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Canadian Gas Exports :

Modeling a Market in Disequilibrium [1]

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Canada provides a major part of the additional volumes required by the huge American gas market. With a rather high reserves-production ratio, Canadian gas production will face no major technical constraints until the end of the century. However, large distortion due to Canadian regulatory policy and disequilibrium in the US gas market constrain supply and demand. In the first section, both volume and price historical regulation are briefly analyzed. Traditional econometric analysis of the North American gas market cannot be used any longer. It is necessary to explicitly take into account the fact that supply of export and demand for import are not necessarily equal to the physical quantities actually exchanged on the market.

This paper provides in section 2 a comparison of various limited dependent variable models to deal with this kind of particularity. In this way, parameters of behavioral relationships of the operators are identifiable. The models are intended to provide a realistic background in an era when markets become deregulated. Statistical aspect of the disequilibrium approach used in this paper has been introduced by FAIR and JAFFEE (1972) and developped by MADDALA and NELSON (1974).

1. Canadian Natural Gas Regulatory Policy

Canada has a large production potential for natural gas with a life index around

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thirty. With a rather small population, indigeneous consumption is not sufficient to support the economic exploitation of those ressources. Natural gas exports are necessary to finance exploration and production activities. The exports share represented around one third of production during the 60's and 70's, to reach 40 % currently. As their only neighbor and one of the major gas consumers, the US is the natural client of Canada. This paramount importance of exports historically led Canadian authorities to regulate both quantities and prices on this market. The feature of this regulatory policy is not only to use exports as a way to increase domestic production profitability but also to ensure national energy requirements.

1.1 Export Volumes Regulation

The discovery of huge natural gas reserves in Western Canada during the 50's leads to the creation of the National Energy Board (NEB) in 1959. One of the task of this institution is to control the export volumes which must be a "surplus to Canadian requirement". To be authorized export volumes must satisfy a reserve test and a deliverability test. Despite those reserve formula, natural gas exports are almost multiply by ten during the 60's. During the next decade, as a result of the first oil shock, the policy of the NEB became a real constraint for the exports (see PUZIENE, 1986). The following table provides an illustration of these restrictions :

Table 1. **Canadian Gas Exports to the US**

MMcf	Authorized Volume (1)	Exported Volume (2)	% (2)/(1)
1970	804	777	97
1971	967	911	94
1972	1032	1009	98
1973	1069	1027	96
1974	1064	959	90
1975	1053	948	90
1976	1046	954	91
1977	1041	997	96
1978	1043	881	84
1979	1050	1001	95
1980	1156	796	69
1985	1614	778	48

Source : Energy Information Administration and N.E.B

At the beginning of the 80's the NEB relax the volume constraint. However the

exports decrease dramatically due to the "gas bubble" within the US gas market and the relatively low competitivity of the Canadian prices. In fact the regulatory policy in the 80's rely mostly on pricing policy.

1.2. Price Regulation

At the very beginning the NEB set that price was supposed to be "just and reasonable". In 1967 the NEB provides a more precise definition of this price. It must cover production costs, exceed domestic prices and be comparable to the least cost alternative fuel in the US. In 1976 the concept of substitution value is advanced. The price of Canadian gas export is related to the cost of oil import. During the 70's, the NEB can increase border prices without diminishing export volumes as a result of chronic excess demand on the US gas market.

The appearance of the "gas bubble" in the US, as well as the second oil shock and his related border price increase, lead to a sharp decline of demand for import gas. Since 1983 Canada has introduced a special Volume-Related Incentice Price applicable to 50 % of annual licenced volume. This is the beginning of a more market-oriented policy. Now, prices are more and more set through direct negociation between buyers and sellers.

Table 2. **US Domestic Prices (1) and Border Prices (2) - $/Mcf**

Year	(1)	(2)	Year	(1)	(2)
1960	0.14	0.21	1977	0.79	1.99
			1978	0.91	2.19
1965	0.16	0.26	1979	1.18	2.61
			1980	1.59	4.33
1970	0.17	0.27	1981	1.98	4.85
1971	0.18	0.28	1982	2.46	4.98
1972	0.19	0.31	1983	2.59	4.51
1973	0.22	0.35	1984	2.66	4.04
1974	0.30	0.55	1985	2.51	3.17
1975	0.45	1.21	1986	1.94	2.42
1976	0.58	1.73	1987	1.71	2.12

Source : C.P.A. Statistical Handbook and E.I.A.

2. Modeling Canadian Natural Gas Exports

The goal of our modelisation is to explain Canadian gas export to the US by taking into account :
- Regulation of the Canadian authorities
- Particular situation of the US gas market.

The brief above analysis of the market gives us some insight about constraints on supply and demand.

During the 70's the supply of export is constrained by the volume authorized by the Canadian regulation. Of course this constraint has never been reached. In our model we consider that the constraint is effective if exports exceed 95 % of authorized volume. This because of the friction prevailing on the market.

The situation has completly reversed during the first years of the 80's as a result of the gas bubble in the US market and the relatively high prices of exported natural gas.

The supply and demand equations are :

(1) $S_t = a1_t + a2_t\, Pe/Pc_t + a3\, RES_{t-1}$

(2) $D_t = b1_t + b2_t\, Pe/Pu_t + b3\, CONS_t$

Where :
S_t = Canadian supply of export at time t
D_t = US demand of import
Pe_t = price of the exported gas
Pc_t = gas price in Canada
Pu_t = gas price in US
Res_t = amount of natural gas reserves in Canada
$Cons_t$ = natural gas consumption in US.

Supply is a function of relative prices and reserves. Producers will offer more natural gas to the export market if exported gas price is high relative to domestic price.

Demand is a function of relative prices and US gas consumption. American pipelines compare border gas price to the domestic one in order to choose the amount they are willing to buy.

All variables are in logarithmic form for the period from 1960 to 1987.

2.1 OLS estimation

If we ignore the constraint on supply and demand, coefficients can be estimated by OLS with the following results :

Table 3. **OLS Estimation**

Variables	Coefficients	t ratios
Supply Curve :		
Constant	-0.4334	0.4127
LPe/Pc	0.4738	1.3713
LRes-1	1.1249	8.7971
For demand :		
Constant	-1.9051	2.1677
LPe/Pu	-0.1236	0.5594
LCons	2.9310	9.1417

For the supply curve as well as for the one of demand, price elasticities, as indicated by t-test, have no explanatory power. Obviously this is a consequence of the misspecification of the model. To use OLS, we need to suppose that equilibrium prevails over the overall estimation period. In fact, as previously mentionned, supply and demand are constrained.

2.2 Tobit Estimation

If we now take into account the volume limitation due to Canadian regulation, model specification became more realistic. A proper way to perform is by using a TOBIT formulation (cf. MADDALA, 1983).

(3) $Y^*_t = X_t B + u_t$

(4) $Y_t = \min (Y^*_t, LIM_t)$

with :
Y^*_t = "latent" supply or demand
X_t = explanatory variables
LIM_t = amount of authorized exportable natural gas

In this case the quantity actually exchanged on the market is the minimum of the "potential" supply or demand and the authorized volume of transaction. The observed export volumes

Table 5. **Disequilibrium Model Estimation**

Variables	Coefficients	t ratios
Supply Curve :		
Constant	1.4479	8.2624
LPe/Pc	1.0240	6.5321
LRes-1	1.1197	14.4263
Demand Curve :		
Constant	-6.2753	14.6388
LPe/Pu	-0.9520	4.4260
LCons	4.7068	26.7350

One of the outstanding result of the disequilibrium model is the possibility to obtain a regime classification for each year.

One may compute probabilities of each observation to be a supply or a demand point (see KIEFER, 1980). Here we have :

Table 6. **Probabilites of Various Regimes**

Year	Prob(S_t<D_t)	Year	Prob(S_t<D_t)
1960	0.0005	1975	0.5586
1961	0.0129	1976	0.6104
1962	0.5958	1977	0.6542
1963	0.6529	1978	0.6275
1964	0.6552	1979	0.6967
1965	0.4815	1980	0.1318
1966	0.4850	1981	0.0277
1967	0.7788	1982	0.0514
1968	0.8551	1983	0.0668
1969	0.9484	1984	0.3770
1970	0.9720	1985	0.6936
1971	0.9747	1986	0.4611
1972	0.9650	1987	0.6009
1973	0.9590		
1974	0.8926		

If Prob(S_t<D_t) is bigger than 1/2 then the observation *t* is on the supply function,

don't represent each year the real supply and demand behavior. Maximum likelihood estimation of such a model gives :

Table 4. **Tobit Estimation**

	Variables	Coefficients	t ratios
Supply Curve :			
	Constant	0.0459	0.0288
	LPe/Pc	0.9323	1.7147
	LRes-1	1.2599	6.4313
Demand Curve :			
	Constant	-4.5692	3.8722
	LPe/Pu	-0.2882	1.0290
	LCons	3.9407	8.8994

Despite a small improvement of magnitude and statistical significance of coefficients, global results remain weak.

2.3 Disequilibrium estimation

In the previous section we suppose that there was a constraint on supply and demand only if the quantity actually transacted is limited by the authorized volume. It doesn't take into account the fact that prices are strongly regulated and that demand is not necessarily equal to supply. The disequilibrium model does (cf. FAIR & JAFFEE, 1972). To obtain this model we just need to add (5) to equations (1) and (2)

(5) $XPORT_t = \min (D_t, S_t)$

Natural gas actually exchanged on the market is the minimum of demand for import and supply for export. If D_t is greater than S_t then the observed export level (XPORT) is on the supply function, else the observed quantity is on the demand function. It is the formalisation of the idea that one cannot be obliged to sell or to buy more that he wants to. The likelihood function of this model is given by MADDALA and NELSON (1974). The maximum likelihood estimation of this new model is as follows :

else it is a demand point.

The classification between supply and demand is a confirmation of the insight we got at the end of our brief analysis of the market (cf. 1.1 and 1.2). From 1960 to 1969 transacted quantities are alternatively demand or supply points. Between 1970 and 1979 all dates are supply points. This a consequence of the shortage era in the US domestic gas market. Furthermore Canadian supply, limited by quotas and price regulation, is smaller than US demand for import. In 1980, with the appearance of the "gas bubble" concurrently to Canadian prices increase, the demand becomes smaller than supply until 1986. It is very interesting to note that, even without any information on sample separation between supply and demand points, the disequilibrium model is able to properly retrieve the sequence of the various states of the export gas market.

Coefficients associated with independent variables in the disequilibrium model seems to be more reasonable than those of the OLS estimation. The TOBIT estimates are intermediate. With our last model, strong improvements in statistical tests are observed. Moreover, the rather high price elasticity of the US demand is shown when most elasticities are strongly underestimated by OLS.

3. Concluding remarks

The disappearance of former constraints leads to new market structures. However, it remains important to be able to keep track of the past. By relaxing former constraints, in the view of new commercial practice between the two partners, and taking into account current technical potential, impact of deregulation can be efficiently quantified.

The disequilibrium model provides good results for the Canadian export gas market. Obviously, one could introduce additional factors to improve its explanatory power. However, it allows to estimate the coefficients of equations properly describing behaviors which have a constrained expression on the market. It is tremendously important to highlight reasonable values for those coefficients in order to forecast the effects of current deregulation. A key conclusion is that demand for Canadian exports is strongly price-responsive. With the new upward movement of natural gas consumption in the US since 1986 and the improved price competitivity of Canadian gas, we might expect a rather large growth of the Canadian gas export.

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Déjà parus

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