Integration in the Natural Gas Industry in South America

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Objective

- To identify the optimal policy for the integration in the South America's NGI using a mathematical model that allows to identify NG flows among different nodes that minimize total costs (production and transmission) for the region.

Importance of Integration

- Integration is a process by which two or more countries start doing complementary actions, and barriers that could have existed start removing.
- In South America energy integration was thought mainly from hydroelectricity. NG market appears as an alternative and now the accent is put on it.
- Integration is weakening as a consequence of the political and economic project embodied in the countries.
- There is a need to restart discussing how important integration is.

Regional Analysis

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- Factors fostering integration of the NG market:
  - Seasonal Complementarity between the three major consumer markets (Argentina, Brazil, and Chile).
  - Significant development of the existing pipeline network linking the countries of the region.
  - Liquefied Natural Gas, an alternative way of promoting NG integration.

Current Status of NG Integration

Regional NG Exchange Matrix

(MM of m³/day)

Year 2004

Exports →

Imports ↓

	Fueg Arg	Nqn Arg	Norte Arg	Argentina	Bolivia	Brazil	Chile	Colombia	Peru	Uruguay	Venezuela	Trin & Tob
Fueg Arg	-			30,6								
Nqn Arg		-		74,9								
Norte Arg			-	17,6								
Argentina				-		1,4	20			0		
Bolivia				2	6	19						
Brazil						26						
Chile							3					
Colombia								17				
Peru									2			
Uruguay										-		
Venezuela											77	
Trin & Tobago												39
Total Consumpt	**-**	**-**	**-**	**103,9**	**5,9**	**47,3**	**22,7**	**17,3**	**2,4**	**0,3**	**77,0**	**38,8**

The Model

Gas Network Model → Transmission Problem

- A node can inject gas (to supply), demand gas, both, or connect two different nodes.
- Flow between nodes is restricted by pipeline capacity.
- NG can flow in both directions.

Assumptions:

- Minimum unit of analysis → nodes (countries).
- No restrictions on transport capacity within each country.

The Model

Objective Function (to be minimized)

$$CT = \sum_{i=1}^{m} \sum_{j>i}^{m} ct_{ij} \left| x_{ij} \right| + \sum_{i=1}^{m} cp_i x_{ii}$$

Where

i,j = 1,2, ..., m, natural gas nodes (exporting, importing, or hubs);
ct_{ij} = transmission cost from node *i* to node *j*;
cp_i = production cost (wellhead price) of natural gas in node i;
x_{ij} = quantity of natural gas transmitted from node *i* to node *j*.

The Model

Constraints

1. Node equilibrium

$$\sum_{i=1}^{m} x_{ij} = D_j$$

For all j = 1,2, …, m

2. Production capacity in each basin

$$x_{ii} \leq a_i$$

For all i = 1,2, …, m

a_i = maximum of NG production in basin i.

The Model

Constraints (continued)

3. Transmission Capacity

$$x_{ij} \leq \gamma_{ij}$$

For all i,j = 1,2, …, m

being γ_{ij} the transmission pipeline capacity between nodes i and j

4. Non-negative level of NG produced

$$x_{ij} \geq 0$$

For all i,j = 1,2, …, m

The Data

Production Capacity: annual volume of NG that may be produced not to exhaust proven reserves for a time horizon of analysis.

Domestic Demand: annual volume of domestic consumption for the calibration year, adjusted by an interannual growth rate applied to the horizon analysis.

The Data

Transmission Capacity: maximum volume (MMm^3/day) of NG that can be transported between nodes.

Transmission Costs: for each "route", expressed in US$ per MMm^3/day.

Results

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- We analyze four cases (basis case, demand growth, peak consumption and NG growth related to GDP).
- Base year for the calibration of the model and for doing forecasts: 2004.
- For each year under study, exogenous demands are verified in each node.

Results: Basis Case

Transmission costs

Argentina: tariff structure authorized (set) by the Regulator.

Argentina-Chile: Noroeste → Norandino pipeline cost; Neuquina → GasAndes pipeline cost; Fueguina → theoretical transport cost estimated from the product between a unit cost and the distance of the longest Methanex pipeline.

Argentina-Brazil: non-interruptible service transport cost of TGN and Aldea Brasilera-Uruguayana pipeline cost.

Results: Basis Case

Transmission costs (continued)

Argentina-Bolivia: theoretical cost multiplied by the distance of Madrejones-Campo Durán pipeline.

Bolivia-Brazil: theoretical cost multiplied by the distance of the GasBol pipeline.

Production limit

Assumption on reserves: increase in production limit of 10%, uniformly for each basin.

Transmission capacity constraint


South America
Caribbean Sea
North Atlantic Ocean
South Pacific Ocean
South Atlantic Ocean
VENEZUELA
COLOMBIA
GUYANA
SURINAME
French Guiana (FRANCE)
ECUADOR
PERU
BRAZIL
BOLIVIA
PARAGUAY
CHILE
ARGENTINA
URUGUAY
PANAMA
COSTA RICA
NICARAGUA
HONDURAS
Caracas
Bogotá
Quito
Lima
La Paz
Asunción
Buenos Aires
Montevideo
Brasília
São Paulo
Santos
Rio de Janeiro
Córdoba
Santa Fe
Mendoza
Valparaíso
Santiago
Concepción
San Miguel de Tucumán
Salta
Antofagasta
Iquique
Arica
Sucre
Potosí
Cochabamba
Porto Alegre
Florianópolis
Curitiba
Mar del Plata
Bahía Blanca
Puerto Montt
San Carlos de Bariloche
Comodoro Rivadavia
Río Gallegos
Punta Arenas
Ushuaia
Strait of Magellan
Stanley
Falkland Islands (Islas Malvinas) (administered by U.K., claimed by ARGENTINA)
South Georgia and the South Sandwich Islands (administered by U.K., claimed by ARGENTINA)
Equator
Tropic of Capricorn
Scale 1:35,000,000
Azimuthal Equal-Area Projection
500 Kilometers
500 Miles
Boundary representation is not necessarily authoritative.
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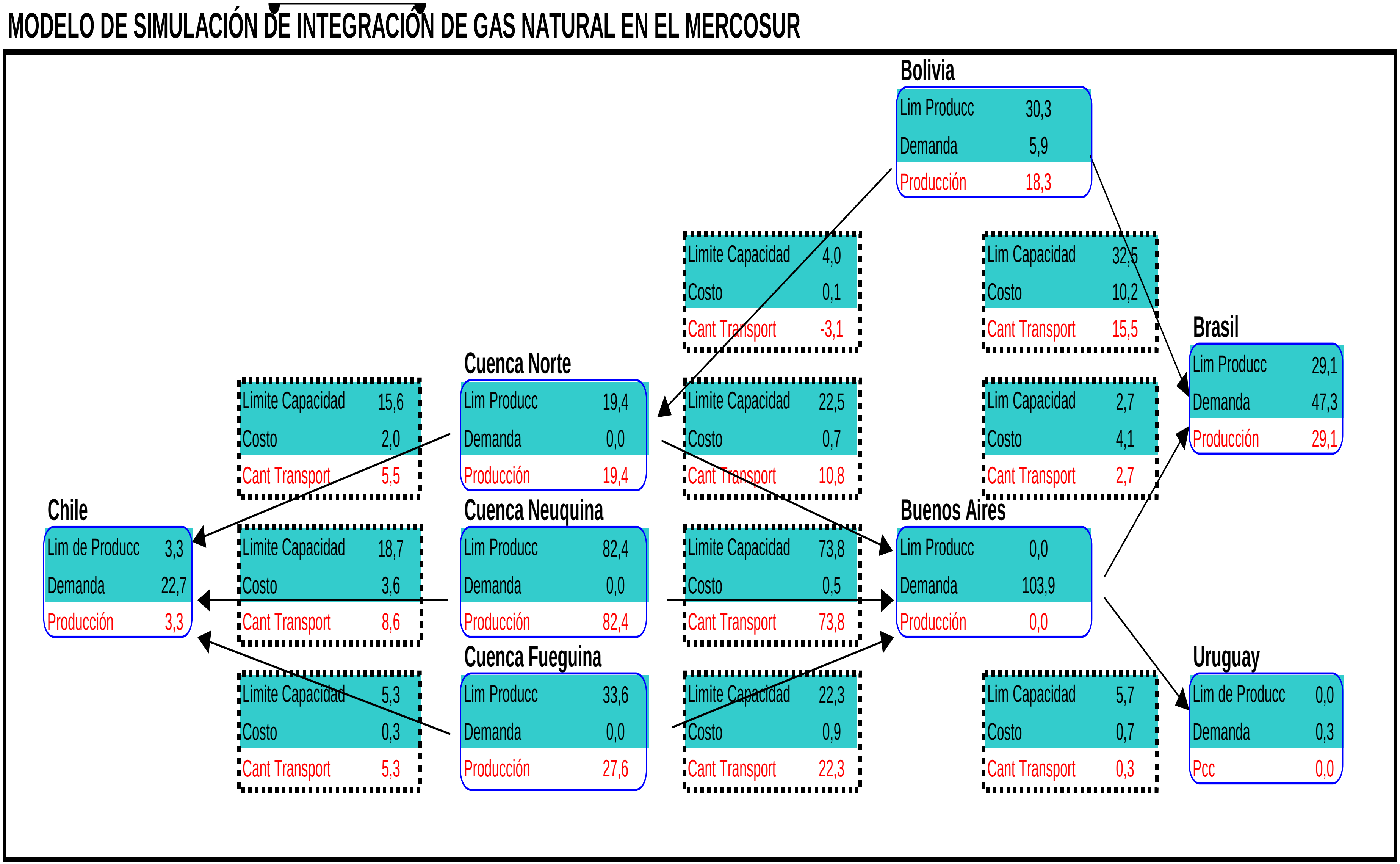
Results: Basis Case



Results: Basis Case

Basis Case

Year ***2004***

Objective Function

Total Cost	**6.470,93**	annual MM US$

1- Node Equilibrium

Nodo	Oferta Total	Condición	Demanda Endógena		Verificación
Argentina	103,9	=	103,9	(MMm3 día)	OK
Bolivia	5,9	=	5,9	(MMm3 día)	OK
Brasil	47,3	=	47,3	(MMm3 día)	OK
Chile	22,7	=	22,7	(MMm3 día)	OK
Uruguay	0,3	=	0,3	(MMm3 día)	OK
Fueg Arg	0,0	=	0,0	(MMm3 día)	OK
Nqn Arg	0,0	=	0,0	(MMm3 día)	OK
Norte Arg	0,0	=	0,0	(MMm3 día)	OK

Results: Demand Growth

Demand

Adjusted in each node using the geometric average of its annual growth rate observed in each country in the last five years.

Model run for 2010 (considering constraints at the time of calibration) → Obstacle for integration?

Results: Demand Growth

Demand Growth Case

Year ***2010***

Objective Function

Total Cost	**6.766,16**	annual MM US$

1- Node Equilibrium

Nodo	Oferta Total	Condición	Demanda Endógena		Verificación
Argentina	72,5	=	72,5	(MMm3 día)	OK
Bolivia	9,6	=	9,6	(MMm3 día)	OK
Brasil	56,5	=	87,7	(MMm3 día)	-31,20
Chile	26,7	=	26,7	(MMm3 día)	OK
Uruguay	2,8	=	2,8	(MMm3 día)	OK
Fueg Arg	0,0	=	0,0	(MMm3 día)	OK
Nqn Arg	0,0	=	0,0	(MMm3 día)	OK
Norte Arg	0,0	=	0,0	(MMm3 día)	OK

Results: Peak Consumption

Average demand is adjusted for the year of calibration by a specific load factor for each country.

Simultaneity peak consumption for different categories of consumers is assumed.

Results:Peak Consumption

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Peak Consumption Case

Year ***2004***

Objective Function

Total Cost	**7.375,20**	annual MM US$

1- Node Equilibrium

Nodo	Oferta Total	Condición	Demanda Endógena		Verificación
Argentina	121,3	=	129,8	(MMm3 día)	-9
Bolivia	6,5	=	6,5	(MMm3 día)	OK
Brasil	47,3	=	47,3	(MMm3 día)	OK
Chile	22,7	=	22,7	(MMm3 día)	OK
Uruguay	0,0	=	0,4	(MMm3 día)	-0,41
Fueg Arg	0,0	=	0,0	(MMm3 día)	OK
Nqn Arg	0,0	=	0,0	(MMm3 día)	OK
Norte Arg	0,0	=	0,0	(MMm3 día)	OK

Results: Demand Growth related to GDP

To forecast the NG demand growth, the GDP growth rate is used.

Model run for 2010 (considering constraints at the time of calibration) → Obstacle for integration?

Results: Demand Growth related to GDP

Demand Growth related to GDP Case

Year ***2010***

Objective Function

Total Cost	**6.470,93**	MM USD/year

1- Node Equilibrium

Node	Total Supply		Demand	Unity	Verification
Argentina	103,9	=	112,6	(MMm3 día)	-9
Bolivia	5,9	=	6,0	(MMm3 día)	0
Brasil	47,3	=	51,1	(MMm3 día)	-3,8
Chile	22,7	=	28,1	(MMm3 día)	-5,37
Uruguay	0,3	=	0,5	(MMm3 día)	-0,13
Fueg Arg	0,0	=	0,0	(MMm3 día)	OK
Nqn Arg	0,0	=	0,0	(MMm3 día)	OK
Norte Arg	0,0	=	0,0	(MMm3 día)	OK

Concluding Remarks

- The Basis Case is a representative one (results adjust to the actual behavior of NG market).
- For the short run, the Peak Consumption Case (Winter Case) shows transport problems.
- When demand growth rates are applied, problems with transport and production emerge.
- When demand growth rates are related to GDP, we also have problems with transport and production, but in a less severe level.
- Different times in peak consumption (particularly considering Argentina, Brazil, and Chile) should encourage a better process of integration.