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Reducing Volatility Due to Natural Gas Exports: Is the Answer a Stabilization Fund?

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Summary:

An important part of Bolivia's fiscal revenues are directly tied to world oil prices. Since oil prices are very volatile, so are Bolivia's fiscal revenues. For example, if oil prices vary as much during the next couple of decades as they did during the previous two decades, then the fiscal revenues arising from our exports of natural gas to Brazil would vary between US$ 141 million per year and US$ 1.1 billion per year, and the revenues in any particular year would be largely unpredictable.

Such volatility of fiscal revenues is undesirable, especially for a country that tries to implement a poverty reduction strategy requiring a steady and predictable flow of funds.

This paper calculates the likely range values for the revenues that Bolivia will derive from natural gas exports, as well as the likely variation from year to year. Based on these calculations we design a Stabilization Fund, which accumulates money when world oil prices are high and distributes money when oil prices are low.

The effect of oil price volatility on the Bolivian economy is evaluated in a CGE model and the advantages and disadvantages of a Stabilization Fund are analyzed.

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1. Introduction

The Bolivian economy is very vulnerable to swings in world commodity prices. Bolivia had some great decades in the 1960s and 1970s due to high tin prices, but when tin-prices plummeted in the early eighties it brought the country's economy so far down that it has only just recently reached the per capita GDP level of 1950.

Bolivia's exports have diversified somewhat since the crisis in the mid-eighties, but due to recent natural gas discoveries and a large natural gas export contract with Brazil, Bolivia's export revenues and fiscal revenues will be very dependent on the future development of world oil prices. During the previous two decades, world oil prices have fluctuated between a low of US$11 per barrel to a high of US$60 per barrel (expressed in real prices using 2000 US dollars). With such a large variation in oil prices, this paper will show that our annual fiscal revenues from natural gas exports could be anywhere between US$141 million and US$1.1 billion.

To put these amounts in perspective, Bolivia is expecting to be granted debt relief through the HIPC Initiative in the order of about US$100 million per year over the next 18 years. The debt relief money – for which Bolivia is currently expending great effort to create a poverty reduction strategy – is thus quite small compared to the money we may receive in the form of royalties and taxes from the companies that extract natural gas for export.

It is quite startling that the government has spent a lot of effort planning for the use of the relatively small amounts of debt relief while there are not any plans for the use of the potentially much larger amounts of revenues from natural gas depletion. The main reason that Bolivia has developed a strategy for the use of the more or less fictional debt relief funds is, of course, that the World Bank put the development of a Poverty Reduction Strategy Paper as a definite requirement for obtaining debt relief. Perhaps one of the reasons why Bolivia does not have a strategy for converting our natural gas wealth into human and physical capital is that the revenues are so volatile and unpredictable that it is dangerous to rely on them. This volatility can be reduced, however, with a properly designed stabilization mechanism. With more predictable revenues it would then be possible to increase the effective use of these resources.

The purpose of this paper is to propose a mechanism for stabilizing the revenues derived from the exportation of natural gas. The paper proceeds as follows. Section two discusses the costs of volatility and the advantages and disadvantages of a Stabilization Fund. Section three describes the natural gas export contract with Brazil. It shows how the price of natural gas is linked to the development of world oil prices, and it shows that most of the sector is operated by foreign companies. Section four calculates the amount of royalties and taxes they will have to pay at alternative oil prices. Section five proposes a stabilization mechanism for reducing the effects of this volatility. Section six and seven use a CGE model of the Bolivian economy to show the impact of natural gas exports on the Bolivian economy, with and without a stabilization mechanism, and discusses different designs of a Stabilization Fund. Section eight concludes.

2. The costs of volatility

The Inter-American Development Bank has estimated that the high volatility in Latin America has caused the region to experience annual growth rates that were on average 1.06 percent lower than if volatility levels had been similar to the industrialized economies during the 1970-1992 period. For Bolivia and Venezuela the estimated costs of volatility were particularly high, with average annual losses of 3.67 percent and 3.22 percent, respectively (IDB 1995). The tendency for high volatility to cause lower growth rates is supported by the cross-country study by Ramey & Ramey (1995) which use a panel of 92 countries and shows a very robust negative relationship between government spending volatility and average growth rates in the period 1960-1985.

The poor are particularly vulnerable to macroeconomic volatility. The IDB study indicates that, if Latin America's macroeconomic instability had been more like that of the industrial economies, an estimated 7 percent of the region's population, or 25 percent of the poor, would have been lifted out of poverty (IDB 1995).

The costs of volatility works through many different channels, and although there is little theoretical literature to draw on, it is possible to imagine some of the mechanisms that might be at work.

First, volatility is bad for productivity since firms have to choose under uncertainty which sectors to invest in and which technologies to use. With relative price volatility firms may choose one technology, only to find later that economic circumstances are substantially different than had been expected, leaving firms with a production structure that is sub-optimal.

Second, volatility is bad for investment since the higher risk means that investors will limit themselves only to investments with correspondingly high expected returns. Dixit & Pindyck (1993) discuss how investment is affected by uncertainty and shows that the irreversibility of many investments may generate a strong reluctance to invest when uncertainty is substantial. This argument is supported by cross-country empirical evidence from IDB (1995), which shows that Latin America's macroeconomic volatility may have reduced the region's investment by nearly 5 percent of GDP, compared with what it would have been had the region experienced the same volatility as that of the industrial economies.

Third, volatility undermines educational progress and human capital formation. If an adverse economic shock puts a member of the household out of work, children may need to be withdrawn from school, either because the expenses associated with education can no longer be borne, or because the child's financial contribution to family income is suddenly required. Once the adverse shock disappears, it may be difficult for the child to return to school, so that even transitory shocks may have permanent effects on school enrollment. In addition, macroeconomic volatility, by raising the rate of job turnover and weakening long-term links between firms and their employees, tends to reduce the value of acquiring firm-specific skills, thus discouraging such training (IDB 1995).

Fourth, volatility is bad for the distribution of income. One important mechanism for this is the impact of volatility on educational attainment, since the groups whose children's education are most threatened by volatility are those with lower incomes.

Fifth, volatility increases poverty and hurts the poor more than the rich. Not only does volatility have an adverse impact on the education of the poor, but the poor are also less equipped to deal with volatility. Wealthier families can use their assets as collateral for loans, or use savings to finance consumption in bad times. The poor often store their limited wealth in informal assets (land and houses without title) that are not accepted as collateral for loans. In addition, governments often respond to adverse shocks with sub-optimal investment and erratic expenditure patterns that undermine the effective provision of public services for the poor. For example, when health and education budgets are temporarily reduced, payroll levels are generally maintained, while critical expenditures on complementary inputs are reduced. Thus, when teachers and doctors have to work without books and medical supplies, the fall in output may easily exceed the reduction in expenditure (IDB 1995).

All these adverse effects of volatility suggest that it would be desirable to implement a stabilization mechanism. Such a mechanism would promote national savings in good times and spend some of this savings in bad times in order to smooth expenditures over time.

In Bolivia, by far the main contributor to volatility of government revenues, and thus volatility of economic policy, comes from the volatility of world oil prices, which directly determines the price of our natural gas. Even though mining products have accounted for about 10 percent of export in the period 1985-1999, while hydrocarbons have accounted for only about 4 percent, hydrocarbons have brought in between 27 and 70 percent of all tax revenues, and mining less than half a percent of all tax revenues (Nina & Brooks, 2001). The Bolivian tax system is thus heavily reliant on hydrocarbon revenues, which makes these the obvious targets for stabilization.

If the Bolivian government receives an unexpected windfall income of several hundred million dollars, we are likely to see a frantic scramble involving all the government players (different ministries, different regional governments, individual government officials, etc) to appropriate as large a share of that windfall as possible. They will do that partly to protect themselves from the demands from other sectors, since their higher investments now would justify a higher share of current expenditure in the future. Such a scramble is unlikely to lead to optimal investment, so it would be better if the unexpected windfall went into a Fund, that could be used in times where revenues fall below the desired level.

As we show below, the quantities of natural gas to be exported during the coming decades are to a large degree fixed by long term contracts. This means that quantities cannot respond to price changes and in that way smooth revenues.

Beyond the direct impact that fossil fuel price volatility has on government revenues, this volatility can affect the entire economy through relative price changes, particularly changes in the real exchange rate. We will assess whether a Stabilization Fund can significantly reduce this means of volatility as well.

3. The Natural Gas export contract with Brazil

On the 16th of August 1996 the president of YPFB and the president of Petrobras (the Brazilian state oil company) signed a comprehensive contract on natural gas exports to Brazil. In this contract Bolivia promises to deliver a total of 7.1 trillion cubic feet of natural gas to Brazil over a 20-year period, starting August 1999.

This contract has had very important consequences for the hydrocarbon sector in Bolivia. A guaranteed market for our natural gas, together with the privatization/capitalization of the sector, encouraged enormous investments in exploration and pipeline construction. The investments in exploration caused the amount of certified (proven and probable) natural gas reserves to multiply several times from a level around 6 trillion cubic feet (TCF) before 1997 to 46.83 TCF by January 1st, 2001. Since natural gas and petroleum are found together in the ground, petroleum reserves also increased dramatically from 200.9 million barrels in 1997 to 892.0 million barrels by January 1st, 2001 (La Prensa, La Paz, 25 March 2001).

3.1 The price of Natural Gas exports to Brazil

Since natural gas and oil are close substitutes, it was decided that the price of the gas at the entry of the pipeline should be linked to a basket of three internationally priced fuel oils and adjusted each trimester according to the following formula:

$$PG_t = 0.5*PG_0[0.5*(FO1_{t-1}/FO1_0) + 0.25*(FO2_{t-1}/FO2_0) + 0.25*(FO3_{t-1}/FO3_0)] + 0.5PG_{t-1},$$

where

PG_t = Price of gas at time t, in US dollars per million BTU (US$/MMBTU)
PG_0 = Initial price of gas set at 0.95 US$/MMBTU.

$FO1_{t-1}$, $FO2_{t-1}$, and $FO3_{t-1}$ are averages of the daily prices in the previous trimester of three internationally quoted fuel oils:

FO1: Fuel Oil with a sulphur content of 3.5%, referred to as “Cargoes FOB Med Basis Italy” in US$ per metric ton.
FO2: Fuel Old No. 6 with a sulphur content of 1.0%, referred to as “U.S. Gulf Coast Waterborne” in US$ per barrel.
FO3: Fuel Oil with a sulphur content of 1.0%, referred to as “Cargoes FOB NWE” in US$ per metric ton.

$FO1_0$, $FO2_0$, and $FO3_0$ are averages of the daily prices of the above mentioned fuel oils during the period between January 1st 1990 and June 30th 1992, excluding the period between August 1st 1990 and January 31st 1991.

If prices remain at the initial level, total sales according to this contract will amount to around US$ 7 billion. In addition, Bolivia will receive approximately US$ 1.6 billion for transporting the gas to the Brazilian border.

The contract is a "Take it or Pay it" contract which means that Brazil is obliged to pay at least 65% of the contractual daily amount, even if they choose not to receive that much gas.

In addition to this large contract, there is a contract to deliver 0.3 trillion cubic feet of natural gas to a thermo power plant in Cuiaba, Brazil over the next 20 years. And another contract to deliver 0.15 trillion cubic feet to a thermo power plant in Puerto Suárez on the border to Brazil, starting in 2001.

3.2 The companies involved in Natural Gas exports

Eight companies are taking part in the exportation of Natural Gas to Brazil. Table 1 shows how they have divided the contract between themselves. Petrobras, who is the buyer, is also by far the largest seller, responsible for almost 70% of the export volume.

Table 1: Companies involved in Natural Gas exportation to Brazil

Company	**Nationality**	**Export amount (trillion cubic feet)**	**Certified reserves (1 Jan 2001)**
Petrobras	Brazilian state	4.93	16.3
Maxus	Argentina	0.26	13.6
Andina	Argentina/Bolivia	0.79	2.8
Chaco	UK/Bolivia	0.48	2.1
Pérez Companc	Argentina	0.26	0.8
Vintage	USA	0.11	1.1
Dong Wong	Korea	0.01	0.2
Tesoro	UK	0.26	0.7
Total		**7.10**	**37.6**

Source:Viceministerio de Energía y Hidrocarburos.

Table 1 shows that most of the hydrocarbon sector in Bolivia is foreign owned, which means that Bolivia has effectively exported most of the volatility in that sector. However, these foreign companies pay royalties and taxes, that together amount to between 40 and 50 percent of gross revenues (YPFB 2001), which means that a substantial amount of volatility remains with the Bolivian government, and it is this part we will consider for stabilization.

Most of the risk has been exported to Brazil, who has used it to hedge their risk as a buyer of natural gas. By being both buyer and seller they have eliminated most of their exposure to the volatility of oil prices.

4. Estimated royalties and tax revenues from the companies involved in natural gas exports to Brazil

As mentioned above, taxes and royalties from the hydrocarbon sector is a very important source of revenue for the Bolivian government. This section will describe the tax regime and estimate the aggregate level of revenues under different scenarios for world oil prices and production levels.

4.1 Tax regime for the hydrocarbon sector

All natural gas and oil extracted from Bolivian ground is currently subject to royalty payments of 18 percent of the gross value. 11 percent goes to the department (state) where it is extracted, 6 percent goes directly to the central government, and 1 percent goes to a Compensation Fund for Beni (2/3) and Pando (1/3). The royalty rate was reduced from 50 percent to 18 percent in 1996. The hydrocarbon fields that were already being exploited by the cut-off date of 30/04/96 have to keep paying the higher royalty rate. By now only about 3 percent (1.6 TCF out of 46.83 TCF) of all certified natural gas reserves are old, and approximately the same ration would hold for liquids, so it is a reasonably approximation to assume a royalty rate of 18 percent for all oil and gas extracted in the next 20 years.

In addition to royalties, companies operating in the hydrocarbon sector have to pay taxes. First there is a 25 percent tax on profits, then there is a 25 percent surtax that are paid on particularly profitable fields after some deductions, and finally there is a 12.5 percent tax on remittances.

The Surtax is the most complicated of these taxes. It was defined in Law No. 1731 of 25 November 1996, which is an amendment to the tax Reform Law No. 843 and the Hydrocarbon Law No. 1689. It is an attempt to recover some of the revenues lost by reducing the royalty rate from 50 percent to 18 percent, and it has the effect that total revenues from 1 cubic feet or barrel of “old” hydrocarbons are approximately equal to total revenues from “new” hydrocarbons. According to Law No. 1731, each operation has to pay 25 percent in Surtax each year on net profits minus deductions of up to 33 percent of investments and 45 percent of net income (up to a maximum of the dollar equivalent of Bs. 250 million in 1997).

It is important to understand that natural gas and liquid oil is found together in pockets deep in the ground. Any well will usually produce both natural gas and oil simultaneously, but in varying proportions. In Bolivia, the natural gas content is relatively high, which means that most wells are exploited primarily for the gas. However, the liquids that are extracted as a side product add substantial value, and this should be taken into account when calculating royalties and taxes.

4.2 Government revenues from the hydrocarbon sector

YPFB (2001) provides detailed estimates for the revenues derived from the hydrocarbon sector in the period 2000 to 2022 under different scenarios for production levels and world oil price levels.

They operate with 4 different scenarios for investment and production and two different scenarios for prices. The most optimistic of the four scenarios assumes investment of US$720 million, annual operating expenses of US$34.5 million for a daily production of 30 million cubic meters of natural gas and an additional annual production of 6,629,000 barrels of liquids. This production level corresponds to the natural gas export volumes agreed with Brazil. We will use this scenario, since the smaller scenarios (down to 3.75 million cubic meters of natural gas per day) seem completely unrealistic.

The initial investment is depreciated in the following manner:

50% is invested in wells and recollection lines, which can be depreciated over 5 years
25% is invested in production facilities, which can be depreciated over 8 years
25% is invested in pipelines, which can be depreciated over 10 years.

It is assumed that all of the production goes to export, so no value added tax (IVA) is considered. Payments for transport of natural gas in export pipeline is set at US$0.23/MMBTU, while payments for liquids to Arica is assumed to be US$2.60/barril.

For the calculation of Surtax, it is assumed the Bs. 250 million limit is translated into US$46.55 million.

YPFB (2001) reports two sets of results, one set assuming that all exports are based on “old” hydrocarbons, and one set assuming all exports are based on “new” hydrocarbons. The aggregate revenues are very similar in the two cases, but since 97% of reserves are “new”, we will report the results for “new” hydrocarbons only. We do not at all have sufficient “old” hydrocarbons to fulfill the contract with Brazil, so half the scenarios in YPFB (2001) are hypothetical, assuming that the royalty and tax regime was not changed in 1996.

That leaves us with two out of their 16 scenarios, which seem realistic to us. The results of these two scenarios are reproduced in Tables A1 and A2 in the Appendix.

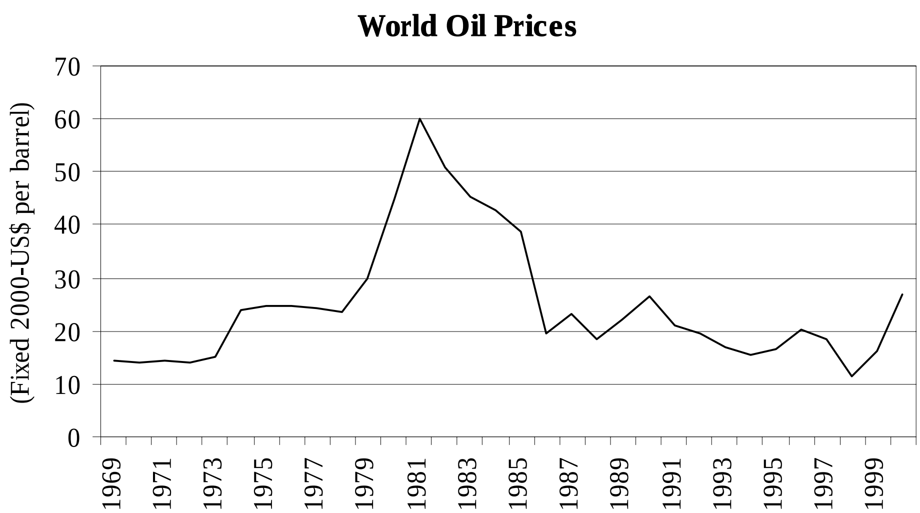
For an oil price of US$ 24/barrel and a corresponding natural gas price of US$ 1.5/MMBTU, YPFB predicts, for the representative year of 2010, royalties of US$116.9 million plus profit taxes of 114.33 million plus Surtax of 102.69 million plus remittance taxes of 35.10 million. Total revenues expected that year would then be US$369.0 million, which corresponds to 48.7% of gross revenues. For 19 years of exports at this level, YPFB predicts total revenues of US$6,784.64 million or 47.09 percent of gross revenues.

For an oil price of US$ 18/barrel and a corresponding natural gas price of US$ 1.2/MMBTU, YPFB predicts, for the representative year of 2010, royalties of US$88.1 million plus profit taxes of 81.61 million plus Surtax of 69.97 million plus remittance taxes of 26.92 million. Total revenues expected that year would then be US$266.6 million, which corresponds to 44.5% of gross revenues. For 19 years of exports at this level, YPFB predicts total revenues of US$4,839.98 million or 42.55 percent of gross revenues.

In both cases, the revenues are substantially higher than the amount of debt relief that Bolivia will receive through the HIPC Initiative that year (about US$95 million, which is average for the period. See Andersen & Nina (2000)).

The two oil prices chosen for the YPFB scenarios are actually quite conservative and do not capture the span of realistic possibilities for the oil prices in the next two decades. If history is any guide to oil prices in the future, the price could increase to as much as US$60/barrel or fall as low as US$11/barrel. During the last three decades we have experienced oil prices (converted to year 2000 US$) anywhere between those two extremes. See Figure 1.

Figure 1: Historic development of world oil prices 1969 – 2000 (converted to year 2000 US$)



Sources: WTRG Economics (www.wtrg.com) for world oil prices and International Financial Statistics by the IMF for the price deflator.

The assumptions of both US$18 and $24 are clearly in the conservative end of the plausible range of oil prices for the next two decades. This means that revenues could be several times higher than even the most optimistic of all YPFB's 16 scenarios.

We have made calculations similar to those in YPFB, but with production and investment details down to company level, which show that revenues could be anywhere between US$141 million per year and US$1.1 billion per year depending on the developments of oil prices.

Since non-hydrocarbon tax revenues in Bolivia are typically in the order of US$ 700 million (average over 1996-1999), the revenues from the hydrocarbon sector can add substantial volatility to total government revenues.

4.3 The regional distribution of hydrocarbon revenues

By law only 1/3 of the hydrocarbon royalties go to the central government. The rest goes directly to the state governments of the states that hold the hydrocarbons within their territory[2]. All taxes paid by the companies operating in the sector go to the central government.

According to the calculations in Andersen & Meza (2001, Table 5), the central government is going to receive approximately 35 percent of all hydrocarbon revenues. The state government of Tarija is going to receive 48 percent of all revenues, which represents a very substantial sum compared to the small population and the small state budget of the state. Santa Cruz is expected to receive approximately 9 percent of all revenues. Since the population of Santa Cruz is much larger than the population of Tarija, and since Santa Cruz's economic activities are substantially more diversified than Tarija's, the impact of natural gas is going to be much smaller in Santa Cruz.

Beni is going to receive about 3.6 percent of total revenues through the Compensation Fund. Because of the small population in Beni, that is going to represent a significant amount of additional income per capita. All other states are going to receive less than 2 percent of total hydrocarbon revenues.

The regional distribution of hydrocarbon revenues will have important implications for volatility and the implementation of stabilization mechanisms. In the next two sections, however, we will assume that the government is one entity only and use a Computable General Equilibrium model to analyze the effects of volatility in hydrocarbon revenues on the Bolivian economy. In the concluding section we will return to the problem of regional differences.

5. A Hydrocarbon Stabilization Fund

Stabilization Funds are designed to reduce volatility by accumulating funds in good years. These funds can subsequently be used in bad years. Some Funds, such as Heritage Funds, aim to increase overall national savings, in the economic sense of the word. The intent with these types of Funds is to transfer wealth from non-renewable resources to future generations by reducing current consumption in favor of future consumption. While certainly worthy of consideration for Bolivia, these Funds have only been implemented in developed countries where current consumption levels are higher. It is important to point out that the question of optimal savings is an economic issue quite different from the question of whether to allocate a fiscal surplus to financial assets or to invest these funds immediately (Davis *et al* 2001). In this paper, we consider the latter issue: the implementation of a Fund that targets financial objectives rather than the question of optimal savings. In considering the financial issues, we attempt to smooth the inter-temporal allocation of national savings to reduce volatility. This strategy has the additional

[2] Except for about 5.6 percent that goes into a compensation fund for Beni and Pando.

benefit of helping to ward off short-term financial crises, which are seen by some to be the most serious cost of volatility (Caballero 2000).

The proposed mechanism for this Stabilization Fund is to set aside a portion of government revenues coming from fossil fuel revenues, thereby reducing the size of the government budget in good years and increasing available funds in bad years, smoothing the fluctuations in the public sector budget. Moreover, if these funds are held abroad, the Stabilization Fund might also act to reduce swings in the real exchange rate that can translate into price volatility across the entire economy.

It is well recognized that government funds are fungible, and that such a Stabilization Fund can be easily rendered ineffective if the government carries out an otherwise pro-cyclical fiscal policy, borrowing to increase expenditures during good years. Stabilization Funds will only be effective if it is accompanied by either borrowing constraints or by a program of fiscal discipline that eschews the temptation of pro-cyclical spending. In fact, conservative fiscal policy by itself has the potential to achieve the same stabilization objectives. The very success and attractiveness of a Stabilization Fund is in its ability to foster fiscal discipline that would not otherwise occur. The political economy arguments for Stabilization Funds are as follows: 1) The existence of the Fund could reduce pressure on the government to raise expenditures in the event of rising revenues; 2) the implementation of the Stabilization Fund could be an opportunity to enact complementary fiscal rules that reduces the scope for borrowing and spending by the government; 3) it might be politically difficult to issue public debt in order to make planned payments to the Stabilization Fund. Normally the government would borrow when oil prices are high and in that way cause pro-cyclical spending. With a Stabilization Fund, people would ask why the government is borrowing only to turn around and put a portion of this money in a Fund (Davis *et al* 2001).

We have argued above that by far the largest part of volatility in government revenues in Bolivia in the coming decades is likely to come from volatility in hydrocarbon revenues. This is therefore the target for our proposed Stabilization Fund. In order for the government to make rational investments and have sufficient funds for corresponding current expenditures it is desirable that the government revenues available are reasonably stable.

Since we are not considering the creation of a Heritage Fund for our hydrocarbon revenues, we would like to choose the operating rules for the Stabilization Fund such that the amount of resources tied up in the Fund is kept to a minimum. In theory, the Stabilization Fund could be operated by borrowing when prices are low and paying back the loan when prices are high. However, this is unrealistic in practical terms for two reasons. First, international financing is generally not available in adequate amounts in bad times. International financial markets will usually allow the country to borrow in good times (as they did in the 1960s in Bolivia), but when the country is hit by an adverse shock it may well lose its creditworthiness and face a decline in its borrowing capacity just when it needs it most. Second, the temptation of high revenues often leads to increased borrowing during good times rather than the opposite as suggested above. Because of these factors, the Stabilization Fund must initially accumulate funds in order to be brought into operation. This reduction in current expenditures entails a cost of instituting the Stabilization Fund in the form of reduced consumption and lost investment and thus lower capital stocks and decreased production. The benefit of Stabilization Fund thus has to be judged against this cost.

We set the rules for managing the Stabilization Fund so that they are based upon the government revenues derived from the taxes and royalties from the fossil fuel sector. We start by setting a benchmark revenue target, around which a band of +/- 10 percent is set. All fossil fuel-based government revenues above the upper limit are deposited into the Stabilization Fund. If fossil fuel revenues fall below the target, withdrawals from the Fund are transferred to the current government budget. We place two additional restrictions on the Fund. First, no more than two thirds of the value of the Fund can be withdrawn in any given year. Second, the value of the Fund cannot exceed 20 percent of GDP. To initiate the Stabilization Fund, we set the initial revenue target at 1.2 billion Bolivianos (corresponding to approximately US$ 185 million). After the third year, the revenue benchmark is set at the average of the government fossil fuel revenue from the three previous years.

The Fund will be held abroad earning a safe international rate of interest (assumed to be 6 percent in the model below). In some circumstances, this might be a disadvantage of such a Fund. If the money could be invested optimally in Bolivia, they were likely to earn a much higher rate of return. However, if the counterfactual includes the frequently poor record of public investment and poorly conceived investments, it might be advantageous to wait on making these investments.

6. Simulating the effects of a Stabilization Fund

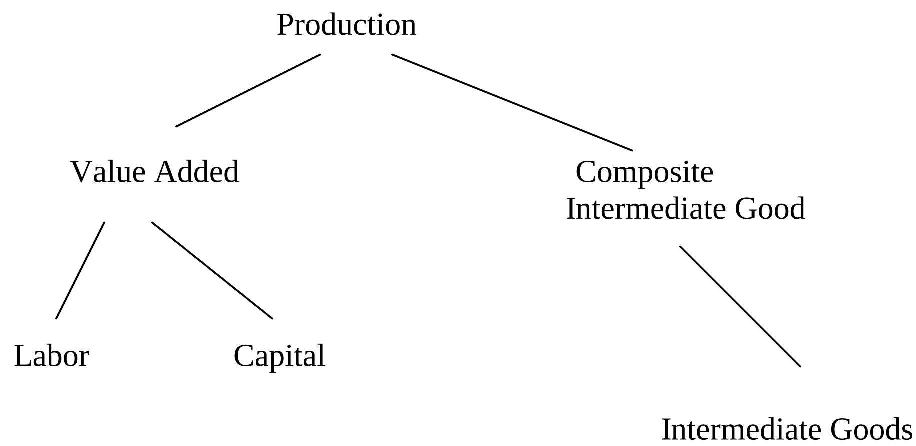
In this section we will first describe the Computable General Equilibrium (CGE) model that we use, and then we will use the model to analyze the costs and benefits of a Stabilization Fund.

6.1. Specifying the key equations of the CGE model

The model used for this study is a standard 12-sector recursively dynamic model. There is one capital category and five types of labor: skilled, unskilled agricultural, unskilled non-agricultural, smallholder, and urban informal. Amongst the labor classes, labor is mobile only between the two unskilled classes and between the smallholders and the informal sector. There are six household categories defined by the source of their income.

This model is constructed using a social accounting matrix (SAM) for Bolivia in 1997, developed by Thiele & Piazolo (2002). The authors of the present paper modified this SAM to estimate the sources and parameters for different fossil fuel taxes and royalties.

For the production sectors, output, prices and factor demands are all determined endogenously within the model. Production is portrayed with a multiple-stage nested function. Labor and capital are combined in a Cobb-Douglas relationship to produce value added. Value added and composite intermediate goods are pooled in a constant elasticity of substitution (CES) function. Intermediate inputs are used in fixed proportions in the creation of the aggregate intermediate factor. This formulation is constructed to reflect the flexibility in production choices for medium to long-term processes.



For the fossil fuel sector, production is fixed at the levels consistent with the contracts negotiated for natural gas exports and planned investments in the sector.

As one of the principal foci of this analysis is the study of the accumulation of capital in the face of price volatility, the treatment of capital is somewhat distinct from what is generally found in these models. Using a putty-clay depiction of capital, factors become more rigid in the production process once capital has been installed. Following Jacoby & Wing (1999), we assume that a given portion of capital is converted to a fixed coefficient production function after each investment period, in this case one year. This builds into this model a production context where managers cannot freely substitute intermediates, labor and capital in response to changes in wage rates and the cost of capital. This introduces creates a context whereby prior investments made upon expected future relative prices can lock producers into sub-optimal production technologies.

The model is solved recursively over a fifteen-year time horizon. The model is run for each time period, after which the stocks of accumulated factors are updated before the model is run again for the next period. The key aspect of defining the dynamic relationship in a macroeconomic model is the treatment of savings and investment behavior. In this model, aggregate investment is determined by national savings. First, savings is fixed as a fixed percentage of income for households and corporations according to their observed marginal propensity to save. Government savings is determined endogenously as the remainder after predetermined expenditures are subtracted from current revenues. In the absence of a solid empirical basis for estimating foreign savings levels, these are set exogenously at historic levels. Once the level of aggregate savings is determined, the allocation of investment is determined by relative profitability based upon current prices. This is an alternative formulation to fully dynamic models where consumers and producers make savings and investment decisions based upon perfect price information for all future periods, recognizing that decision-makers are imperfect predictors of the future.

Factor demands are determined by profit maximizing behavior. Two types of rigidities are built into the model to better mirror reality. Firstly, investment decisions are made according to prices that prevail at the time of the decision. This acts as a proxy for expected prices. This investment is committed to the sector, even though prices will have changed when the investment is brought into production in the next time period. This means that investment decisions, and hence capital allocation decisions, are made with imperfect information regarding future prices, allowing for the sub-optimal allocation of capital. The second rigidity arises from the putty-clay formulation of capital mentioned earlier. The combination of capital, labor and intermediates is made at the time of the investment decision. In future periods, a portion of the production process takes place with this less-than-perfect mixture of factors and inputs. The magnitude of both of these impacts varies with the size of relative price changes across different time periods.

The relationship between imports and domestically produced commodities, as well as the relationship between exports and domestically consumed commodities, are treated in the standard way for CGE models, using an Armington function for imports and a constant elasticity of transformation (CET) function for exports. This formulation entails the imperfect substitution between these different commodities, which allows for two-way trade as in observed trade relations. The sectoral definitions of the SAM distinguish between industrial sectors that produce goods that are used primarily for consumption, intermediate production and capital investments. This permits the elasticity of substitution between imports and domestically produced goods for these different sectors to vary, and hence for scenarios to look at different taxation schemes and world price trends by import type.

Labor markets operate in the manner used by De Santis (2000). Using the empirical observations of Blanchflower & Osward (1994) and others, a relationship between real wage rates and unemployment is specified, where higher wages coincide with lower unemployment. The empirical basis of the 'wage curve' mimics a labor supply curve when specified in a simulation model. Thus the labor markets operate on the principles of supply and demand in the model, rather than the usual choice between fixing wage rates or fixing labor supply curves.

The specification of production in the hydrocarbon sector differs from the other sectors of the economy, in that production is not allowed to respond to changing prices. Output of petroleum and natural gas is predetermined in the model by the currently projected exports under contract with Brazil and the associated investments in the sector.[3]

6.2 The costs of a Stabilization Fund

The costs of having a Stabilization Fund amounts to reduced expenditures and the loss of investment and subsequent capital accumulation and growth which is caused by placing a

[3] A full list of equations and the computer code for the model is available from the authors: Robert_Faris@Harvard.edu and landersen@ucb.edu.bo.

portion of fossil fuel revenues in a Fund abroad rather than putting them to work in the Bolivian economy. A CGE model is well suited to estimate the magnitude of this loss. Our model with different types of workers and households can also predict who is likely to bear the main costs of having a Stabilization Fund.

In order to simulate the costs of having a Stabilization Fund, we first develop a base scenario with no Fund and no price volatility. The price of oil is assumed to be constant at the level it was in 1997 and natural gas exports are assumed to follow the contractual amounts as agreed in the present contract with Brazil.

The model predicts a growth rate for the Bolivian economy of between 2 and 3 percent annually, except for the years with rapid expansion of natural gas production, where growth rises to between 4 and 5 percent annually. It is important to note that we do not suggest that this model will be a good predictor of future levels of economic growth. The model ignores the important influence of productivity gains on growth so that growth in production reflects factor accumulation only. While this is an important component of growth, it presents an incomplete picture. Secondly, this is a model of the real economy. Therefore, it does not incorporate the influence of financial and nominal factors on economic performance. Finally, we don't presume to know what international prices will do over the next 15 years. This model is most useful in observing the difference in performance of the economy between different scenarios, rather than predicting accurately future levels of economic output.

The first question we approach is the impact of the Stabilization Fund on the economy under the assumptions of the base scenario. Figures 2 and 3 show that the impact on growth and output is quite small. The drop in growth is the result of the Stabilization Fund drawing savings and investments away from the economy. Under this scenario, deposits are made into the Stabilization Fund for 5 of the 15 years. No withdrawals take place in this scenario, and the Fund reaches a level of 5.2 billion Bolivianos by year 2012, or about 8 percent of GDP.

Figure 2: Impact of the Stabilization Fund on GDP

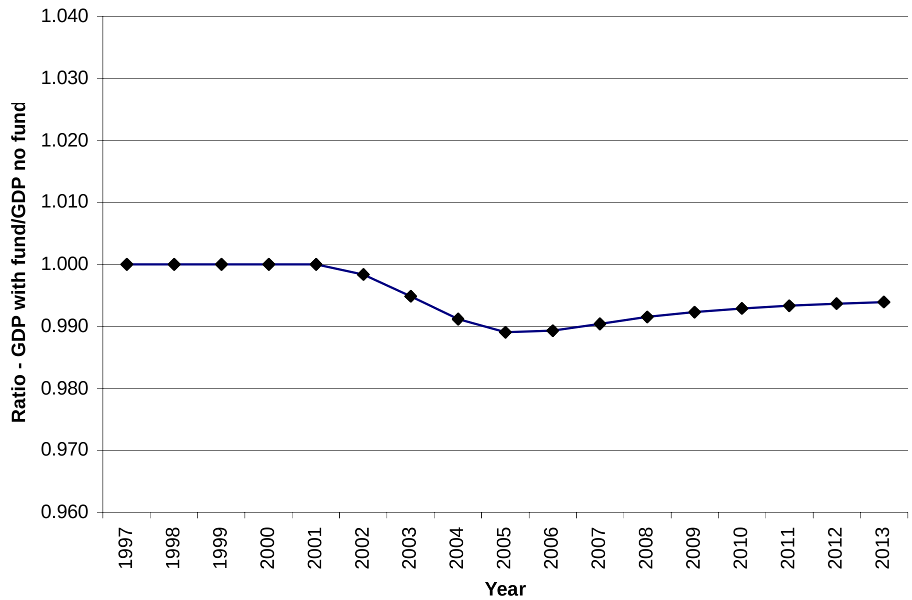
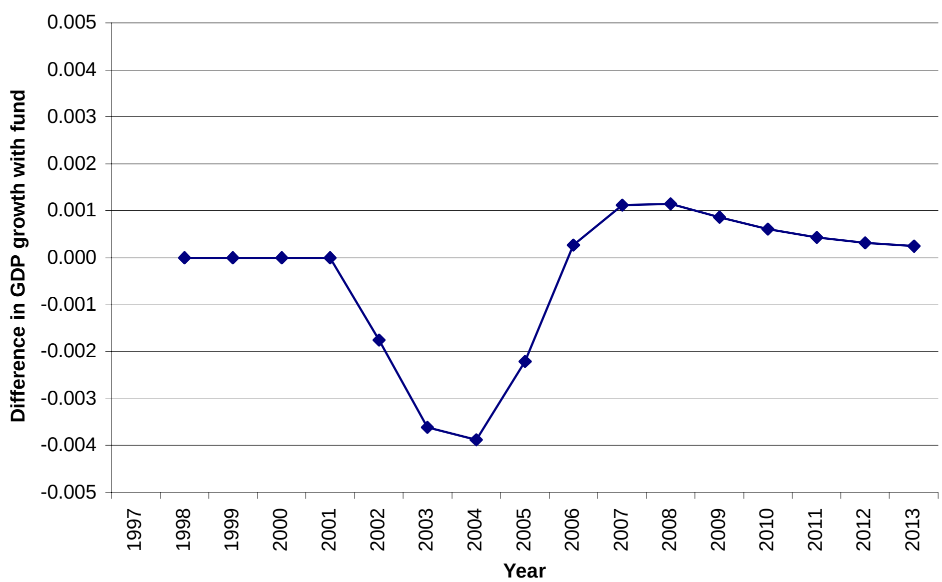
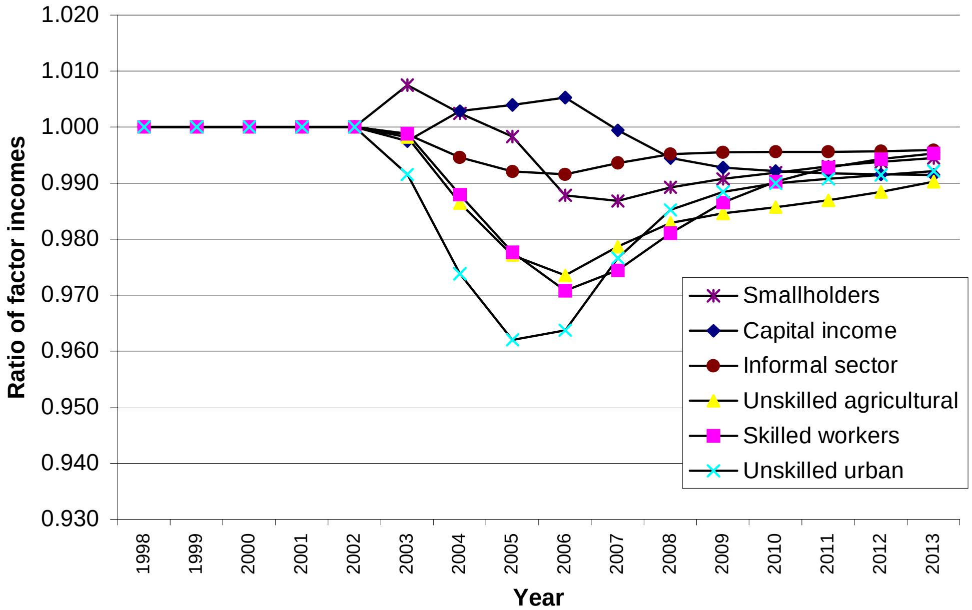


Figure 3: Impact of the Stabilization Fund on GDP Growth



Factor incomes are significantly affected by the initiation of the Stabilization Fund. Most labor categories show lower incomes during the boom period with the Fund. Unskilled urban workers suffer the most from the Stabilization Fund, but over time incomes converge to a level approximately 0.7 percent lower than if there were no Stabilization Fund. Capital income is somewhat higher initially with the Fund in operation, as the increase in capital returns due to relative scarcity is higher than the corresponding decrease in capital stocks. This reverses over time as the influence of growing capital stocks predominates.

Figure 4: Impact of the Stabilization Fund on Factor Incomes



The costs of having a Stabilization Fund will vary depending on the actual path of oil prices. If prices are high initially, the Fund will grow rapidly and the costs of having the Fund will be relatively high. If prices are low, the Fund will accumulate funds very slowly and the related costs in terms of lost investment will therefore be low. When the costs are low the benefits will also be low, since there will be little funds available to smooth with.

In order to calculate the average costs, or expected costs, of having a Fund we run several different price scenarios and calculate the average loss in GDP growth rate across all scenarios and all periods. The conclusion to this exercise is that the average costs of having a Stabilization Fund as specified above is less than 0.1 percentage point loss in the annual GDP growth rate. This is quite a small cost compared to the costs of high volatility. Of course the Fund will not be able to stabilize the economy completely, but even if it can reduce volatility by only 10 percent it seems to be a price worth paying.

The next section will look at some of the benefits of a Stabilization Fund.

6.3 The benefits of a Stabilization Fund

Many of the benefits of having a Stabilization Fund arise from the constraints that it puts on government spending. By imposing rules and diverting excess funds away from politicians, it in effect reduces the governments' ability to spend unexpected money unwisely. In

Bolivia, a large part of the revenues from the Natural Gas boom is going to go to the state governments in the form of royalties. The state governments find themselves in a position between the central government and the municipal governments that is not well defined. They have no clear responsibilities and no clear priorities. The governors are not elected but appointed by the president, which is the first indication of their lack of accountability. They don't have the administrative systems in place to handle a large and volatile inflow of funds, and the chance that funds get lost through corruption and mismanagement is considerable.

Since CGE models are all about optimization, this kind of inefficient government behavior is difficult to capture in the model. The same holds for costs like the interruption of education in poor households and the increase in strikes and civil unrest in bad times.

Knowing that our model can only capture a small part of the benefits of a Stabilization Fund, we will now present some simulations that highlight these benefits.

We have argued earlier that oil price volatility can greatly affect the level of government revenues. Now we will use the CGE model to show how oil price volatility affects the overall economy. The first experiment is a temporary doubling of international oil prices from year 2004 through year 2009. A doubling of the oil price is not a dramatic event in historical perspective. The oil price doubled in the early 1970s, more than tripled in the early 1980s, and doubled in the late 1990s. Lately it has fallen by 50 percent.

Figure 5 shows that even a significant external shock such as a doubling of the oil price do not have dramatic effects on the growth rate of the Bolivian economy. In fact, a positive price shock will initially have a negative effect on the growth rate because it causes an appreciation of the exchange rate, which in turn causes a drop in exports and a surge in imports. This is bad for overall production in the economy. The opposite happens when the price drops again in year 2009. The resulting depreciation causes an increase in exports and is generally good for production. During the period of high oil prices, growth is slightly higher than in the base scenario and by the end of the simulation period we end up with higher overall GDP (See Figure 6). Due to the appreciation of the exchange rate, however, the positive effect of high oil prices is somewhat less than what would intuitively be expected from such favorable prices of our main export product.

Figure 5: Impact of a positive temporary price shock on GDP growth

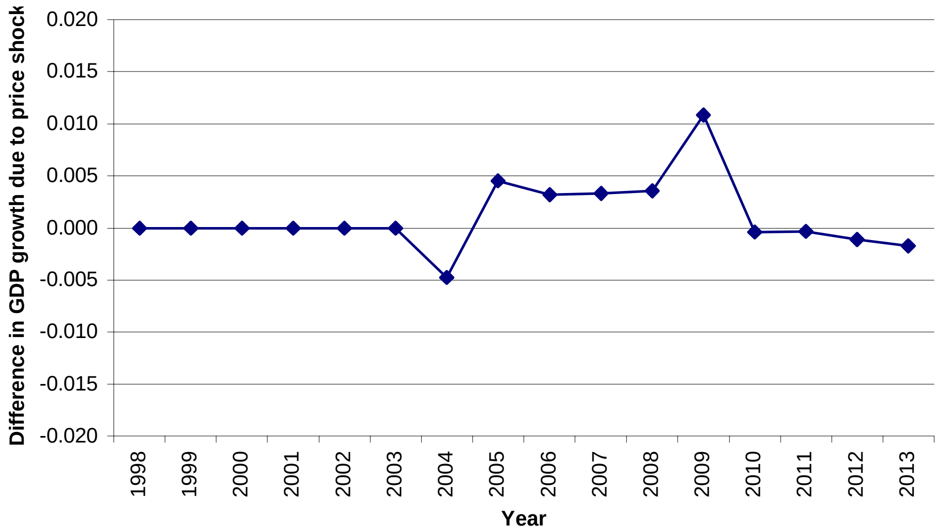
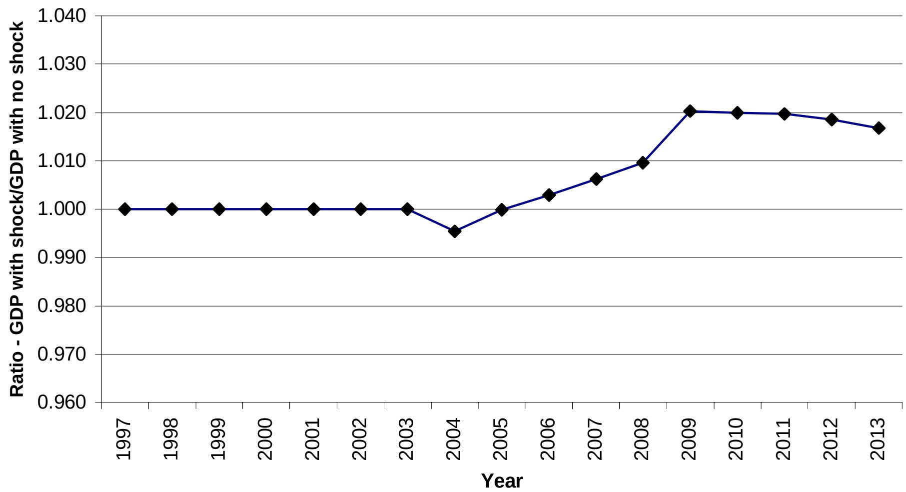
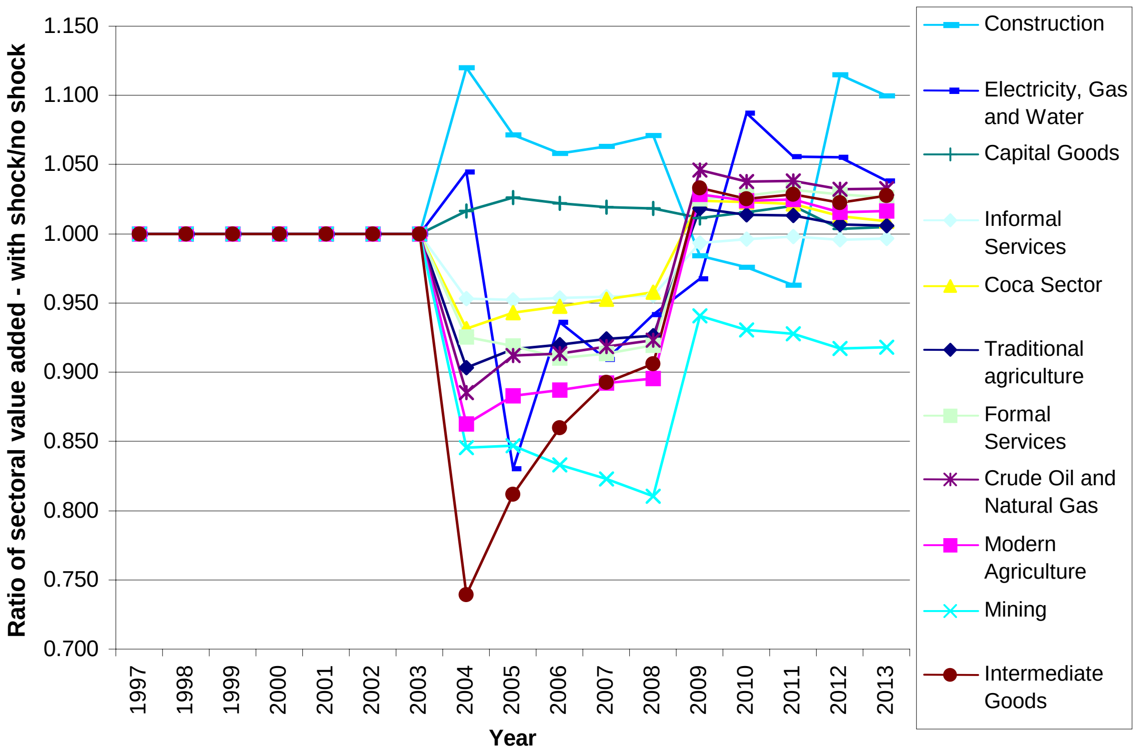


Figure 6: Impact of a positive temporary price shock on GDP



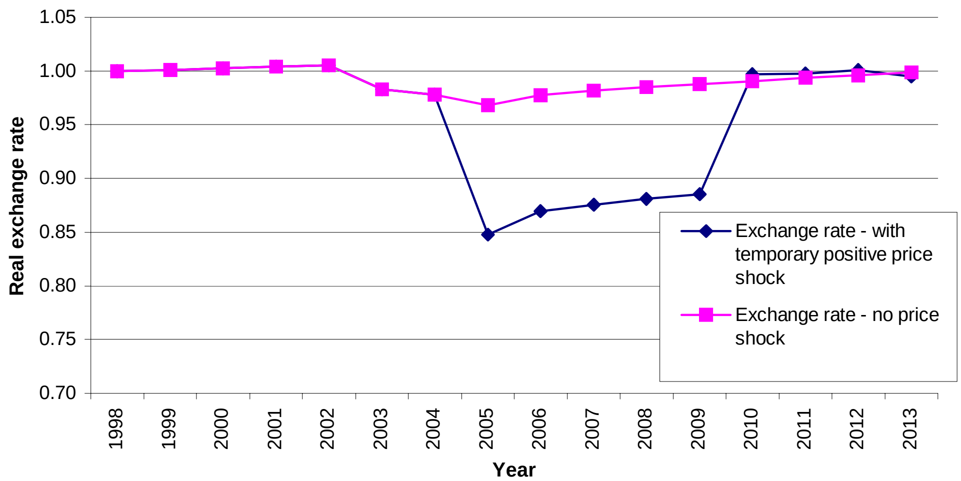
This relatively small overall impact of the price shock hides considerable volatility in the sectoral composition of the economy. The degree and speed of adjustment of the economy to these relative price shifts will determine the actual cost of volatility. In this model, capital, once installed, can not be reallocated to other sectors. Labor, however, is freely mobile between sectors, allowing a quick response to shocks such as these. This probably overstates the ease by which production can adjust, and therefore, understates the costs of volatility.

Figure 7: Impact of a temporary positive oil price shock on sectoral value added



The sectors helped by the increase in oil prices are those that have a greater non-tradeable content in their production and are less dependent on investment spending: construction and capital goods. Those hurt by the higher oil prices and weaker currency are the sectors with higher tradeable content such as the agricultural sectors. The real exchange rate is the primary transmission factor for the price volatility in the Bolivian economy. The appreciation of the real exchange rate can be seen in Figure 8. The temporary positive shock causes the real exchange rate to appreciate by 12-15 percent, which hurts the mining sector in particular.

Figure 8: Exchange rate with and without a positive petroleum price shock



The relatively small aggregate impact of the price shock on the economy can be explained in a number of ways. First, the fossil fuel sector, while growing in importance, remains a small fraction of total economic output. Second, this analysis suggests that the main avenues for volatility induced problems are through financial channels and not through the real economy. This is consistent with the conclusions of many researchers (e.g. Caballero 2000).

The results of these simulations cast into doubt one theory that asserts that one of the costs of volatility is the result of the under-performance of capital as many investments are directed into sectors that suffer from price shocks (Ramey & Ramey 1995). The present model allows for this possibility, yet does not find that impact to be significant. This point is strengthened where volatility is characterized as a fluctuation around a stable mean, rather than a movement in either direction. In this case, the capital stocks that under-perform because of shifting relative prices in one time period over-perform in the next, such that the net impact is very small.

Another theory on the costs of volatility suggests that volatility can induce levels of investment in good times that are unsustainable in the sense that the recurrent costs of these investments such as maintenance can not be sustained during down times, and that this capital falls into disrepair. We provide no new evidence to confirm or deny this theory. Nonetheless, it stands to reason that the costs of maintaining existing capital is a fraction of the cost of creating new capital, and that if these investments were well chosen, then the logical choice of scarce investment funds would be to maintain existing investments before instigating new projects. For this reason, we suspect that this is indeed a real problem, but better described as poor investment choices, not over-investment per se.

In summary, we find that the results of these simulations add support to the theory that the costs of volatility are largely manifest through financial channels. This is not to say that volatility in the composition of sectoral production does not present problems, but rather that the ability to adjust to real shocks is exacerbated by financial problems. Reducing real volatility is still a useful goal.

Next we will try to assess the success of the Stabilization Fund in reducing fluctuations in government revenues and in mitigating swings in the real exchange rate and the concomitant impact on sectoral production. Figure 9 shows the impacts of the Stabilization Fund on government budget under two scenarios. The first is a temporary doubling of the oil price from year 2004 through 2009. The second is a temporary 50 percent drop in oil prices during the same period.

Figure 9. Impact of oil price shocks on the government budget

Figure 9a: Positive temporary oil price shock

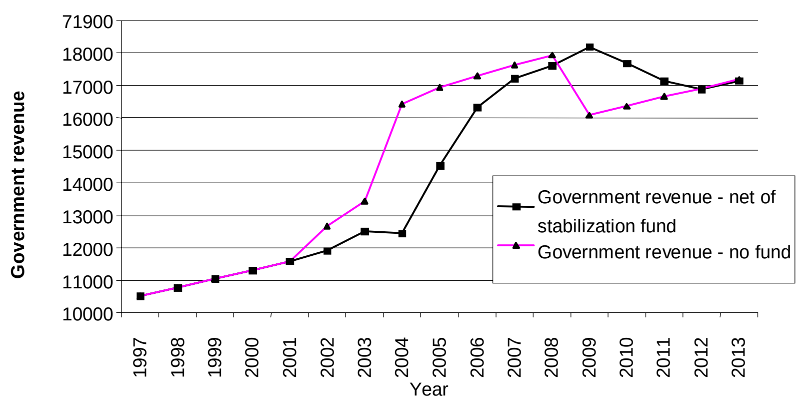
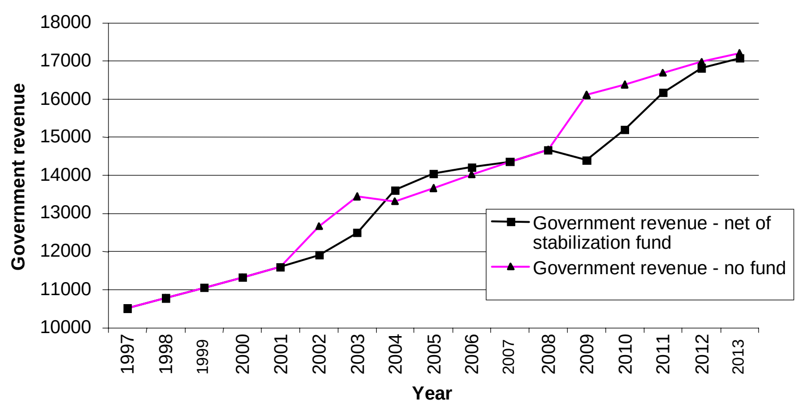


Figure 9b: Negative temporary oil price shock



As is apparent in Figure 9, the Stabilization Fund is effective at smoothing volatility in government revenues. There is no surprise here as the Stabilization Fund targets this variable. This result still depends on the adherence to complementary fiscal borrowing and spending policies such that the intent of the Stabilization Fund is not defeated by incurring additional public debt. The value of the Stabilization Fund in reducing fluctuations in revenue is higher in the presence of a temporary shock compared to a permanent shock. Among temporary shocks, there is not a meaningful distinction between positive and negative shocks as both entail upward and downward movements. There is no benefit of maintaining a Stabilization Fund in a world where there are only positive permanent price shocks.

As presented here, the stabilization of government revenues is less than perfect. This reflects the targeting of fossil fuel revenues and not overall government revenues. Targeting fossil fuel revenues can produce the unexpected result that when oil prices rise rapidly the operation of the stabilization produces a decline in government revenues. This occurs when the appreciation in the real exchange rate leads to a drop in non-fossil fuel government revenues and the stabilization limits the increase in fossil fuel revenues. Targeting the overall government budget would be problematic as the result inflows and outflows would not be linked to the availability to resources as in the case of natural gas revenues. This would make it much more difficult to maintain a reasonable sized Fund, possibly leading to either an excessive accumulation of funds or the depletion of the Fund.

We have argued so far that the costs on aggregate growth and GDP of reducing volatility in the public sector are quite small. The benefits of doing so are potentially quite large, though these benefits are not of the nature that they can be estimated using formal models. The benefits include better overall fiscal management and improved performance of public investment projects. The remaining question is the impact of the Fund on the volatility borne on the overall economy. We now turn to that question.

To assess the impact of oil price volatility on the economy, we use the real exchange rate as a summary indictor. Movements in the real exchange rate are highly correlated with changes in sectoral output in the economy as shown earlier in Figure 8.

In Figure 10a-d we show the impact of the Stabilization Fund on the real exchange rate under four different price scenarios. Figure 10a shows a temporary doubling of oil prices from year 2005 through 2009. Figure 10b shows a temporary 50 percent drop in oil prices during the same period. Figure 10c shows a permanent doubling of oil prices from year 2005 onward, and finally, Figure 10d shows a permanent 50 percent drop in oil prices occurring in 2005.

Figure 10: The impact of the Stabilization Fund on the real exchange rate.

Figure10a: Positive temporary price shock

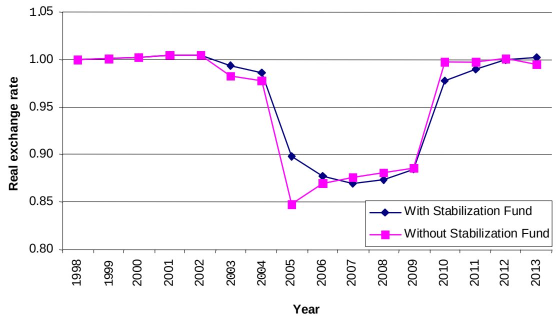


Figure10b: Negative temporary price shock

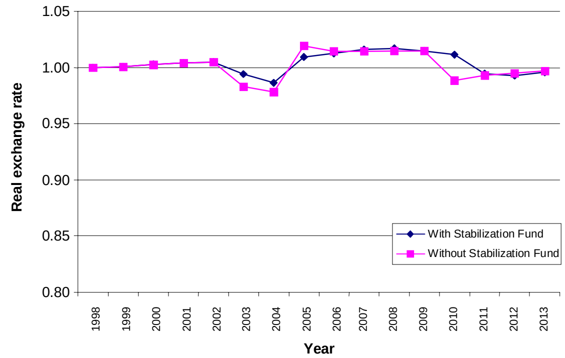


Figure10c: Positive permanent price shock

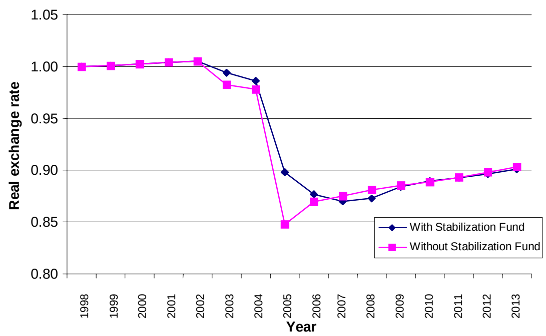
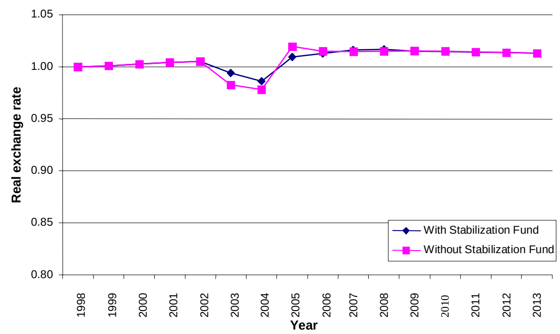


Figure10d: Negative permanent price shock



The first conclusion that we can draw from the four scenarios depicted in Figure 10 is that a Stabilization Fund similar in size to the one presented here can have a significant impact on real exchange rates. For example, in the event of a sudden doubling of the oil price, the real exchange rate would appreciate by 15 percent when the shock occurs, if there were no Stabilization Fund. The Stabilization Fund would reduce this immediate appreciation to 10 percent.

The second observation is that targeting government revenues with a contingent-rule-based Stabilization Fund can also reduce volatility. In the scenarios presented here, the Fund performs significantly better than the no-Fund scenario both in smoothing transitions from higher and lower real exchange rates and in reducing the range of values observed. Considerable volatility does remain as we assume that we are only able to manage the portion of the revenue from fossil fuel exports that goes to the government.

We urge caution in interpreting the magnitude of the real exchange rate movements depicted here. Considerable uncertainty exists over the impact of fossil fuel revenues on private capital flows, which play a key role in real exchange rate determination. A substantial proportion of the profits from fossil fuel exports will accrue to foreign companies and stay abroad, not contributing to either Dutch disease or economic development in Bolivia. These capital flows are fairly predictable. Not so predictable is the role that an increase in fossil fuel exports would have on capital flows not directly related to the fossil fuel sector. Depending on the context, these capital flows could be either positively or negatively correlated with fossil fuel export revenues, which in turn would either reduce or exacerbate real exchange rate volatility.

6.4 Stabilization Fund Design Considerations

There are a number of choices for determining the rules for managing the Stabilization Fund. The first issue is the question of applying strict contingent rules versus allowing flexibility in the implementation of the Fund. The reason to consider allowing flexibility in the implementation of the rules is that no fixed rule scheme will perform equally well in every economic context. Earlier we showed how overall government revenues might actually drop with an increase in oil prices while using a Fund that targets fossil fuel revenues accruing to the government. Other scenarios not presented here produced unexpected volatility in the real exchange rate while using the Stabilization Fund. In one scenario using a temporary negative shock, the rules of the Fund dictated that a large deposit be made into the Fund at the point where oil prices recover. This brought about a short-lived spike in the real exchange rate, depreciating the currency despite a rise in natural gas prices. We conclude that a Stabilization Fund that has rigid rules describing the size and timing of deposits and withdrawals, targets government revenues, and specifies how much of the proceeds to be held in foreign currency, may not necessarily succeed in reducing real exchange rate volatility brought on by international oil price changes. While it would be helpful in designing the Fund to know beforehand the duration and severity of shocks, there are large uncertainties in making such predictions. This analysis is consistent with the problems of contingent Funds that has been recognized by earlier studies (Hausmann 1995).

We should recall that one of the advantages of a Stabilization Fund is that it restricts the discretionary spending of the government. In fact, this might also be presented as a necessary condition for the success of such a Fund. Building in flexibility in the size and timing of withdrawals and deposits would defeat this purpose. In light of this, we should be searching for Stabilization Funds that maintains strict rules yet allows for complementary measures to reduce real exchange rate volatility. One solution is a Fund that fixes the magnitude and timing of deposits and withdrawals, yet allows for the funds to be allocated between foreign and domestic assets as a tool for real exchange rate management. An attractive institutional arrangement would have the government transfer resources into a Stabilization Fund managed by the Central Bank. This would permit the Fund managers at the Bank to manage the portfolio without the distraction of budgetary pressures and somewhat apart from political pressures, while coordinating the management of the Fund with overall monetary and external balance objectives.

When considering a strict contingent rule-based Fund, the design of the rules becomes very important. The most important aspect is the determination of the benchmark that will trigger deposits and withdrawals. The long-term benchmark determination rules may also vary from the initial conditions put into place to accumulate resources in the Fund. As we indicated earlier, the most likely course of action is to build up a balance in the Fund for possible use in the future. For Bolivia, this would be logical as fossil fuel revenues will be increasing with rising production over the next few years. Deposits into the Fund to build up reserves would therefore not entail a politically difficult cut in government spending. The accumulation of an initial working balance could also be accomplished by the securitization of future sales. The distinction between these two approaches constitutes only an inter-temporal choice, whether to pay for the creation of the Fund now or later.

The decision regarding the initial accumulation path for the Stabilization Fund centers on the trade-off over the size of the Fund. Limiting the size of Fund will reduce the financial resources sequestered away from productive ends, yet risks leaving the Fund without sufficient resources to address negative price movements. We reiterate that the results presented here suggest that the cost of ensuring adequate funding is small, such that a fairly aggressive accumulation course would cost very little in the long-term.

The two simplest options for setting the initial accumulation path are to use a fixed benchmark or fixed contributions for the first few years. The trade-off between these options is that fixed contribution option ensures that projected deposits will be made, but leaves government revenues subject to volatility for the initial periods. The fixed benchmark option reduces revenue volatility at the cost of less certainty in the accumulation path. The difference in approaches will only be evident if there is a significant deviation from projected future prices. The use of future markets could be used to reduce this risk.

The rules for setting the long-term benchmark levels will determine the speed of adjustment to changes in fossil fuel revenues. The primary choices in this case are whether to use past revenues, projected future revenues or a fixed target. A fixed target might be useful for accumulating resources into a Heritage Fund. However, since it does not hold any advantages for reducing volatility, we will not consider it here. In figure 11 and 12 we present the result of using two different benchmarks based on past revenues. One uses the moving average of the prior three years and the other the moving average of the prior seven years. Note that in these simulations we use a five year period for temporary price shocks. The figures show that the benchmark determination using a longer time period produces both a smoother adjustment path to shocks and less volatility in response to temporary shocks. One of the difficulties of the shorter-term determination rule is an overreaction to temporary price shocks. Unless an argument can be made for a more rapid adjustment to shocks, the longer-term determination rule is a decisively more attractive option. The reason for wanting a more rapid adjustment is to limit the required size of the Fund – we find that choosing the long-term benchmark determination rules is based again on the same balance between the size of the Fund and the potential of the Fund for meeting stabilization needs. As long as volatility is costly and reduction of this volatility is reasonably effective, the longer-term benchmark determination rule with a larger Stabilization Fund is preferable.

Figure 11: The impact of the design of the Stabilization Fund on government revenues

Figure11a: Positive temporary price shock

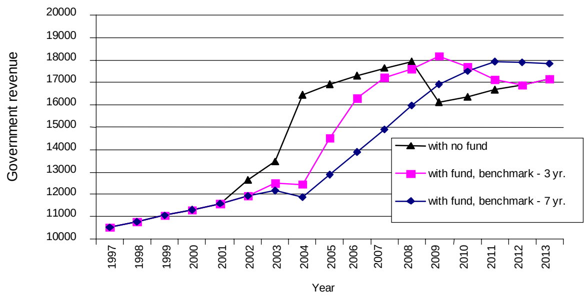


Figure 11b: Negative temporary price shock

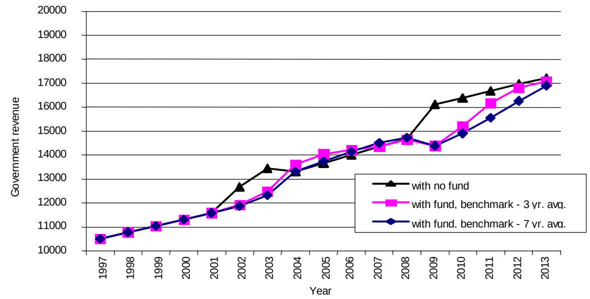


Figure11c: Positive permanent price shock

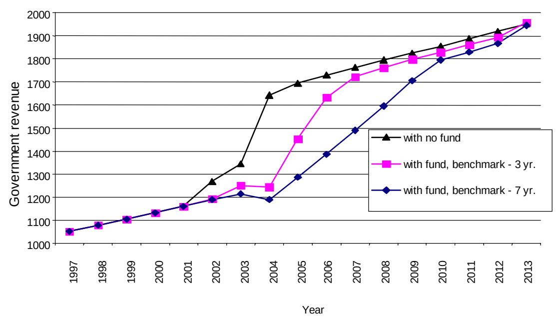


Figure11d: Negative permanent price shock

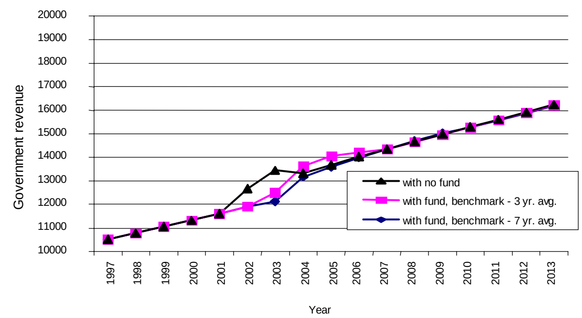


Figure 12: The impact of the design of the Stabilization Fund on the exchange rate

Figure12a: Positive temporary price shock

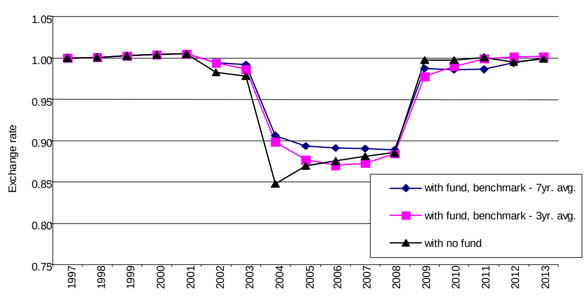


Figure12b: Negative temporary price shock

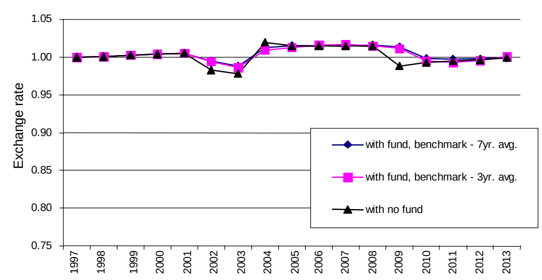


Figure12c: Positive permanent price shock

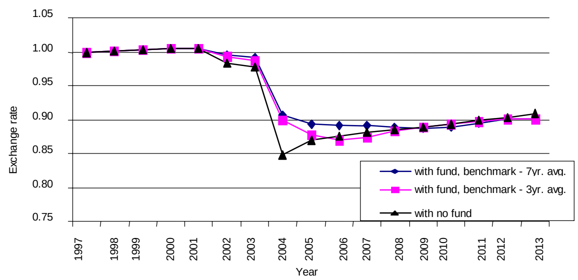
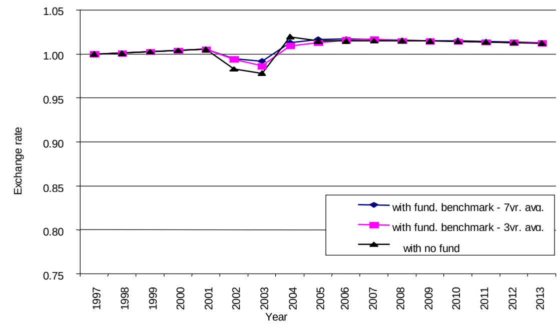


Figure12d: Negative permanent price shock



The impact of using future price projections in the benchmark determination is closely related to the impact of using past prices for benchmark determination of shorter or longer time periods. Including future price projections, if correct, will increase the speed of adjustment to price movements.

Davis *et al* (2001) assert that “prudence would suggest that a negative shock should be seen as permanent, and a positive shock as temporary, until proven otherwise.” In the absence of a Stabilization Fund, this could provide a reasonable guide for action. The downside of this asymmetric approach is that it provides a bias towards conservative fiscal behavior and limits the scope for taking advantage of positive price increases. One can envision ways to enact this philosophy in conjunction with a Stabilization Fund. However, we do not see any compelling arguments for introducing asymmetric rules into a Stabilization Fund unless one wishes to bias the operation of the Fund in favor of accumulating resources as in the case of a Heritage Fund. The Stabilization Fund provides an alternative to this more conservative fiscal response to price changes.

The use of price bands around a benchmark figure allows for a bit of volatility within the limits of the price band. This could be attractive as it reduces the number of required transactions in the face of small price movements. One might also envision reasons why maintaining a small degree of volatility might be desirable. The presence of the band does not significantly change the impact of the Stabilization Fund in the presence of significant changes in prices or production. We do not report the results of the simulations used to test the impact of different bands on the performance of the Fund as the changes were insignificant for any reasonable sized band.

The final consideration is placing a limit on the overall size of the Fund. There are a number of price evolution scenarios, particularly with rising prices, whereby a contingent rule based Stabilization Fund could accumulate more resources than are practically necessary. Apart from unnecessarily sequestering funds, this would create political pressure to change the rules of the Fund. One simple fix would be to place an upper limit on the size of the Fund, for example, as a percentage of GDP, after which no further deposits would be made and excess funds would be withdrawn. The problem with this is that this provision would create discontinuities in the accumulation path leading to unwanted volatility. For example, a price rise could be associated with a withdrawal of funds contributing to a rapid appreciation of the real exchange rate. A better solution to this problem is to express the benchmark not only as a function of past and/or future prices but also as a function of the size of the Stabilization Fund. As the size of the Stabilization Fund grows, the effective benchmark level would decrease, and visa versa. This would produce a smooth transition to higher expenditure patterns after a sustained period of higher prices without creating an excessively large Stabilization Fund.

7. Conclusions

The expected dramatic increase in Natural Gas exports, coupled with the usual high volatility of oil prices, is likely to cause a significant increase in the volatility of government revenues in Bolivia in the coming decades. This paper has applied a Computable General Equilibrium (CGE) model to analyze the likely effects of this volatility on the Bolivian economy. The model has also been used to analyze the costs and benefits of implementing a Stabilization Fund to reduce this volatility.

The volatility will have a direct impact through the public sector budget as well as indirect effects through relative price changes mediated through the real exchange rate. In general, a positive oil price shock will increase public sector revenues, but at the same time it will cause an appreciation of the real exchange rate, which will hurt the other exporting sectors, such as mining and modern agriculture. The net effect on the overall growth rate of the economy will be small, but this hides substantial structural changes within the economy. The big winner from a positive oil price shock is likely to be the construction sector due to the increase in investment that would follow an increase in public sector revenues. The big loser is the mining sector, because the appreciation of the exchange rate reduces the profitability of selling output in world markets.

The implementation of a Stabilization Fund has the potential to reduce the expected volatility, both through government budgets and the real exchange rate. The Stabilization Fund we propose directly targets the stabilization of hydrocarbon revenues, but by keeping excess funds out of the country in good times, it also helps to stabilize the real exchange rate.

The potential of a Stabilization Fund depends heavily upon complementary fiscal policies put into place. It is theoretically possible for the government to completely offset the benefits of the Stabilization Fund, for example if they borrow against it. It is also theoretically possible for the government to smooth its spending and the impact on the economy without a Stabilization Fund, by saving in good times and spending some of the savings in bad times. This means that a Stabilization Fund is neither a necessary nor a sufficient condition for a reduction in volatility. However, a Stabilization Fund may act as a catalyst for promoting sound fiscal policies, by focusing attention on the potential problems and by putting in place control mechanisms that minimize the possibility of mismanagement and sacrificing of long-term growth in favor of short-term objectives.

Important design features of the Stabilization Fund include the definition of baselines for Fund activity and the trade-offs between the benefits of a rigid rule-based Fund and the benefits of discretionary power to tailor responses to the specifics of a given situation. We believe that the best solution is to enact strict contingent rules for deciding the timing and size of government deposits and withdrawals into a Stabilization Fund, while leaving more discretionary power in the management of the portfolio, particularly in the mix of domestic and foreign assets. This allows for a multiple objective Fund, addressing both public sector budgetary objectives and real exchange rate movements, while continuing to act as a mechanism for fiscal discipline.

In our model the government is treated as one entity, but in reality the hydrocarbon revenues will be split between the central government and state governments. Since Tarija holds by far the largest share of certified hydrocarbon reserves, this state will receive particularly large hydrocarbon revenues, especially compared to other revenue sources and especially measured in per capita terms. The government of Tarija has already expressed interest in borrowing against its natural gas reserves, which may be reasonably in a time of recession, but it could also be a warning sign of short-termism and irresponsible government spending. Since the volatility of hydrocarbon revenues is going to have a disproportionately large impact on the small state budget of Tarija, it would seem particularly important to implement a Stabilization Fund and supporting control mechanisms for those revenues.

The central government is only going to receive about 35 percent of total hydrocarbon revenues. Since it has many other sources of revenue that are not positively correlated with oil prices, the impact of oil price volatility will be substantially smaller than in the state of Tarija. While a Stabilization Fund accompanied by additional control mechanisms seem very important for Tarija's part of hydrocarbon revenues, it seems less crucial for the central government, where hydrocarbon revenue volatility will have a smaller impact on total revenue volatility.

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Appendix : Government revenue projections from YPFB (2001)

Natural Gas price at 1,5 $us/MMBTU and production at 30 MMm3D (All new hydrocarbons)

Year	Oil price ($us/ barrel)	Natural gas price ($us/M MBTU)	Production of natural gas (MM m3/D)	Production of natural gas (T BTU)	Oil production (thousand barrels)	Capital investments (mio. $US)	Operating costs Extr+Adm (mio. $us)	Operating costs Pipeline fees (mio. $us)	Gross income (mio.$us)	Royalties (mio $us) 18%	Depreciation (mio $us)	Tax base (mio $us)	Profit tax (mio $us)	Deductions for the sur-tax: Inv. Up to 33% (mio $us)	Deductions for the sur-tax: Mio. B$ 250 de 1997 (MM$us)	Sur-tax (mio $us)	Cash flow: Anual (mio $us)	Cash flow: Accumulated (mio $us)	Remission tax (mio.$US)
	(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(z)	(j)	(l)	(m)	(n)	(ñ)	(p)	(q)	(r)	(s)	(t)
0																			
1	24.0	1.5				240											-240	-240.00	
2	24.0	1.5				240											-240	-480.00	
3	24.0	1.5				240											-240	-720.00	
4	24.0	1.5	30.0	399.5	6,629.0		34.5	109.1	758.3	116.9	112.50	385.32	96.33	240.00	46.55	24.69	376.80	-343.20	
5	24.0	1.5	30.0	399.5	6,629.0		34.5	109.1	758.3	116.9	112.50	385.32	96.33	240.00	46.55	24.69	376.80	33.59	4.20
6	24.0	1.5	30.0	399.5	6,629.0		34.5	109.1	758.3	116.9	112.50	385.32	96.33	240.00	46.55	24.69	376.80	410.39	47.10
7	24.0	1.5	30.0	399.5	6,629.0		34.5	109.1	758.3	116.9	112.50	385.32	96.33		46.55	84.69	316.80	727.19	39.60
8	24.0	1.5	30.0	399.5	6,629.0		34.5	109.1	758.3	116.9	112.50	385.32	96.33		46.55	84.69	316.80	1,043.99	39.60
9	24.0	1.5	30.0	399.5	6,629.0		34.5	109.1	758.3	116.9	40.50	457.32	114.33		46.55	102.69	280.80	1,324.78	35.10
10	24.0	1.5	30.0	399.5	6,629.0		34.5	109.1	758.3	116.9	40.50	457.32	114.33		46.55	102.69	280.80	1,605.58	35.10
11	24.0	1.5	30.0	399.5	6,629.0		34.5	109.1	758.3	116.9	40.50	457.32	114.33		46.55	102.69	280.80	1,886.38	35.10
12	24.0	1.5	30.0	399.5	6,629.0		34.5	109.1	758.3	116.9	18.00	479.82	119.95		46.55	108.32	269.55	2,155.93	33.69
13	24.0	1.5	30.0	399.5	6,629.0		34.5	109.1	758.3	116.9	18.00	479.82	119.95		46.55	108.32	269.55	2,425.47	33.69
14	24.0	1.5	30.0	399.5	6,629.0		34.5	109.1	758.3	116.9		497.82	124.45		46.55	112.82	260.55	2,686.02	32.57
15	24.0	1.5	30.0	399.5	6,629.0		34.5	109.1	758.3	116.9		497.82	124.45		46.55	112.82	260.55	2,946.57	32.57
16	24.0	1.5	30.0	399.5	6,629.0		34.5	109.1	758.3	116.9		497.82	124.45		46.55	112.82	260.55	3,207.12	32.57
17	24.0	1.5	30.0	399.5	6,629.0		34.5	109.1	758.3	116.9		497.82	124.45		46.55	112.82	260.55	3,467.66	32.57
18	24.0	1.5	30.0	399.5	6,629.0		34.5	109.1	758.3	116.9		497.82	124.45		46.55	112.82	260.55	3,728.21	32.57
19	24.0	1.5	30.0	399.5	6,629.0		34.5	109.1	758.3	116.9		497.82	124.45		46.55	112.82	260.55	3,988.76	32.57
20	24.0	1.5	30.0	399.5	6,629.0		34.5	109.1	758.3	116.9		497.82	124.45		46.55	112.82	260.55	4,249.31	32.57
21	24.0	1.5	30.0	399.5	6,629.0		34.5	109.1	758.3	116.9		497.82	124.45		46.55	112.82	260.55	4,509.85	32.57
22	24.0	1.5	30.0	399.5	6,629.0		34.5	109.1	758.3	116.9		497.82	124.45		46.55	112.82	260.55	4,770.40	32.57
			208,050.00	MMm3	125,951.00	720.00	655.50	2,073.10	14,407.34	2,220.16	720.00	8,738.58	2,184.64	720.00	884.45	1,783.53	4,770.40		596.30

Total royalties and taxes (mio $US)	6,784.64
Percentage of gross revenues (%)	47.09

Year	Oil price ($us/ barrel)	Natural gas price ($us/M MBTU)	Production of natural gas (MM m3/D)	Production of natural gas (T BTU)	Oil production (thousand barrels)	Capital investments (mio. $US)	Operating costs Extr+Adm (mio. $us)	Operating costs Pipeline fees (mio. $us)	Gross income (mio.$us)	Royalties (mio $us) 18%	Depreciation (mio $us)	Tax base (mio $us)	Profit tax (mio $us)	Deductions for the sur-tax		Sur-tax (mio $us)	Cash flow		Remission tax (mio.$US)
														Inv. Up to 33% (mio $us)	Mio. B$ 250 de 1997 (MM$us)		Anual (mio $us)	Accumulated (mio $us)	
	(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(z)	(j)	(l)	(m)	(n)	(ñ)	(p)	(q)	(r)	(s)	(t)
0																			
1	18.8	1.2				240											-240	-240.00	
2	18.8	1.2				240											-240	-480.00	
3	18.8	1.2				240											-240	-720.00	
4	18.8	1.2	30.0	399.5	6,629.0		34.5	109.1	604.0	89.1	112.50	258.79	64.70	207.90	46.55	1.08	305.51	-414.49	
5	18.8	1.2	30.0	399.5	6,629.0		34.5	109.1	604.0	89.1	112.50	258.79	64.70	207.90	46.55	1.08	305.51	-108.99	
6	18.8	1.2	30.0	399.5	6,629.0		34.5	109.1	604.0	89.1	112.50	258.79	64.70	207.90	46.55	1.08	305.51	196.52	24.56
7	18.8	1.2	30.0	399.5	6,629.0		34.5	109.1	604.0	89.1	112.50	258.79	64.70	96.3	46.55	28.98	277.61	474.12	34.70
8	18.8	1.2	30.0	399.5	6,629.0		34.5	109.1	604.0	89.1	112.50	258.79	64.70		46.55	53.06	253.53	727.66	31.69
9	18.8	1.2	30.0	399.5	6,629.0		34.5	109.1	604.0	89.1	40.50	330.79	82.70		46.55	71.06	217.53	945.19	27.19
10	18.8	1.2	30.0	399.5	6,629.0		34.5	109.1	604.0	89.1	40.50	330.79	82.70		46.55	71.06	217.53	1,162.72	27.19
11	18.8	1.2	30.0	399.5	6,629.0		34.5	109.1	604.0	89.1	40.50	330.79	82.70		46.55	71.06	217.53	1,380.25	27.19
12	18.8	1.2	30.0	399.5	6,629.0		34.5	109.1	604.0	89.1	18.00	353.29	88.32		46.55	76.68	206.28	1,586.53	25.79
13	18.8	1.2	30.0	399.5	6,629.0		34.5	109.1	604.0	89.1	18.00	353.29	88.32		46.55	76.68	206.28	1,792.81	25.79
14	18.8	1.2	30.0	399.5	6,629.0		34.5	109.1	604.0	89.1		371.29	92.82		46.55	81.18	197.28	1,990.09	24.66
15	18.8	1.2	30.0	399.5	6,629.0		34.5	109.1	604.0	89.1		371.29	92.82		46.55	81.18	197.28	2,187.37	24.66
16	18.8	1.2	30.0	399.5	6,629.0		34.5	109.1	604.0	89.1		371.29	92.82		46.55	81.18	197.28	2,384.66	24.66
17	18.8	1.2	30.0	399.5	6,629.0		34.5	109.1	604.0	89.1		371.29	92.82		46.55	81.18	197.28	2,581.94	24.66
18	18.8	1.2	30.0	399.5	6,629.0		34.5	109.1	604.0	89.1		371.29	92.82		46.55	81.18	197.28	2,779.22	24.66
19	18.8	1.2	30.0	399.5	6,629.0		34.5	109.1	604.0	89.1		371.29	92.82		46.55	81.18	197.28	2,976.50	24.66
20	18.8	1.2	30.0	399.5	6,629.0		34.5	109.1	604.0	89.1		371.29	92.82		46.55	81.18	197.28	3,173.78	24.66
21	18.8	1.2	30.0	399.5	6,629.0		34.5	109.1	604.0	89.1		371.29	92.82		46.55	81.18	197.28	3,371.06	24.66
22	18.8	1.2	30.0	399.5	6,629.0		34.5	109.1	604.0	89.1		371.29	92.82		46.55	81.18	197.28	3,568.34	24.66
			208,050.00	MMm3	125,951.00	720.00	655.50	2,073.10	11,475.49	1,692.43	720.00	6,334.46	1,583.62	720.00	884.45	1,182.50	3,568.34		446.04

Total royalties and taxes (mio $US)	4,904.59
Percentage of gross revenues (%)	42.74