MODELLING TO ASSES POLICIES ON GAS PENETRATION IN THE COLOMBIAN ENERGY SECTOR

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ABSTRACT

As the Colombian gas industry rapidly captures a larger share of the energy market, it is difficult to assess the extent of its effect both within the gas sector as in connection with its substitutes. For years politicians and experts have argued in favour of an extensive gas plan for Colombia, yet little has been done in terms of valuing negative impacts. Gas benefits have been partially evaluated, as a substitute in the household and commerce sectors for cooking and water heating as well as in the power supply industry for electricity generation – some progress has been made in this sense.

However, little is known in relation to gas availability (reserves and transport) and its use for large-scale urban transport (taxis and buses). Many questions still remain unanswered, such as supply reliability, market penetration and environmental impacts. This paper exhibits a model as support tool to address some of these questions, particularly with respect to the sustainability and discovery issues. Some results are exhibited.

INTRODUCTION

The implementation of an extensive natural gas plan in Colombia, since the beginning of the 1990's, has led to a more diversified energy market in this country. Natural gas is being used mainly for power generation, as a substitute for hydroelectricity, and also for cooking and water heating in the household sector - thus the motivation for evaluating its impact into the market.

As liberalisation policies are strengthen in Colombia, analysts have observed that: a) most of the new generation capacity being built (under private schemes) is based on natural gas, and b) the residential and commercial gas markets are rapidly growing as a result of the new urban gas distribution networks now being constructed. However, both government and energy analysts have not carefully addressed the issue of reliability of supply. In this industry, supply reliability is conditioned on the transport and production capacity (AHLBRANDT and TAYLOR, 1993).

In the following sections, a model for the natural gas supply-system is exhibited. This model includes reserves, supply and transportation modules. The model, system dynamics-based, represents interactions between supply, demand and transportation capacity. Demand is modelled here for six regions in order to define the consumer nodes in the gas network and to consider regional particularities (NESBITT, 1973). Supply is divided into two zones that are the supply nodes at the gas network; its evolution is based on reserves potential and varies according to the market dynamics. The model structure makes possible to consider prices, supply and probable reserves scenarios, to support the evaluation of policies on gas penetration in Colombia.

BACKGROUND

Although the exploration activity in Colombia is low, there have been significant gas discoveries in four of the five most explored sedimentary basins. The exploration activity is mainly undertaken by private companies in association with Ecopetrol, the state-owned company, which having little participation as an exploration company itself, has oriented its policies towards a more important involvement of foreign investment in exploration.

Despite considerable findings in the 1970´s, the natural gas market has been limited because of the inappropriate transportation infrastructure, confining its use to areas influenced by the production fields. During the 1990s, construction of gas pipelines had begun with the objective of connecting large urban centres with the production fields. The construction of both pipeline networks and the urban distribution systems are being undertaken by private companies under the scheme of government concessions.

Power generation and other industrial sectors are the principal consumers of the growing natural gas market. In recent years, the residential sector has increase its participation in the natural gas market while its demand for natural compressed gas is less than incipient.

A ceiling top regulates gas prices for fields discovered before 1995. Ceiling fixation for natural gas prices is defined as reference to the prices of substitutes and will be maintained until the year 2005, when it will disappear. Transportation prices now depend on the network connecting costs and on take or pay volumes contracted.

MODEL DESCRIPTION

The model, developed to assess policies on gas penetration in Colombia, comprises modules for demand, supply and transportation whose interactions allow simulating the system behaviour.

In the gas industry, not only demand but also production growth are closely related to the existence and capacity of networks connecting supply and demand nodes. If such a capacity turns insufficient, there will be little incentives for investment in exploration or in new gas based power generation projects, as well as in equipment or appliances for domestic use. Similarly, there is not incentive for investment in transportation infrastructure unless there are sufficient potential users and gas reserves. The relations described before are shown in Figure 1.

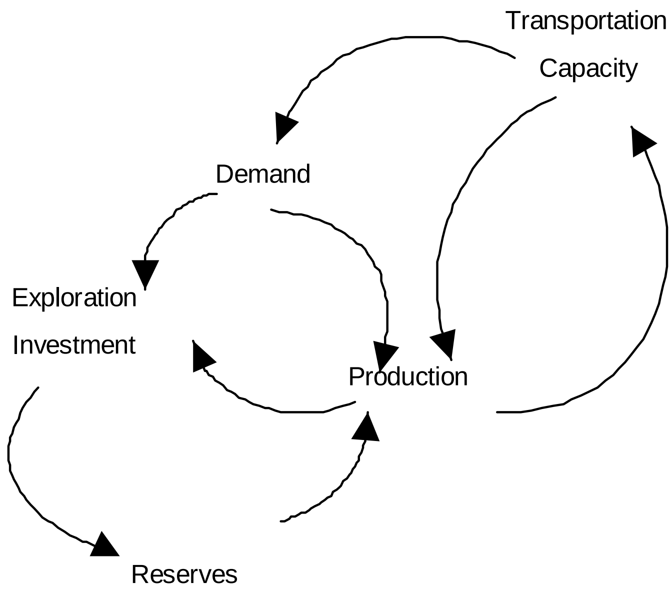

Figure 1. Dynamics of demand, exploration, production and transport of natural gas.

A. SUPPLY MODULE

The supply module is based on the finite resource life cycle, as in the US natural gas case (NAILL, 1979; NAILL and BEHRENS, 1980). Its principal characteristics are: a) finite resource availability, b) the lack of interaction between the natural gas and petroleum industries, and c) the same agent is in charged of both exploration and production. The basic supposition is that prospecting and exploration investments, which are stimulated by prices, must lead to new proven reserve discoveries given an initial reserve level. It is considered that estimates of the initial reserves potential in a region can change depending on the knowledge achieved through exploration and the new technologies for development.

The task of estimating fossil fuel reserves is always a difficult one for it is essentially a behavioural, judgmental decision making process, despite the seemingly hard, scientific and geological inputs to the process. As a result, estimations show a tendency to exaggerate size of recoverable reserves (MORECROFT and VAN DER HEIDJEN, 1991).

There are not estimates for gas reserves in the Colombian sedimentary basins, though it is commonly accepted that there is a great reserve potential. For this reason, the model described uses scenarios of reserve levels to evaluate pessimistic and optimistic scenarios.

A diagram for the supply module and its relations with demand and transport is shown in Figure 2.

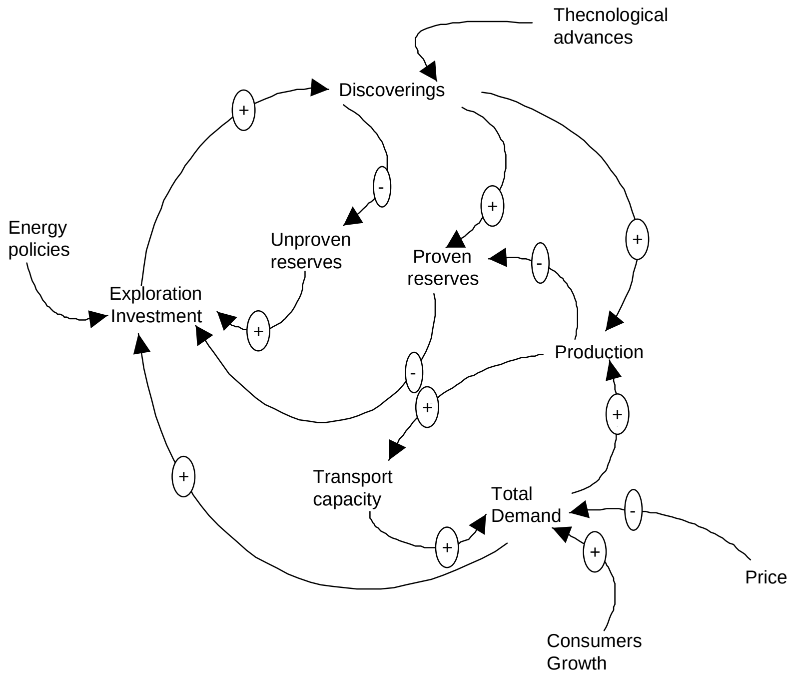

Figure 2. Supply module

B. DEMAND MODULE

The demand module is based on the UN - UPME model (Dyner and Bunn, 1997; Franco and Dyner, 1998). Residential, Industrial (except electricity production) and Power generation are the three consumer sectors considered in the model. Residential demand is a function of both the connection rate into the gas pipeline and the household mean consumption rate. Industrial demand depends on industry growth and conversion plans, whereas thermal generation demand is obtained from the 'indicative expansion plan' on power generation. Demand is geographically located in the grid node of the corresponding distribution system linked to the network.

C. TRANSPORT MODULE

The transport module focuses on the distribution problem from the production sites to the demand nodes. It aims to minimise transportation costs, taking into account the maximum productive capacity of the existing fields, the capacity of the network and demand of consuming centres.

The transport module is capable of determining the expansion needs of the network according to the demand and production growth at each node within the grid. Note that the optimal transportation solution includes production costs.

The problem formulation is as follows:

Minimise

$$\sum_{i}^{n}\sum_{k}^{m} Cik * Xik + \sum_{i}^{n} CPi * (\sum_{k}^{m} Xik)$$

i=1..n	Production nodes
k=1..m	Demand nodes

S.T:

$$\sum_{i}^{n} Xik \geq Dk$$

$$Xik \leq Cik$$
$$Xik \geq 0$$

Cik	Transport cost between nodes i - k
Xik	Transported volume
$Capik$	Pipeline capacity between nodes i- k
CPi	Production cost node i
D_K	Demand node k

When connected to the supply module, the transport module finds an optimal production rate for the two producing zones considered. This optimal value adjusts the production rate in the supply module at each simulation step.

SCENARIO ANALYSIS AND RESULTS

Estimations of reserve potential are subject to uncertainty. For this reason, two scenarios for the system's initial reserves were analysed. The first scenario considers reserves equivalent to 1400Mbeq(Millions of equivalent barrels) while the second considers initial reserves amounting to 200Mbeq. Price regulation is an important issue to be examined, for it imposes an artificial restriction to market growth. During price regulation periods, production is reduced when supply is limited (NAILL, 1973). Due to the expected future market liberalisation, high and low price projections were included. Figure 3 shows price projections in terms of US$/MCF(Millions of Cubic feet).

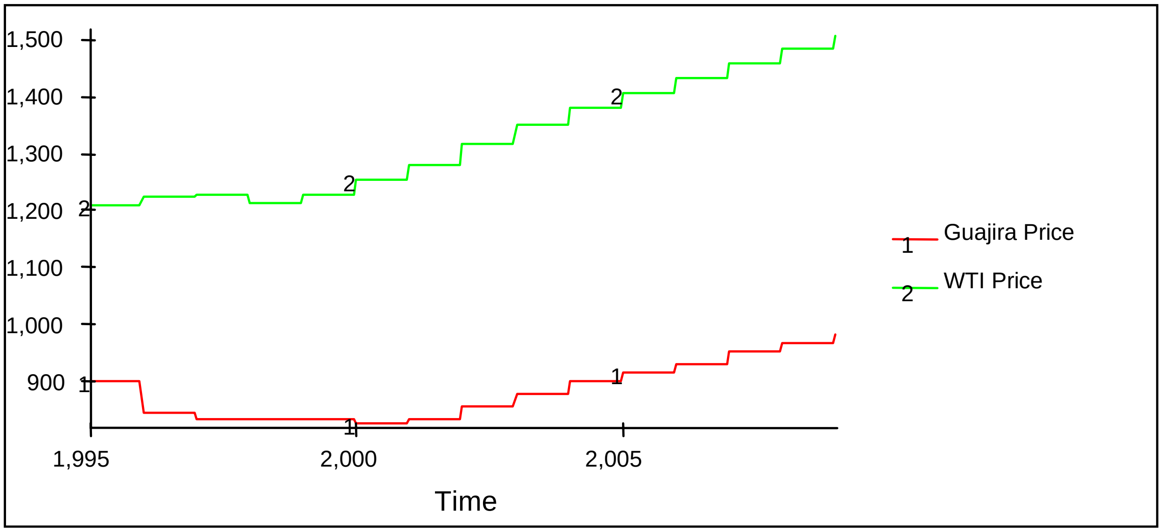

Figure 3. Price projection 1995-2005

The scenarios constructed here considered a number of alternatives including system behaviour when production is not dependent on transportation cost. Table 1 presents the number given to each of the analysed scenarios.

Table 1. ANALYSED SCENARIOS

	PRODUCTION FOR OPTIMAL TRANSPORTATION	DEMAND - DEPENDENT PRODUCTION
HIGH RESERVES POTENCIAL HIGH GAS PRICES	1: Basic scenario	2
LOW RESERVE POTENTIAL HIGH GAS PRICES	3	4
HIGH RESERVES POTENTIAL LOW GAS PRICES	5	6

As can be observed in Figure 4, when the initial reserves potential is below 2800GPC, it is not possible to fulfil the natural gas plan, neither for the residential and industrial sectors, nor for the expansion of the power industry. Fortunately, this minimum level is lower than the most pessimistic estimates.

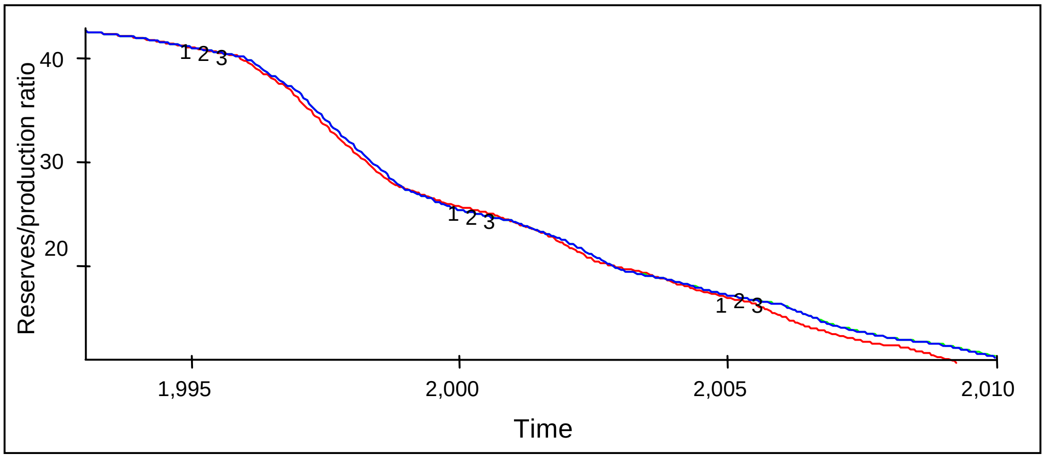

Figure 4. Production reserves ratio. Line 1 for initial reserves below 2800GPC.

Under price-regulated scenarios, there were not major production changes, and demand satisfaction levels remained constant both for low and high prices. Similarly, there were not changes in the reserves level. Low prices, however, may lead to a reduction on production - yet sufficiently large to attended demand.

Under unregulated scenarios, market prices lead to increases in production and discoveries, thus reducing the lifecycle of resources. Figure 5 shows the production evolution under regulated and unregulated price scenarios. Line 2 corresponds to market prices.

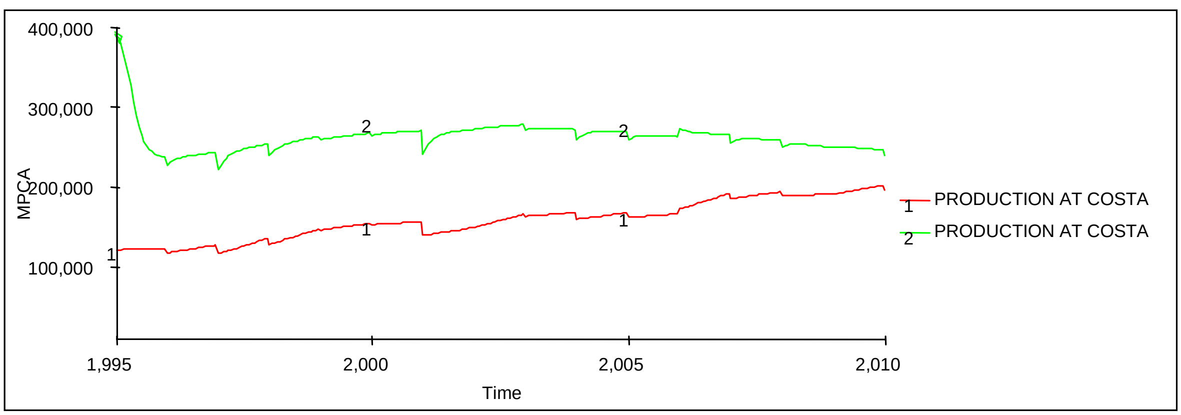

Figure 5. Production rates. Line 1 regulated prices scenario, line 2 unregulated prices scenario.

Security of supply is mostly influenced by the transportation capacity - lack of it can delay demand growth or favour the use of substitutes. Figure 6 shows how under one of the demand scenarios, all available transportation capacity will be used by the year 2007.

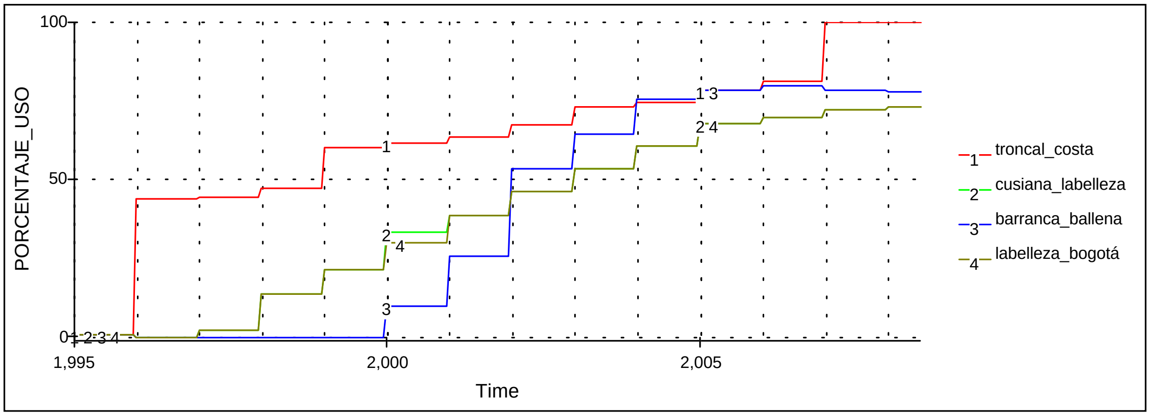

Figure 6. Percentage of transportation capacity used.

When transportation is optimised, the use of most the economical resources are favoured as can be seen in Figure 7. Lines 1 and 3 represent proven reserves for productive regions when the supply module is connected to the transportation module. Lines 2 and 4 show the reserves behaviour when production is not optimised by transportation costs. Figure 7 also indicates how exhaustion of economical reserves prompts production increments in other zones

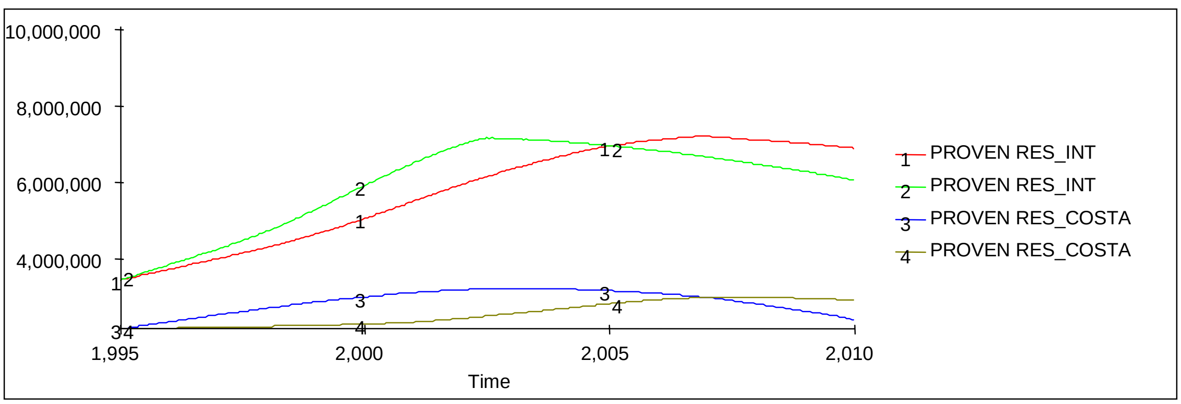

Figure 7. Proven reserves under transportation-optimisation scenarios.

CONCLUSIONS

The model described in this paper allows analysing the evolution of natural gas supply under different conditions on prices, reserves and production. The model can be modified to consider the effect of the demand growth generated by the use of compressed natural gas in large-scale transportation systems.

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