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The Natural Gas Sector in Bolivia: An Overview

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Summary:
This paper provides a thorough overview of the natural gas sector in Bolivia, with the purpose of identifying critical questions to be answered in subsequent research.

The paper shows that the Bolivian benefits from natural gas exports are rather limited. The sector generates very little employment, there are few linkages with the rest of the economy, and most of the profits accrue to foreigners. The royalties and tax income that remain in Bolivia are highly volatile and may amount to anything between US$ 85 million and US$ 1.4 billion per year, depending on the development of international oil prices. The high volatility is cause for concern, since Bolivia's tax system relies heavily on the hydrocarbon sector for revenues.

Another cause for concern is the uneven distribution of benefits across departments. Tarija, which holds 80% of certified natural gas resources but only 5% of the Bolivian population, will receive substantial additional resources through royalties. This windfall may cause localized problems in terms of rent seeking behavior and corruption, displacement of other productive sectors, under-development of alternative tax-bases, and addiction to easy natural gas dollars.

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1. Introduction

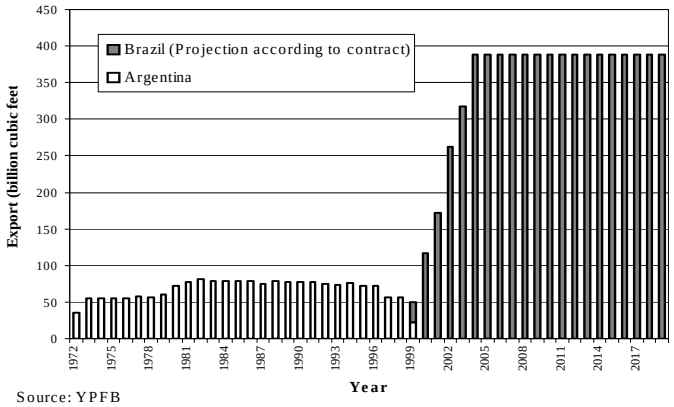
With exports and imports together amounting to approximately 37% of GDP[2], Bolivia is one of the most open economies in Latin America (Jemio 1993). However, while imports are composed of a diverse selection of manufactured goods, exports are dominated by a few primary commodities. Tin has traditionally been Bolivia's most important export commodity, accounting for more than 60% of exports during the period 1930-1970. In the early 80s, however, when tin-prices plummeted and oil prices soared, natural gas replaced tin as the most important export commodity. With recent new natural gas discoveries and a large demand for clean energy in Brazil, natural gas is likely to dominate exports in the coming decades. Bolivia will thus return to the status of a largely primary mono-commodity exporter.

The dependence of natural gas is in some ways worse than the dependence of tin, since there are only a few potential buyers. Until now, there has actually only been one foreign customer at a time. The first customer was Argentina, who received a total of 1.87 trillion cubic feet ($1.87 * 10^{12}$ CF) during the period 1 May 1972 – 31 August 1999 at a total price of US$ 4.56 billion (YPFB, Informe Mensual, August 1999). This amounts to an average daily rate of 187 million cubic feet, and an average price of US$ 2.44 per thousand cubic feet. Exports to Argentina have now stopped completely, since Argentina has become self-sufficient, and even exports natural gas to Chile (Jadresic 2000). Argentina has also just signed a large export contract with Brazil (La Razón, 20/09/2000).

Currently all natural gas exports are being directed at Brazil at a daily rate of 320 million cubic feet scheduled to increase to 1,062 million cubic feet per day by 2004 and stay at that level until 2019. The total amount scheduled to be exported to Brazil by the current 20-year contract is 7.7 trillion cubic feet, i.e. more than 4 times more than the amount exported to Argentina. The price is negotiated to start at approximately 1 dollar per thousand cubic feet (actually US$0.95 per million British thermal units) and then follow a basket of international fuel oils (See section 4.3 for the exact formula).

Figure 1 show clearly that the Brazilian contract is substantially larger than the contract with Argentina. Additional contracts with Brazil are already being negotiated, and these will further increase export volumes.

Figure 1: Natural gas exports from Bolivia (1972 – 2019)



Source: YPFB

[2] Average over the period 1994-1998 (International Financial Statistics 08/1999, CD-ROM).

While export volumes are guaranteed by long-term contracts, the revenues are highly sensitive to the development of fuel oil prices. Bolivia may well again experience an export-led economic boom as in the 1970s followed by a bust as in the 1980s if the fuel oil prices were to plummet. It is very important to learn the lessons from the previous boom-bust cycle, to avoid another severe recession.

The purpose of this paper is to analyze the natural gas sector in Bolivia, and especially to identify technological, institutional, environmental, and contractual constraints, that may prevent Bolivia from following the theoretically optimal extraction path.

The overall purpose of the project, of which this paper is a part, is to identify the linkages between the natural gas sector and the rest of the economy, so that we can promote the aspects which augment overall competitiveness and minimize the aspects which impede competitiveness.

The paper proceeds as follows. Section 2 describes the main local and international players in the Bolivian natural gas sector. Section 3 describes the main classes of market failures in the sector and explains how these market failures affect the optimal extraction path. Section 4 identifies technological, legal, contractual, and environmental constraints. Section 5 shows the projected government revenues from natural gas exploitation and their expected distribution within Bolivia. Section 6 concludes and provides direction for further research on the topic.

2. The players

The natural gas sector in Bolivia can be divided into two parts. The part involved with exploration and extraction (upstream); and the part involved with transportation and distribution (downstream). We will group the players accordingly.

2.1 Exploration and extraction of natural gas

Until 1996, the state oil company, YPFB (Yacimientos Petrolíferos Fiscales Bolivianos) had all the rights to explore and extract natural gas and oil in Bolivia[3]. But YPFB's investment in exploration was insufficient to prevent natural gas reserves from declining and insufficient to meet the local demand for gasoline, so the government decided to capitalize the company in order to secure fresh funds for investment.

The capitalization process consisted of dividing up the state company in three independent parts and inviting the private sector to invest in the new companies in return for administrative control of the enterprises and 50 percent of the shares. The private partners had to promise to invest resources at least equal to the capitalization value of the companies within 8 years.

By the end of 1999 the foreign partners had already invested 45 % funds more than promised, and the certified reserves had multiplied several times, from 6.8 trillion cubic feet before the capitalization process to 32.2 trillion cubic feet by January 1st, 2000 (Jemio 2000).

A part of YPFB has remained a state enterprise with the sole purpose of overseeing all exploration, exploitation, and commercialization of hydrocarbons in Bolivia. The only way private companies can get involved is through joint ventures with YPFB.

Currently 18 enterprises are involved in exploration and exploitation under joint venture contracts with YPFB. The main ones are listed in Table 2.

[3] Some of the work was contracted out to private companies, however.

Certification of reserves is conducted once a year, by January 1st, by an independent company, DeGolyer & McNaughton. By the beginning of 2000, there was a total of 32.2 trillion cubic feet of natural gas certified, but since then there has already been substantial new discoveries. When the numbers for January 1st, 2001 are announced, they may reach almost 40 trillion cubic feet (EnergyPress).

Table 1: The Capitalization of YPFB

Capitalized enterprise	Activity	Private partner (country)	Capitalization value (million US$)	Investment executed by 31/12/99 (million US$)
Chaco	Exploration and production	Amoco (UK)	306.6	278.5
		YPF (Argentina), Pérez	264.7	384.4
Andina	Exploration and production	Compac (Argentina), Plus	263.5	544.3
		Petrol (Argentina)	**834.9**	**1,207.2**
Transredes	Transportation through pipelines	Enron (USA), Shell (Holland)		

Source: Jemio (2000).

The Brazilian company, Petrobras and its two associates, Total and Andina, account for 51 percent of all reserves. However, due to preferential treatment in the export contract with Brazil, they account for 62.4 percent of exports (see section 4.3 below). The remaining 27.6 percent is divided between Chaco, Pérez Compac, Vintage Petroleum, Maxus, and Pluspetrol (Jemio 2000). The preferential treatment of Petrobras is annoying the other exploration companies greatly. Some of them have declared a stop to further exploration because they already have more reserves than they can see markets for during the next 20 years.

Table 2: Companies involved in exploration and exploitation of natural gas in Bolivia

Company	Number of fields being exploited	Certified Reserves 1/1/2000 (trillion CF)	Annual Investments (average 1997-1999) (million US$)
Chaco	11	2.1	69.9
Andina	8	8.1	124.6
Maxus	3	2.5	88.5
BG-Tesoro	3	4.8	27.1
Pérez Compac	1	0.8	14.3
Petrobras Bolivia	5	3.7	46.5
Vintage	1	1.1	21.2
Total S.A.	1	4.5	24.3 [b]
Exxon Mobil	3	2.5	
Unión Texas Bolivia	1	1.6	
Other companies[a]	8	0.5	**675.0**
Total	**45**	**32.2**	

Sources: Certified reserves were published in La Razón, August 6, 2000 based on information from YPFB. Company investment information was also collected by YPFB. Total investment was calculated from VMEH estimates for the period 1997-2000.

Notes: *a*. Other companies include: PlusPetrol, BHP, Dong Won, Bolipetro, Petrolex, RTB Gamma, CFI, Canadian. *b*. Only 1998-1999.

2.2 Transportation and distribution of natural gas

According to Ley de Hidrocarburos (No. 1689) any person or company, domestic or foreign, can construct and operate pipelines for the transport of hydrocarbons. In practice it is a natural monopoly, however. Until 1997 this monopoly was run by the state oil company YPFB. In May 1997, as part of the National Capitalization Process, the ownership and management of the natural gas pipeline network was transferred to TRANSREDES S.A. which is a consortium consisting of 25% Enron, 25% Shell, 34% Bolivian pension funds, and 16% other investors. Shell and Enron have administrative control over the company, but by far the largest share of the 460 employees are Bolivians (Transredes 2000). Since 1997 a handful of other companies have entered the natural gas transportation market, but TRANSREDES S.A. holds majority shares in the two significant ones (Gas TransBoliviano, who delivers natural gas to southern Brazil, and Gas Oriente Boliviano, who will deliver natural gas to Cuiaba in Brazil), and the rest are insignificant (SH 1999a).

The total length of the natural gas pipelines on Bolivian territory is 3,662 km. In addition there are 2,271 km of oil pipelines and 1,510 km of multipurpose pipelines (poliductos) (SH 1999a). Approximately half of the total length of pipelines are above ground and half of the length below ground. Diameters vary between 2 inches and 32 inches (Transredes 1999). Data on the main export pipelines are given in Table 3.

As a natural monopoly, TRANSREDES is heavily regulated through the Superintendencia de Hidrocarburos (the regulatory agency). The tariff for transportation is set by the Superintendencia, currently at a flat rate of US$ 0.41 per thousand cubic feet for domestic transport and US$ 0.18 per thousand cubic feet for export (VMEH). This is a postal stamp type of tariff, since it is independent on the distance of transportation. Short distance customers are thus subsidizing long distance customers, and domestic customers are subsidizing foreign customers.

To avoid monopolistic behavior, TRANSREDES is required to give free access to all customers (within capacity).

Table 3: The major export pipelines in Bolivia

Pipeline (administrator)	**Length (in Bolivia)** (km)	**Capacity** (million cubic feet/day)	**Investment (in Bolivia)** (million US$)
Gasoducto Bolivia-Brazil (GAS TRANS BOLIVIANO)	557	1,062	435
Gasoducto Cuiabá, Brazil (GAS ORIENTE BOLIVIANO, Under construction)	359	91	124
Gasoducto Paraguay (Planned)	102	117	180
Gasoducto Argentina (Currently unused)		200	
Polyducto Ilo, Peru (Planned, for liquids)	113	50,000[a]	60

Source: ENERGY in Bolivia, Information Bulletin of the Viceministry of Energy and Hydrocarbons, No. 3, 1999 and SH (1999b).

Note: *a.* Barrels per day.

2.3 Investments in the hydrocarbon sector

Since natural gas and oil are found together in the ground, it is impossible to separate investments in natural gas from investments in liquid hydrocarbons. The latter are almost exclusively used for the domestic market, where it does not quite satisfy demand at the moment.

The Viceministerio de Energía e Hidrocarburos (VMEH) predicts that investments in the hydrocarbon sector will amount to US$ 4.4 billion in the period 1998-2005. This is a substantial increase from previous levels. In the period 1993-1996 total investments in the sector amounted to only 802 million.

Currently, 75% of all foreign direct investment (FDI) goes to the hydrocarbon sector. Consequently, more than 70% of FDI goes to the departments of Santa Cruz and Tarija, which contain the geologically most promising areas for hydrocarbon extraction (La Razón, 26/07/2000).

2.4. Employment in the hydrocarbon sector

The hydrocarbon sector is extremely capital intensive and employs very little labor. In 1990, well before the capitalization process, YPFB employed 5,661 workers, of which only 11% were professionals. By June 1998 the total employment at YPFB and the capitalized companies were only 3,352 (Ayala 2000). Further reductions are expected due to the completion of the pipelines to Brazil and due to productivity increases arising from the more modern technologies used by the capitalized companies. This means that the hydrocarbon sector employs less than 0.2% of the Bolivian labor force.

3. Market failures

The natural gas market in Bolivia suffers from numerous market failures, which imply that market forces by themselves cannot be expected to allocate resources efficiently among users and over time.

The purpose of this section is to describe these market failures and to analyze how each of them would tend to affect the theoretically optimal extraction path. Notice that we do not yet know the theoretically optimal extraction path, nor is it necessary to know it in order to do this analysis. We follow the taxonomy of market failures given by Panayotou (1993, p.34)

3.1 Insecurity of resource ownership

One of the most fundamental conditions for the efficient operation of markets is the existence of well-defined, exclusive, secure, transferable, and enforceable property rights over all resources. The natural gas sector violates this condition in several ways.

First, the actual amount of natural gas in Bolivia is unknown, so even if property rights were well-defined, the owner would not know exactly what he owns. Some of the natural gas in Bolivia is proven with high probability, some is considered likely, some is considered possible, but most of it has probably not yet been found.

Since it is difficult to grant property rights over something, which has not even been proved to exist, the government instead grants companies rights to explore and to extract the

resource if they find something. Such rights are time-limited (see section 4.2 below), which implies that those who hold the rights have no incentives to conserve the resource. They have incentives to search and extract intensively within their time-limit without any regards to the socially optimal extraction path. Thus, the incomplete ownership works in the direction of too rapid exploitation.

The very fact that natural gas is hidden in the ground, and require expensive exploration to be found, works in the direction of too slow exploitation, however.

3.2 Thin markets

Due to the need for pipelines for the transportation of natural gas, there is no world market for natural gas, and no homogeneous world price as there is for oil. The price of natural gas is instead negotiated between a few sellers and buyers in the vicinity of the natural gas field.

The price that Bolivia is able to charge for its natural gas is therefore highly dependent on the energy needs and energy policies in neighboring countries. As it happens, there is an almost unlimited demand for clean energy from the São Paulo area in Brazil, and this makes it feasible for Bolivia to export its natural gas, rather than just burning it as a dangerous waste product from oil production.

The price is usually settled in bi-national negotiations. In the case of exports to Brazil, a price formula has been developed (see secion 4.3 below) that clearly does not take into account any social opportunity costs or externalities. And specifically it does not take into account any intertemporal user costs (the effect of current use on future availability). Thus, the price mechanism does not assure that the resource goes to the users with the highest benefits now or in the future. Since both prices and quantities are typically negotiated for periods spanning several decades, there is little room for adjustments to unexpected changes in scarcity value, and actual extraction rates can be both below or above the socially optimal extraction path.

3.3 High transaction costs

Transaction costs are very high in the natural gas sector, for several reasons. First, the price of natural gas is not given by world markets, but has to be negotiated and this is expensive in terms of information requirements and negotiation skills.

Second, a contract has to be constructed that takes into account many possible scenarios several decades into the future. Such a contract may run to hundreds of pages and is therefore expensive. Compliance to the contract also has to be monitored and enforced, which adds to the cost.

Third, an expensive pipeline has to be built to transport the gas to the buyer. While the marginal cost of transportation is very low, the initial investment required may be prohibitive if financial markets do not function perfectly.

These very high transaction costs prevent a well-functioning market for natural gas to develop spontaneously. It is therefore left to the government to secure that all beneficial transactions take place, and they may not have the human and financial resources to do that. This implies that extraction may actually be lower than what is socially optimal.

3.4 Uncompetitive market

For markets to be efficient there should be a large number of buyers and sellers, or at least a lack of barriers to entry and a large number of potential entrants as insurance against monopolistic practices by existing firms.

The natural gas sector in Bolivia, however, has so few buyers and sellers, that each of them has a significant influence on the price. Basically, the price of natural gas in Bolivia is negotiated bilaterally between the government of Bolivia (one seller) and the governments of neighboring countries (a few buyers).

Due to the very few potential buyers, the seller of natural gas is not able to appropriate monopoly rent by restricting supply and raising prices. Rather, he has to promise a sufficiently low price, for a sufficiently long time, to induce potential buyers to make the large investments needed to switch to natural gas instead of more traditional energy sources.

Extraction is therefore not below the optimal level due to monopolistic behavior, but it may be below the optimal level because the low price needed to create demand discourages exploration and exploitation.

3.5 Myopic planning horizons and high discount rates

Since private companies operate in the natural gas market under time-limited constraints they cannot be expected to give much consideration to the state of the resource in the future beyond their contract.

It is thus the government's responsibility to secure adequate conservation over time. However, the government itself is likely to apply much higher discount rates than a fictive social planner. Governments are chosen for even shorter time-spans than the natural gas contracts, and the present government has a strong preference for producing results and income in their own period, rather than a future period, where the opposition might be in charge. This myopia would tend to imply a too rapid extraction compared to the optimal path.

3.6 Risk aversion

The variable that affects the optimal extraction path of natural gas most, is the price of its closest substitute, which is currently high quality fuel oil. This price is notoriously difficult to predict. It may rise over time due to scarcity, but it may also fall as other more environmentally friendly energy sources become economically attractive. In addition, there are large OPEC induced fluctuations in the oil prices, which makes the price difficult to predict even in the short run.

Limiting current extraction of natural gas in the hope that it will command higher prices in the future is a risky strategy. Given the high level of poverty and low current levels of income, Bolivia is not likely to assume such a high risk, even if the expected value of postponing extraction were higher than the expected value of extracting now.

3.7 Irreversibility

Extracting natural gas is an irreversible process and the option value of not extracting it should be taken into account. Theoretically, it is possible to re-inject natural gas that has

already been extracted, but since natural gas is very difficult to store, it has to be done immediately. Re-injection is a mechanism used to adjust production levels to export targets, not a mechanism that can be used to reverse investment decisions. If millions of dollars have been spent exploring and locating natural gas pockets, and billions of dollars have been spent building pipelines to consumers, then extraction is likely to go on until the gas pockets involved have been exhausted, even if the whole project would have been rejected under new circumstances. Investments in the natural gas sector are almost completely irreversible.

4. Other constraints on the optimal extraction path

4.1 Technological constraints

Oil and natural gas are usually found together in varying proportions, and the technological constraints of natural gas extraction depend heavily on the proportion of natural gas in each field. If the proportion is small, the gas is usually vented or flaired for safety purposes, or re-injected to maintain pressure for oil extraction (Codoni *et al* 1985).

In Bolivia, the natural gas content is usually high compared to the oil content, and in many cases there is sufficient gas to justify the enormous investment that is needed to transport natural gas in pipelines to the buyers.

However, a large part of the natural gas extracted is still not sold. For example, between 1972 and 1991, only 41.3% of total natural gas production in Bolivia was exported and 3.8% sold to domestic consumers. The rest was burned/vented (7.7%), used by the production company (2.9%), converted to liquids (1.3%), or re-injected (43%).

The Bolivian level of burning/venting is considered low (and thus responsible) by international comparisons (World Energy Council 1992).

The contract of natural gas exports to Brazil requires that all associated liquids must be extracted before delivery. Large amounts of Liquefied Petroleum Gas (LPG) will therefore be obtained as a side product, and this needs to be processed and marketed. A polyducto to Ilo in Peru is currently being negotiated for the purpose (VMEH 1999).

4.2 Legal constraints

The natural gas sector in Bolivia is governed by Ley de Hydrocarburos (1996), which states that all natural gas and oil in Bolivian ground is state property. A part of YPFB has remained a state enterprise with the responsibility of representing the state in the administration and signing of joint venture contracts for exploration, exploitation, and commercialization of hydrocarbons in Bolivia.

The law is basically designed to speed up exploration and exploitation. The process works in the following way: When a company wishes to produce natural gas, it first has to obtain the right to explore. Such rights are allocated in parcels of 2,500 hectares in an auction process to the company that promises to do the greatest amount of exploration work No company can have more than 40 parcels in traditional areas and no more than 400 parcels in non-traditional areas.

The right lasts for 40 years, but comes with some restrictions and requires some commitment. The company has to make a certain amount of exploration work (measured in Unidades de Trabajo para la Exploración (UTE)) each year, and each year they have to give back a certain amount of their parcel and limit their search to the remaining area. If they have

not found enough gas for commercial exploitation before the 15th year, the contract expires. If they find gas in sufficient quantities, they have to start exploiting it commercially within 10 years. Otherwise the contract expires.

The amount of exploration actually taking place is to a large degree determined by the size of the royalties that companies have to pay for the extraction of natural gas. To make sure that Bolivia would be able to meet the huge demand from Brazil, the government decided in 1996 that it was necessary to improve the incentives for exploration. They ruled that royalties on "new" natural gas (from fields not being exploited at the cut-off date of 30/04/96) would only be 18% compared to a royalty of 50% on "old" natural gas (Law No. 10170). Together, the favorable demand conditions and the favorable taxation laws implied a dramatic increase in certified reserves (proven reserves and likely reserves). By January 1, 2000, 94.8% of certified reserves were new and only 5.2% old (La Razón, 06/08/2000).

As a natural monopoly, transportation of natural gas is heavily regulated by the Superintendencia de Hydrocarburos. The tariff for transportation of natural gas in pipelines is set by the Superintendencia, currently (1997-2001) at a flat rate of US$ 0.41 per thousand cubic feet for domestic transport and US$ 0.18 per thousand cubic feet for export (Anuario Estadístico 1998, Superintendencia de Hidrocaburos). These rates were chosen to give Transredes a 12% return on their investments. The 12% return is guaranteed by the Superintendencia through an adjustment fund, which means that TRANSREDES has little incentive to be cost-efficient. In fact, they are likely to over-invest and inflate costs.

4.3 Contractual constraints

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 7.7 trillion cubic feet of natural gas to Brazil over a 20 year period according to the time profile shown in Figure 1.

The price of the gas at the entry of the pipeline is 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$ 7.7 billion. In addition, Bolivia will receive approximately US$ 1.4 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.

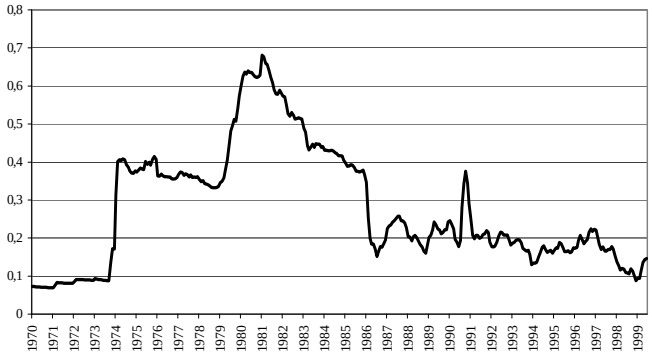
There is an important clause in the contract that gives the Brazilian oil company, Petrobras preferential treatment in the supply of natural gas to Brazil. This clause implies that Petrobras and its two associates, Total and Andina, is going to supply almost two thirds of the volume specified in this contract (Jemio 2000).

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.

If oil prices change, the contractual price of natural gas will change too, but with a lag. If oil prices double, it will take 2 years for the natural gas price to increase by 97 percent.

The natural gas price is anchored to the oil price level in the beginning of the 1990s, excluding the price hike in the first half of 1990. As Figure 2 shows, the oil price index averaged 0.20 during the reference period. Historically we have seen the price index vary between 0.07 and 0.68.

Figure 2: Oil price index (real terms)



Sources: www.energy.org for the oil prices in current US dollars and the IMF for the US consumer price index.

Using historical oil prices as guidelines, we can calculate likely minimum and maximum prices of the natural gas we are going to export to Brazil during the next couple of decades. If the oil price index stays at the reference level (0.20) then we will get approximately US$ 1.00 per thousand cubic feet of natural gas. If the oil price index increases to 0.68, the price of our gas will increase to US$ 3.40 per thousand cubic feet. If the oil price index falls to 0.07, the price of our gas will drop to US$ 0.35 per thousand cubic feet. There is a factor of ten between the minimum and the maximum price, so the amount of royalties we are going to receive is subject to considerable uncertainty.

4.4 Environmental and social constraints

The natural gas sector in Bolivia has to comply with the environmental regulations set out in Ley de Medio Ambiento No. 1333 and Reglamiento Ambiental para el Sector Hidrocarburos (Decreto Supremo No. 24335). These laws state in general that all activities should be carried out in ways that minimize environmental damage, and that all sites should be restored to their natural state when exploitation or extraction activities have ended. The companies have to make Environmental Impact Studies (EIS) before any construction begins, and these have to be approved by the regulating agency.

Since the companies operating in the natural gas sector depend on the goodwill of the people that are affected by their activities, they dedicate a substantial part of their budget (around 15%) to reducing environmental and social damage. As an example, the EIS for the Bolivian part of the Cuiaba pipeline, included both a Community Development Program, an Indigenous Development Program, the San Matías Integrated Natural Management Area, as well as the required program for erosion control, restoration, re-planting, and monitoring.

While natural gas causes relatively little environmental damage compared to other energy sources and compared to other mining products, it has environmental impacts in both the exploration phase, the extraction phase, and the transportation phase. There have already been several cases of oil spills during extraction and transportation. Last year there was a pipeline leak in Oruro, where 29,000 barrels of oil went into the river system (La Razón 13/08/2000). Transredes had to pay US$ 710,000 to farmers in the area for the damages caused (La Razón 20/08/2000).

Although the environmental regulations look tough on the books, in reality they are not stringently enforced and there are therefore plenty of cases of destruction of habitat and contamination of waters. What counts is not the law itself, but its actual implementation and its effects on cost and behavior (Panayotou 1997).

A map of Protected Areas and petroleum concessions in Bolivia show that there is considerable overlap between the two. In fact, more than half of all concessions in the departments of La Paz and Beni are located in protected areas. The two pipelines to Brazil both cross directly through two large protected areas (Atlas Estadístico de Municipios de Bolivia 1999, p. 29). This shows that in practice, economic activity tends to have priority over environmental protection in Bolivia.

Environmental organizations are especially concerned that the corridors opened by the pipelines may facilitate access for small farmers and loggers, in which case it will cause much more deforestation and disruption of fragile areas than just the right of way (La Razón, 13/08/2000).

Four environmental organizations (Fundación Amigos de la Naturaleza, Museo de Historia Noel Kempff Mercado, Missiouri Botanical Garden, and Wildlife Concervation Society) received US$ 20 million from the US Overseas Private Investment Corporation (OPIC) to protect the fragile dry forests that are affected by the pipeline to Brazil. However, the indigenous peoples living in the area complain that the construction of the pipeline is doing considerable damage to the environment, that biological resources are being stolen, that the environmental organizations are doing nothing to protect the area, and that the local communities have not been consulted and involved properly. In fact, in letters to the Ministry of Sustainable Development (16/05/2000 and 10/08/2000), indigenous people say that the pipeline, as well as the four environmental organizations, are unwelcome at their territories (La Razón, 13/08/2000 and 20/08/2000).

4.5 Demand constraints

Of the 32.2 trillion cubic feet (TCF) of certified natural gas reserves in Bolivia, there has been found markets for less than 10 TCF so far: 7.7 TCF to Southern Brazil, 0.3 TCF to the thermo power plant in Cuiaba, 0.15 TCF to the thermo power plant in Puerto Suárez, and 1.8 TCF for the domestic market, for the next 20 years.

In order to spread its risk and encourage price competition, Brazil has recently signed a contract with Argentina of approximately the same volume of natural gas as their contract with Bolivia. Thus, Bolivia lost this chance of expanding the Brazilian market for its natural gas. There may still be possibilities of selling natural gas to other neighbors. Chile is currently buying natural gas from Argentina, but they may also want to spread the risk and buy some gas from Bolivia.

Demand constraints are likely to be the most binding of all constraints, which implies that natural gas production will be below what Bolivia considers optimal. The experience of the past few years shows that when promising new markets have been identified, there is plenty of foreign capital available for doing the necessary exploration, extraction, and construction work to supply the natural gas.

Since companies cannot keep certified reserves for more than 10 years without starting commercial exploitation, we will probably see a slow down in exploration activity until new markets have been secured. It does not make sense to search for and certify natural gas that won't be needed until several decades into the future.

If we assume, pessimistically, that demand will not increase, but that we can fully use the currently planned pipeline capacity, then current certified reserves would last approximately till year 2075. The double of presently certified reserves would last to the middle of the next century.

If we assume, more optimistically, that Bolivia is able to increase demand for its natural gas by 10% per year, then current certified reserves will be used up by the year 2025. Already by 2032 would we have used twice the current certified reserves. There is no way we could find enough reserves to satisfy such demand growth for more than 40 years.

4.5.1 Local demand

The local demand for natural gas amounted to 41.4 billion cubic feet in 1999. 54% of the domestic demand comes from electricity generators, 38 % from local natural gas distributors, and the rest from refineries, pipeline operators, and other direct consumers (SH 1999a).

Local demand may be expanded if Bolivia makes a strong effort to change its energy matrix. Air pollution and the cost of transportation in Bolivia's cities would be reduced if all collective transportation vehicles (buses, mini-buses, trufis, and taxis) would switch to natural gas. The lower energy costs are likely to be a particular advantage for the poor, so the change would have several desirable effects.

It would require a big initial investment to adapt all the vehicles and service stations, but with a substantially lower price per kilometer, this investment would pay back relatively quickly for vehicles that drive a lot of kilometers. Due to borrowing constraints and short time horizons, this desirable change may not take place without government intervention.

5. Projected government revenues

The hydrocarbon sector is contributing substantially to the fiscal revenues of the Bolivian government. During the last decade, it has provided an average of 34 percent of current fiscal revenues. Most of these revenues, however, come from local gasoline taxes, which are levied on both imported and locally produced gasoline. Only 6 percent of revenues could be attributed directly to natural gas exports (Unidad de Programación Fiscal). The contribution from natural gas exports is going to increase dramatically, however, when the main export pipeline to Brazil starts operating at full capacity.

According to Ley de Hidrocarburos, 11 percent of the gross value of natural gas has to be paid as royalty to the department where the gas is extracted, 6 percent has to be paid to the central government, and 1 percent has to be paid to a compensation fund for Beni and Pando. In addition, there is a 25 percent tax on profits (and a 25 percent surtax on unusually large profits, which has not yet been accurately defined). Finally, there is a 12.5 percent tax on remittances to abroad. Below we will analyze the magnitudes of these royalties and taxes in more detail.

5.1 Royalties

Assuming that oil prices will fall from the current high level, but still stay above the reference price during the next 19 years, we estimate that royalties from natural gas exports will amount to approximately US$ 1.3 billion.

Since there will be a substantial production of liquid petroleum as a side benefit of the natural gas production, we should add the royalties that the extraction of this petroleum will generate. The gas/liquid ratio varies from field to field, but on average the value of the liquids will be of approximately the same magnitude as the value of the natural gas. Using the gas/liquid ratios observed for each company in the period January to August 2000, we estimate that the royalties from associated liquids will amount to approximately US$ 1.9 billion over the next 19 years.

Figure 4: Distribution of natural gas reserves among departments (by January 2000)

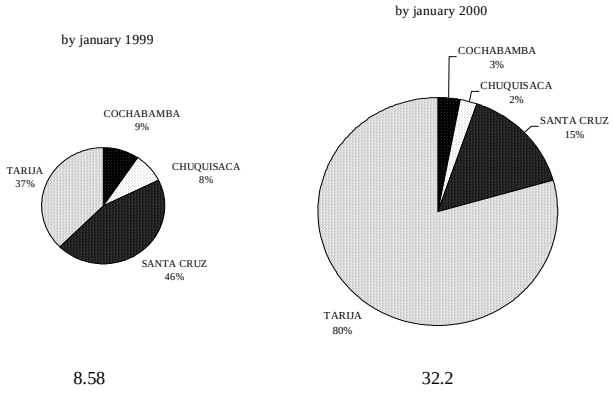


Table 5: Estimated royalties from Natural Gas exports & associated liquids (million US$)

Year	TGN	Tarija	Sta. Cruz	Cocha-bamba	Chuqui-saca	Beni	Pando	TOTAL
1999	2.75	1.39	2.98	0.28	0.24	0.30	0.15	**8.08**
2000	22.61	17.90	16.80	2.52	2.15	2.39	1.19	**65.54**
2001	30.92	32.91	16.00	2.67	2.27	3.26	1.63	**89.66**
2002	44.04	56.64	15.19	2.64	2.25	4.65	2.32	**127.73**
2003	50.90	69.29	14.69	2.53	2.16	5.37	2.69	**147.62**
2004	59.72	85.40	14.14	2.40	2.05	6.30	3.15	**173.17**
2005	57.01	81.47	13.23	2.44	2.08	6.01	3.01	**165.25**
2006	57.02	81.48	13.24	2.44	2.09	6.01	3.01	**165.28**
2007	57.14	81.78	13.40	2.30	1.96	6.03	3.01	**165.62**
2008	57.41	82.46	14.04	1.82	1.55	6.05	3.03	**166.36**
2009	57.41	82.46	14.04	1.82	1.55	6.05	3.03	**166.36**
2010	58.51	85.00	12.95	1.97	1.68	6.16	3.08	**169.36**
2011	58.54	85.11	12.64	2.10	1.79	6.16	3.08	**169.42**
2012	58.85	82.61	14.56	2.68	2.29	6.19	3.10	**170.27**
2013	58.87	82.55	14.51	2.76	2.35	6.19	3.10	**170.33**
2014	58.91	82.56	14.54	2.77	2.36	6.20	3.10	**170.43**
2015	59.45	83.11	14.82	2.79	2.38	6.25	3.12	**171.91**
2016	59.45	83.09	14.83	2.79	2.38	6.25	3.12	**171.91**
2017	59.45	83.07	14.84	2.80	2.39	6.25	3.12	**171.92**
2018	59.46	83.05	14.85	2.81	2.40	6.25	3.12	**171.93**
2019	59.46	83.03	14.85	2.82	2.40	6.25	3.12	**171.94**
TOTAL	**1,087.86**	**1,506.35**	**291.12**	**50.14**	**42.78**	**114.57**	**57.28**	**3,150.09**

Source: Authors' elaboration.
Note: Royalties are slightly underestimated, because these calculations assume that all hydrocarbons are new, while a small percentage is actually old, and have to pay the higher rate of royalties.

Since most of the royalties are paid to the departmental governments, rather than the central government, the distribution of natural gas among departments is important. So far, natural gas reserves are restricted to four of Bolivia's ten states: Tarija, Santa Cruz, Cochabamba, and Chuquisaca. As indicated in Figure 4, Tarija holds by far the largest reserves.

The uneven distribution of natural gas reserves is reflected in Table 5, which shows the estimated royalties derived from natural gas and associated liquids during the 20 year period of the Brazilian contract. Beni and Pando do not have any hydrocarbon reserves, but they receive royalties through the special 1% compensation fund.

The three highland departments (La Paz, Oruro, and Potosí) will only benefit from the natural gas adventure to the extent that the central government will spend some of their fiscal revenues there, and it is not likely to amount to more than a few dollars per person per year.

Tarija, on the other hand, will receive substantial royalties, amounting to around US$ 130 per person per year, if oil prices do not fall dramatically. Pando will also receive significant additional funds through the compensation fund. Pando receives one third of the one percent compensation fund, but due to the small population in Pando, that amounts to around US$ 35 per person per year.

Overall, the amount of royalties will be of approximately twice the size as the amount of HIPC debt relief over the next 20 years. On top of that the government will receive substantial amounts of taxes, as explained below.

Table 5: Predicted regional distribution of royalties from the hydrocarbon exploitation, 1999-2019

Department	Share of royalties from natural gas production (%)	Share of certified reserves by Jan. 1st, 2000 (%)	Share of population (%)	Royalties (% of GDP)	Average Royalties per capita per year (US$)
Central government	*34.5*				*4.6*
Tarija	47.8	80	4.8	8.4	131.0
Santa Cruz	9.2	15	21.6	0.3	5.8
Cochabamba	1.6	3	18.2	0.1	1.2
Chuquisaca	1.4	2	7.1	0.4	2.6
Beni	3.6	0	4.4	0.9	11.0
Pando	1.8	0	0.7	1.7	35.2
La Paz	0	0	29.0	0	0
Potosí	0	0	9.4	0	0
Oruro	0	0	4.8	0	0
Bolivia	100.0	100	100.0	1.1	13.3

Source: Authors' elaboration. Population growth rates by department are based on extended projections from INE for 2000-2010. GDP growth rates by department are extensions of the growth rates experienced in the period from 1992 to 1997, also from INE.

5.2 Taxes

Estimating taxes from the upstream part of the hydrocarbon sector is more difficult than estimating royalties. It is fairly easy to estimate the income of each company, because the amount of gas they are going to estimate is already fixed by 20-year contracts. The problem is information about investments and operating costs for each company, because such information is restricted and thus not available to us for all companies. Investment information is available for the capitalized companies (Chaco and Andina) and for the whole sector together.

To arrive at investment amounts for the non-capitalized companies in the sector, we assume that each company's investment is proportional to the quantity of gas they are going to export to Brazil. Operating costs were assumed to be US$ 200 per million cubic feet of natural gas and US$ 7 per barrel of liquid petroleum for all companies[4]. These assumptions together with contractual export quantities by company lead to the estimated taxes shown in Table 6 below. It is assumed that the companies do not try to evade taxes by inflating costs or otherwise. Notice that the total amount of taxes is predicted to be higher than the toatal amount of royalties.

Table 6 shows that Petrobras is going to be the largest tax contributor, by far, followed by Maxus, Andina, and Chaco. From 2004, when the pipeline to Brazil is operating at full capacity, the upstream part of the hydrocarbon sector should provide about US$ 190 million in taxes per year. This amount may be considerably reduced if oil-prices fall dramatically or if the companies manage to reduce taxes by inflating costs artificially or through other types of creative accounting. The taxes may turn out higher than estimated if world oil prices remain high and the surtax kicks in.

[4] According to Edgar Aguirre at YPFB. Personal communication.

Table 6: Estimated taxes form Natural Gas exports and associated liquids (million US$)

Year	Andina	Chaco	Vintage	Maxus	Perez Co.	Dong Wong	Tesoro	Petrobras	TOTAL
1,999	0.45	0.34	1.20	0.00	0.90	0.00	1.23	0.00	**4.11**
2,000	3.31	7.13	9.41	12.50	9.59	0.10	11.19	2.84	**56.07**
2,001	9.18	12.83	7.88	13.23	9.32	0.15	10.48	23.05	**86.12**
2,002	8.99	12.66	6.58	12.45	8.71	0.14	9.78	80.29	**139.59**
2,003	8.75	11.99	5.86	12.13	8.39	0.14	9.39	107.12	**163.77**
2,004	8.55	11.24	4.90	12.34	8.17	0.14	9.03	140.25	**194.63**
2,005	9.22	11.48	2.18	11.94	7.72	0.13	8.49	131.12	**182.28**
2,006	9.32	11.50	2.08	11.83	7.73	0.12	8.50	131.12	**182.19**
2,007	9.53	10.59	2.16	12.66	7.91	0.00	8.56	131.12	**182.53**
2,008	9.96	7.72	2.54	14.72	8.36	0.00	8.73	131.12	**183.15**
2,009	9.96	7.72	2.54	14.72	8.36	0.00	8.73	131.12	**183.15**
2,010	11.82	8.65	0.00	19.20	6.64	0.00	9.10	131.12	**186.53**
2,011	12.58	9.40	0.00	19.20	5.00	0.00	9.10	131.12	**186.41**
2,012	16.10	12.95	0.00	19.49	4.69	0.00	2.38	131.12	**186.73**
2,013	16.54	13.38	0.00	19.50	4.04	0.00	2.12	131.12	**186.69**
2,014	16.66	13.46	0.00	19.65	3.95	0.00	1.94	131.12	**186.77**
2,015	17.26	13.57	0.00	22.26	3.78	0.00	0.33	131.12	**188.32**
2,016	17.31	13.61	0.00	22.26	3.75	0.00	0.26	131.12	**188.32**
2,017	17.37	13.67	0.00	22.26	3.69	0.00	0.20	131.12	**188.31**
2,018	17.42	13.71	0.00	22.26	3.66	0.00	0.15	131.12	**188.31**
2,019	17.46	13.75	0.00	22.26	3.62	0.00	0.10	131.12	**188.31**
TOTAL	**247.73**	**231.33**	**47.33**	**336.88**	**127.97**	**0.92**	**119.81**	**2320.32**	**3432.29**

Source: Authors' calculations.
Note: We only include profit taxes and taxes on remissions to foreign countries. The sur-tax is ignored, since it has not yet been defined.

The total fiscal revenues from natural gas exports are extremely sensitive to the development of world oil prices. If oil prices will be just as volatile during the next 20 years as they were during the previous 20 years, Bolivia may receive any amount between US$ 85 million and US$ 1.4 billion per year. This volatility has serious consequences for the government's ability to plan and carry out a successful poverty reduction strategy, and some mechanism should be implemented to smooth out the effects of this volatility.

6. Conclusions and further research

This paper has presented an overview of the natural gas sector in Bolivia, with the purpose of identifying the most relevant policy-oriented questions to be addressed in subsequent research.

For policy purposes it would be highly desirable to know the optimal extraction path of our natural gas. However, calculating the optimal extraction path requires more foresight on the future developments of natural gas prices than we can muster. The future price of gas will depend in a very complicated way on the decisions of oil and gas suppliers around the world, on the energy taxation decisions of governments around the world, on the technological developments of alternative sources of energy, etc, etc.

What we have done instead in this paper is to identify factors that limit our ability to reach the optimal extraction path. Some factors are limiting from above, in the sense that they prevent us from increasing extraction rates, while other factors are limiting from below, i.e. they prevent us from reducing extraction rates. Since we do not know the optimal extraction path, we do not know which factors are binding and which are not. Box 1 below summarizes

the most important constraints that may prevent us from following the optimal extraction path.

It is important to realize that most of the companies operating in the Natural Gas sector in Bolivia are either state companies from neighboring countries or multinational corporations. Neither of these have Bolivia's long run interests in mind when they make decisions. However, their decisions can be affected through the way the industry is regulated. Currently all regulations are designed to induce companies to speed up extraction. This shows that Bolivian authorities believe that we are currently extracting at a slower rate than optimal.

A social planner with a longer time horizon than a typical Bolivian government might disagree with that. A rapid extraction rate only makes sense if the private and public sector can absorb and reinvest the rents from natural gas in a productive way. If they cannot invest the rents wisely, future generations would be better off with the natural gas in the ground.

This paper has shown that virtually all the benefits of the Natural Gas sector in Bolivia comes in the form of royalties and taxes to the central and departmental governments. These rents are highly volatile, however, and a mechanism for smoothing out the effects of this volatility is called for.

When making decisions on how to reinvest natural gas rents, the government should have two main objectives in mind: Long run economic growth and poverty reduction. These do not necessarily go hand in hand. Cross country evidence show that growth based on natural resources tends to increase inequality and therefore be less poverty reducing than other types of growth. The challenge for Bolivia is to reinvest the money so that it both promotes growth and reduces inequality.

Box 1: Factors that work to speed up or slow down extraction of Natural Gas

Factors that speed up extraction:

- *Imperfect resource ownership*
  Companies in the Natural Gas sector do not own the natural gas in the ground. Instead they have contracts that allow them to extract and sell the gas they find within a certain time period. Therefore they have no incentive to preserve the gas beyond their contract period.
- *The Hydrocarbon Law*
  The laws governing the hydrocarbon sector gives companies strong incentives to speed up extraction.
- *High discount rates*
  The official decision to speed up extraction is a consequence of the high discount rates used by the Bolivian government.

Factors that slow down extraction:

- *Large transaction costs*
  Before selling the first cubic foot of natural gas to a new customer, billions of dollars have to be spent to locate the natural gas, to negociate a contract, and to build the necessary infrastructure. Such high transaction costs prevent a well-functioning market from developing spontaneously. It is therefore the government's responsibility to make sure that all desirable transactions take place, and they may not have the capacity to do so.
- *Limited demand*
  There is no world market for natural gas, so the value of natural gas depends very much on the availability of markets nearby. Such markets need to be developed and nurtured, because due to the high transaction costs, they do not develop spontaneously. This also holds for local demand.

To analyze these issues and to be able to make recommendations to the government, we recommend the construction of a dynamic Computable General Equilibrium (CGE) model of the Bolivian economy. The model should be fairly dis-aggregated in the household sector so that the distributional effects of any policy initiative and investment choice can be analyzed.

In order to analyze the effects of different re-investment options, we need to have at least three categories of capital: human capital, incorporated physical capital, and unincorporated physical capital. Each of these would have different effects on growth and poverty.

This paper has shown that the benefits of the natural gas sector is going to be concentrated in a few departments. Tarija currently holds 80 percent of all certified natural gas reserves while it only holds 5 percent of the Bolivian population. This means that the impact of natural gas is going to be substantial in Tarija, but rather limited in the other eight departments. We therefore suggest to do an in depth analysis of the impacts of the natural gas sector in Tarija.

Most countries or regions that have found oil and decided to base their development strategy on this resource have been overly optimistic about the developmental effects of the oil rents. Instead of sustainable long run growth, they have experienced problems in terms of increased rent seeking behavior, increased corruption, displacement of other productive sectors, under-development of alternative tax bases, and addiction to easy oil dollars (Karl 1999). We fear that this might happen in Tarija also, and suggest that it would be wise to look for early warning signs. In that way it may be possible to suggest initiatives that would reduce bad side-effects of the natural gas sector and increase the good side-effects.

With the one percent compensation fund for Beni and Pando, the government is trying to secure a more even distribution of the benefits from Bolivia's natural resource wealth, but it is not clear that this is enough. It would be interesting to test whether the natural gas sector is contributing to regional divergence or to regional convergence. The answer is not clear, a priori, since Tarija was one of the poorest departments in terms of per capita GDP before the capitalization of YPFP and Santa Cruz was the richest department. The answer can be found relatively easily, by assuming that the government revenues from natural gas are invested with the same rates of return in each department. This will allow us to project per capita GDPs forward to year 2019 for two scenarios: one with the natural gas sector and one without. We can then regress the average growth rates in the two scenarios on the initial level of GDPs (year 1999). If the coefficient estimate in the regression including the natural gas sector comes out higher than the coefficient estimate in the regression without natural gas sector, we can conclude that the natural gas sector (and the laws governing it) contributes to regional divergence.

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