodity dependence and growth, Sinnott, Nash and De la Torre (2010) argue that the most important issue is the effect of dependence on macroeconomic instability, exacerbated by concentrating exports (as opposed to the arguments of secularly declining prices (Prebisch-Singer hypothesis) or features of commodity production that make it inferior as an engine of growth). The solution is diversification and revenue management, both of which are determined by institutional quality (an NRC issue).

¹⁷ Natural gas exports are also concentrated in two buyers: Brazil and Argentina.

(roads, terminals, airports, communication networks, electricity generation and distribution, expansion of natural gas and oil derivatives networks, expansion of water and sanitation networks) as suggested by Sachs (2007).

2.4 Effects on the Monetary and Financial Sectors

Increase in money inflows would be the main channel towards DD. In the monetary sector, the increase in net international reserves (NIR) did increase the monetary base (MB) in a *de facto* fixed exchange rate regime. However, this increase was counterbalanced by a significant negative net credit to the non-financial public sector (NCFS) or government savings, so much so that countercyclical monetary policy like net credit to private banks (NCB) and open market operations (OMO) were moderately used (Figure A13) and the net increase of the monetary base was basically growth determined, in addition to the requirements of “Bolivianization.”¹⁸ The Central Bank reports, that by the end of 2013, government deposits in the Central Bank have reached a magnitude of 27 percent of GDP, and 16 percent of GDP when credit operations are considered (Figure A14).¹⁹

Regarding the financial sector, a credit boom would also be a channel for DD. The combination of low interest rates and high liquidity in global markets plus highly favorable commodity prices and terms of trade faced by Bolivia, also generated internally a prolonged period of unusually low real interest rates (Figures A15 and A16) and virtually an exponential increase in credits and deposits in the financial system²⁰ in real value terms (Figure A17)²¹ as well as excess liquidity (i.e., a stock of deposits higher than the stock of credits). However, if seen as a percentage of GDP (Figure A18) the booming effect disappears because private sector

¹⁸ It refers to the government policy of de-dollarization of the financial sector and therefore greater use of the Bolivian currency in deposit and credit operations. The decline in financial dollarization from above 90 percent in 2004 to below 30 percent in 2013 required an expansionary monetary policy. However, this was demand driven and not necessarily inflationary, as it is only substituting currencies; therefore de-dollarization helped the economy in absorbing needed domestic currency and at the same time reducing the pressure for nominal appreciation.

¹⁹ Adler and Magud (2013) find that the current level of savings experienced by Latin American countries during the recent boom is mostly a result of the size of the windfall rather than savings effort.

²⁰ The Bolivian financial system is made up of banks and non-banks, with the first on average managing above 80 percent of credit and deposit operations and both under the close supervision of the financial sector regulator (Autoridad de Supervisión del Sistema Financiero, ASFI). The system shows a consistent downward trend in delinquency loans towards below 2 percent (Figure A19).

²¹ Some changes have been observed regarding the structure of loans. There has been a significant increase in real terms of loans to micro, small and medium firms terms compared to larger firms. Loans have increased substantially for all productive, commercial and service activities of firms. In real terms, households have exponentially increased exponentially their loans for housing and consumption since 2006.

investment has increased only since 2009. The most important innovation in the financial system has been financial de-dollarization or *Bolivianization* of the system mentioned before (Figure A20), reaching 77 percent of deposits and 88 percent of credits by 2013, with the effect of returning seignorage and monetary policy to the Central Bank as well as diminishing the risks of a banking crisis derived from currency mismatches.

2.5 Effects on the Government Sector

The countercyclical effect of government savings is not a minor topic of analysis in the Bolivian case, especially when it has been central to macroeconomic stabilization during the boom. This might suggest that the government learned that to fight DD and NCR it is necessary to implement countercyclical fiscal policies. This is not exactly the case, however, as the sources of those savings did not follow any particular countercyclical fiscal rule. They are instead the surpluses of different levels of the public sector: State Owned Enterprises (SOEs), subnational governments and the central government, in that order on average, and in amounts that have varied from year to year.²²

Government savings came from three main sources. The first source is related to SOEs savings, coming basically from the State Petroleum Company (YPFB) in a sector recently intervened with several nationalizations and changes in regulations and government royalties, and a sector with large investment requirements in the short and medium term. The second source is the savings of subnational governments,²³ which resulted from the accumulation of fiscal transfers that were not spent. This last factor is an unplanned effect of a long-term public policy of decentralization and fiscal transfers²⁴ of commodity rents, which since 2005 became the basis for extraordinary levels of income for subnational government, due to the nationalization process and, particularly, to the creation of the Direct Hydrocarbon Tax (IDH in Spanish). In addition, these transfers grew substantially as a result of recent external shocks. In other words, the unexpected large growth of fiscal transfers compared to planned subnational expenditure,

²² The use of a lower international oil price reference for the budgetary process could be regarded as a countercyclical fiscal rule. It had the double effect of avoiding an expenditure spree and generates savings at the same time.

²³ Nine *Gobernaciones* (intermediate level) and 327 *Municipios* (local level).

²⁴ The process began with the 1994 *Popular Participation Law* and the objective of facing the “social debt.”

given their expenditure capacity,²⁵ generated large subnational government deposits in the Central Bank, which in turn contributed to the observed countercyclical effect. The increase in transfers also generated other unplanned effects such as misalignment with local interests, disincentive to local contributions and lower VAT collection (Barja, Villarroel and Zavaleta, 2013).

The third and final source is related to central government savings, which only occurred in 2012 and was in fact considered a surprise given its traditional history of deficits due to budget restrictions. Given the above, it is possible to conclude that government savings are a “nationalization effect” in an environment of high international oil prices and domestic transfer requirements due to decentralization.²⁶

Consistent with the above result, a recent study portrays Bolivia as a “recent graduate” for having escaped the procyclicality trap (Frankel, Végh and Vuletin, 2011). However, it is important to note that the Bolivian government has failed to formally create a natural resource based stabilization fund²⁷ this time around. From a strictly DD and macroeconomic point of view it does not matter if government savings are a formal or informal fund as long as savings are accumulated during the boom.²⁸ However, from a strictly NRC and institutional point of view, the above explanation suggests that “graduation” was unplanned and has not been institutionalized.²⁹ This institutional failure could be considered as evidence of the NRC. Sinnott, Nash and De la Torre (2010) have pointed out that less formal stabilization-oriented fiscal-saving mechanisms face a greater risk of being breached, for example via off-budget spending driven by clientelistic considerations.³⁰

²⁵ Central government deferral in approvals/disbursements of subnational expenditures has also occurred to some unknown degree.

²⁶ It is important to note that prior to the 2005 IDH tax on natural gas production, subnational governments were not dependent on natural resource transfers. Also, both the central and subnational governments treat these flows as income transfers and not as capital transfers.

²⁷ Two distinct options are a stabilization fund and an investment fund. A stabilization fund held abroad was proposed by Andersen and Faris (2001). Guzmán et al. (2010) propose a mix of sovereign investment fund and stabilization fund.

²⁸ Excess reserve accumulation could also be part of the fund.

²⁹ The Bolivian government must comply with recent own legislation (Ley Marco de Autonomías y Descentralización of July 2010, Estado Plurinacional de Bolivia) requiring a fiscal pact and a stabilization fund during 2014. The requirement has been pushed to 2015 after the 2014 national elections. Nevertheless, this should be the scenario for institutionalizing a stabilization fund as well as countercyclical fiscal rules in a decentralized context, generating incentives for greater local contributions as condition for fiscal transfers associated with minimum social rights.

³⁰ An important question in this area is what is the political economy of natural resources in Bolivia and why are institutional issues particularly difficult to promote. Andrade and Morales (2007) argue that Bolivia is less prone to a

The discussion between the creation of a fund (and their different types³¹) or simply the consumption of the benefits from natural resources is still active in the economic literature. Humphreys, Sachs and Stiglitz (2007) argue that any consumption coming from non-renewable revenues or rents should be viewed as consumption of capital rather than consumption of income. Therefore, the optimal strategy involves converting the natural resource stock into financial assets and investing them in a diversified portfolio and treating the interest earned as income. However, Sachs (2007) argues there is no universal treatment of non-renewable earnings as these can vary according to the stage of economic development and suggests that in low-income countries they should be turned into public investments rather than into increased private consumption in order to break out of the poverty trap. Investment should be in public goods that raise the productivity of workers in both the tradable and non-tradable sectors and therefore serve as a platform for private investment (see also Collier et al., 2010). Government investment in infrastructure sectors in Bolivia has traditionally been the largest with respect to total public investment and has grown from 3.5 percent of GDP in 2005 to 4.9 percent of GDP in 2013 (Figures A21 and A22).

DD theory suggests that in a windfall situation, the government's current and capital expenditures would increase substantially, particularly wages and investment, financed not only by the revenue windfall which would represent a larger portion of fiscal revenues, but also by an increasing government debt based on the present value of future flows. In essence, government spending tends to be pro-cyclical. Regarding the behavior of General Government³² revenues in the Bolivian case, natural resource rents (mineral and hydrocarbon) have increased by 182 percent in real terms from 2004 to 2006 and an additional 73 percent from 2010 to 2013, making fiscal revenues more dependent on resource rents (Figures A23 and A24). Tax revenues increased by 42 percent in real terms between 2004 and 2008 and an additional 61 percent from 2010 to 2013, in part as an effect of the resource boom itself.

As expected, total General Government expenditures have increased by 155 percent in real terms from 2000 to 2013, in three stages: 41 percent in the 2000-05 period, only 20 percent in the 2005-10 boom period and 48 percent in the 2010-13 periods. However, the dominant

long lasting conflict between two factions for the control and management of the natural resource because in Bolivia there are more than two groups. Frank (2010) disagrees and identifies two groups, the highland Departments and the lowlands Departments (known as the "Media Luna"), among which an agreement is uncertain.

³¹ See Davis et al. (2003) in the context of experience and fiscal policy implications.

³² General Government does not include State Owned Enterprises.

determinants of the expenditure increase throughout the decade were capital expenditures and transfers before wages³³ (Figures A25 and A26). General Government expenditures were procyclical in that they decreased in 2010, a year after the international financial crisis. Sometimes a significant increase in resource rents could become a negative incentive for tax payment and thus negatively affect the collection of tax revenues. In the literature this has been called the revenue curse (Crivelli and Gupta, 2014). Observation of the tax revenue/resource rents ratio (Figure A27) shows a large drop between 2004 and 2006 as resource rents were increasing in the structure of General Government revenues, but since then the trend has been slowly reversing, suggesting that efforts at tax generation and collection were important even though resource rents continued their increasing tendency. Another approximate measure of the size of fiscal vulnerability faced by the public sector due to fiscal dependence on natural resource rents is the comparison of the primary public sector balance³⁴ with and without the size of resource rents (Figure A28).³⁵ The gap between these two measures in the Bolivian case has increased from 5.2 percent of GDP in 2000 to 13.3 percent in 2013, and it explains the overall public sector primary surplus observed since 2005. This gap, however, has varied within a wide range, from a minimum of 4.65 percent of GDP in 2003 to a maximum of 13.3 percent of GDP in 2013 and an average of 11.1 percent between 2005 and 2013.

The data do not support the prediction that government will additionally use expected future resource flows in order to expand public debt financing expenditures in the present. On the contrary, the data show that total public debt (Figures A29 and A30) experienced an important drop in both foreign and domestic debt in percent of GDP since 2006, down to 30.5 percent of GDP by 2013. In real terms, both kinds of debt have increased, although by only 12 percent between 2007 and 2013, which results from a 61 percent increase in foreign debt but a 20 percent decrease in domestic debt in the same period. Does the presence of government saving deposits in the Bolivian Central Bank contradict the above prediction? Not completely. Those deposits are a net result of credit and deposit operations of the government with the Central Bank. The Central Government has instated a policy of State Owned Enterprises (SOEs) access to Central Bank credit based on their international reserves, particularly the State Petroleum Company

³³ The current government introduced in 2006 a policy that in the public sector nobody could obtain a salary greater than that of the President, together with a substantial decrease in the President's salary. This was a policy that may have signaled a salary ceiling in the private sector as well.

³⁴ This balance contains State Owned Enterprises in addition to the General Government.

³⁵ This time including State Owned Enterprises.

(YPFB), in order to promote large-scale government investment in strategic areas of the economy. The fact that government deposits are larger than credit to SOEs tends to hide the behavior predicted by DD theory.

2.6 Effects on Poverty and Inequality

The NRC literature predicts that the environment of large resource inflows motivates politically unsustainable transfers. From the point of view of social policy, the Bolivian government has established special transfers³⁶ and subsidies directed to protect and improve social welfare, particularly that of poor households. The special transfers are the *Bono Juancito Pinto* in education, *Bono Juana Azurduy* in health and *Renta Dignidad* for the elderly. The first two were established in 2006 and 2009, respectively, while the latter (and largest) has been in place since 1997 under different names and at different sizes. Another important benefit in terms of size and economic impact is the energy subsidy.³⁷ One question from the NRC perspective would be if these transfers and subsidies are financially dependent on the resource windfall. Other subsidies in place for decades are related to government expenditures in the provision of education, health and other public goods and services (old and new), much of which is currently provided through fiscal transfers to subnational governments. The impact of social policy in general will also depend on how it interacts with the general macroeconomic environment.³⁸

Bolivia has made substantial progress on the poverty and inequality fronts (Figures A31 and A32). A recent paper by Uribe and Hernani (2013), based on a harmonized household survey series, shows that the poverty headcount ratio and the Gini coefficient have been decreasing since 2000, irrespective of changes in the political regime. In effect, i) the proportion of moderately poor households has dropped from 75.2 percent in 2000 to 62 percent in 2005 and 48.2 percent in 2011; ii) the proportion of extremely poor households has dropped from 51.5 percent in 2000 to 37.1 percent in 2005 and 21.2 percent in 2011; iii) the Gini index has dropped

³⁶ These household conditional transfers plus the fiscal transfers to subnational governments (of which only the IDH is new) are conceptually different from the oil-to-cash literature; however, the discussion on direct distribution to citizens has been promoted in Bolivia by Laserna, Gordillo and Komadina (2011).

³⁷ All refinery product prices and natural gas network prices were fixed for the domestic market at their corresponding pre-boom international oil and gas input prices. This way increases and volatility of international prices would not be transmitted to domestic consumers (industry, vehicles and households). Bolivia is not self-sufficient in diesel oil, and about 50 percent of domestic demand must be imported at the international price. Coady et al. (2006), in a study that includes Bolivia, argue that energy subsidies have significant social and fiscal costs and are badly targeted.

³⁸ The social and fiscal impact analysis of current social policy can be found in Canavire and Mariscal (2010), Paz et al. (2013) and Escobar, Martínez and Mendizábal (2013).

from 0.62 in 2000 to 0.56 in 2005 and 0.46 in 2011;³⁹ and iv) average real per capita income (Figure A33) has also been improving during the same period at a rate of 20.1 percent in 2000-06 and an additional 30 percent in 2006-11. The same authors show that 75 percent of poverty reduction throughout the whole period 1999-2011 is explained by the income effect and 25 percent by the redistribution effect, with the latter being important only in the 2005-2011 period. An important question is if these welfare gains will hold in the post-crisis era.

2.7 Summary and Research Strategy

The above descriptive analysis contrasted observed data with the literature and provided different perspectives on potential evidence (or not) and degree of the DD and in some cases the NRC. A necessary guiding question is why is it important to know if DD and NRC have happened. In essence, DD implies that the booming natural resource export sectors (gas and oil and minerals) have damaged past efforts made at diversifying and developing other tradable sectors (food industry and manufactures), a cost that would be felt when resource export prices fall because they would be diminished when needed plus in need of rebuilding. NRC thus implies that if the proceeds of natural resource exports were consumed rather than invested, with social rentist behavior, then future growth and development was lost.

What have other researchers found? Cerruti and Mansilla (2008) conclude there is not enough statistical evidence for DD because: i) the booming hydrocarbon sector is an “enclave” in that it is not labor intensive and would not attract massive labor from other non-booming sectors, but rather it is capital intensive and dependent on FDI, and ii) fiscal savings have offset the increase in international reserves as a main channel of pressure for appreciation. Mevius and Albarracín (2008) conclude that Bolivia was not experiencing full-blown DD because real exchange rate depreciation was being observed rather than appreciation, but they acknowledge the risk of appreciation. The IMF (Article IV, 2012) as well as the Bolivian Central Bank (Banco Central de Bolivia, 2012) concluded that the Bolivian currency was roughly in line with fundamentals. Del Granado et al. (2010) present evidence suggesting some initial levels of DD in the 2005-08 period compared to the 1999-2004 period. Finally, Cerezo (2014) finds no empirical evidence of DD beyond some marginal appreciation of the real exchange rate.

³⁹ The main explanation of this result is the change in relative wages, in favor of lower level wages, that has occurred particularly during the second period.

Settling the issue is important for a better understanding of how shocks impact the economy but even more important for its effect on policy during the boom and bust cycle. In effect, diminishing commodity prices and increasing world interest rates are the expected outcomes of the slowdown of emerging economies and the growth recovery of advanced economies in the post-international crisis period. In the Bolivian context diminishing commodity prices translate into a negative price shock to the mineral sector with current price levels in the gas and oil sectors, at least in the medium term. The international prices of mineral commodities have entered a declining tendency since 2011. This raises a first main concern, that of the cost of adjustment from large shifts in GDP composition in one direction in the pre-crisis period and now in the opposite direction in the post-crisis period, as the real exchange rate appreciated and real absorption expanded in the pre-crisis period and now the new macroeconomic equilibrium requires movements in the opposite direction for these variables in the post-crisis period. One question raised by these conditions is the size of the required adjustments in the current account balance and the government balance. Another question is the amount of adjustment required in the labor market considering labor migration from one sector to other and problems of skills mismatch. A third and final question involves the expected social impacts and welfare losses from the adjustment and whether these will end the economic boom despite still-favorable international economic conditions for the gas and oil sector.

A second concern is the combination of deteriorating commodity prices (mainly in minerals) with an increasing tendency in world interest rates. Foreign capital inflows to the Bolivian economy have been very weak during the boom (“nationalization cost”), so capital outflows due to higher interest rates abroad cannot happen in the Bolivian case. However, the prolonged period of low interest rates abroad and at home with a booming home economy with excess liquidity may have promoted higher risk-taking and overvaluation of assets in the expansion of credit. Data shows a significant increase of credit on all fronts, particularly after 2009, from banks and non-banks to firms (productive, service and commerce) and households (consumption and housing). When interest rates also rise at home along with deteriorating commodity prices, then debt default from firms and household might increase. The probability of a banking crisis has diminished because of improved regulation of banks and non-banks, but also because currency mismatch problems and term mismatch problems have been reduced thanks to de-dollarization and growth. Nevertheless, in a situation of economic recession, with significant

exchange rate depreciation and a return to dollarization, the scenario for the financial system could change. In this scenario the perception of risk could promote capital flight as some firms and households would want to protect their profits and savings by shifting them to a foreign currency and even depositing them abroad or at least out of the domestic financial system.⁴⁰

These two concerns are the main objective of this paper and are analyzed using a general equilibrium framework, which is implemented taking into account two different but complementary modeling perspectives. The first is a computable general equilibrium (CGE) model for Bolivia that will capture, in a comparative statics fashion, the direct and indirect impacts of external shocks in generating some degree of DD effects and growth opportunities when shocks are positive, and the degree of required macroeconomic adjustment when shocks are negative. The second perspective consists in the application of a Dynamic Stochastic General Equilibrium (DSGE) model calibrated for Bolivia that will examine the dynamics of capital flight when world interest rates increase and external negative shocks deteriorate the domestic environment.

3. A CGE Model of a Natural Resource-Based Developing Country

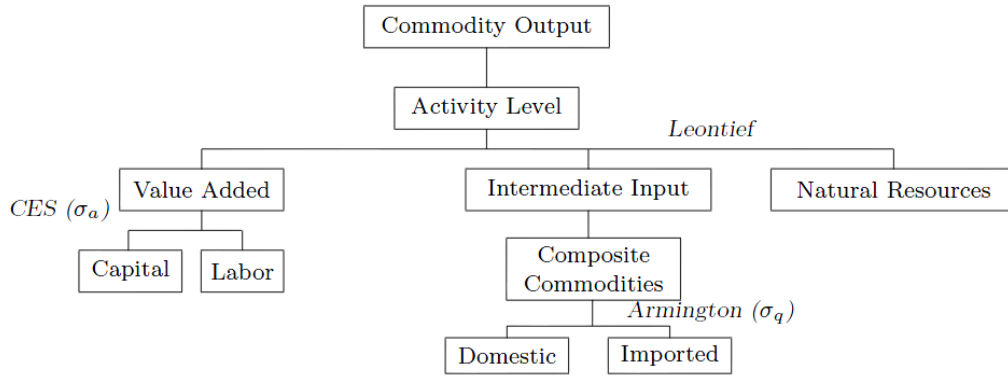
The framework proposed in this chapter is a CGE model, which will enable the comparison of different scenarios of external price shocks and their impact on key macroeconomic variables. The CGE model used in this work is based upon a standard model built by Lofgren, Harris and Robinson (2002) and adapted to the Bolivian economy in Zavaleta (2003 and 2010). Appendix A present the CGE model equations in detail. One key feature is that natural gas resources are modeled as an input for the oil and gas sector through a Leontief production function. This feature will allow the introduction of shocks in the model through changes in price and quantities of the resource. Another feature is the creation of a government fund from a fraction of collected taxes and royalties in the oil and gas sector, as in Clemente, Faris and Puente (2002). While the previous section presented observed data on the behavior of macroeconomic variables corresponding to the real and monetary-financial sides of the economy, the CGE model presented here concentrates only on the real side of the economy.

⁴⁰ A similar scenario was identified by Barja, Monterrey and Villarroel (2006) during the 1998-2002 Bolivian recession.

3.1 Model Features

While all of the model's details can be found in Lofgren, Harris and Robinson (2002), here we present some of its main characteristics. For the activities, production and factor markets, each producer, representative of a production sector, is assumed to maximize profits subject to a production technology. The production function has a nested structure, as illustrated in the figure below.

Figure 7. Nested Production Function



Source: Lofgren, Harris and Robinson (2002).

At the top level, the activity level is a function of value-added, aggregate intermediate input and natural resources. The latter are for the oil and gas sector only, which are combined through a Leontief technology function, meaning that all inputs at the top level are used in fixed proportions to produce the output. Next, value added is specified by a CES function of primary factors which are labor and capital. These factors are free to move across activities.

$$QVA_a = \alpha_a^{va} \cdot \left(\sum_{f \in F} \delta_{fa}^{va} \cdot QF_{fa}^{-\rho_a^{va}} \right)^{-\frac{1}{\rho_a^{va}}}$$

where QVA_a is the quantity of value added in activity a ; QF_{fa} is the quantity of factor f in activity a ; and α_a^{va} , δ_{fa}^{va} and ρ_a^{va} are parameters of the CES production function.

The aggregate intermediate input is a function of disaggregated intermediate inputs, imported or domestic, modeled by an Armington function. Finally, marketed commodities are

either exported or sold in the domestic market. The model assumes imperfect transformation between these two destinations. A constant elasticity of transformation (CET) is used to represent this hypothesis.

The model considers three types of domestic institutions: households, enterprises and the government. Non-government institutions' total income is the sum of their income from factors, transfers from other domestic non-government institutions, net transfers from the government and net transfers from the rest of the world.

Households' consumption is obtained from maximization of their utility function, in this case the Stone and Geary function, subject to a consumption expenditure constraint. The resulting first order conditions are referred to as linear expenditure system (LES) functions.

Fixed investment demand is defined as the base-year quantity multiplied by an adjustment factor. In the model, the adjustment factor is considered endogenous, thus making the investment quantity endogenous too.

Government consumption demand is also defined as the base-year quantity multiplied by an adjustment factor which is exogenous. Total government revenue is the sum of revenues from taxes, royalties from natural resources and transfers from the rest of the world. Government expenditure is the sum of its consumption and transfers.

Prices constitute an important and large set of equations in the model. This set consists of equations in which endogenous model prices are linked to other prices and to non-price model variables. This set of equations has not been modified from the original model (Lofgren, Harris and Robinson, 2002).

3.2 Constraints and Model Closure

The constraints in the model are set in order to satisfy macroeconomic equilibrium conditions. Besides the equilibrium between demand and supply of factors and commodities, these constraints include equilibrium in the current account balance, in the government balance and in the savings-investment balance (savings equals investment).

Each of the three macroeconomic balances must have a model closure, which must reflect the political behavior of the country, or the expected policies for the future. For the government balance, the closure is that government savings is a flexible residual, whereas all tax rates are fixed. For the external balance, which is expressed in foreign currency, the closure is that the real

exchange rate is flexible, while foreign savings are fixed. Keeping the real exchange rate flexible will allow for finding possible DD symptoms (i.e., through an appreciation of the real exchange rate). For the savings-investment balance, the model closure considers government savings as not fixed. Given that savings from the private, government and foreign sectors must equal total investment in the economy, with exogenous foreign savings and exogenous private propensity to save, then investment will mostly be driven by government savings. This closure characterizes more closely the current vision and policy action of a government-driven growth model which would express its dominance over the economy's investment. At the same time, it is consistent with observed poor private sector participation in investment.

3.3 Data and Calibration

The CGE model is based on a social accounting matrix (SAM) for Bolivia built by UDAPE⁴¹ for the year 2006 and adapted for this analysis.⁴² The SAM is composed of the following accounts: 17 activities and 17 commodity groups (Table 1), value added, households, government, savings (fixed capital and changes in stocks), investment, and rest of the world.

Value added is disaggregated into production factors and indirect taxes for the different activities. These factors are labor, capital and natural resources for the OIL sector. Labor is also disaggregated into three different skill levels: unskilled, semiskilled and skilled.

To calibrate the CGE model, additional information must be introduced. This information includes four different sets of elasticities: the Armington substitution elasticities between domestic and imported commodities (σ_q), the factor substitution elasticities for each activity (σ_a), the transformation elasticities between domestic marketed and exported commodities (σ_t), and the output aggregation elasticity for each commodity (τ). These elasticities were taken from Zavaleta (2010) and are presented in Table 2.

Table 1. Activities and Commodities in the SAM

1. NIA Non-industrial agriculture	10. COM Communications
2. IAG Industrial agriculture	11. TRS Transport and storage
3. OAG Other agriculture and livestock	12. OPS Other private services
4. OIL Oil and natural gas	13. PBE Public education services

⁴¹ An economic analysis office within the Bolivian government.

⁴² UDAPE built the 2006 SAM as part of their participation in a research project on “External Shocks, Macroeconomic Policy and Social Protection in Latin America” with ECLAC/Mexico and UN/DESA, 2010.

5. MIN Mining	14. PBH Public health services
6. FOO Food products	15. PRH Private health services
7. OPR Oil refinery products	16. PRE Private education services
8. OIND Other industrial products	17. PUB Other public services
9. ENR Electricity gas and water	

Source: Authors' compilation.

Table 2. Elasticities Used for Calibrating the CGE Model

Commodity - activity	σ_q	σ_t	τ	σ_a
1. NIA Non-industrial agriculture	2.2	4	4	0.24
2. IAG Industrial agriculture	2.2	4	4	0.24
3. OAG Other agriculture and livestock	2.8	4	4	0.24
4. OIL Oil and natural gas	2.8	7	4	0.2
5. MIN Mining	2.8	4	4	0.2
6. FOO Food products	2.2	4	4	1.12
7. OPR Oil refinery products	1.9	2	4	1.26
8. OIND Other industrial products	1.9	4	4	1.26
9. ENR Electricity gas and water	2.8	4	4	1.26
10. COM Communications	1.9	4	4	1.68
11. TRS Transport and storage	1.9	4	4	1.26
12. OPS Other private services	1.9	4	4	1.26
13. PBE Public education services	1.9	4	4	1.26
14. PBH Public health services	1.9	4	4	1.26
15. PRH Private health services	1.9	4	4	1.26
16. PRE Private education services	1.9	4	4	1.26
17. PUB Other public services	1.9	4	4	1.26

Source: Authors' compilation.

A consumer price index (CPI) and a producer price index for domestically marketed output (DPI) are computed. Since the model is homogeneous of degree zero in prices, one of these indices must be set as *numéraire*. For this work, the CPI is the *numéraire*.

Once the model is calibrated, the first simulations are made to withdraw stock changes. Since a CGE model is a long-run model, it is reasonable to consider that in the long-run, stock changes no longer exist. Once the stock changes are withdrawn, the resulting simulation is the *base scenario* for this work.

3.4 Model Experiments and Results

3.4.1 Individual and Combined Price and Quantity Shocks by Commodity Sectors

Table 3 presents key results from model simulations considering different price-quantity scenarios or combination of them, without a government fund. All numbers are rates of change compared to the base scenario. The model closure explained above was equally applied to all simulations. Simulation 1 considers a 40 percent increase in the price of the gas and oil commodity alone (upstream sector), with no corresponding quantity increase. Simulation 2 adds to Simulation 1 an 8.6 percent quantity increase of the gas and oil commodity. Simulation 3 considers a 17 percent increase in the price of the mineral commodity alone, with no corresponding quantity increase. Simulation 4 adds to Simulation 2 the price increase in the mineral commodity. All of these shocks have been observed between 2006 and 2008, the years of maximum shocks to the Bolivian economy, which gave place to the period of highest windfall and reserve accumulation as shown in Figure 2.

Table 3. Rates of Change from Different Price-Volume Scenarios with No Government Fund

	SIM 1	SIM 2	SIM 3	SIM 4
GDP growth rate	7.0	9.1	1.7	10.3
Household consumption	2.9	3.9	2.4	6.2
Investment	40.8	51.3	2.5	49.9
Government income	16.6	21.5	-5.7	14.5
Government expenditure	-0.5	0.1	0.9	1.6
Exports	-8.3	-7.7	2.2	-4.4
Natural gas and oil	2.6	13.3	2.9	15.3
Mining	-24.2	-38.3	83.5	34.5
Food products	-9.6	-11.8	-47.1	-50.2
Other Industrial products	-21.4	-25.8	-47.4	-55.1
Imports	11.7	14.8	11.2	25.6
Mining	14.7	30.0	-29.6	-8.5
Food products	10.7	13.6	32.5	46.2
Other Industrial products	10.8	13.6	6.1	18.9
Factor prices				
Unskilled	-1.2	-1.1	2.7	2.4
Semiskilled	-1.0	-0.2	2.9	3.5
Skilled	-0.6	1.2	2.1	4.2
Capital	-4.3	-4.4	9.3	4.3
Real exchange rate	-3.1	-3.8	-10.3	-12.7

Output (Intermediate + VA)				
Non-Industrial agriculture	1.6	1.8	-8.8	-6.4
Industrial agriculture	0.6	0.5	-20.7	-17.6
Other agriculture and livestock	-0.1	-0.6	-6.4	-5.7
Natural gas and oil	0.0	8.6	0.0	8.6
Minerals	-22.3	-35.1	75.0	30.1
Food products	0.7	1.0	-11.9	-9.0
Refined oil products	-15.0	-13.1	-9.0	-19.1
Other Industrial products	-8.5	-10.2	-27.1	-28.2
Electricity, water and gas	0.9	1.9	-1.2	1.1
Communications	2.0	1.8	-5.4	-3.4
Transport and storage	-0.2	0.9	-9.2	-6.8
Other private services	10.0	12.5	-5.7	6.3

SIM1 = 40 percent price increase in the gas and oil commodity; SIM2 = SIM1 + 8.6 percent quantity increase in the gas and oil commodity; SIM3 = 17% price increase in the mineral commodity; SIM4 = SIM2 + SIM3.

Source: Authors' calculations.

Analysis of the differential impact of independent and combined price and quantity shocks to the gas and oil and mineral sectors is not a minor issue. It reveals key structural characteristics of the Bolivian economy. Shocks to the gas and oil sector alone (SIM1 and SIM2) promote output growth of the agricultural and food tradable sectors as well as of the infrastructure and service non-tradable sectors, having a negative effect only on the mineral and industry tradable sectors (oil refinery products and other industrials). When the gas and oil sector is in a boom it benefits several tradable and non-tradable sectors through greater government investment but also harms other tradable sectors, while shocks to the mineral sector alone (SIM3) favor only that sector. This last result happens because when the mineral sector is in a boom it will pull labor and capital away from the rest of the economy, therefore decreasing output in all other tradable and non-tradable sectors. Here it is important to note that, while basically all mineral products are exported and therefore not linked to other intermediate and final good sectors, oil refinery products (downstream of the gas and oil sector) faces an inelastic domestic demand from almost all other sectors of the economy.

Factor prices of labor and capital decrease in the case of a gas and oil price shock (SIM1), except for the skilled when the quantity shock is included (SIM2), while they all increase in the case of a mineral price shock (SIM3). The main explanation is that the mineral sector in Bolivia on average tends to be more labor intensive given its degree of informality and low technological development, benefiting the unskilled and semiskilled more than the skilled, as the model

outcome shows, which helps in the reduction of inequality. This increase on the return to labor and capital is the incentive to attract these factors from all other sectors. On the contrary, the gas and oil sector tends to be more capital-intensive and skills oriented, but it responds to the shock and windfall by reducing the return to capital and labor of the economy, though in this tendency benefiting the skilled more than the semiskilled and even more than the unskilled, as the model outcome shows, which increases inequality.

Appreciation of the real exchange is significantly greater with the mineral price shock (SIM3) than with the gas and oil price and quantity shocks (SIM1 and SIM2). The main explanation is that the mineral sector in Bolivia tends to be better connected with the rest of the economy in its backward linkages compared to the gas and oil industry, which from this perspective functions more like an enclave.

The differential impact on the structure of exports is also important to observe. When considering a price and quantity shocks to the gas and oil sector alone (SIM1 and SIM2), its own export rate increases while the other sectors must adjust their exports downwards, producing a negative net result. When considering a price shock to the mineral sector alone (SIM3), it increases mineral exports at a very high rate but also pulls exports from the gas and oil sector, while exports from the food and industry sectors must adjust downwards at very high rates, producing, however, a positive net effect. Although shocks to each sector individually show differences of impact on the structure of exports, they have in common the discouragement of incipient food and industry sectors exports.

The differential impact on the structure of imports is also important to observe. When considering price and quantity shocks to the gas and oil sector alone (SIM1 and SIM2), there is an increase of imports from all other sectors, especially the mineral sector, producing an important positive net result. When considering a price shock to the mineral sector alone (SIM3), it decreases mineral imports at a high rate but it encourages imports from the food and industry sectors, especially food imports, producing a positive net effect. Although shocks to each sector individually show differences of impact on the structure of imports, they have in common the encouragement of food and industry products imports.

Government income is more dependent on the magnitude of taxes and royalties derived from the gas and oil industry than from the mineral sector (SIM1, 2, 3). That explains the high rates at which government income increases as well as total investment, the latter through

government investment. In contrast, the mineral sector benefits more from the income transfers it receives compared to the taxes and royalties it pays, affecting government income negatively. This explains the smaller rate at which total investment will increase.

The net effect from independent price shocks to both sectors does generate an increase in household consumption, total investment and therefore an increase in real GDP (SIM1, 2, 3). The larger the shocks to the gas and oil sector, the larger their impact on consumption, investment and GDP growth compared to the smaller impact on these variables from price shocks to the mineral sector alone. However, independent of shock size, the gas and oil sector ensures a larger increase in the rate of investment over consumption compared to the mineral sector. The explanation is that, although the gas and oil sector is less interconnected with the other sectors, the government revenue it generates is shared with the rest of the economy through rent distribution to subnational governments and through government investment (national and subnational). The opposite happens with the mineral sector.

When considering the price and quantity shocks to both the mineral and the gas and oil sectors simultaneously (SIM4), as has happened, the net results are certainly the largest in terms of economic growth (10.3 percent),⁴³ household consumption and global investment, but also a positive scenario across all factor prices in the economy and exports from both industries. These results would certainly generate a perception of an economic boom and an environment for increased household expenditure and welfare, but in fact they also hide to some extent the highest degree of appreciation of the real exchange rate (-12.7 percent)⁴⁴ as well as the displacement of output and exports away from the agriculture-food and industrial sectors (among others), affecting the achieved economic diversification in favor of greater concentration in the booming resource export sectors. This result demonstrates that commodity price shocks to the Bolivian economy do generate Dutch Disease, but at the same time those shocks provide a growth and development opportunity. This opportunity depends upon whether growth is accomplished through greater investment or greater consumption. In this case growth is achieved through greater investment given the dominant effects of shocks to the gas and oil sector. The growth opportunity also depends on the size of shocks and to which sector. In this case the size

⁴³ The observed accumulated GDP growth between 2006 and 2008 was 11 percent.

⁴⁴ The observed multilateral real exchange rate appreciation from 2006 to 2008 was on average -14.1 percent and from 2006 to 2013 was on average -29 percent. Using the Hodrick-Prescott filter, the long-term or equilibrium real exchange rate appreciated -5.8 percent on average between 2006 and 2008 and -25 percent on average between 2006 and 2013 (Figure A34).

of shocks to the gas and oil sector generates DD plus an important growth opportunity given its impact on investment and GDP growth.⁴⁵ While the size of shocks to the mineral sector generate DD plus a modest growth opportunity given its smaller impact on investment and GDP growth.

The distinction between the differential impacts caused by shocks to the gas and oil sector and to the mineral sector is central for understanding how and why DD happens in Bolivia. SIM 4 is the net effect of shocks to both sectors simultaneously; however, from the previous analysis we know that net GDP growth, as well as net government income growth and total investment growth were dominantly determined by shocks to the gas and oil sector. This is not the case for net household consumption growth, which was determined by both; the mineral sector does so by directly improving the return to factors, while the gas and oil sector does so indirectly through rent distribution and government investment. It is important to note, however, that the net result of having an investment growth rate much larger than consumption is exclusively determined by shocks to the gas and oil sector.

The negative net result of total exports growth was determined by both sectors given that both strongly discourage exports from the emerging food and industry sectors. Their effect is the opposite regarding total imports, where both strongly encourage the import of food and industry products, especially food products. The concentration of exports in the booming resource tradable sectors, together with the discouragement of exports from other emerging non-resource tradable sectors but rather the promotion of their import, constitutes a structural change that qualifies as DD.

Similar structural changes can be observed in the net result of sector output growth. While the two resource tradable sectors expand, all other sectors contract, especially the tradable agriculture related sectors, as well as the food and industry tradable sectors and even the non-tradable transport and communications sectors. The only sectors that expand are the non-tradable electricity, water and gas and service sectors. Again this is a result consistent with DD. However, we also know that the negative impact on all other sectors is mostly determined by shock to the mineral sector.

⁴⁵ The concept of growth opportunity used here is consistent with the CGE model closure which is dependent on government-led investment. The purpose of its use is to differentiate actual and potential government investment's impact on growth, which in practice is dependent on the quality and efficiency of government investment. See Chakraborty and Dabla-Norris (2009) and Warner (2014).

Regarding the key net result of appreciation of the real exchange rate (-12.7 percent), this was dominantly produced by shock to the mineral sector rather than by shock to the gas and oil sector. The argument by Cerruti and Mansilla (2008) that the booming hydrocarbon sector does not generate enough evidence of DD because it is an enclave in the economy is basically correct. However, our model also shows: i) that a significant appreciation of the exchange rate did occur in real terms (DD), as analyzed above; ii) that most of this appreciation (DD) was caused by shocks to the mineral sector; and iii) that most of the growth opportunity was caused by shocks to the gas and oil sector.

A proposition that can be derived from this result is that the Bolivian mineral sector behaves more in line with NRC, which could be defined as a situation where DD effects (measured by the rate of real appreciation) are larger than growth opportunity effects (measured by GDP growth rate), while the Bolivian gas and oil sector has an opposite NRB⁴⁶ behavior that could be defined as a situation where growth opportunity effects are larger than DD effects, more in line with the RRDC literature. In both cases there is an institutional challenge, in the first the need to diminish the sources of DD and in the second the need to manage the windfall.

The Bolivian mineral sector is characterized by few medium-size high-productivity-large-scale-technology-intensive operations that generate taxes and royalties and a large and growing mass of small to very-small-scale-low-productivity-low-technology operations. The small-scale operations generate little government revenue but many low-productivity jobs as a strategy against poverty (subsistence mining⁴⁷), which in practice is almost equivalent to consumption of the natural resource but with the addition of negative externalities.⁴⁸ Both poor skilled labor and small scale capital tend to migrate from other economic sectors (small-scale traditional agriculture, informal manufacturing, construction, informal commerce and transportation) to the mineral sector and back, depending on which are the most profitable activities at the moment. In a mineral boom situation excess demand for non-tradable goods, services and skills will increase their price relative to the non-resource tradable. To diminish this DD effect, policy must provide

⁴⁶ NRB meaning natural resource “blessing.”

⁴⁷ Sometimes there can be strikes of richness.

⁴⁸ Espinoza (2012) reports that small-scale operations employed up to 60,000 mine workers in 2011, representing 84 percent of the mineral sector labor force. Those operations accounted for 31 percent and 45 percent of total mineral exports in 2011 and the first semester of 2012, respectively, with royalty payments of 4.1 percent of the value of Bolivia’s mineral exports in 2011 and no profit taxes but rather exemptions and transfers of different sort. Also, even though most small-scale operations are legally registered, they are not required to absorb exploration costs, environmental costs and labor-related responsibilities.

infrastructure and incentives that promote use of larger-scale production technologies, improved skills and new firm organizations that can reduce production costs and survive at lower international mineral prices.⁴⁹

3.4.2 Incorporation of a Government Fund

Now we turn to the analysis of key results from model simulations considering a scenario with the existence of a government fund with size equivalent to 30 percent of the royalties generated in the gas and oil industry.⁵⁰ The purpose of a government fund policy is to avoid pro-cyclical government expenditure during the boom period of the cycle, avoid the transfer of international price volatility to government income, and generate funds for use during the bust period of the cycle (more in line with a stability fund). In the specific scenario of significant depreciation pressures due to a contraction of the mineral sector, the role of the fund could be that of employment generation while fund resources are invested in infrastructure projects that generate platforms for productive activities and enterprise development.⁵¹

The effects of independent price shocks to the gas and oil and mineral sectors are presented in Table 4, with the following interpretation in comparison to Table 3. The same growth rate of real GDP and household consumption is achieved with or without the government fund (SIM1' to SIM4'). This result suggests that the objective of generating the fund has no costs in terms of lost GDP growth or lost household consumption growth. The reason is the source of funding of the government fund, which is a windfall rather than domestic tax effort. Therefore the best moment to create the fund is during the boom period of the cycle, the “good times.”

The government fund does decrease the growth rates of government expenditure and global investment as expected (SIM1' to SIM4'), compared to their rates under no fund. The effect is small in the first variable but substantial in the second. Both results show the fund generates overall countercyclical fiscal behavior, which is the desired objective.

⁴⁹ This is consistent with the argument made in the introduction that problems of productivity, poverty and precarious political economy in itself must be a big part of the DD and NRC story.

⁵⁰ The actual fund would not be generated this simple way given current distribution of rents between the central and subnational governments. It would have to be a result of contributions from all government levels as suggested by Guzman et al. (2010), except that most likely it would be a stabilization fund rather than an intergenerational fund.

⁵¹ Small scale operations in the mining sector have their origin in past boom-bust episodes with government unable to generate employment alternatives. Like most informal sector activities, they are a private entrepreneurial solution to unemployment.

A secondary effect of the government fund is that it slightly lowers the degree of appreciation⁵² compared to the scenario with no government fund, more so with the gas and oil price shock (SIM1') alone than with the mineral price shock (SIM3') alone. The source of this secondary effect is a decrease in the growth rate of government investment and therefore of total investment. However, when all shocks are considered together (SIM4'), the lowering of real exchange rate appreciation, compared to the scenario with no fund, is marginal.

As with the appreciation rate, the impact of the fund on other variables like exports, imports, output and factor prices contains the same tendencies already discussed under the scenario with no fund, though in some cases either moderating or amplifying them. For example, the rate of exports improves and the rate of imports increases less, generating a better trade result. The output of the mineral sector improves significantly, but output from all other sectors either remains the same or diminishes slightly. The rate of change in factor prices decreases as well.

Table 4. Rates of Change from Different Price-Volume Scenarios with Government Fund

	SIM 1'	SIM 2'	SIM 3'	SIM 4'
GDP growth rate	7.0	9.2	1.7	10.2
Household consumption	2.9	3.9	2.4	6.1
Investment	9.6	17.7	-18.2	19.1
Government income	15.6	20.6	-6.6	13.3
Government expenditure	-1.2	-0.6	0.4	0.8
Exports	-3.1	-2.2	5.7	0.7
Natural gas and oil	2.7	13.3	3.1	15.5
Mining	-3.4	-17.8	100.0	58.6
Food products	-6.5	-7.6	-46.8	-49.7
Other Industrial products	-17.8	-20.9	-47.8	-55.1
Imports	5.8	8.2	7.3	19.6
Mining	-5.6	4.7	-37.1	-23.4
Food products	7.6	9.8	30.7	43.3
Other Industrial products	3.9	6.0	1.6	12.1
Factor prices				
Unskilled	-1.7	-1.6	2.3	1.8
Semiskilled	-2.1	-1.4	2.0	2.3
Skilled	-2.2	-0.4	0.9	2.6

⁵² Not enough, however, to confirm the strong statement made by Cerruti and Mansilla (2008) that government savings have reduced pressure for appreciation. This assertion can perhaps be proved in connection with a monetary model.

Capital	-3.8	-4.0	10.1	5.2
Real exchange rate	-2.3	-2.7	-10.0	-12.3
Output (Intermediate + VA)				
Non-Industrial agriculture	2.2	2.6	-8.7	-6.2
Industrial agriculture	0.7	1.1	-21.4	-18.5
Other agriculture and livestock	0.3	0.0	-6.4	-5.7
Natural gas and oil	0.0	8.6	0.0	8.6
Minerals	-3.5	-16.7	90.1	52.0
Food products	0.7	1.3	-12.4	-9.7
Refined oil products	-15.0	-13.0	-9.3	-19.4
Other Industrial products	-9.0	-10.0	-28.9	-30.5
Electricity, water and gas	0.3	1.3	-1.7	0.4
Communications	2.7	2.6	-5.3	-3.2
Transport and storage	-0.6	0.7	-9.6	-7.5
Other private services	3.6	5.8	-10.1	-0.1

SIM1 = 40 percent price increase in the gas and oil commodity; SIM2 = SIM1 + 8.6 percent quantity increase in the gas and oil commodity; SIM3 = 17 percent price increase in the mineral commodity; SIM4 = SIM2 + SIM3.

Source: Authors' compilation.

The explanation of why the model produces the same GDP growth rate given no change in household consumption and given the important drop in overall investment is in the improvement of net exports (export rates increase but also imports decrease at higher rates). In fact, greater imports rates would be the economy's response to its lack of absorptive capacity under no fund. To improve the economy's absorptive capacity investment must be made in non-tradable capital (van der Ploeg and Venables, 2013).

3.5 Risks and Adjustment in the Post-Crisis Period

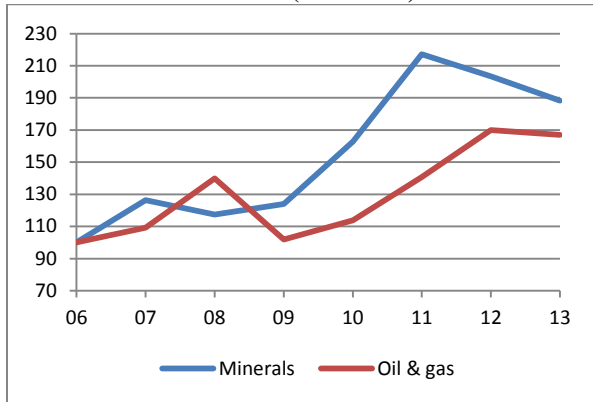
3.5.1 Macroeconomic Adjustment in a Reversal Scenario

At this point it is important to make the conceptual distinction between a real exchange rate appreciation that leads to DD and a real exchange rate appreciation that is consistent with fundamentals or long-term macro equilibrium. Following Reinhart and Rogoff (2009), the degree of real exchange rate misalignment is the most important indicator for anticipating a financial crisis, particularly a banking crisis and a currency crisis that can lead to a debt crisis. In the Bolivian case the data as well as arguments by the Bolivian Central Bank, the IMF and other analysts tend to indicate there is no danger of a potential crisis because there is not enough evidence of real exchange rate misalignment. The concept of DD in the literature is entirely

different, however. It does not matter if the real exchange rate is aligned with fundamentals or not; the mere fact that it appreciates will generate DD effects: change in the production structure of the economy benefitting the booming natural resource tradable as well as non-tradable sectors at the expense of non-resource tradable sectors. The larger the appreciation rate, the larger the DD effects will be. From this perspective the worst macroeconomic scenario would be that of DD plus misalignment. In the Bolivian case the scenario so far has been that of DD plus alignment.

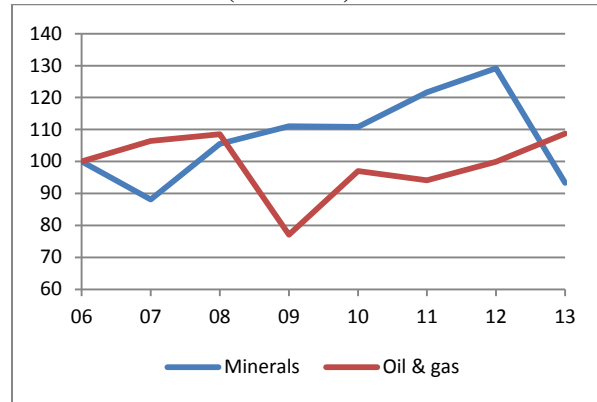
Following this reasoning, if the international economic environment in the post-international crisis changes, as it already is doing, by a decreasing tendency in the international prices of minerals but not of oil (at least so far), then the Bolivian economy would have to move from a SIM4' equilibrium to a SIM2' equilibrium, which requires a real exchange rate depreciation of 9.6 percent (12.3 percent - 2.7 percent). This implies that to avoid an economic crisis the real exchange rate would have to depreciate that much in order to keep itself aligned with fundamentals. In this case fundamentals also require a contraction of domestic absorption expressed in a 1.4 percent (0.8 percent + 0.6 percent) decrease in government expenditure and 1.4 percent (19.1 percent - 17.7 percent) decrease in total investment as well as a 2.2 percent decrease (6.1 percent - 3.9 percent) in household consumption and a decrease in labor factor prices over all skill levels. The drop is largest for the semiskilled (-3.7 percent), followed by the unskilled (-3.4 percent) and finally the skilled (-3.0 percent), suggesting not only loss of welfare for all but also loss in poverty and equality gains. The labor force released by the mining sector cannot be absorbed by the gas and oil sector given the skill mismatch between them, but unemployment could be avoided if absorbed by other sectors of the economy indirectly benefiting from the gas and oil sector, mainly the basic industrial and non-industrial agriculture and livestock industries, the export-oriented food industry as well as all non-tradable sectors which, as predicted by the model, require full employment. These are all sectors from which this labor probably migrated to the mining sector during the boom. From a DD perspective the economic structure would have to be adjusted again, especially if the perception of the new equilibrium is permanent. All of the above plus additional export and import structure adjustments make up the total cost of adjustment.

**Figure 8. Export Price Indexes
(2006=100)**



Source: Bolivian Central Bank.

**Figure 9. Export Quantum Indexes
(2006=100)**



Source: Bolivian Central Bank.

The figures above show the actual behavior of price and quantity indexes for the gas and oil and mineral commodities after 2008-09 (the base year is 2006). After reaching an average annual export price index of 117 in 2008, the mineral commodity price continued its increasing tendency up to the average annual export price index of 217 in 2011 and only after then began its decreasing tendency down to 188 by 2013. After reaching an average annual export price index of 140 in 2008, the export price trajectory of the gas and oil commodity was different; decreasing to an average annual level of 102 in 2009 due to the international financial crisis, then slowly recovering and reaching an average level of 170 by 2012 and 167 in 2013.

After reaching an average annual export quantity index of 105.5 in 2008, the mineral commodity slowly continued its tendency to increase up to the average annual level of 129.1 in 2012, and only afterward did it plunge to 93.3 in 2013. After reaching an average annual export quantity index of 108.6 in 2008, the export quantity trajectory of the gas and oil commodity was also different, decreasing to its lowest of an average annual export quantity index of 77.1 in 2009 due to the international financial crisis, then slowly returning to its average 2008 level by 2013.

From observation of these price and quantity indexes, together with the above model outcome analysis, it is easy to conclude the following:

1. The scale of positive price shocks experienced by the gas and oil and mineral sectors has been larger in the post-crisis period than in the pre-crisis period,

suggesting that the scale of impacts from these sources was also much larger compared to the smaller-scale analysis made with the CGE model, although the direction of results would be the same.

2. The scale of positive quantity shocks experienced by the mineral sector has also been much larger in the post-crisis period than in the pre-crisis period, suggesting that the scale of impacts from the mineral sector was also much larger compared to the smaller-scale price impact alone impacts analyzed with the CGE model.
3. The vast majority of the observed real exchange rate appreciation after 2008-09 (Figure A34) was determined by the mineral sector rather than by the gas and oil sector. Therefore the price and quantity downturn in the mineral sector due to changing international economic conditions constitutes the main source of potential macroeconomic disequilibrium, because to avoid misalignment the real exchange rate would have to depreciate substantially. From this perspective a negative price/quantity shock to the mineral sector seems more dangerous than a negative price/quantity shock to the gas and oil sector.⁵³ The real depreciation would have to come either from a nominal depreciation, probably under a more flexible exchange rate regime (which is unlikely at least at the beginning,⁵⁴ given current levels of international reserves) or from low inflation which is possible if the economy enters a low growth period (not predicted by the model under SIM2') or from a productivity increase in the non-tradable sectors and the non-resource tradable sectors, which is possible as the energy substitution policy deepens.⁵⁵
4. Figures 8 and 9 also show the differential negative price and quantity shocks experienced by both sectors during the international financial crisis. While the gas and oil sector did experience a substantial drop in both price and quantity in 2009, the mineral sector negative price shocks in 2008 was mild and the negative quantity shock in 2007 seems to be disconnected from the crisis

⁵³ The implicit assumption made here is that the gas & oil sector will not face resource reserves restrictions as well as foreign demand restrictions. This would be the worst case or pessimist scenario, analyzed in SIM8.

⁵⁴ The reason is that a nominal depreciation will begin dollarization of the financial system once again.

⁵⁵ The energy substitution taking place since the early 2000s is that from gasoline, diesel and electricity to natural gas use by households and vehicles.

itself. It is possible that international prices of minerals exported by Bolivia were behaving more in accordance with Asian growth (mainly that of China and India), which also explains its current downward trend, while the international price of oil was behaving more in accordance with the international financial crisis that began in the United States, which would also help explain its current stable level as the US economy recovers.

Nevertheless the model main result remains that as long as the gas and oil sector remains strong the economy will be able to handle a crisis in the mineral sector. If the international gas and oil price remains around its current level on average and revenues from this source remain dominant in government income (no fiscal risks), then the economy will maintain its growth opportunity based on high government savings and investment as main determinants, along with a substantially weaker DD secondary effect (low appreciation rate) given the enclave nature of the gas and oil sector. This result helps to diminish potential uncertainties and negative expectations about the Bolivian economy that could arise with a crisis in the mineral sector. However, a crisis in the mineral sector would require the economy to adjust to a higher degree than the model predicts by depreciating the real exchange rate and contracting real absorption to their new equilibrium levels. The most difficult aspect of this adjustment will be the larger scale of labor released by the mineral sector. Although the model predicts some natural migration of labor to other tradable and non-tradable sectors, the scale of labor released will require complementary government policy and action, like investing natural resource proceeds in needed infrastructure projects that can absorb unskilled and semiskilled workers, as well as investing in human skills.

3.5.2 Additional Price and Quantity Commodity Shocks in the Post-Crisis Period

The above conclusion is highly influenced by the pre-crisis scenario where the gas and oil commodity price had increased at a higher rate than the mineral commodity price (2008 in Figure 8). In the post-crisis period, the opposite has consistently been the case, as the mineral commodity price has increased at a higher rate than the gas and oil commodity price (2010-13 in Figure 2008). Table 5 presents results from the exercise of simulating the post-crisis behavior of

prices⁵⁶. SIM5 considers a 30 percent price increase of the gas and oil commodity alone. SIM6 considers a 40 percent increase in the price of the mineral commodity alone, and SIM7 performs SIM5 and SIM6 simultaneously. SIM 8 is different because it is a more pessimistic post-crisis scenario, where the price of the gas and oil commodity drops to its 2006 level, the quantity of the gas and oil commodity drops 20 percent below its 2006 level (similar to what was observed in 2009) and the price of the mineral commodity drops 20 percent below its 2006 level (much closer to its pre-boom level).

Comparing SIM7 with SIM5 would be equivalent to having a negative price shock that eliminates the 40 percent mineral price increase and reverses the price to its 2006 level but maintains the 30 percent gas & oil price increase. Again the main finding remains that, as long as the gas and oil commodity price remains high, the economy will be able to handle even a larger crisis in the mineral sector. Of course, the degree of macroeconomic adjustment will require a higher depreciation rate and larger contraction of absorption.

Comparing SIM7 with SIM8 would be equivalent to a much more pessimistic scenario, where not only do both commodities lose their pre and post crisis price gains, but also the mineral commodity price drops an additional 20 percent and the gas and oil commodity even experiences a 20 percent decline in demand. From a booming GDP growth rate of 9.9 percent under SIM7, this last scenario throws the economy into recession with a negative 4.4 GDP growth rate and almost all other indicators in negative growth rates. When the international economic environment is not favorable to mineral and gas and oil commodities, the Bolivian economy adjusts and falls back on its agriculture, food, basic industry and non-tradable sectors, as occurred during the 1990s. This scenario represents the reversal of all welfare gains beyond simple income poverty and inequality gains.

However, this is the “bad times” scenario that can be confronted with use of accumulated government savings in an institutionalized⁵⁷ stabilization fund. The fund’s financial resources would be introduced to the economy through government investments whose size and macroeconomic impact can avoid recession and diminish the degree of adjustment. The specific projects financed by the fund would depend on the perception about which commodity prices are

⁵⁶ The post-crisis scenarios implicitly assume that the basic Bolivian production structure did not change.

⁵⁷ Institutionalization here means the political and administrative process that would allow the stabilization fund to smoothly fill up during good times and smoothly deplete during bad times.

expected to bounce back or not, which projects can best contribute to economic diversification and which projects can best serve multiple purposes.

Table 5. Rates of Change from Different Price Scenarios in the Post-Crisis Period

	SIM 5	SIM 6	SIM 7	SIM 8
GDP growth rate	5.3	5.3	9.9	-4.4
Household consumption	2.2	6.8	8.9	-2.7
Investment	30.7	9.9	35.5	-16.6
Government income	12.6	-9.6	0.9	-2.1
Government expenditure	-0.4	3.4	3.6	-1.2
Exports	-6.2	4.0	-0.8	-7.0
Natural gas and oil	2.1	5.2	6.3	-27.6
Mining	-17.9	134.7	112.1	-80.0
Food products	-7.2	-73.6	-74.5	83.9
Other Industrial products	-16.5	-75.5	-77.2	39.9
Imports	8.7	30.2	39.1	-10.0
Mining	10.0	-29.5	-20.5	93.7
Food products	7.9	85.8	96.0	-23.0
Other Industrial products	8.0	16.2	23.6	-7.1
Factor prices				
Unskilled	-1.0	8.1	8.1	-0.7
Semiskilled	-0.8	8.5	8.8	-2.8
Skilled	-0.6	7.3	7.9	-3.8
Capital	-3.3	20.3	17.0	-7.5
Real exchange rate	-2.3	-21.2	-22.4	9.7
Output (Int + VA)				
NonIndustrial agriculture	1.2	-15.4	-14.2	11.7
Industrial agriculture	0.5	-33.7	-32.0	35.0
Other agriculture and livestock	-0.1	-9.7	-9.0	12.0
Natural gas and oil		0.0	0.0	-20.0
Minerals	-16.5	121.3	100.5	-70.0
Food products	0.5	-18.2	-16.5	20.5
Refinery products	-11.8	-17.6	-25.2	3.2
Other Industrial products	-6.5	-45.8	-45.4	19.1
Electricity, water and gas	0.7	-0.8	0.2	0.3
Communications	1.5	-8.3	-7.1	10.6
Transport and storage	-0.2	-15.9	-15.1	8.7
Other private services	7.5	-8.5	-2.3	3.4

SIM5 = 30 percent price increase in the gas and oil commodity; SIM6 = 40 percent price increase in the mineral commodity; SIM7 = SIM5 + SIM6; SIM8 = No price increase in the gas and oil commodity + 20 percent price decrease in the mineral commodity + 20 percent quantity decrease in the gas and oil commodity.

Source: Own.

SIM8 shows that it is the negative shock to the gas and oil sector that can potentially cause a national economic crisis. To prevent such a crisis, policy is needed in this sector for the consolidation and expansion of foreign gas and oil markets based on investments in reserve expansion and on investments in other forms of energy demanded by foreign and domestic markets. The strategy would be one of market and product diversification.⁵⁸

4. A DSGE Model of Capital Flight

The aim of this section of the paper is to provide a dynamic view of the implications of large and unexpected negative shocks that might hit the Bolivian economy once the current favorable context of high commodity prices and, particularly, low interest rates in the world comes to an end. A Dynamic Stochastic General Equilibrium (DSGE) of the real business cycle type is built for this purpose, with the intention of identifying specific thresholds for some critical macro variables over which the negative impact of the external shocks considered might be significant. Appendix B present the DSGE model equations in detail.

4.1 Model Features

We build an open-economy DSGE model comprised of two types of agents, skilled and unskilled workers, and a productive sector divided in two main sub-sectors, one (identified with the superscript TRD) devoted to the production of a single tradable good and a second one (identified with the superscript NTRD) devoted to the production of a single non-tradable good. Both types of agents can consume tradable and non-tradable goods and supply labor in the factor market in return for labor income. Also, subject to intermediation costs, skilled workers can allocate savings to physical capital and foreign bonds in return for capital income, while unskilled workers cannot participate in such markets due to prohibitively high intermediation costs.

⁵⁸ It is beyond the scope of this research to establish detailed sectorial policies, particularly in the resource export sectors, however some general suggestions are made in connection to the topics of this paper: DD, NRC and RRDC. For more detailed discussions on problems, perspectives and policy for the gas and oil sector see Del Granado et al. (2010). For the much wider energy sector see Torres et al. (2012). For the mineral sector see Jordán et al. (2010) and Oporto et al. (2012 and 2013).

The representative firm producing tradable goods is thus owned by the representative skilled worker, leases physical capital for which it pays the competitive interest rate and hires skilled and unskilled labor, for which it pays the competitive skilled and unskilled wages, respectively. Finally, the government provides public goods (which are produced in the non-tradable sector) and net transfers to the private sector, which are financed via taxes and large revenues related to significant natural gas exports.

4.1.1 Population Composition

The population size, N , is exogenous and constant. Among N , N^u are identical unskilled workers and $N^s = N - N^u$ are identical skilled workers. There are also N^f firms, with $N^{f,TD}$ of them producing tradable goods and $N^{f,NTD}$ producing non-tradable goods. For simplicity, we assume that the number of firms ($N^f = N^{f,TD} + N^{f,NTD}$) equals the number of skilled workers and that each skilled worker owns one firm. It is useful, for what follows, to define $N^s/N = n^s$, $N^u/N = n^u$ and $N^f/N = n^f$. The shares of each type of agent in the population are assumed to be constant, consistent with the notion of low social mobility.

4.1.2 Firms

Each firm in the tradable or non-tradable sector produces a single output, $Y^{f,i}$, with $i=TD, NTD$, using physical capital, $K^{f,i}$, and two distinct types of labor, unskilled, $H^{f,u,i}$, and skilled, $H^{f,s,i}$, where skilled labor is relatively more complementary to capital than unskilled labor. The production function for both subsectors is given by a constant return to scale (CRS) technology assumed to take a constant elasticity of substitution (CES) specification following, e.g., Krusell et al. (2000) and He (2012):

$$Y_t^{f,i} = Z_t^i \left\{ \left[\mu (H_t^{f,u,i})^\alpha + (1 - \mu) \left[\rho (K_t^{f,i})^\nu + (1 - \rho) (H_t^{f,s,i})^\nu \right]^{\frac{\alpha}{\nu}} \right]^{\frac{1}{\alpha}} \right\}$$

where $Z^i > 0$ is constant productivity; $0 < \alpha, \nu < 1$, are the parameters determining the factor elasticities, i.e. $1/(1-\alpha)$ is the elasticity of substitution between capital and skilled labor with respect to unskilled labor, whereas $1/(1-\nu)$ is the elasticity of substitution between capital and skilled labor; and $0 < \mu, \rho < 1$ are the share parameters. The above CES form allows us to capture the capital-skill complementarity, which is considered to be a main driver of the skill premium and wage inequality (see, e.g., Krusell et al., 2000, and Hornstein, Krusell and Violante, 2005).

In each subsector i , each firm acts competitively, taking prices and policy variables as given, and maximizes profits given by:

$$\Pi_t^{f,i} = P_t^i Y_t^{f,i} - r_t^{k,i} K_t^{f,i} - w_t^{s,i} H_t^{f,s,i} - w_t^{u,i} H_t^{f,u,i}$$

Where $w_t^{s,i}$ and $w_t^{u,i}$ are, respectively, the wage rates of skilled and unskilled labour and $r_t^{k,i}$ is the interest rate on capital. Note that, in equilibrium, profits are driven to zero due to perfect competition.

The different roles in the production function for skilled and unskilled labor imply that there will be a skill premium for the former, in the sense that the ratio of $w_t^{s,i}$ and $w_t^{u,i}$ will be larger than unity. In the same line, a manifestation of DD might lead to a situation in which factor prices in the tradable sector are higher than those in the non-tradable sector.

4.1.3 Households

Each type of household j , where $j = \text{skilled, unskilled}$, maximizes:

$$E_0 \sum_{t=0}^{\infty} \beta^t U(C_t^j, H_t^{j,NTD}, H_t^{j,TD})$$

subject to the budget constraints described below, where E_0 is the conditional expectations operator. We use the instantaneous utility function:

$$U_t^j = \frac{\left[(C_t^j)^{\mu_1} (1 - H_t^{j,NTD} - H_t^{j,TD})^{\mu_2} (G_t^c)^{1-\mu_1-\mu_2} \right]^{\sigma}}{1 - \sigma}$$

where $0 < \mu_1, \mu_2, \mu_3 < 1$ are the weights of consumption, leisure and public goods in utility (which must sum up to 1), and $\sigma > 1$ is the coefficient of relative risk aversion. The variable G^c represents the total amount of public goods per capita. This utility-enhancing feature of public goods is consistent with the fact that Bolivia remains one of the poorest countries of South America and around 60 percent of its population is still below the poverty line. In this sense, the relative dependence of this large part of the population on public goods, services and transfers is quite significant with respect to total income.

For each type of agent total consumption is a composite of tradable and non-tradable goods:

$$C_t^j = (C_t^{j,TD})^\phi (C_t^{j,NTD})^{1-\phi}$$

The representative skilled worker owns one firm and receives its profits. He also receives income from providing skilled labor services to both the tradable and non-tradable sectors, and income from interests on his accumulated stock of financial assets, in the form of capital, K_t , and foreign bonds, B_t^* . The interest rate on bonds is given by r_b^* and its determination is explained below when closing the model. All these sources of income are taxed. In particular, financial asset and profit income are taxed at the constant rate τ_k , while skilled labor income is taxed at the constant rate τ_h .

We assume that those agents holding assets need to pay intermediation or transaction premium due to imperfections in capital markets. For instance, this premium can represent the costs of gathering extra information relating to legal issues, asset-specific government regulations, intermediation fees, shoe-leather costs and so on. We follow Persson and Tabellini (1992) and Benigno (2009) and assume a quadratic cost function such that the agent incurs a cost of $\varphi^k (K^{TRD})^2$ for holding physical capital used in the tradable sector or $\varphi^k (K^{NTRD})^2$ for holding physical used in the non-tradable sector, and of $\varphi^b (B^*)^2$ for holding foreign bonds, where the various φ 's (all positive) measure the size of the transaction costs. The presence of this capital market imperfection and of the associated transaction costs helps the model to capture a feature of realism.

The skilled worker uses his income for consumption of both tradable ($C^{s,TRD}$) and non-tradable goods, ($C^{s,NTRD}$) and investment in capital used in the tradable (I^{TRD}) or the non-tradable sectors (I^{NTRD}), and investment in foreign bonds, D^* . He pays taxes on capital income and labor income, where τ^k and τ^k are the respective tax rates. He also receives average (per agent) transfers from the government, $\bar{G} = G/N$. Thus, his budget constraint is:

$$\begin{aligned}
& (1 + \tau^c)(C_t^{s,TRD} + C_t^{s,NTRD}) + (I_t^{TRD} + I_t^{NTRD}) + D_t^* \\
& = (1 - \tau^k)(r_t^{k,TRD} K_t^{TRD} + r_t^{k,NTRD} K_t^{NTRD} + r_t^b B_t^* + \pi_t^f) \\
& + (1 - \tau^s)(w_t^{s,TRD} H_t^{s,TRD} + w_t^{s,NTRD} H_t^{s,NTRD}) + \bar{G}_t - \varphi^k [(K_t^{NTRD})^2 + (K_t^{TRD})^2] \\
& - \varphi^b (B_t^*)^2
\end{aligned}$$

while the evolution of the stock of capital (both in the tradable and non-tradable sectors) and foreign bonds, respectively, are given by:

$$\begin{aligned}
K_{t+1}^{TRD} &= (1 - \delta)K_t^{TRD} + I_t^{TRD} \\
K_{t+1}^{NTRD} &= (1 - \delta)K_t^{NTRD} + I_t^{NTRD} \\
B_{t+1}^* &= B_t^* + D_t^*
\end{aligned}$$

where $0 < \delta < 1$ is a depreciation rate, assumed for simplicity to be the same between the two productive sectors, and K_0^{TRD} , K_0^{NTRD} and B_0^* are given.

In turn, unskilled workers differ from skilled workers in two important respects. First, they start with zero initial holdings of assets, and capital market imperfections result in their exclusion from financial markets as in the models of Bénabou (1996) and Aghion and Howitt (2009). Second, we assume that exclusion from capital markets does not allow them to acquire the skills to provide skilled labor services, so that their labor effort differs, in nature, from the labor effort of the other type of agent. Thus, the budget constraint of the representative unskilled worker is:

$$(1 + \tau^c)(C_t^{u,TRD} + C_t^{u,NTRD}) = (1 - \tau^u)(w_t^{u,TRD} H_t^{u,TRD} + w_t^{u,NTRD} H_t^{u,NTRD}) + \bar{G}_t$$

where $0 \leq \tau^u < 1$ is the tax rate on unskilled labor income.

4.1.4 Government Budget Constraint

The government provides the private agents with utility-enhancing services, in the form of government consumption, as well as net transfers. In order to finance these expenses, it taxes consumption and income from labor and physical assets. In addition, as is the case in a number of emerging/developing economies, the government also obtains significant revenues, denoted by R_t , from selling a natural resource often produced within a natural-monopoly structure and thus usually owned entirely (or almost entirely) by the government. Very well-known cases are

the copper industry in Chile and, of course, the oil industry in several Latin American, African and Middle Eastern countries.

Due to a significant increase in exploration activity since the late 1990s, Bolivia is known to hold the second largest reserves of natural gas in South America (after Venezuela). After a major investment to build a cross-border pipeline to Brazil in addition to the existing one to Argentina (built in the early 1970s), revenues from exports of this resource to both countries have represented on average around 6 percent of the country's GDP in the last three years.

Following García and Restrepo (2007) and García, Restrepo and Tanner (2011), given the nature of this strategic industry, the additional revenues coming from natural gas exports are modeled here as net revenues or commodity windfalls, hereafter denoted by R_t . Therefore, the budget constraint of the government is given by:

$$\begin{aligned} G_t^T + G_t^c = & N^s \tau^c (C_t^{s,TRD} + C_t^{s,NTRD}) + N^s \tau^s (w_t^{s,TRD} H_t^{s,TRD} + w_t^{s,NTRD} H_t^{s,NTRD}) + N^s \tau^k B_t^* \\ & + N^s \tau^k (r^{k,TRD} K_t^{TRD} + r^{k,NTRD} K_t^{NTRD}) + N^u \tau^c (C_t^{u,TRD} + C_t^{u,NTRD}) \\ & + N^u \tau^u (w_t^{u,TRD} H_t^{u,TRD} + w_t^{u,NTRD} H_t^{u,NTRD}) + R_t \end{aligned}$$

4.2 Constraints and Model Closure

4.2.1 Closing the Model

Following the seminal paper by Schimdt-Grohé and Uribe (2003), it is assumed that the country is a small open economy which takes the world's equilibrium interest rate on foreign bonds as given. Hence, the interest rate on these securities faced by the country is given by:

$$r_{b,t}^* = r^w$$

where r^w is the world's interest rate, which follows an AR(1) exogenous process, described next.

4.2.2 Market-Clearing Conditions

The market-clearing conditions for the capital, bond, skilled and unskilled labor and product markets respectively are:

$$\begin{aligned} N^{f,TRD} K_t^{f,TRD} &= N^s (K_t^{TRD}) \\ N^{f,NTRD} K_t^{f,NTRD} &= N^s K_t^{NTRD} \end{aligned}$$

$$\begin{aligned}
B_t^* &= N^S B_{s,t}^* \\
N^{f,s,NTDR} H_t^{f,s,NTRD} &= N^S (H_t^{S,NTRD}) \\
N^{f,s,TDR} H_t^{f,s,TRD} &= N^S (H_t^{S,TRD}) \\
N^{f,u,NTDR} H_t^{f,u,NTRD} &= N^u (H_t^{u,NTRD}) \\
N^{f,u,TDR} H_t^{f,u,TRD} &= N^u (H_t^{u,TRD}) \\
N^{f,TRD} Y_t^{f,TRD} + N^{f,NTRD} Y_t^{f,NTRD} \\
&= N_t^S C_t^{S,TRD} + N_t^u C_t^{u,TRD} + N_t^S C_t^{S,NTRD} + N_t^u C_t^{u,NTRD} + N_t^S I_t^S + G_t^C \\
&+ N_t^S [\varphi^{NTRD,k} (K_t^{NTRD})^2 + \varphi^{TRD,k} (K_t^{TRD})^2 + \varphi^b (B_t^*)^2]
\end{aligned}$$

where the last equation gives the aggregate resource constraint of the economy.

4.2.3. Exogenous Processes

Four exogenous processes describing the behavior of the natural resource revenues, the technology shocks affecting both the tradable and non-tradable sector and the world's interest rate, are considered. Hence, for $X_t = \{R_t, Z_t^{TRD}, Z_t^{NTRD}, r_t^w\}$, the behavior of any variable X will be assumed to be best described by an AR(1) process of the form:

$$X_{t+1} = X_0^{(1-\rho^X)} X_t^{\rho^X} e^{\varepsilon_t^X}$$

with $X_0 > 0$, $0 < \rho^X < 1$ and ε_t^X assumed to be normally distributed with zero mean and standard deviation σ_{ε^X}

4.2.4 Competitive Equilibrium

The decentralized competitive equilibrium (DCE) is defined when i) each representative skilled worker takes good and factor prices as well as policy as given and chooses $\{C_t^{S,TRD}, C_t^{S,NTRD}, H_t^{S,TRD}, H_t^{S,NTRD}, K_t^{S,TRD}, K_t^{S,NTRD}, B_t^*\}_{t=0}^{\infty}$ to maximise his discounted lifetime utility subject to his budget constraint; whereas each unskilled worker also takes good and factor prices as well as policy as given and chooses $\{C_t^{u,TRD}, C_t^{u,NTRD}, H_t^{u,TRD}, H_t^{u,NTRD}\}_{t=0}^{\infty}$ subject to his respective budget constraint; and ii) each representative firm producing tradable goods chooses $\{H_t^{S,f,TRD}, H_t^{u,f,TRD}, K_t^{S,f,TRD}\}$ to maximize profits subject to the technology constraint given by the CES production function described earlier, while each firm producing non-tradable goods

chooses $\{H_t^{S,f,NTRD}, H_t^{U,f,NTRD}, K_t^{S,f,TRD}\}$ to maximize profits subject to its relevant technology constraint.

In addition to these, the DCE assumes that all markets clear in terms of what was described above and also includes the two production functions for tradable and non-tradable goods, one of the two conditions involving the Lagrangian multipliers from the households problems, the government budget constraint, the aggregate resource constraint, the evolution of the interest rate of the net foreign assets and the four AR(1) exogenous processes defined in the previous section.⁵⁹

4.3 Parameterization and Calibration of the Model

The model is parameterized and calibrated using annual data for Bolivia from 1986 to 2012, as reported in Table 6 below.

4.3.1 Parameters Related to Households

First, in order to map out agent heterogeneity and define the shares in the population of the two types of households described in the model, we consider the Financial Services Access in Latin-America Survey by the Latin American Development Bank (known as CAF) presented in April, 2011. According to this survey, only 35 percent of the Bolivian population currently has access to formal (i.e., regulated) financial services, while the rest have to rely on informal and much more costly sources of funding, if any. Hence, the percentage of skilled workers in the model will be placed at this level, implying that the remaining 65 percent will be considered under the category of unskilled workers.

Table 6. Parameter Values

Parameter	Description	Value	Source
δ	Depreciation rate of capital	0.07	Data
μ_1	Consumption weight in utility	0.6	Calibration
μ_2	Leisure weight in utility	0.3	Calibration
ϕ	Tradable goods weight in consumption	0.57	Data
Σ	Risk aversion factor	2	Assumption

⁵⁹ The DCE will be provided in the Appendix.

B	Rate of time preference	0.94	Data
n_s	Population share of skilled workers	0.35	Data
G^T/Y	Government transfers to the private sector	0.039	Calibration
v^{Trd}, v^{Ntrd}	Capital to skilled labor elasticity	-0.495	Assumption
$\alpha^{Trd}, \alpha^{Ntrd}$	Capital/skilled to unskilled labor elasticity	0.401	Assumption
μ^{Trd}, μ^{Ntrd}	Unskilled labor weight	0.275	Calibration
ρ^{Trd}	Capital weight in composite input share – tradable	0.741	Calibration
ρ^{Ntrd}	Capital weight in composite input share – non tradable	0.740	Calibration
G^c/Y	Government expenditure in public goods (% of GDP)	0.14	Calibration
ρ^R	Persistence of gas price AR(1) process	0.72	Data
σ_R	Standard deviation of gas price process	0.12	Data
R_0	Natural gas revenues	0.013	Calibration
Z_0^{TR}, Z_0^{NTR}	Total factor productivity	1	Assumption
ρ^{Ztr}, ρ^{Zntr}	Persistence of productivity AR(1) process	0.602	Data
$\sigma_{\varepsilon^{Ztr}}, \sigma_{\varepsilon^{Zntr}}$	Standard deviation of productivity process	0.028	Data
r_t^w	World interest rate	0.086	Calibration
$\rho^{r_t^w}$	Persistence of world interest rate AR(1) process	0.582	Data
$\sigma_{\varepsilon^{r_t^w}}$	Standard deviation of world interest rate process	0.01	Data
$\varphi^{TRD,k}, \varphi^{NTR,k}$	Transaction costs in the financial markets	0.005	Calibration
τ^k	Capital gains effective tax	0.23	Data
τ^h	Labor income effective tax – skilled	0.12	Data
τ^u	Labor income effective tax - unskilled	0.10	Data
τ^c	Value Added Tax	0.13	Data

Source: Authors' compilation.

Second, we approximate the subjective time preference, β , so that it is consistent with the average real interest rate in the Bolivian formal credit market from 2004 to 2010 (see, e.g., Central Bank of Bolivia, 2010)⁶⁰ which we calculated to be around 6.2 percent.⁶¹ This gives a parameter value of $\beta=0.94$.

⁶⁰ We do not use previous years in this calculation as the financial market was highly dollarized during that period, and thus the interest rates in domestic currency did not fully reflect the conditions of the markets. Since the mid-2000s, however, dollarization levels have decreased significantly.

⁶¹ Data source: <http://www.udape.gob.bo> (see statistical dossier section).

Parameters μ_1 , μ_2 and $\mu_3=1-\mu_1-\mu_2$ in the utility function of both types of agents have been set at the usual values in the literature (i.e., leisure is almost twice as important as consumption, while the utility provided by public goods is quite small) in order to match the key aggregate ratios observed in the data (i.e., C/Y and G/Y)⁶² as well as the notion that agents spend between 15 to 35 percent of their available time working (in either the tradable and/or the non-tradable sectors), with unskilled workers at the top of this range.

Third, parameter ϕ , which determines the relative preference for tradable goods and services, is set to 0.57, as implied by the composition of the latest official basket of goods and services considered by the Bolivian National Statistics Institute (INE) in order to compute the Consumer Price Index since 2007. Next, following a large part of the relevant literature (see, e.g., Angelopoulos, Jiang and Malley, 2013), the coefficient of risk aversion, σ , is set equal to two.

4.3.2 Parameters Related to Firms

We next turn to heterogeneity in productivity and returns to labor, which governs the choice of the relevant production parameters, which in some cases will be assumed to be slightly different between productive sectors (i.e., tradable and non-tradable).

Using the estimates in Krusell et al. (2000), we set $\nu=-0.495$ and $\alpha=0.401$, implying elasticities of substitution between capital and skilled labor and between capital (or skilled labor) and unskilled labor of about 0.67 and 1.67, respectively. With these parameters, our calibration of $\rho=0.741$ (0.74 in the case of the non-tradable sector, denoting a slightly lower capital weight in output as compared to the tradable sector) and $\mu=0.275$ (for both sectors) allows us to approximate the labor share of income at 0.63, which is well within the range estimated by Gollin (2002) for Bolivia (between 0.484 to 0.65), and also to obtain a skill premium of 2.3, which is also within the range reported by the national labor survey carried by UPB (2005), according to which the wage of the average skilled worker in Bolivia is between two to four times the wage of the average unskilled worker.

To obtain the best possible approximation of the depreciation rate (again assumed to be the same in both the tradable and non-tradable sectors), first we make use of an important finding by Cole et al. (2005), who show that the capital-to-output ratio for a sample of 11 Latin

⁶² National accounts data source: International Financial Statistics (IMF).

American economies (in which Bolivia is included) is in fact quite similar (i.e., slightly higher) to that of the US, which in turn is known to have stabilized at around $K/Y=2$ since the 1950s (see, e.g., Evans, 2000).

Then, by applying the perpetual inventory method to compute the capital stock for Bolivia using data on gross capital formation for the last 60 years, we find that an annual depreciation rate, δ , of 7 percent (assumed to be equal in both the tradable and the non-tradable sector) is consistent with a capital-to-output ratio that oscillates around a value slightly below two.⁶³

4.3.3 Parameters Related to Government

The steady-state effective average tax rate for capital gains is taken from Chen and Mintz (2011), who estimate it to be equal to 23 percent, quite close to the nominal rate of 25 percent as defined by law (Law No.1606, passed in December, 1994). For the case of the labor income tax, due to the lack of up-to-date estimates and reliable data on their effective counterparts, we take the figures provided by Rocabado (2006), which suggest that the effective income tax for the upper tier of contributors is around 12 percent, while that of the lower tier (those who earn less than Bs1400 or around USD 220 in 2006 prices) is around 10 percent, well below the nominal rate of 13 percent established by law. The consumption tax rate (value added tax rate) is set to its nominal rate of 13 percent.

On the expenditure side, the government-to-output ratio at the steady state, G/Y , is set to match its 20-year average according to the data, of around 14 percent. Likewise, the government transfers are set to a value such that the G^{tr}/Y ratio matches its respective 20-year average, as given by data, of around 17 percent of GDP.

4.3.4 Parameters Related to Financial Markets

The value of the financial transaction cost parameters faced by the skilled worker in order to take part in the financial markets is set at a very low level (i.e., 0.005) such that the key aggregates of the economy as predicted by the model match with the real data. For simplicity, all these costs will be assumed to be identical for each representative agent.

⁶³ This depreciation rate is similar to the rate used by both Feu (2004) and Feu et al. (2007) for the case of Brazil. Also, Gelos and Isgut (2001) considered depreciation rates between 4 percent and 7 percent when studying the cases of Mexico and Colombia.

In addition, the value of the steady state's world interest rate faced by Bolivian residents with respect to the rest of the world (at which they borrow or lend from/to the international financial markets) is set to 0.0865, so that the current net creditor position of Bolivia can be replicated. In effect, given that the international reserves of the country have oscillated around USD13.2 billion over the last years up to the end of 2013, it follows that the country's overall net creditor position as a percentage of the GDP (which has been estimated by the current government to be around USD 30.6 billion for 2013), is of around 43 per cent.

4.3.5 Parameters Related to Sources of Volatility

To conclude this parameterization procedure, we now focus on the parameters of the exogenous sources of volatility considered in the model. First, for the process of gas revenues, we assume that the constant term R_0 is equal to 0.0265, which ensures that at the steady state the gas revenue to GDP ratio is equal to 6 percent, as observed in the data between 2008 to 2012 (see BCB, 2012).

Parameters ρ^R and σ_R are set to 0.72 and 0.12, respectively, suggesting high price volatility but moderate persistence of the shock. These parameters were obtained by estimating an AR(1) process for the evolution of the average price per British Thermal Unit of gas sales to Brazil between 2007 and 2011,⁶⁴ because changes in the volumes sold are less likely as these depend on the pipeline's capacity and thus can only be affected by other unexpected events such as geopolitical issues, civil unrest in the producing regions or natural disasters. High and increasing price volatility in the natural gas and most energy markets in recent times have been widely documented elsewhere in this document, but see, for instance, Pindyck (2004) for an in-depth discussion about this matter.

Next, in the case of the AR(1) process assumed to be followed by the world's interest rate, we take the figures estimated by Martín-Moreno, Pérez and Ruiz (2014), setting $\rho^{r^w} = 0.58$ and $\sigma_{r^w} = 0.01$, considering US government securities data.

Finally, to estimate the AR(1) relation for the exogenous productivity processes, total factor productivity data for Bolivia were constructed as in King and Rebelo (2000) using the

⁶⁴ Data provided by the Ministry of Hydrocarbons. Gas sales to Brazil represent 76 percent of the total. The gas sale price is determined by a formula which considers the international market prices of a basket of oil-related products. See <http://www.hidrocarburosbolivia.com>.

IFS's National Accounts annual data for Bolivia from 1986 to 2010,⁶⁵ in order to avoid the adverse effects in the estimations that arise when earlier periods, characterized by severe episodes of economic crisis (e.g., the late 1970s and early 1980s), are included in the estimation sample. For simplicity, this estimation is considered to be relevant for both the tradable sector and the non-tradable sector. Thus the parameter estimates are $\rho^{Z^{TRD}} = \rho^{Z^{NTRD}} = 0.602$ and $\sigma_{Z^{NTRD}} = \sigma_{Z^{TRD}} = 0.028$, while the constant terms Z_0^{TRD} and Z_0^{NTRD} have been set equal to one.

4.3.6 The Steady State Solution

The steady-state solution of the model is given in Table 7 below in terms of the aggregate variables. First, note that the chosen parameterization allows the model to match the key aggregate ratios observed in Bolivian data between 1990 and 2010. That is, the K/Y and I/Y ratios are just below their expected values of 2.00 and 0.16, respectively. For the remaining aggregate ratios—K/Y, B/Y, G/Y and R/Y—the match is virtually perfect, as intended during the parameterization procedure discussed earlier.

Second, note that a representative skilled worker consumes relatively more than the unskilled worker since $C_s = 0.26$ and $C_u = 0.10$. This implies that in aggregate terms skilled workers—who represent only 35 per cent of the population—account for 58 per cent of total consumption in the economy. On the other hand, the variables h_s ($h_{s,TRD} + h_{s,NTRD}$) and h_u ($h_{u,TRD} + h_{u,NTRD}$) show that, as expected, skilled agents work considerably less than unskilled ones. Thus, in terms of welfare, higher consumption and lower work effort make the skilled workers relatively better off as indicated by U_s , which is smaller than U_u in absolute terms.

Table 7. Steady State Values

Variable	Value	Variable	Value
C/Y	0.72	h_s	0.21
$(n_s * C_s)/Y$	0.42	$H_{s,TRD}$	0.11
$(n_u * C_u)/Y$	0.30	$H_{s,NTRD}$	0.10
I/Y	0.15	H_u	0.31
G^c/Y	0.14	$H_{u,TRD}$	0.16
$r_{k,TRD}$	0.1822	$H_{u,NTRD}$	0.15

⁶⁵ An aggregate production function was first written in per-worker terms (considering the economically active population data provided by the Bolivian National Statistics Office - INE), and solved for a general TFP factor Z_t . By feeding the per-worker time series of output and (also newly built) capital stock, an estimated TFP series was obtained. This was then expressed in logs and detrended, and then an AR(1) process was fitted to it.

$r_{k,NTRD}$	0.1815	U_s	-2.97
r_{bx}	0.0865	U_u	-4.34
R/Y	0.06	U_a	-3.86
K/Y	1.93	$w_{s,TRD}/w_{u,TRD}$	2.31
B/Y	0.43	H_{TRD}/H_{NTRD}	1.09
G^{tr}/Y	0.17	<i>Labor Income (% of GDP)</i>	0.64

Source: Authors' calculations.

Finally, note too that the following facts related to the labor market have also been matched by the model: the wage of a representative skilled worker is 2.3 times the wage of an unskilled worker, the labor income share with respect to GDP is 0.64 and the labor supply is slightly higher in the tradable sector.

4.4 Model Experiments and Results

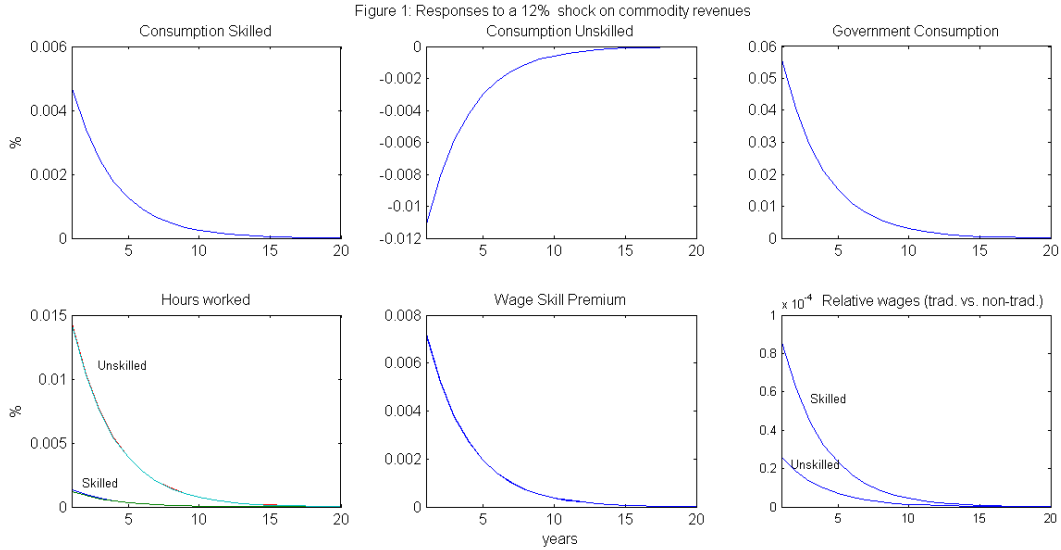
To solve the dynamic version of the model, we start by taking the first order Taylor series expansion of the decentralized competitive equilibrium and exogenous processes around their respective steady-states. For any variable X_t , these values are denoted $\widehat{X}_t = \log X_t - \log \bar{X}$, where \widehat{X}_t is the log-linear approximation of variable X_t around its steady state value, \bar{X} . The solution method proposed by Klein (2000) was next used and the policy functions obtained.

Now, a number of experiments can be performed assuming different shocks that might hit the economy. First, we focus on two possible shocks (an increase in resource export revenues and an increase in the world interest rate) under the baseline calibration of the model describing the current economic boom. Next, we consider an alternative scenario in which the booming period comes to an end and the economy has deteriorated significantly.

4.4.1 A Commodity Price Shock

Figure 10 shows the economic impact of a 12 percent increase in natural gas revenues. It is important to recall that such revenues are received by the government, as they fully own this strategic industry. The first striking result predicted by the model is that skilled workers will increase their consumption and reduce the total number of hours worked (see upper left and bottom left panels in the Figure), due to the income effect generated by the increase in their salaries motivated by the exogenous shock.

Figure 10. Responses to a 12 Percent Shock to Commodity Revenues



Source: Authors' calculations.

In effect, since the shock increases government revenues and a balanced budget must be preserved, the provision of public goods must increase significantly (see the upper right panel in the figure). This in turn motivates more production in both the tradable and non-tradable sector (not shown in the figure), raising salaries of the skilled workers in general but slightly more in the tradable sector than in the non-tradable sector (see center and right panels at the bottom of the figure).

The second result is related to the behavior of unskilled workers. Since the model assumes a certain level of capital-skill complementarity (depicted by parameter α in the model), the positive exogenous shock led to higher levels of production but in a context of slightly lower unskilled wages. This can be seen indirectly in the bottom-center panel of the figure, where the skill premium (the ratio between skilled and unskilled wages) increases right after the shock. Hence, to compensate for this fall, the unskilled workers must increase their hours worked. However, this increase in the hours worked will (perhaps deliberately) not fully compensate the decrease in their income and, as a result, in consumption. This is because the large increase in the provision of public goods will allow them to preserve their levels of welfare, something that could be associated with rent-seeking behavior, according to which the poorest segments of the population become accustomed to the free provision of public goods (e.g., health, education and

a variety of bonuses) and thus opt not to increase their own private effort in order to achieve higher levels of welfare.

Last but not least, a word must be said about the possibility of finding some evidence about DD effects from the perspective of a DSGE model for Bolivia. While an increase in both welfare and income inequality seem to be quite clear in this experiment, the symptoms of DD are also present, thus confirming the results found in the previous section of this document. In effect, the bottom-right panel of the figure shows that the ratio between wages in the tradable sector and those in the non-tradable sector increases after the shock (especially in the case of the skilled workers), although such increases are not too strong. A stronger effect is observed, however, in the case of the rates of return to capital, with returns in the tradable sector growing at a faster pace than in the non-tradable sector.

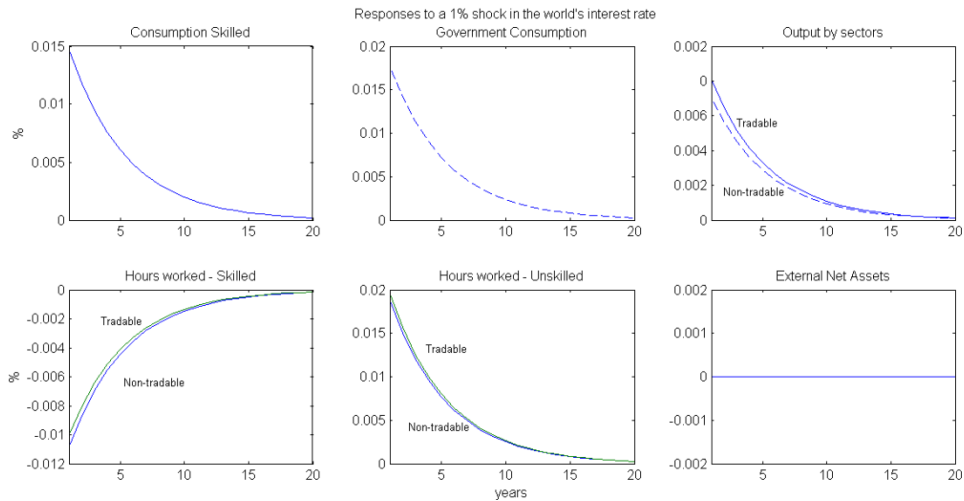
4.4.2 A World Interest Rate Shock

Figure 11 next presents the response of the economy after a 1 percent increase in the world interest rate,⁶⁶ which in turn affects the way residents interact with external financial markets. It is worth recalling that, in the calibrated steady state aiming to depict the boom period experienced over the last years, Bolivia is a net creditor in the international financial markets due mainly to the record high international reserves held by the Bolivian Central Bank, as shown in Figure 2 above.

The main impact of this exogenous shock is, as expected, related to the behavior of skilled workers since they, unlike the unskilled workers, are able to save and borrow from abroad. Hence the increase in the world's interest rate directly affects the rate of return of their external assets. This increase in their disposable income leads them to increase their consumption (upper-left panel of the figure) and reduce the number of hours worked (bottom-left panel), with a consequent increase in welfare, which is also enhanced by a small increase in the provision of public goods (upper-center panel).

Figure 11. Responses to a 1 Percent Shock in the World Interest Rate

⁶⁶ The results of this experiment are qualitatively similar for stronger shocks in the world interest rate.



Source: Authors' calculations.

More importantly, note that an increase in the returns to investment worldwide does not seem to be associated with capital outflows for Bolivia, as can be seen in the bottom-right panel of the figure. The increase in income due to the higher interest rate allows skilled residents to increase their welfare by working less and consuming more, which implies the presence of a much higher substitution effect (rather than an income effect) in response to this particular shock.

In fact, this has been the trend of financial flows to and from Bolivia in the last eight years, even after the second half of 2013 in which most of the developed world (and thus, most of the key international interest rates) has shown some signs of recovery.⁶⁷ This result is necessarily related to the type of capital inflows received by Bolivia over the last few years (i.e., Foreign Direct Investment—FDI, foreign aid and remittances from nationals abroad) which tend to show less volatility than other more speculative sources of capital such as portfolio investment and commercial loans. Hence, the pull factors that might lead to a significant capital flight in Bolivia are probably more directly related to the health of the domestic economy rather than to the improvement of the economic situation in the developed world, usually associated with higher rates of return on investment.

⁶⁷ In line with this result, the latest report of the Central Bank of Bolivia (dated February 11, 2014), the level of international reserves has remained at its record peak with no major changes. See http://www.bcb.gob.bo/webdocs/2014/ReservasInternacionales/RIN_PAGWEB11mar14.pdf.

Finally, note too that the increase in the disposable income of skilled workers generated by this shock, combined with the fact that Bolivian residents tend to consume a larger share of tradable goods and services (as depicted by the $\phi=0.57$ parameter in the model), leads to a slightly uneven growth path in the economy. In effect, the share of tradable output with respect to total output increases as relatively more tradable goods and services are demanded by the economy. Once more, this could be taken as evidence of DD effects on the Bolivian economy, in this case due to a change in a different source of income given the particular structure of the country's productive sector.

4.4.3 Capital Flights in a Deteriorated Economy

In this final experiment, we try to identify under which circumstances an increase in the world interest rate might in fact motivate capital outflows from Bolivia. As discussed in the previous experiment, the types of capital that usually enter the country seem to barely respond to changes in the world interest rate in the current economic boom. However, the response might be much more significant under an alternative scenario characterized by a permanent deterioration of key macroeconomic variables.

In this sense, a trial-and-error procedure—involving the foreign bond interest rate as a model closure variable as described above—was performed in order to recalibrate⁶⁸ the model economy at a worse general situation and, in this way, to verify whether a threshold for a key macro variable exists, below which capital flights start to occur as a result of higher interest rates in the rest of the world. We can report that such a threshold was identified for the particular case of the country's net external assets. Namely, if external assets decrease in a permanent fashion from, 43 percent of GDP to 27 percent of GDP or a fall of more than US\$4.3 billion with respect to its current level, then a 20 percent⁶⁹ temporary increase in the world interest rate will further deteriorate the external position of the economy, as shown by the impulse-response function in the bottom-right panel of Figure 11.⁷⁰

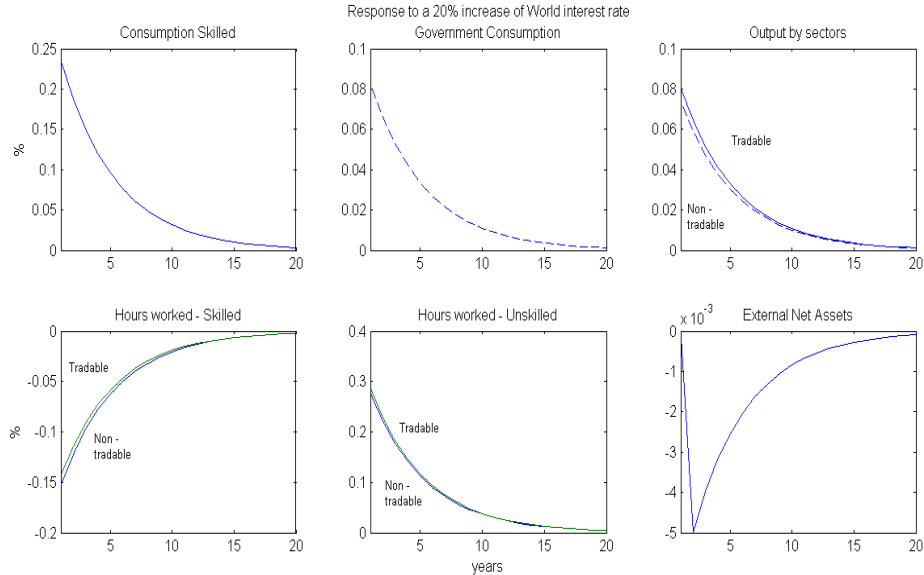
Figure 12. Responses to a 20 Percent Shock in the World's Interest Rate

⁶⁸ The re-calibration process only focused on the model closure variable (i.e. the foreign bond interest rates), while the rest of the deep parameters of the model were preserved at their baseline calibration values.

⁶⁹ A 20 percent increase in the interest rate might seem too large, but it effectively implies an increase from 1 percent to 1.2 percent in a context of very low interest rates in most financial markets of the developed world.

⁷⁰ Since the other variables presented in Figure 11 display qualitatively similar behavior to that in the previous experiment, we focus our attention on the case of net external assets.

in a Deteriorated Economy



Source: Authors' calculations.

Some important points regarding this last result deserve further attention. First, the proposed permanent deterioration of the external position of the economy can be the result of a number of factors such as: i) a permanent fall of resource exports revenues (gas and oil and/or minerals); ii) a depreciating trend of the Boliviano-US\$ exchange rate (after several years of appreciation pressures) which, in turn, might stop or even reverse the ongoing de-dollarization process of the economy; and iii) a general deterioration of the economic fundamentals (e.g., lower domestic consumption, lower investment rates or higher and unsustainable fiscal deficits, a speculative attack against the fixed exchange rate regime) or the local financial system (e.g., bank runs, increase of nonperforming credits, severe currency mismatches in their operations), motivating those less speculative investors to leave the country in search of safer investment destinations.

Second, the degree of deterioration required in order to obtain the above result is quite significant, as it implies a fall of US\$ 4.3 billion (or 37 percent with respect to current observed value) in the level of net external assets, due to one or (a combination of) some of the causes described above. While not improbable, the increasing trend shown by international reserves over the last few years (see Figure 2) implies that the possibility of seeing this variable falling

very quickly on the magnitude suggested by the model might not be very high,⁷¹ but experiencing such a drop over a relatively small number of years is much more likely, since the pace at which these reserves were accumulated over the last few years was also very high (see Figure 2).

In this sense, a level of net external assets close to 27 percent of GDP could be thought as an approximation to the optimal level of international reserves that Bolivia's central bank should hold, given the fixed exchange rate regime prevailing in the country.⁷² That is, below this threshold level, domestic demand for US dollars starts to press the fixed exchange rate and capital outflows start to occur as a result, for example, of an increase in the international interest rate.

On the other side, it is important to highlight that, despite the important degree of deterioration required by the model in order to allow for capital flights from Bolivia due to a 20 percent temporary increase in the world interest rate in the post crisis, the predicted impact of that shock on capital outflows is not too strong (see bottom-right panel in Figure 11). Once more, this suggests that the most relevant pull factors which will effectively motivate capital flights from Bolivia are more closely related to domestic macroeconomic issues rather than the effects of an improving economic environment in the developed economies.

In light of the above, and since admittedly the probability of experiencing a significant deterioration of the level of international reserves is not zero as discussed above, the key issues for public policy purposes are the following: i) preserving and monitoring the credibility and sustainability of the current exchange rate regime vis-à-vis the behavior of the level of intentional reserves held by the Bolivian monetary authority, ii) keeping external debt at low and sustainable levels, and iii) prudential management of the currently highly favorable public finances, which are made possible by commodity export revenues, in order to minimize their procyclicality and negative effects on domestic inflation.

5. Conclusions

⁷¹ A fall of 37 percent or more in the level of external assets has not been seen in this country since 1962, when this variable fell 46 percent but recovered dramatically in the following two years. Likewise, the latest decrease was registered in 2002, when it fell about 22 percent, only to recover by an almost identical percentage the following year (Source: World Bank Data).

⁷² This topic has received some attention in the recent economic debate regarding the potential use of the international reserves held by the Central Bank of Bolivia and the search for the optimal level of these, which ensure credibility on fixed exchange rate will be preserved over time (see Cerezo, 2010, and Valencia, 2010, who also suggest optimal levels similar to that proposed in our model).

This paper is motivated by questions on what can happen to the Bolivian economy in the post-international crisis period. Will the expected increase in international interest rates generate capital flight? Will negative commodity price shocks reverse the Bolivian economic boom? Is Bolivia prepared for a change in the international economic environment, which has been highly favorable since 2005?

Answers to those questions motivated a literature review in the areas of Dutch Disease (DD), Natural Resource Curse (NRC) and Resource-Rich Developing Countries (RRDC). Administrative data show real exchange rate appreciation since 2006 and important DD effects expressed in higher concentration of exports in two natural resource commodities (gas and oil, and minerals) and a significant decrease in the export share of nontraditional products (food commodities and basic industry). Consistent with DD, the data also show a significant increase in imports as well as increased growth of non-tradable sectors (particularly housing, the financial sector and commerce). At the same time, the data show overall economic growth and welfare gains in an environment of no real exchange misalignment and consistent countercyclical fiscal and monetary policy during the boom.

Diminishing commodity prices and increasing world interest rates are the two main outcomes expected from a slowdown of emerging economies and growth recovery of advanced economies in the post-financial crisis period. In the Bolivian near-term context, diminishing commodity prices will be translated into a negative price shock to the mineral sector, as is already occurring, while at the time of writing current average price levels in the gas and oil sectors are expected to remain high into the medium term. This scenario is not enough to begin reversal of the boom because the windfall is essentially caused by the gas and oil sector. However, the worst-case scenario would be a negative price shock to both sectors. The main concern for the Bolivian economy, given its high degree of openness and dependence on commodity exports, is its vulnerability to shocks and the degree of economic adjustment that must occur afterwards, usually in the form of real exchange rate depreciation and contraction of real absorption.

A combination of diminishing commodity prices and increasing world interest rates is also a concern because of an increased risk of capital flight. In a worst-case scenario, where negative shocks and economic adjustment are large and deep enough to generate a perception of significant risk from saving in domestic currency in the domestic banking system, a portion of

firm and household depositors might prefer to protect their savings and profits by shifting them to a foreign currency and even depositing them abroad, or at least out of the domestic financial system. If capital flight is large enough, that could worsen the degree of macroeconomic adjustment and even lead to an economic crisis.

A CGE model is used to analyze shocks in a natural resource country framework with two export-oriented resource sectors (gas and oil and minerals) and two emerging tradable sectors (food and industry) with domestic market orientation, among its features. The model shows that positive shocks of unusual magnitude to both resource export sectors in the pre-financial crisis have generated strong Dutch Disease effects. Most of these effects were determined by the mineral sector rather than by the gas and oil sector. The model also shows that the same positive shocks have generated unusual levels of government income, savings and investment, giving rise to an important growth opportunity. This opportunity was mostly determined by the gas and oil sector rather than by the mineral sector. The mineral sector seems to behave more in line with the NRC literature, where DD effects are larger than growth opportunity effects. The gas and oil sector seem to behave more in line with the RRDC literature, where growth opportunity effects are larger than DD effects. This last two paragraphs are a novelty way of looking at these issues derived from this study. In both cases there is an institutional challenge, in the first the need to diminish the sources of DD and in the second the need to manage the windfall.

For the post-crisis period the model shows that negative price shocks to the mineral sector do not, in the absence of price shocks to the gas and oil sector, reverse the current growth opportunity. However, negative price shocks to both sectors can take the economy into recession. This last “bad times” scenario can be confronted with a stability fund created during “good times,” that in practice can be approximated by current government savings and reserves accumulation.

In terms of policy, besides institutionalization of a stability fund, structural reform of the mineral production system and organization is needed in order to reduce DD effects and avoid consumption of the natural resource. Reform must introduce the use of larger-scale production technologies as well as new forms of firm organization that are consistent with larger-scale production. Investment in non-tradable capital and skills is also needed to diminish the economy’s built-in DD effects as well as contribute to economic diversification. However, in

order to avoid a potential source of a national economic crisis, policy is needed for the consolidation, expansion and diversification of foreign markets for the gas and oil commodity based on investments in reserve expansion, as well as policy to promote investment in other forms of energy demanded by foreign and domestic markets. Recommendations have mostly a sector policy orientation.

An open-economy DSGE model with tradable/non-tradable sectors and skilled/unskilled and savers/non-savers workers is implemented to analyze the conditions under which capital flight might occur under increasing world interest rates. The international interest rate affects the way residents interact with international financial markets, where Bolivia is a net creditor. In the DSGE model only skilled workers are allowed to save and borrow from abroad. An increase in the international interest rate affects the return of their external assets, increasing their disposable income, which in turn increases their consumption and reduces their hours worked. It does not, however, seem to generate capital flight given the current macroeconomic boom context that is implicitly modeled. The question then is how much the current economic environment needs to deteriorate, for example due to a changing international economic environment, in order to generate the domestic conditions for capital flight. The model shows that those conditions exist but require a significant degree of macroeconomic deterioration that is not currently being observed in the data; nonetheless, capital flight cannot be ruled out if that deterioration takes place over a relatively small ~~high~~ number of periods. The model further identifies some key variables to follow, such as the level of international reserves held by the Bolivian central bank, that can be influenced by policy.

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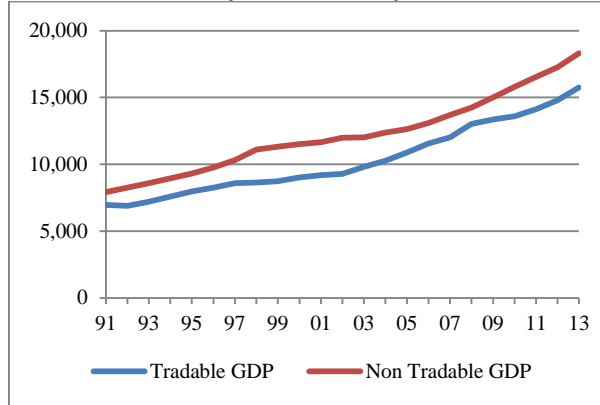
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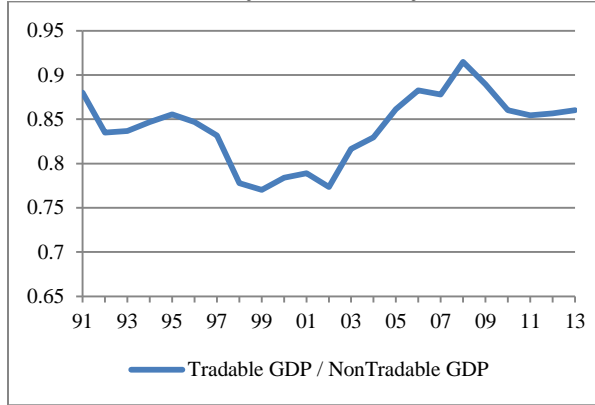
GRAPH APPENDIX

A1. Real GDP by Tradability

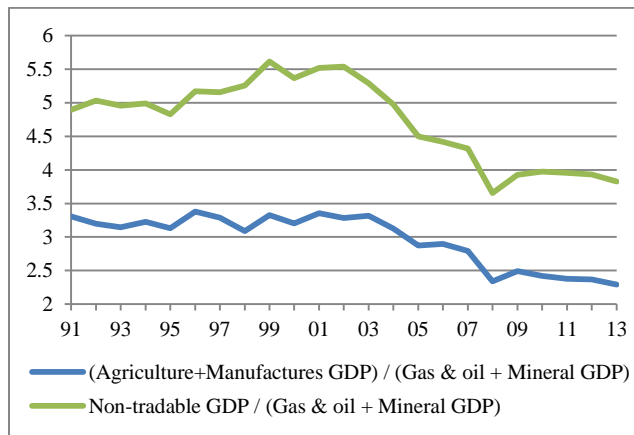


Source: MEFP and UDAPE.

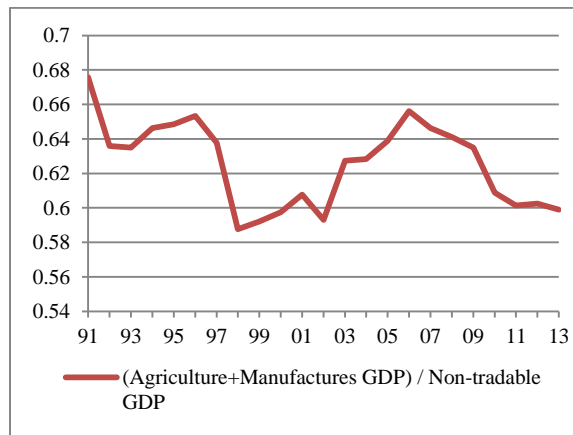
A2. GDP Ratio by Tradability (T / NT)



A3. Other Industries to Resource Exporters Ratio

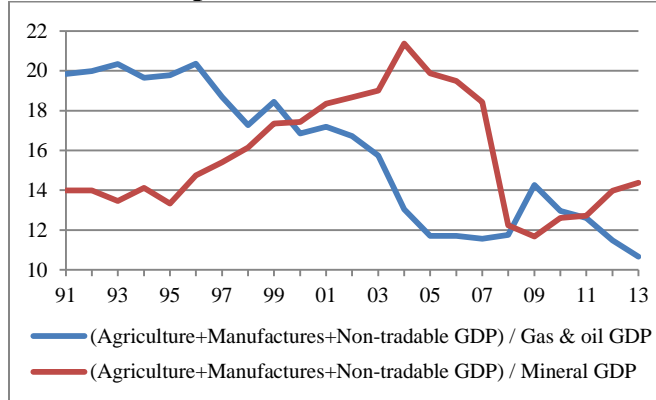


A4. Non-Traditional T to NT Ratio



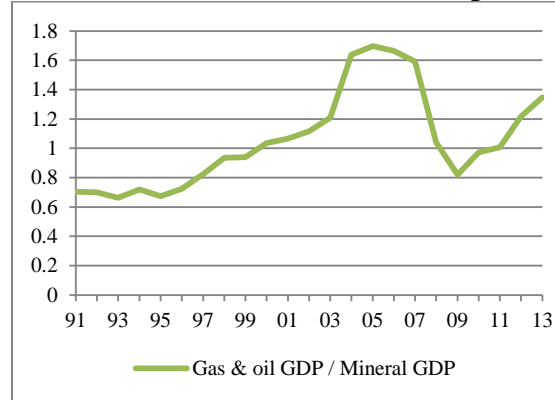
Source: MEFP and UDAPE.

A5. Other Important Sector GDP Ratios

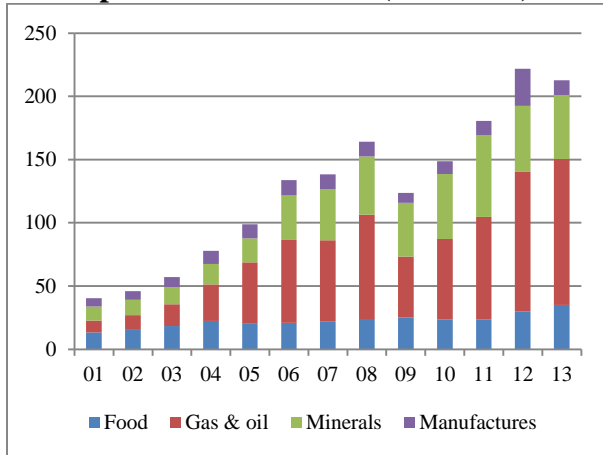


Source: MEFP and UDAPE.

A6. GDP Ratio between Resource Exporters

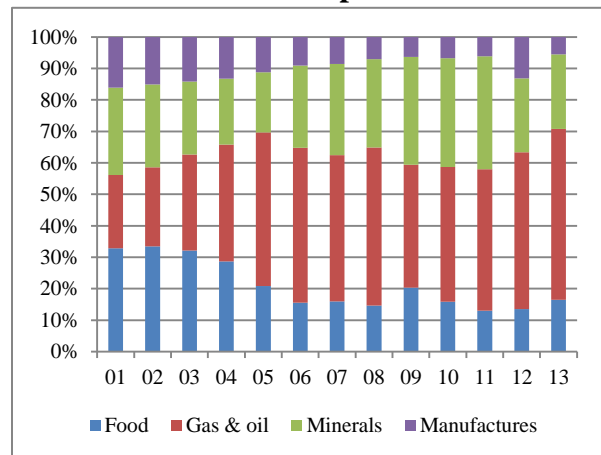


A7. Exports in Real Terms (1991=100)

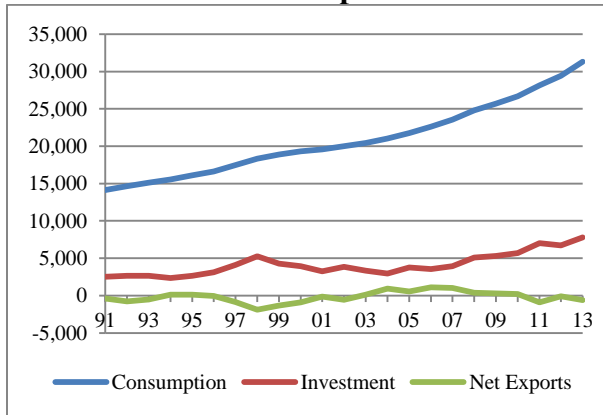


Source: MEFP and UDAPE.

A8. Structure of Exports

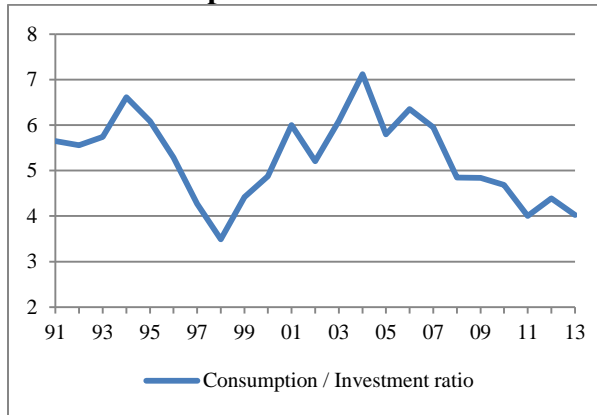


A9. Real GDP Expenditure

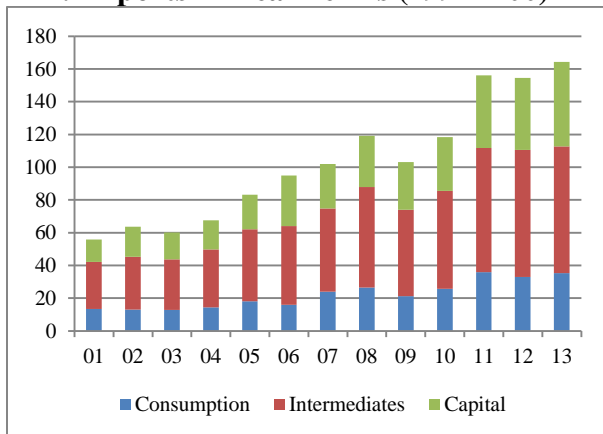


Source: MEFP and UDAPE.

A10. Consumption to Investment Ratio

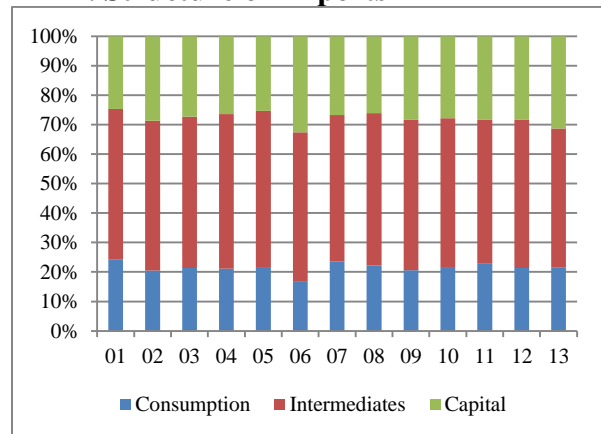


A11. Imports in Real Terms (1991=100)

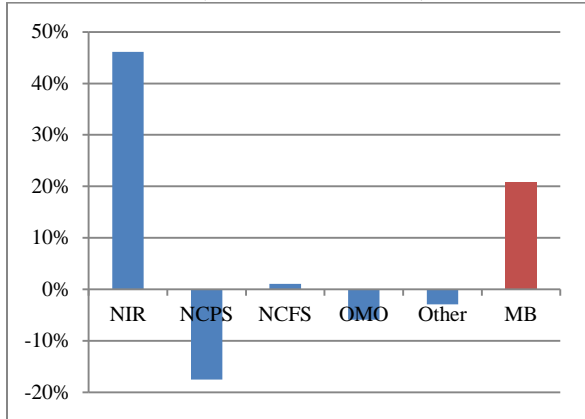


Source: MEFP and UDAPE.

A12. Structure of Imports

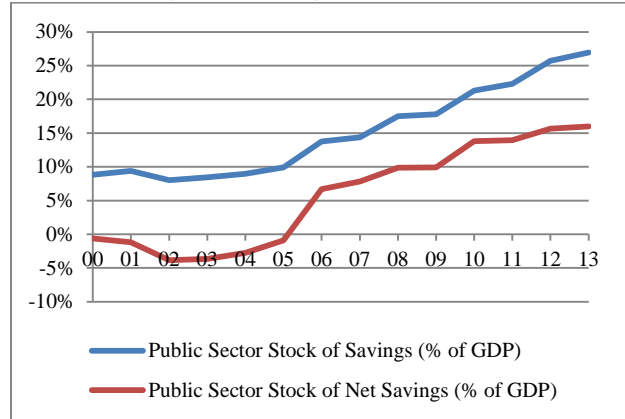


**A13. Monetary Base, Dec. 2013
(% of 2013 GDP)**

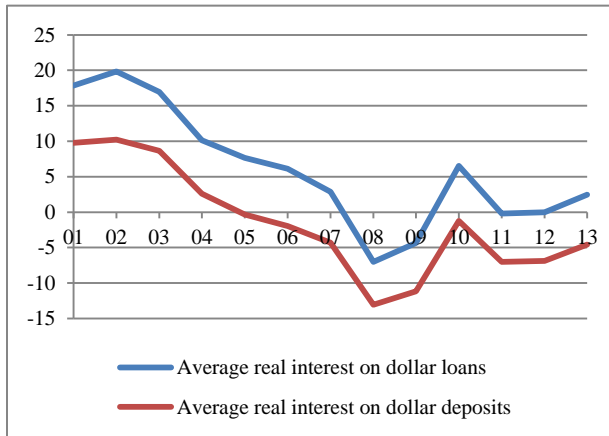


Source: Bolivian Central Bank.

**A14. Public Sector Savings
(% of GDP)**

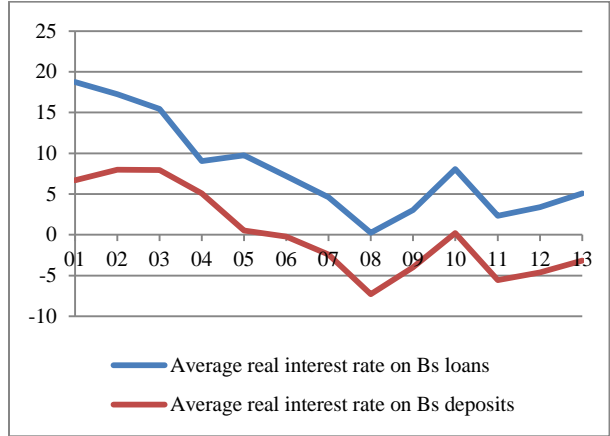


A15. Banks' Dollar Real Interest Rates

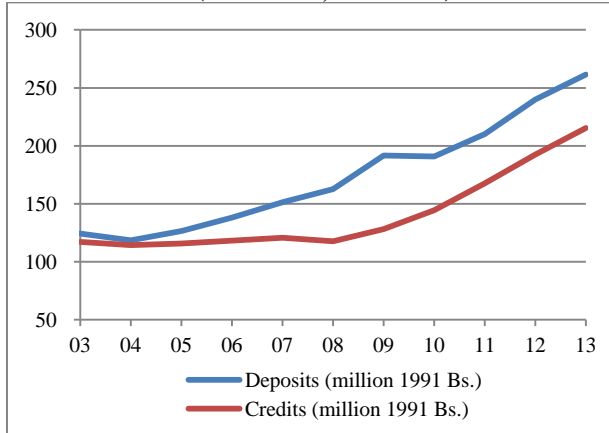


Source: Banco Central de Bolivia.

A16. Banks' Bs Real Interest Rates

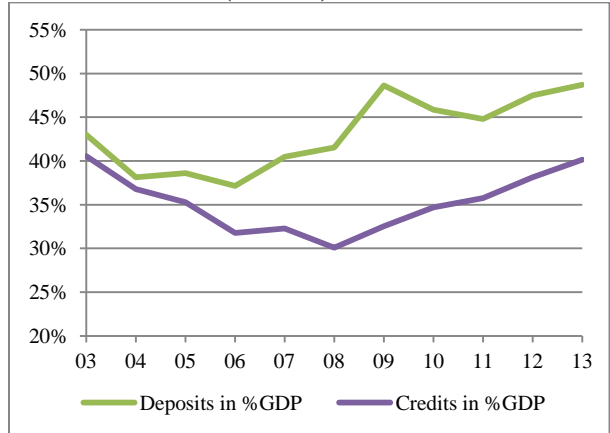


**A17. Credits and Deposits
(Million Bs, 1991=100)**

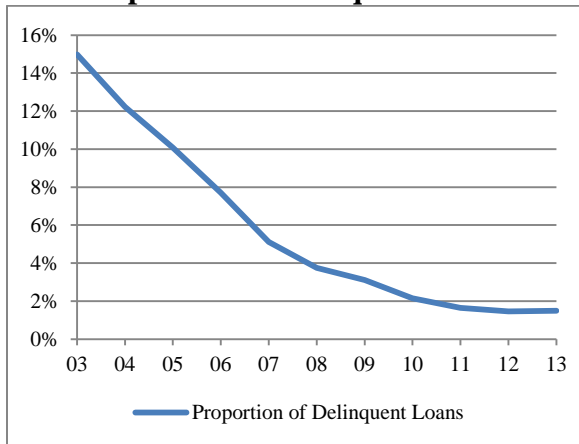


Source: ASFI.

**A18. Credits and Deposits
(% GDP)**

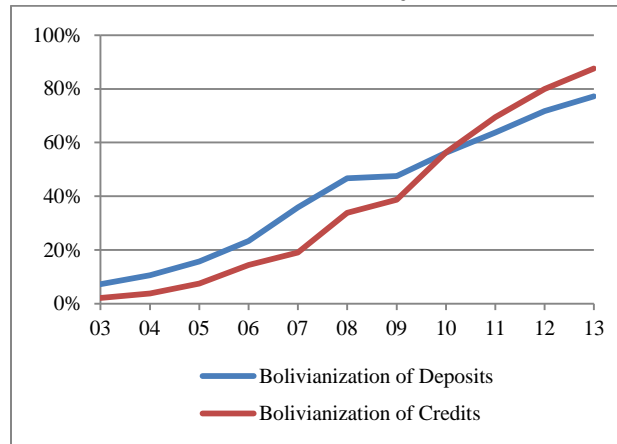


A19. Proportion of Delinquent Loans

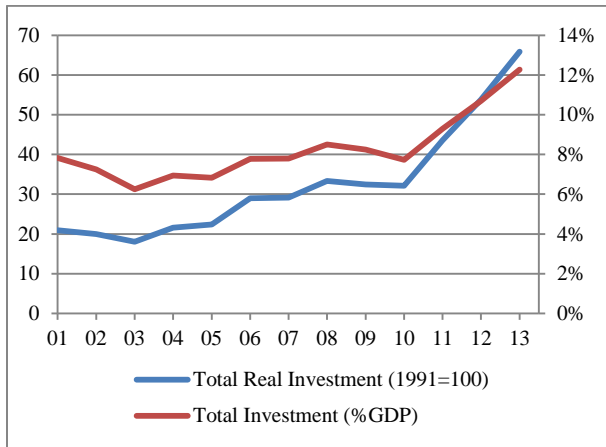


Source: ASFI.

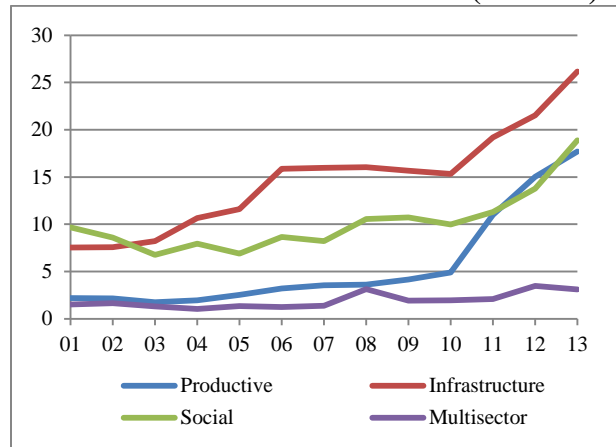
A20. Financial Bolivianization



A21. Public investment / GDP

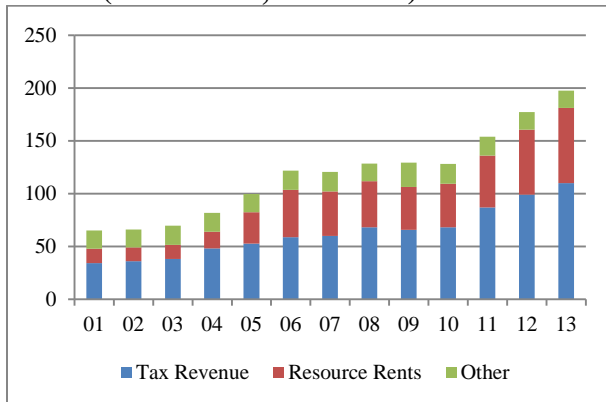


A22. Structure of Public Investment (% GDP)

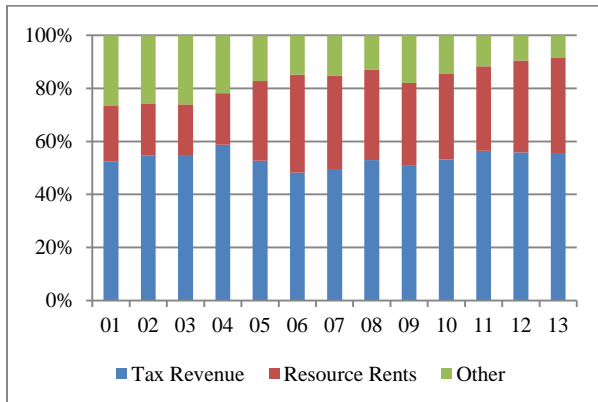


Source: Viceministerio de Inversión Pública y Financiamiento Externo.

A23. General Government (GG) Revenues (Million Bs., 1991=100)

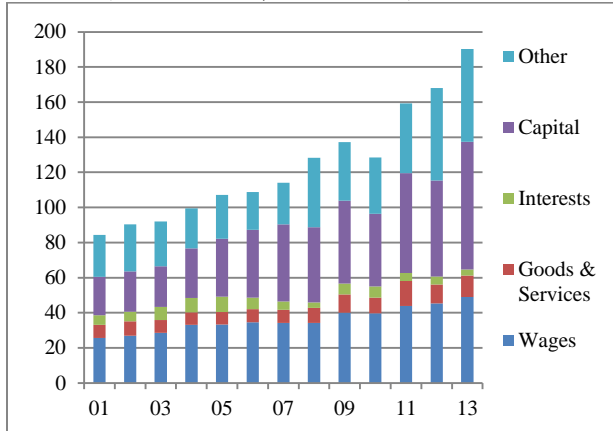


A24. Structure of GG Revenues



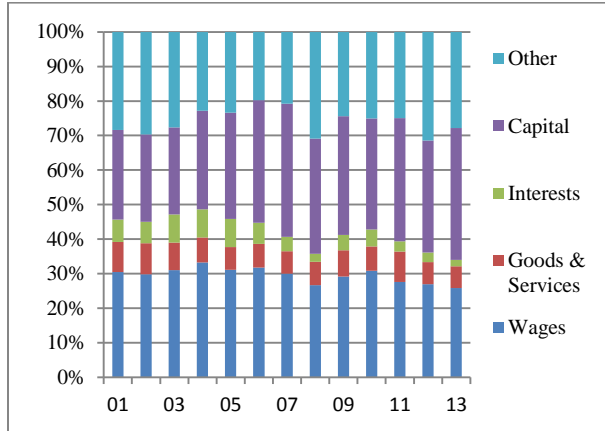
Source: MEFP and UDAPE.

**A25. GG Expenditures
(Million Bs., 1991=100)**

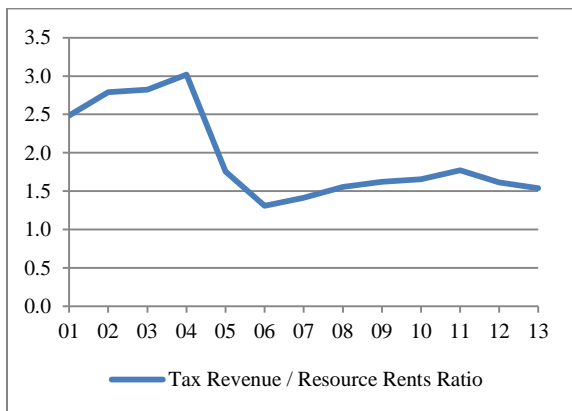


Source: MEFP and UDAPE.

A26. Structure of GG Expenditures

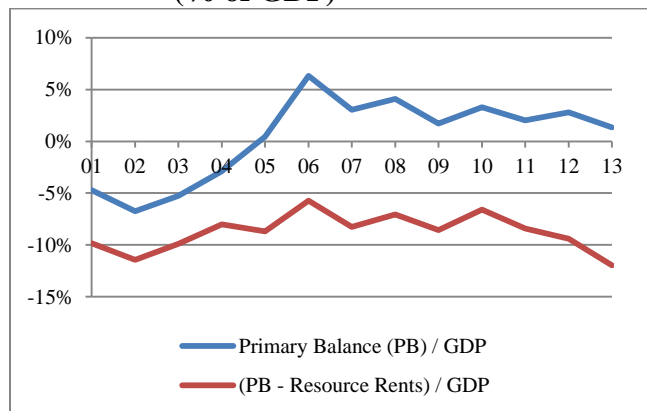


A27. Taxes / Rents Ratio

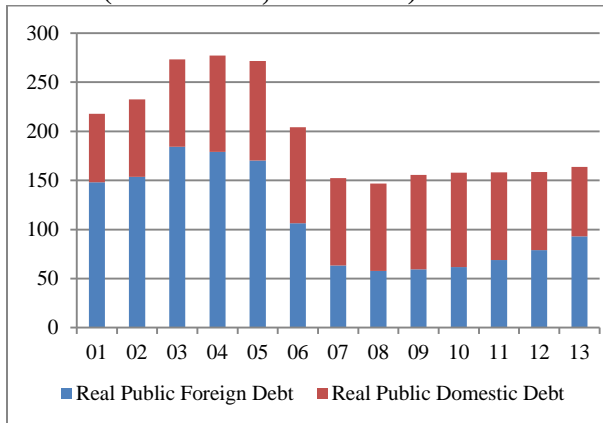


Source: MEFP and UDAPE.

**A28. Public Sector Fiscal Balance
(% of GDP)**

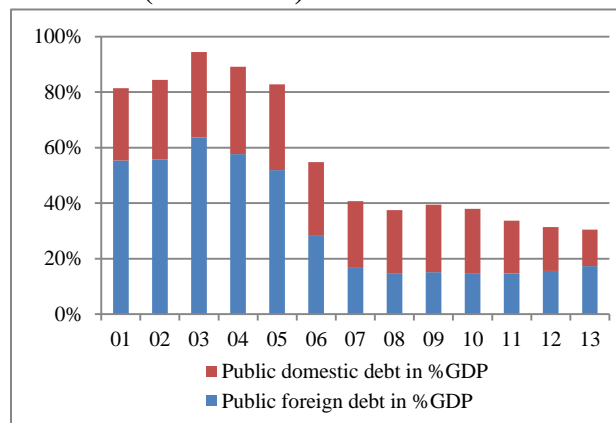


**A29. Total Public Debt
(Million Bs., 1991=100)**

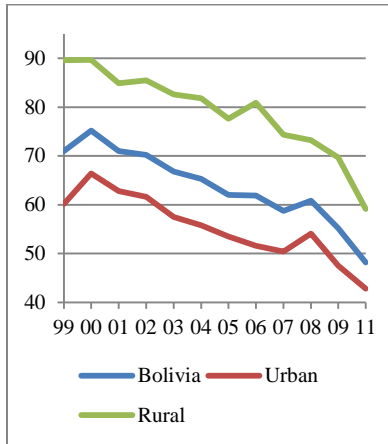


Source: MEFP and UDAPE.

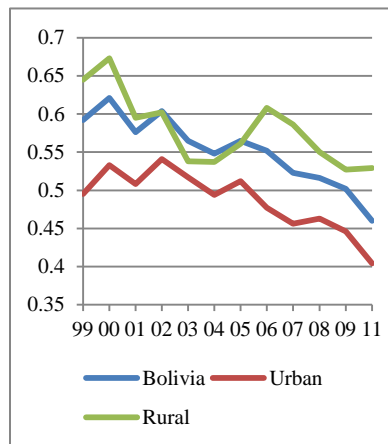
**A30. Total Public Debt
(% of GDP)**



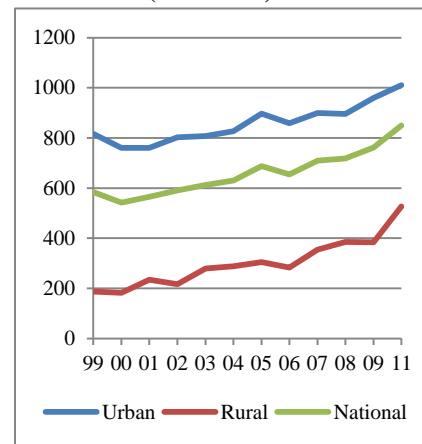
A31. Poverty Ratio



A32. Inequality Index

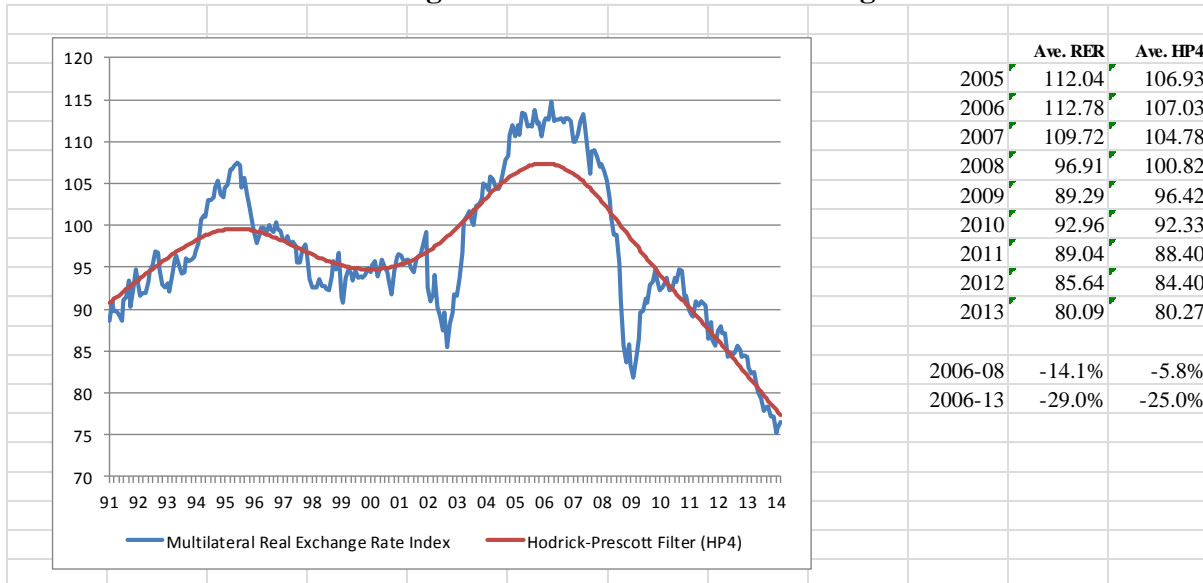


A33. Average pc Income (2009=100)



Source: Uribe and Hernani (2013) and Fundación ARU.

A34. The Real Exchange Rate Time Series and its Long-Term Behavior



Source: Banco Central de Bolivia.

APPENDIX A: THE CGE MODEL EQUATIONS

Price block

$$PM(C) = pwm(C)*(1 + tm(C))*EXR;$$

$$PE(C) = pwe(C)*(1 - te(C))*EXR;$$

$$PDD(C) = PDS(C);$$

$$PQ(C)*(1 - tq(c))*QQ(C) = PDD(C)*QD(C) + PM(C)*QM(C);$$

$$PX(C)*QX(C) = PDS(C)*QD(C) + PE(C)*QE(C);$$

$$PA(A) = SUM(C, PXAC(A,C)*theta(A,C));$$

$$PINTA(A) = SUM(C, PQ(C)*ica(C,A)) ;$$

$$PA(A)*(1-ta(A))*QA(A) = PVA(A)*QVA(A) + PFR*QFR0(A)+PINTA(A)*QINTA(A);$$

$$CPI = SUM(C, cwts(C)*PQ(C)) ;$$

$$DPI = SUM(CD, dwts(CD)*PDS(CD)) ;$$

Production and trade block

$$QINTA(A) = inta(A)*QA(A);$$

$$QVA(A) = iva(A)*QA(A) ;$$

$$QFR0(A) = ifr(A)*QA(A) ;$$

$$QVA(A) = alphava(A)*(SUM(F,deltava(F,A)*QF(F,A)**(-rhova(A))))**(-1/rhova(A)) ;$$

$$WF(F) = PVA(A)*QVA(A) * SUM(FP,deltava(FP,A)*QF(FP,A)**(-rhova(A)))**(-1) *deltava(F,A)*QF(F,A)**(-rhova(A)-1);$$

$$QINT(C,A) = ica(C,A)*QINTA(A);$$

$$QXAC(A,C) + SUM(H, QHA(A,C,H)) = theta(A,C)*QA(A) ;$$

$$QX(C) = alphaac(C)*SUM(A, deltaac(A,C)*QXAC(A,C)**(-rhoac(C)))**(-1/rhoac(C));$$

$$PXAC(A,C) = PX(C)*QX(C) * SUM(AP, deltaac(AP,C)*QXAC(AP,C)**(-rhoac(C))) **(-1) *deltaac(A,C)*QXAC(A,C)**(-rhoac(C)-1);$$

$$QX(C) = \text{alphan}(C) * (\text{deltat}(C) * QE(C) ** \text{rhot}(C) + (1 - \text{deltat}(C)) * QD(C) ** \text{rhot}(C)) ** (1/\text{rhot}(C));$$

$$QE(C) = QD(C) * ((PE(C)/PDS(C)) * ((1 - \text{deltat}(C))/\text{deltat}(C))) ** (1/(\text{rhot}(C)-1)) ;$$

$$QX(C) = QD(C) + QE(C);$$

$$QQ(C) = \text{alphaq}(C) * (\text{deltaq}(C) * QM(C) ** (-\text{rhoq}(C)) + (1 - \text{deltaq}(C)) * QD(C) ** (-\text{rhoq}(C))) ** (-1/\text{rhoq}(C));$$

$$QM(C) = QD(C) * ((PDD(C)/PM(C)) * (\text{deltaq}(C)/(1 - \text{deltaq}(C)))) ** (1/(1 + \text{rhoq}(C)));$$

$$QQ(C) = QD(C) + QM(C);$$

Institution block

$$YBS(BS,F) = \text{tibs}(F) * YF(F);$$

$$QBS(C,BS) = \text{SUM}(F, YBS(BS,F)/PQ(C));$$

$$YF(F) = \text{SUM}(A, WF(F) * QF(F,A));$$

$$YNR(NRES) = \text{SUM}(A, PFR * QFR0(A));$$

$$YIF(INSDF) = \text{shif}(INSDF) * (YF(F) - \text{trnsfr}('ROW',F) * EXR);$$

$$YINR(INSDF, NRES) = \text{shinr}(INSDF, NRES) * (YNR(NRES));$$

$$YI(INSDF) = \text{SUM}(F, YIF(INSDF, F)) + \text{SUM}(INSDF, \text{TRII}(INSDF, INSDF)) + \text{trnsfr}(INSDF, 'GOV') * CPI + \text{trnsfr}(INSDF, 'ROW') * EXR + \text{SUM}(NRES, YINR(INSDF, NRES));$$

$$\text{TRII}(INSDF, INSDF) = \text{shii}(INSDF, INSDF) * (1 - \text{MPS}(INSDF)) * (1 - \text{TINS}(INSDF)) * YI(INSDF);$$

$$EH(H) = (1 - \text{SUM}(INSDF, \text{shii}(INSDF, H))) * (1 - \text{MPS}(H)) * (1 - \text{TINS}(H)) * YI(H);$$

$$PQ(C) * QH(C,H) = PQ(C) * \text{gammam}(C,H) + \text{betam}(C,H) * (EH(H) - \text{SUM}(CP, PQ(CP) * \text{gammam}(CP,H)));$$

$$QINV(C) = \text{IADJ} * \text{qbarinv}(C);$$

$$QG(C) = \text{GADJ} * \text{qbarg}(C);$$

$$YG = \text{SUM}(\text{INSDNG}, \text{TINS}(\text{INSDNG}) * \text{YI}(\text{INSDNG})) + \text{SUM}(\text{A}, \text{ta}(\text{A}) * \text{PA}(\text{A}) * \text{QA}(\text{A})) + \text{SUM}(\text{CM}, \text{tm}(\text{CM}) * \text{pwm}(\text{CM}) * \text{QM}(\text{CM})) * \text{EXR} + \text{SUM}(\text{C}, \text{tq}(\text{C}) * \text{PQ}(\text{C}) * \text{QQ}(\text{C})) + \text{trnsfr}(\text{'GOV'}, \text{'ROW'}) * \text{EXR} + \text{SUM}(\text{NRES}, \text{YINR}(\text{'GOV'}, \text{NRES}));$$

$$\text{EG} = \text{SUM}(\text{C}, \text{PQ}(\text{C}) * \text{QG}(\text{C})) + \text{SUM}(\text{INSDNG}, \text{trnsfr}(\text{INSDNG}, \text{'GOV'})) * \text{CPI};$$

$$\text{FONDO} * \text{EXR} = \text{shnsv} * \text{ta}(\text{'APG'}) * \text{PA}(\text{'APG'}) * \text{QA}(\text{'APG'});$$

System constraint block

$$\text{SUM}(\text{A}, \text{QF}(\text{F}, \text{A})) = \text{QFS}(\text{F});$$

$$\text{SUM}((\text{F2}, \text{A}), \text{QF}(\text{F2}, \text{A})) = \text{SUM}(\text{F2}, \text{QFS}(\text{F2}));$$

$$\text{QQ}(\text{C}) = \text{SUM}(\text{A}, \text{QINT}(\text{C}, \text{A})) + \text{SUM}(\text{H}, \text{QH}(\text{C}, \text{H})) + \text{QG}(\text{C}) + \text{QINV}(\text{C}) + \text{qdst}(\text{C});$$

$$\text{SUM}(\text{C}, \text{pwm}(\text{C}) * \text{QM}(\text{C})) + \text{SUM}(\text{F}, \text{trnsfr}(\text{'ROW'}, \text{F})) = \text{SUM}(\text{C}, \text{pwe}(\text{C}) * \text{QE}(\text{C})) + \text{SUM}(\text{INSD}, \text{trnsfr}(\text{INSD}, \text{'ROW'})) + \text{FSAV} - \text{FONDO};$$

$$\text{YG} = \text{EG} + \text{GSAV} + \text{FONDO} * \text{EXR};$$

$$\text{TINS}(\text{INSDNG}) = \text{tinsbar}(\text{INSDNG}) * (1 + \text{TINSADJ} * \text{tins01}(\text{INSDNG})) + \text{DTINS} * \text{tins01}(\text{INSDNG});$$

$$\text{MPS}(\text{INSDNG}) = \text{mpsbar}(\text{INSDNG}) * (1 + \text{MPSADJ} * \text{mps01}(\text{INSDNG})) + \text{DMPS} * \text{mps01}(\text{INSDNG});$$

$$\text{SUM}(\text{INSDNG}, \text{MPS}(\text{INSDNG}) * (1 - \text{TINS}(\text{INSDNG})) * \text{YI}(\text{INSDNG})) + \text{GSAV} + \text{FSAV0} * \text{EXR} = \text{SUM}(\text{C}, \text{PQ}(\text{C}) * \text{QINV}(\text{C})) + \text{SUM}(\text{C}, \text{PQ}(\text{C}) * \text{qdst}(\text{C})) + \text{WALRAS};$$

$$\text{TABS} = \text{SUM}((\text{C}, \text{H}), \text{PQ}(\text{C}) * \text{QH}(\text{C}, \text{H})) + \text{SUM}((\text{A}, \text{C}, \text{H}), \text{PXAC}(\text{A}, \text{C}) * \text{QHA}(\text{A}, \text{C}, \text{H})) + \text{SUM}(\text{C}, \text{PQ}(\text{C}) * \text{QG}(\text{C})) + \text{SUM}(\text{C}, \text{PQ}(\text{C}) * \text{QINV}(\text{C})) + \text{SUM}(\text{C}, \text{PQ}(\text{C}) * \text{qdst}(\text{C}));$$

$$\text{INVSHR} * \text{TABS} = \text{SUM}(\text{C}, \text{PQ}(\text{C}) * \text{QINV}(\text{C})) + \text{SUM}(\text{C}, \text{PQ}(\text{C}) * \text{qdst}(\text{C}));$$

$$\text{GOVSHR} * \text{TABS} = \text{SUM}(\text{C}, \text{PQ}(\text{C}) * \text{QG}(\text{C}));$$

$$\text{WALRASSQR} = \text{WALRAS} * \text{WALRAS};$$

Sets

A = Activities

C = Commodities

F = Factors

APPENDIX B: THE DSGE MODEL EQUATIONS

The Decentralized Competitive Equilibrium of the DSGE model

$$\frac{\beta \mu_1 (\varphi - 1) (Gc^{\mu_3} (C_{S_{NTRD}})^{1-\varphi} C_{S_{TRD}}^\varphi)^{\mu_1} (1 - h_{S_{TRD}} - h_{S_{NTRD}})^{\mu_2}}{C_{S_{NTRD}}} \\ = - \frac{\beta \varphi \mu_1 (Gc^{\mu_3} (C_{S_{NTRD}})^{1-\varphi} C_{S_{TRD}}^\varphi)^{\mu_1} (1 - h_{S_{TRD}} - h_{S_{NTRD}})^{\mu_2}}{C_{S_{TRD}}}^{1-\sigma}$$

Eq. 1

$$- \frac{\beta \mu_2 B}{h_{S_{NTRD}} + h_{S_{TRD}} - 1} =$$

$$[\beta \varphi \mu_1 z_{TRD} (h_{S_{TRD}} n_s)^{v_{TRD}} (\tau_h - 1) B (\mu_{TRD} (h u_{TRD} n_u)^{\alpha_{TRD}} - \mu_{TRD} A + A)^{\frac{1}{\alpha_{TRD}}} A (\mu_{TRD} \\ + \rho_{TRD} - \mu_{TRD} \rho_{TRD} - 1)] \\ / \{ C_{S_{TRD}} h_{S_{TRD}} n_s (\tau_c + 1) ((h_{S_{TRD}} n_s)^{v_{TRD}} A + \rho_{TRD} (K_{S_{TRD}} n_s)^{v_{TRD}} A \\ - \mu_{TRD} (h_{S_{TRD}} n_s)^{v_{TRD}} A - \rho_{TRD} (h_{S_{TRD}} n_s)^{v_{TRD}} A \\ + \mu_{TRD} (h_{S_{TRD}} n_s)^{v_{TRD}} (h u_{TRD} n_u)^{\alpha_{TRD}} - \mu_{TRD} \rho_{TRD} (K_{S_{TRD}} n_s)^{v_{TRD}} A \\ + \mu_{TRD} \rho_{TRD} (K_{S_{TRD}} n_s)^{v_{TRD}} (h u_{TRD} n_u)^{\alpha_{TRD}} + \mu_{TRD} \rho_{TRD} (h_{S_{TRD}} n_s)^{v_{TRD}} A \\ - \mu_{TRD} \rho_{TRD} (h_{S_{TRD}} n_s)^{v_{TRD}} (h u_{TRD} n_u)^{\alpha_{TRD}}) \}$$

$$\text{where: } A = ((h_{S_{TRD}} n_s)^{v_{TRD}} + \rho_{TRD} (K_{S_{TRD}} n_s)^{v_{TRD}} - \rho_{TRD} (h_{S_{TRD}} n_s)^{v_{TRD}})^{\alpha_{TRD}/v_{TRD}}$$

$$B = (Gc^{\mu_3} (C_{S_{NTRD}})^{1-\varphi} C_{S_{TRD}}^\varphi)^{\mu_1} (1 - h_{S_{TRD}} - h_{S_{NTRD}})^{\mu_2}^{1-\sigma}$$

Eq. 2

$$- \frac{\beta \mu_2 B}{h_{S_{NTRD}} + h_{S_{TRD}} - 1} =$$

$$(\beta \varphi \mu_1 z_{NTRD} (h_{S_{NTRD}} n_s)^{v_{NTRD}} (\tau_h \\ - 1) B (\mu_{NTRD} (h u_{NTRD} n_u)^{\alpha_{NTRD}} - \mu_{NTRD} A + A)^{\frac{1}{\alpha_{NTRD}}} A (\mu_{NTRD} + \rho_{NTRD} \\ - \mu_{NTRD} \rho_{NTRD} - 1)) \\ / (C_{S_{TRD}} h_{S_{NTRD}} n_s (\tau_c + 1) ((h_{S_{NTRD}} n_s)^{v_{NTRD}} A + \rho_{NTRD} (K_{S_{NTRD}} n_s)^{v_{NTRD}} A \\ - \mu_{NTRD} (h_{S_{NTRD}} n_s)^{v_{NTRD}} A - \rho_{NTRD} (h_{S_{NTRD}} n_s)^{v_{NTRD}} A \\ + \mu_{NTRD} (h_{S_{NTRD}} n_s)^{v_{NTRD}} (h u_{NTRD} n_u)^{\alpha_{nt}} - \mu_{NTRD} \rho_{NTRD} (K_{S_{NTRD}} n_s)^{v_{NTRD}} A \\ + \mu_{NTRD} \rho_{NTRD} (K_{S_{NTRD}} n_s)^{v_{NTRD}} (h u_{NTRD} n_u)^{\alpha_{nt}} \\ + \mu_{NTRD} \rho_{NTRD} (h_{S_{NTRD}} n_s)^{v_{NTRD}} A \\ - \mu_{NTRD} \rho_{NTRD} (h_{S_{NTRD}} n_s)^{v_{NTRD}} (h u_{NTRD} n_u)^{\alpha_{nt}}))$$

$$\text{where: } A = ((h_{S_{NTRD}} n_s)^{v_{NTRD}} + \rho_{NTRD} (K_{S_{NTRD}} n_s)^{v_{NTRD}} - \rho_{NTRD} (h_{S_{NTRD}} n_s)^{v_{NTRD}})^{\alpha_{TRD}/v_{NTRD}}$$

$$B = (Gc^{\mu_3} (C_{S_{NTRD}})^{1-\varphi} C_{S_{TRD}}^\varphi)^{\mu_1} (1 - h_{S_{TRD}} - h_{S_{NTRD}})^{\mu_2})^{1-\sigma}$$

Eq. 3

$$\begin{aligned} & \frac{1}{C_{S_{TRD}}(\tau_c + 1)} (-\beta \mu_1 \varphi B) \\ &= \frac{1}{C_{S_{TRD}}(\tau_c + 1)} ((\beta^2 \mu_1 \varphi B (\delta + 2K_{S_{TRD}} \varphi_{Kts} \\ & - (\rho_{TRD} z_{TRD} (K_{S_{TRD}} n_s)^{v_{TRD}} (\mu_{TRD} - 1)(\tau_k \\ & - 1)(\mu_{TRD} (hu_{TRD} n_u)^{\alpha_{TRD}} - \mu_{TRD} A + A)^{\frac{1}{\alpha_{TRD}}}) / \end{aligned}$$

$$\begin{aligned} & (K_{S_{TRD}} n_s ((h_{S_{TRD}} n_s)^{v_{TRD}} A + \rho_{TRD} (K_{S_{TRD}} n_s)^{v_{TRD}} A - \mu_{TRD} (h_{S_{TRD}} n_s)^{v_{TRD}} A \\ & - \rho_{TRD} (h_{S_{TRD}} n_s)^{v_{TRD}} A + \mu_{TRD} (h_{S_{TRD}} n_s)^{v_{TRD}} (hu_{TRD} n_u)^{\alpha_{TRD}} \\ & - \mu_{TRD} \rho_{TRD} (K_{S_{TRD}} n_s)^{v_{TRD}} A + \mu_{TRD} \rho_{TRD} (K_{S_{TRD}} n_s)^{v_{TRD}} (hu_{TRD} n_u)^{\alpha_{TRD}} \\ & + \mu_{TRD} \rho_{TRD} (h_{S_{TRD}} n_s)^{v_{TRD}} A - \mu_{TRD} \rho_{TRD} (h_{S_{TRD}} n_s)^{v_{TRD}} (hu_{TRD} n_u)^{\alpha_{TRD}} \\ & - 1))) \end{aligned}$$

$$\text{where: } A = ((h_{S_{TRD}} n_s)^{v_{TRD}} + \rho_{TRD} (K_{S_{TRD}} n_s)^{v_{TRD}} - \rho_{TRD} (h_{S_{TRD}} n_s)^{v_{TRD}})^{\alpha_{TRD}/v_{TRD}}$$

$$B = (Gc^{\mu_3} (C_{S_{NTRD}})^{1-\varphi} C_{S_{TRD}}^\varphi)^{\mu_1} (1 - h_{S_{TRD}} - h_{S_{NTRD}})^{\mu_2})^{1-\sigma}$$

Eq. 4

$$\begin{aligned} & \frac{1}{C_{S_{TRD}}(\tau_c + 1)} (\beta \mu_1 \varphi B) = - \frac{1}{C_{S_{TRD}}(\tau_c + 1)} ((\beta^2 \mu_1 \varphi B (\delta + 2K_{S_{NTRD}} \varphi_{Knts} \\ & - (\rho_{NTRD} z_{NTRD} (K_{S_{NTRD}} n_s)^{v_{NTRD}} (\mu_{NTRD} - 1)(\tau_k \\ & - 1)(\mu_{NTRD} (hu_{NTRD} n_u)^{\alpha_{NTRD}} - \mu_{NTRD} A + A)^{\frac{1}{\alpha_{NTRD}}}) / \end{aligned}$$

$$\begin{aligned}
& (K_{S_{NTRD}} n_s ((h_{S_{NTRD}} n_s)^{v_{NTRD}} A + \rho_{NTRD} (K_{S_{NTRD}} n_s)^{v_{NTRD}} A - \mu_{NTRD} (h_{S_{NTRD}} n_s)^{v_{NTRD}} A \\
& \quad - \rho_{NTRD} (h_{S_{NTRD}} n_s)^{v_{NTRD}} A + \mu_{NTRD} (h_{S_{NTRD}} n_s)^{v_{NTRD}} (h_{u_{NTRD}} n_u)^{\alpha_{NTRD}} \\
& \quad - \mu_{NTRD} \rho_{NTRD} (K_{S_{NTRD}} n_s)^{v_{NTRD}} A \\
& \quad + \mu_{NTRD} \rho_{NTRD} (K_{S_{NTRD}} n_s)^{v_{NTRD}} (h_{u_{NTRD}} n_u)^{\alpha_{NTRD}} \\
& \quad + \mu_{NTRD} \rho_{NTRD} (h_{S_{NTRD}} n_s)^{v_{NTRD}} A \\
& \quad - \mu_{NTRD} \rho_{NTRD} (h_{S_{NTRD}} n_s)^{v_{NTRD}} (h_{u_{NTRD}} n_u)^{\alpha_{NTRD}})) - 1)))
\end{aligned}$$

$$\begin{aligned}
\text{where: } A = & ((h_{S_{NTRD}} n_s)^{v_{NTRD}} + \rho_{NTRD} (K_{S_{NTRD}} n_s)^{v_{NTRD}} \\
& - \rho_{NTRD} (h_{S_{NTRD}} n_s)^{v_{NTRD}})^{\alpha_{TRD}/v_{NTRD}}
\end{aligned}$$

$$B = (Gc^{\mu_3} (C_{S_{NTRD}})^{1-\varphi} C_{STRD}^\varphi)^{\mu_1} (1 - h_{STRD} - h_{S_{NTRD}})^{\mu_2})^{1-\sigma}$$

Eq. 5

$$\begin{aligned}
-\frac{\beta \mu_1 \varphi A}{C_{STRD}(\tau_c + 1)} &= \frac{\beta^2 \mu_1 \varphi (2 B s x \varphi_{bxs} + r b x (\tau_k - 1) - 1) A}{C_{STRD}(\tau_c + 1)} \\
\text{where: } A &= (Gc^{\mu_3} (C_{S_{NTRD}})^{1-\varphi} h_{STRD}^\varphi)^{\mu_1} (1 - h_{STRD} - h_{S_{NTRD}})^{\mu_2})^{1-\sigma}
\end{aligned}$$

Eq. 6

$$\begin{aligned}
& \beta \left\{ K_{S_{NTRD}} - G t r + K_{STRD} + (\tau_c + 1)(C_{S_{NTRD}} + C_{STRD}) \right. \\
& \quad - (\tau_k - 1) \left[\frac{\rho_{NTRD} z_{NTRD} (K_{S_{NTRD}} n_s)^{v_{NTRD}} (\mu_{NTRD} - 1) D F}{B} - B s x r b x \right. \\
& \quad \left. + \frac{\rho_{TRD} z_{TRD} (K_{STRD} n_s)^{v_{TRD}} (\mu_{TRD} - 1) C E}{A} \right] + K_{S_{NTRD}}(\delta - 1) + K_{STRD}(\delta - 1) \\
& \quad + B s x^2 \varphi_{bxs} + K_{S_{NTRD}}^2 \varphi_{knts} + K_{STRD}^2 \varphi_{kts} \\
& \quad - \left[\frac{z_{NTRD} (h_{S_{NTRD}} n_s)^{v_{NTRD}} D F (\mu_{NTRD} + \rho_{NTRD} - \mu_{NTRD} \rho_{NTRD} - 1)}{B} \right. \\
& \quad \left. + \frac{z_{TRD} (h_{STRD} n_s)^{v_{TRD}} C E (\mu_{TRD} + \rho_{TRD} - \mu_{TRD} \rho_{TRD} - 1)}{A} \right] (\tau_h - 1) \left. \right\}
\end{aligned}$$

where:

$$\begin{aligned}
A = n_s [& (h_{STRD} n_s)^{v_{TRD}} E + \rho_{TRD} (K_{STRD} n_s)^{v_{TRD}} E - \mu_{TRD} (h_{STRD} n_s)^{v_{TRD}} E \\
& - \rho_{TRD} (h_{STRD} n_s)^{v_{TRD}} E + \mu_{TRD} (h_{STRD} n_s)^{v_{TRD}} (hu_{TRD} n_u)^{\alpha_{TRD}} \\
& - \mu_{TRD} \rho_{TRD} (K_{STRD} n_s)^{v_{TRD}} E + \mu_{TRD} \rho_{TRD} (K_{STRD} n_s)^{v_{TRD}} (hu_{TRD} n_u)^{\alpha_{TRD}} \\
& + \mu_{TRD} \rho_{TRD} (h_{STRD} n_s)^{v_{TRD}} E - \mu_{TRD} \rho_{TRD} (h_{STRD} n_s)^{v_{TRD}} (hu_{TRD} n_u)^{\alpha_{TRD}}]
\end{aligned}$$

$$\begin{aligned}
B = n_s [& (h_{NTRD} n_s)^{v_{NTRD}} F + \rho_{NTRD} (K_{NTRD} n_s)^{v_{NTRD}} F - \mu_{NTRD} (h_{NTRD} n_s)^{v_{NTRD}} F \\
& - \rho_{NTRD} (h_{NTRD} n_s)^{v_{NTRD}} F + \mu_{NTRD} (h_{NTRD} n_s)^{v_{NTRD}} (hu_{NTRD} n_u)^{\alpha_{NTRD}} \\
& - \mu_{NTRD} \rho_{NTRD} (K_{NTRD} n_s)^{v_{NTRD}} F \\
& + \mu_{NTRD} \rho_{NTRD} (K_{NTRD} n_s)^{v_{NTRD}} (hu_{NTRD} n_u)^{\alpha_{NTRD}} \\
& + \mu_{NTRD} \rho_{NTRD} (h_{NTRD} n_s)^{v_{NTRD}} F \\
& - \mu_{NTRD} \rho_{NTRD} (h_{NTRD} n_s)^{v_{NTRD}} (hu_{NTRD} n_u)^{\alpha_{NTRD}}]
\end{aligned}$$

$$C = [\mu_{TRD} (hu_{TRD} n_u)^{\alpha_{TRD}} - \mu_{TRD} E + E]^{\frac{1}{\alpha_{TRD}}}$$

$$D = [\mu_{NTRD} (hu_{NTRD} n_u)^{\alpha_{NTRD}} - \mu_{NTRD} F + F]^{\frac{1}{\alpha_{NTRD}}}$$

$$E = [(h_{STRD} n_s)^{v_{TRD}} + \rho_{TRD} (K_{STRD} n_s)^{v_{TRD}} - \rho_{TRD} (h_{STRD} n_s)^{v_{TRD}}]^{\alpha_{TRD}/v_{TRD}}$$

$$F = [(h_{NTRD} n_s)^{v_{NTRD}} + \rho_{NTRD} (K_{NTRD} n_s)^{v_{NTRD}} - \rho_{NTRD} (h_{NTRD} n_s)^{v_{NTRD}}]^{\alpha_{NTRD}/v_{NTRD}}$$

Eq. 7

$$\begin{aligned}
& \frac{\beta \mu_1 (\varphi - 1) (Gc^{\mu_3} (Cu_{NTRD}^{1-\varphi} Cu_{TRD}^\varphi)^{\mu_1} (1 - hu_{TRD} - hu_{NTRD})^{\mu_2})^{1-\sigma}}{Cu_{NTRD}} \\
& = - \frac{\beta \varphi \mu_1 (Gc^{\mu_3} (Cu_{NTRD}^{1-\varphi} Cu_{TRD}^\varphi)^{\mu_1} (1 - hu_{TRD} - hu_{NTRD})^{\mu_2})^{1-\sigma}}{Cu_{TRD}}
\end{aligned}$$

Eq. 8

$$\frac{\beta \mu_2 A}{hu_{NTRD} + hu_{TRD} - 1} = \frac{\beta \varphi \mu_1 \mu_{TRD} z_{TRD} (hu_{TRD} n_u)^{\alpha_{TRD}} (\tau_u - 1) A B^{\frac{1}{\alpha_{TRD}}}}{Cu_{TRD} hu_{TRD} n_u (\tau_c + 1) B}$$

where:

$$A = (Gc^{\mu_3} (Cu_{NTRD}^{1-\varphi} Cu_{TRD}^\varphi)^{\mu_{TRD}} (1 - hu_{TRD} - hu_{NTRD})^{\mu_2})^{1-\sigma}$$

$$B = \mu_{TRD} (hu_{TRD} n_u)^{\alpha_{TRD}} - \mu_t C + C$$

$$C = ((hS_{TRD} n_s)^{v_{TRD}} + \rho_{TRD}(KS_{TRD} n_s)^{v_{TRD}} - \rho_{TRD}(hS_{TRD} n_s)^{v_{TRD}})^{\alpha_{TRD}/v_{TRD}}$$

Eq. 9

$$\frac{\beta \mu_2 A}{hu_{NTRD} + hu_{TRD} - 1} = \frac{\beta \varphi \mu_1 \mu_{NTRD} z_{NTRD} (hu_{NTRD} n_u)^{\alpha_{NTRD}} (\tau_u - 1) AB^{\frac{1}{\alpha_{NTRD}}}}{Cu_{TRD} hu_{NTRD} n_u (\tau_c + 1) B}$$

where:

$$A = (Gc^{\mu_3} (Cu_{NTRD}^{1-\varphi} Cu_{TRD}^{\varphi})^{\mu_1} (1 - hu_{TRD} - hu_{NTRD})^{\mu_2})^{1-\sigma}$$

$$B = \mu_{NTRD} (hu_{NTRD} n_u)^{\alpha_{NTRD}} - \mu_{NTRD} C + C$$

$$C = ((hS_{NTRD} n_s)^{v_{NTRD}} + \rho_{NTRD}(KS_{NTRD} n_s)^{v_{NTRD}} - \rho_{NTRD}(hS_{NTRD} n_s)^{v_{NTRD}})^{\alpha_{NTRD}/v_{NTRD}}$$

Eq. 10

$$\begin{aligned} Rng = & Gc + Gtr - n_s \tau_c (CS_{NTRD} + CS_{TRD}) - n_u \tau_c (Cu_{NTRD} + Cu_{TRD}) \\ & + n_s \tau_k \left[\frac{\rho_{NTRD} (KS_{NTRD} n_s)^{v_{NTRD}} (\mu_{NTRD} - 1) D^{\frac{1}{\alpha_{NTRD}}} F}{n_s B} \right. \\ & \left. + \frac{\rho_{NTRD} z_{TRD} (KS_{NTRD} n_s)^{v_{NTRD}} (\mu_t - 1) C^{\frac{1}{\alpha_{NTRD}}} E}{n_s A} \right] - Bsx n_s r b x \tau_k \\ & - \frac{\mu_{NTRD} \tau_u z_{NTRD} (hu_{NTRD} n_u)^{\alpha_{NTRD}} D^{\frac{1}{\alpha_{NTRD}}}}{D} \\ & - \frac{\mu_{NTRD} \tau_u z_{TRD} (hu_{TRD} n_u)^{\alpha_{TRD}} C^{\frac{1}{\alpha_{TRD}}}}{C} \\ & + \frac{\tau_h z_{NTRD} (hS_{NTRD} n_s)^{v_{TRD}} D^{\frac{1}{\alpha_{NTRD}}} F (\mu_{NTRD} + \rho_{NTRD} - \mu_{NTRD} \rho_{NTRD} - 1)}{B} \\ & + \frac{\tau_h z_{TRD} (hS_{TRD} n_s)^{v_{TRD}} C^{\frac{1}{\alpha_{TRD}}} F (\mu_{TRD} + \rho_{TRD} - \mu_{TRD} \rho_{TRD} - 1)}{A} \end{aligned}$$

where:

$$\begin{aligned} A = & (hS_{TRD} n_s)^{v_{TRD}} E + \rho_{TRD} (KS_{TRD} n_s)^{v_{TRD}} E - \mu_{TRD} (hS_{TRD} n_s)^{v_{TRD}} E \\ & - \rho_{TRD} (hS_{TRD} n_s)^{v_{TRD}} E + \mu_{TRD} (hS_{TRD} n_s)^{v_{TRD}} (hu_{TRD} n_u)^{\alpha_{TRD}} \\ & - \mu_{TRD} \rho_{TRD} (KS_{TRD} n_s)^{v_{TRD}} E + \mu_{TRD} \rho_{TRD} (KS_{TRD} n_s)^{v_{TRD}} (hu_{TRD} n_u)^{\alpha_{TRD}} \\ & + \mu_{TRD} \rho_{TRD} (hS_{TRD} n_s)^{v_{TRD}} E - \mu_{TRD} \rho_{TRD} (hS_{TRD} n_s)^{v_{TRD}} (hu_{TRD} n_u)^{\alpha_{TRD}} \end{aligned}$$

$$\begin{aligned}
B = & (h_{S_{NTRD}} n_s)^{v_{NTRD}} F + \rho_{NTRD} (K_{S_{NTRD}} n_s)^{v_{NTRD}} F - \mu_{NTRD} (h_{S_{NTRD}} n_s)^{v_{NTRD}} F \\
& - \rho_{NTRD} (h_{S_{NTRD}} n_s)^{v_{NTRD}} F + \mu_{NTRD} (h_{S_{NTRD}} n_s)^{v_{NTRD}} (h_{u_{NTRD}} n_u)^{\alpha_{NTRD}} \\
& - \mu_{NTRD} \rho_{NTRD} (K_{S_{NTRD}} n_s)^{v_{NTRD}} F \\
& + \mu_{NTRD} \rho_{NTRD} (K_{S_{NTRD}} n_s)^{v_{NTRD}} (h_{u_{NTRD}} n_u)^{\alpha_{NTRD}} \\
& + \mu_{NTRD} \rho_{NTRD} (h_{S_{NTRD}} n_s)^{v_{NTRD}} F \\
& - \mu_{NTRD} \rho_{NTRD} (h_{S_{NTRD}} n_s)^{v_{NTRD}} (h_{u_{NTRD}} n_u)^{\alpha_{NTRD}}
\end{aligned}$$

$$\begin{aligned}
C &= \mu_{TRD} (h_{u_{TRD}} n_u)^{\alpha_{TRD}} - \mu_{TRD} E + E \\
D &= \mu_{NTRD} (h_{u_{NTRD}} n_u)^{\alpha_{NTRD}} - \mu_{NTRD} F + F
\end{aligned}$$

$$\begin{aligned}
E &= [(h_{S_{TRD}} n_s)^{v_{TRD}} + \rho_{TRD} (K_{S_{TRD}} n_s)^{v_{TRD}} - \rho_{TRD} (h_{S_{TRD}} n_s)^{v_{TRD}}]^{\alpha_{TRD}/v_{TRD}} \\
F &= [(h_{S_{NTRD}} n_s)^{v_{NTRD}} + \rho_{NTRD} (K_{S_{NTRD}} n_s)^{v_{NTRD}} - \rho_{NTRD} (h_{S_{NTRD}} n_s)^{v_{NTRD}}]^{\alpha_{NTRD}/v_{NTRD}}
\end{aligned}$$

Eq. 11

$$\begin{aligned}
& z_{NTRD} \left(\mu_{NTRD} (h_{u_{NTRD}} n_u)^{\alpha_{NTRD}} \right. \\
& \quad - (\rho_{NTRD} (K_{S_{NTRD}} n_s)^{v_{NTRD}} \\
& \quad \left. - (h_{S_{NTRD}} n_s)^{v_{NTRD}} (\rho_{NTRD} - 1))^{\alpha_{NTRD}/v_{NTRD}} (\mu_{NTRD} - 1) \right)^{\frac{1}{\alpha_{NTRD}}} \\
& z_{TRD} \left(\mu_{TRD} (h_{u_{TRD}} n_u)^{\alpha_{TRD}} \right. \\
& \quad - (\rho_{TRD} (K_{S_{TRD}} n_s)^{v_{TRD}} - (h_{S_{TRD}} n_s)^{v_{TRD}} (\rho_{TRD} - 1))^{\alpha_{TRD}/v_{TRD}} (\mu_{t} \\
& \quad \left. - 1) \right)^{\frac{1}{\alpha_{NTRD}}} \\
& = Gc + K_{S_{NTRD}} n_s + K_{S_{TRD}} n_s + n_s (C_{S_{NTRD}} + C_{S_{TRD}}) \\
& \quad + n_u (C_{u_{NTRD}} + C_{u_{TRD}}) + K_{S_{NTRD}} n_s (\delta - 1) + K_{S_{TRD}} n_s (\delta - 1) \\
& \quad + Bsx^2 n_s \varphi_{bxs} + K_{S_{NTRD}}^2 n_s \varphi_{knts} + K_{S_{TRD}}^2 n_s \varphi_{kts}
\end{aligned}$$

Eq. 12

$$rbx = rworld$$

Eq. 13

$$Z_{TRD p} = Z_{TRD}^{\rho_{TRD}} Z_{TRD 0}^{1-\rho_{TRD}}$$

Eq. 14

$$Z_{NTRD p} = Z_{NTRD}^{\rho_{NTRD}} Z_{NTRD 0}^{1-\rho_{NTRD}}$$

Eq. 15

$$Rng_p = Rng^{\rho_{Rng}} Rng_0^{1-\rho_{Rng}}$$

Eq. 16