A Strategic Model of European Gas Supply (GASMOD)[*]

Franziska Holz[a], Christian von Hirschhausen[a,b], Claudia Kemfert[a,c]

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Corresponding author:
Franziska Holz
DIW Berlin
Koenigin-Luise-Str. 5
D-14195 Berlin
Tel. +49-30-89789-337
Fax +49-30-89789-305
fholz@diw.de

Abstract:

Structural changes in the European natural gas market such as liberalization, increasing demand, and growing import dependency have triggered new attempts to model this market accurately. This paper presents a model of the European natural gas supply, Gasmod, which is structured as a two-stage-game of successive natural gas exports to Europe (upstream market) and wholesale trade within Europe (downstream market) and which explicitly includes infrastructure capacities. We compare three possible market scenarios: Cournot competition on both markets, perfect competition on both markets, and perfect competition on the downstream with Cournot competition on the upstream market. We find that Cournot competition on both markets is the most realistic representation of today's European natural gas market, where suppliers at both stages generate a mark-up at the expense of the final customer (double marginalization). Our results yield a diversified supply portfolio with newly emerging (LNG) exporters gaining market shares. Enforcing perfect competition on the European downstream market would lead to lower prices and higher quantities by avoiding the welfare-reducing effects of double marginalization. The limited infrastructure strongly influences the results, and we identify bottlenecks mainly for intra-European trade relations whereas transport capacity on the upstream market is sufficient (with the exception of Norwegian exports) in the Cournot scenario.

Keywords: natural gas, strategic behavior, non-linear optimization, Europe

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[a] DIW Berlin
[b] Dresden University of Technology, Chair of Energy Economics and Public Sector Management
[c] Humbold University

1 Introduction

The natural gas market in the European Union is undergoing considerable change. Three main challenges for the next decades can be identified: the liberalization of the industry initiated by the European Commission, an increasing demand for natural gas and, simultaneously, an increasing import dependency on gas supplied from outside the European Union. These changes and the high political stakes motivate a closer look at the gas sector. The market structure within the European Union as well as the import relations to gas producing countries are issues that need further research. The numerical simulation model developed in this paper, called "Gasmod", is a contribution to this research, taking a close look with regard to demand and supply structures, and in particular the infrastructure component, remains unsatisfying. The Gasmod model developed in this paper aims at combining a realistic representation of the market structure with an analysis of required infrastructure. Moreover, we try to develop and detail the available data. The remainder of the paper is structured as follows: after a survey of the literature, we will outline the current state of the literature and the structure of the European gas market, with an emphasis on natural gas trade. We will then explain the model and the used data. The subsequent presentation of the main simulation results will be followed by the conclusions.

2 State of the literature

The Gasmod model follows a number of other modeling attempts of the European gas sector. The structure of the sector suggests modeling the market with oligopolistic competition in a game theoretic framework. Most models actually distinguish the upstream market amongst producers (gas extraction/production taking place mostly outside Europe) and the downstream trader market (i.e. the wholesale market inside Europe). Mathiesen et al. (1987) were the first of the recent literature to study the phenomenon of market power in the European natural gas market. They are followed by Golombek et al. (1995) who analyze the effects of liberalizing the natural gas market in Western Europe, distinguishing between upstream (producers) and downstream (traders) agents on the gas market. Here, liberalization of the European gas market is defined as the situation where downstream traders can exploit arbitrage possibilities between countries as well as between market segments (industry, and local distribution companies for households). The numerical simulation of their model indicates that liberalization increases upstream competition and thus welfare. Golombek et al. (1995) have had a lasting influence on the further research in the field because it suggested marginal cost curves for several natural gas producers (Algeria, Russia/CIS, the Netherlands, Norway, and the United Kingdom) which have been widely used since.

The EUGAS model (Perner (2002), Perner and Seeliger (2004)) analyzes the long-term gas supply to Europe. It is a dynamic model of linear optimization of European gas supply, taking into account production and transport capacities, but treating gas demand exogenously. The most interesting feature of the model is the explicit recognition of infrastructure capacities and their expansion. The EUGAS model has been the basis for several extensions, as for instance the combination with electricity market models (Perner (2002), Bartels and Seeliger (2005)), the introduction of global gas reserves (Düweke and Hamacher (2005)), and the extension to a global model currently under way.

The GASTALE model (Boots et al. (2004)) is the first attempt to apply the structure of successive oligopoly in gas production and trading. This model is similar to ours in that its underlying structure is a two-stage game. However, a number of simplifying assumptions, such as symmetry of traders, diminish the generality of this approach of double marginalization. Boots et al. (2004) also assume the domestic production to be an exogenous value instead of including it in the optimization. Another difference with Gasmod (see details in section 3) is the use of cost functions and linear demand functions from Golombek et al. (1995). Boots et al. (2004) do not consider infrastructure capacity limitations yet but intend to extend their model.

Besides models of partial equilibrium, there are also general equilibrium models with a high disaggregation for the gas sector. One example on the global level is the World Gas Trade Model (Hartley and Medlock (2004)). Another branch of the literature about the European gas market deals with strategic aspects of gas production and transport. These articles also use game theoretic approaches to analyze the European natural gas supply. An example of this is the Stackelberg game model of the European East-West gas trade of Grais and Zheng (1996) where Russia is considered as the leader in the game while transit countries such as the Czech Republic and Ukraine are the followers. In the same perspective, Hirschhausen et al. (2005) consider the options for Russia to transport its gas to Western Europe. Here, the players Russia and Ukraine could either play a cooperative or a non-cooperative game, and the outcome changes when an additional player (Belarus) enters the game. Along similar lines, Hubert and Ikonnikova (2003) analyze the strategic behavior of gas supplying countries (Russia) and transit countries. They use the Shapley value which reflects the bargaining power of a player in a coalition, and which is determined by both, already existing pipelines as well as planned pipelines projects. Russia currently depends on transit countries to transport its gas to Western Europe but has strategic incentives to construct direct pipelines to Western Europe (the North TransGas Pipeline in the Baltic Sea) although construction and maintenance costs are very high. However, Gasmod does not include theses questions of transit; it is a model of the international gas market.[1]

3 Structure and Dynamics of the European Natural Gas Sector

There are currently changes ongoing on the demand as well as on the supply side of the European natural gas sector. The speed of reforms is accelerating. These changes do not only have an impact on

1 Gasmod does also not deal with the question of technically optimally flows in the pipeline grid. In this class of models, and unlike our focus, market relationships are not considered and the underlying assumption is a market in perfect competition. These models serve to optimize technical parameters such as capacity use, generally with linear optimization programs, for relatively small geographical areas. In contrast, Gasmod does not consider each pipeline in the natural gas grid but takes into account total capacities of cross-border trade.

the natural gas market within Europe but also on the supply relations of Europe with other gas producing countries. Hence, the gas sector has been identified as a strategic sector by the European Commission (European EC (2001)) and by the International Energy Agency (IEA). Let us briefly examine the three main challenges for the sector:

- First, European demand of natural gas is likely to rise further over the next decades. Natural gas is expected to play an increasing role in the energy mix, mainly because of its relatively low carbon dioxide emissions within the context of growing climate concerns and political climate measures. Thus, the share of natural gas in the total primary energy demand in the European Union (EU-25) is expected to increase from 23% at present to a projected 32% in 2020. This goes hand in hand with an increase of the absolute level of gas consumption from approximately 430 billion cubic meters (bcm) per year today to a projected 790 bcm per year in 2020 (IEA (2004d)). The rise in demand will mainly be driven by an increasing utilization for power generation; the share of natural gas in power generation is expected to rise from 15% in 2002 to over 35% in 2030 (IEA (2004d), p. 154).
- Second, since Europe can only partly satisfy its gas demand with indigenous production, rising demand also implies increasing import dependency. Indigenous production in Europe is concentrated in the United Kingdom and the Netherlands which account for three quarters of the European production.[2] However, production in these countries will at best remain at the current level but will probably decrease because the fields in the North Sea are running out of gas.[3] Especially the UK is going to become a net importer of natural gas soon; most analysts expect the turning point to be reached within the next decade (e.g. IEA (2004d). So, in different scenarios, the gas import dependency of the EU-25 is estimated by the International Energy Agency to increase from the current 49% (233 bcm in 2002) to over 80% (639 bcm) in 2020.
  A crucial question is where the future gas supplies will come from. Russia, the country with the largest gas reserves in the world[4], currently is the most important gas supplying country to the European Union (see Table 1) and is expected to expand this role. Its market share is projected to increase from the current 40% of EU imports to around two-thirds (EC (2001). However, this forecast ignores the high investment costs that are needed to bring gas from new fields on stream, the large investments required to modernize and expand the transport infrastructure, and a certain political cautiousness in the EU not to rely to heavily on gas imports from Russia. North Africa, and especially Algeria, Egypt and Libya, have made significant efforts to improve their status as reliable, large-scale suppliers to Europe. However, the region has yet to conquer a market share in European supply that corresponds to its low-cost reserves, be it via pipeline or

[2] In our model, we do not consider Norway as a part of Europe since it is one of the big producers from outside the European Union. However we do not define Europe exclusively as the European Union since we have included a number of non-EU gas importing countries such as Romania, Bulgaria, and Turkey.

[3] This is reflected by the reserves-production ratio, which was equal to 6.1 and 21.7 at end 2004 for the UK and the Netherlands, respectively.

[4] 48000 bcm, i.e. 26.7 % of the global proved natural gas reserves (BP (2005)).

as Liquefied Natural Gas (LNG). Additional gas supplies will also have to come from new areas such as the Middle East, where 40% of the proven global gas reserves are located and where LNG export terminals have been constructed for about a decade now.

Table 1: Natural gas supplies to Europe from major exporters in bcm per year (2004)

2004	Norway		Nether-lands		Russian Fed.		Algeria		Middle East		Nigeria		Total imports
	bcm	%	bcm	%	bcm	%	bcm	%	bcm	%	bcm	%	
Belgium /Luxemb.	7	35%	8	37%	0	1%	3		–		–		21
Germany	26	29%	22	24%	38	41%	–		–		–		92
Finland / Sweden	–		–		5	81%	–		–		–		6
France	15	33%	–		12	26%	7	15%	0,1	0,2%	1	2%	45
Greece	–		–		2	80%	1	20%	–		–		3
UK	9	80%	1	4%	–		–		–		–		11
Italy	7	10%	10	14%	21	30%	26	37%	–		4	5%	70
Netherlands	4	32%			3	20%	–		–		–		14
Austria	1	10%	–		6	77%	–		–		–		8
Spain / Portugal	2	7%	–		–		16	53%	5	17%	6	20%	31
Baltic*	–		–		5	100%	–		–		–		5
Poland	1	5%	–		8	87%	–		–		–		9
Czech /Slov. /Hun.	3	9%	–		24	85%	–		–		–		28
Slovenia / Croatia	–		–		2	73%	0	20%	–		–		2
Bulgar. / Romania	–		–		8	85%	–		–		–		9
Turkey	–		–		14	65%	3	15%	–		1	5%	22
Total Exports to Europe	75		40		146		56		5		12		374

Source: BP (2005),
* Estonia from IEA (2004b) for 2003

LNG is a form of supply with a growing importance for Europe. LNG imports are bound by regasification capacity. More and more regasification terminals are built in Europe. LNG shipments mainly come from North Africa, Nigeria and the Middle East. Contrary to pipeline trade, there is an element of competition on the LNG market, because Europe is in direct price competition with the North American market. The higher flexibility is one of the main differences of LNG with pipeline supply which is bound by asset-specific infrastructure availability.

- Third, the European Commission has pushed for a progressive liberalization of the European natural gas sector, a process that is still ongoing.[5] Ownership unbundling, third party access to gas transport infrastructure, end of the destination clause are some of the keywords in this process. Liberalization of the downstream wholesale market and of gas distribution has led to a reduction of the part of long-term contracts in the supply relationships. Previous liberalization

[5] Cf. “Acceleration Directive” 2003/55/EC, which followed Directive 98/30/EC. Also see the Benchmarking Reports annually issued by the European Commission (EC (2005)).

experiences in the US and the UK have shown that the share of long-term contracts diminishes, although it always remains (well) above 50% (IEA (2004c)).[6]

4 Data and Model Description

4.1 Data

We aim at having an exhaustive representation of all relevant players on the European natural gas market. Table 1 summarizes the exporting and importing regions included in the model. We include Iraq and Venezuela although they have no gas export capacity yet because we want to be able to compute forecasts of their exports in other versions of the model. In this version of Gasmod we assume that there is one gas company per country or region, which is justified by still existing national (quasi-) monopolies in reality, such as GdF in France, Gazprom in Russia etc.[7]

Table 2: Regions in the Gasmod model

Exporting Regions	Importing Regions
Algeria	United Kingdom
Libya	Netherlands
Egypt	Spain / Portugal
Iraq	France
Iran	Italy / Switzerland
Middle East (Qatar, UAE, Oman, Yemen)	Belgium / Luxemburg
Former Soviet Union	Germany
Norway	Denmark
Netherlands	Sweden / Finland
United Kingdom	Austria
Nigeria	Poland
Trinidad	Czech Rep. / Slovak Rep. / Hungary
Venezuela	Former Yugoslavia / Albania
	Romania / Bulgaria
	Baltic States (Estonia, Latvia, Lithuania)
	Greece
	Turkey

We use data for the base year 2003. Data on reference trade flows and prices come from the International Energy Agency (IEA (2004a), IEA (2004b)) and from BP (2004). Data on production capacity in the European regions is taken from IEA (2004b). Transport capacity data mainly comes from GTE[8], the European organization of the national TSOs (transmission system operators) for intra-European capacities, and from OME (2001) for exporter capacities.

Production and transport cost data ("border prices") are taken from OME (2001). This is long-run marginal cost data, including likely investments on existing infrastructure. We add transport costs within Europe as unit costs per unit of gas and km of average distance between countries as assumed

[6] Also see Neumann and Hirschhausen (2004) for a study of the evolution of long-term contracts in continental Europe.

[7] This assumption is not uncommon in the literature, see for instance Egging and Gabriel (forthcoming). However, the model formulation is such that there is the possibility to include more than one player per country which would be more realistic when modeling the future European natural gas market.

[8] www.gte.be

by Oostvoorn (2003); they include transport costs (e.g. gas used for compression), losses and possible transit fees. The cost data is a crucial input to the model with an important influence on the results. Given the long distance to the market, Russian gas is among the expensive suppliers in Europe. In the OME (2001) data, LNG is still a high-cost supplier with costs of around 3 US-$ per Mbtu (million British Thermal unit) to the EU border for typical LNG exporters as Nigeria, Venezuela and the Middle East (Table 3). Norway is a producer at fairly high costs, whereas Algeria and the European producers United Kingdom and the Netherlands can export at relatively low costs to Europe. Political and other "soft" considerations (e.g. the reliability of an exporter) do not enter the cost data and consequently not the model. The same is true for reserves which do not enter in the calculation of the production capacity of the producers.

Table 3: Cost data (border prices) of selected producer countries

Producer country	Border price in US-$ per Mbtu	Border price in US-$ per tcm
Netherlands	1.65	52.15
Norway (to Germany)	2.10	82.06
Russia via Ukraine*	2.55	79.92
Algeria to Italy**/ Spain**	2.07 / 2.15	84.41 / 85.63
Middle East (LNG)**	2.91	104.75

Source: OME (2001), and own calculations
* unweighted average border price at the Slovak border
** average border price weighted by export capacity

4.2 Model

We structure the European natural gas market as a two-stage-game of successive imports to Europe (first stage, upstream) and trade within Europe (second stage, downstream). First, gas producing companies decide on their exports, mostly from countries outside Europe, to European countries. Simultaneously, indigenous producers in Europe, for instance in Germany, Italy, Austria, etc. decide about their production quantities. Thus, indigenous producers and exporters are directly competing. Note that the endogenous determination of indigenous production quantities is a novelty compared to other gas market models where indigenous production is entered as an exogenous, pre-determined value (Boots et al. (2004), Perner (2002), Egging and Gabriel (forthcoming)).

On the second stage, gas trading companies in Europe which have imported gas and which have bought indigenously produced gas sell this gas in the European countries, including their own country.

We implicitly assume a liberalized, but oligopolistic market in Europe: TPA (Third Party Access) to the gas network is ensured for each exporter and each European trading company, and consumers are free to choose their supplier which may well come from abroad (e.g. French consumers can purchase from the German trader). Since the focus of our model is on the strategic relations between the producers on the first stage, and between the traders on the second stage, we do not distinguish several market segments (such as industry, power generation, residential sector).

Gasmod can be characterized as a game theoretic model assuming perfect information. The producers on the first stage have perfect information about the demand situation on the second stage and decide on their production quantities by taking into account the downstream market situation. According to standard game theory the appropriate method of determining equilibrium prices and quantities is backwards induction (e.g. Gibbons (1992) p. 55). We assume the exporters to be Stackelberg leaders over the traders, that is the traders on the second stage are price-takers of the equilibrium prices determined on the first stage.

On both stages, the players play a non-cooperative game and maximize their individual payoffs. Following the literature of energy market modeling, we model the oligopolistic markets on both stages with Cournot (quantity) competition instead of Bertrand (price) competition.[9] By assuming an oligopolistic market structure on both stages the problem of double marginalization is represented: both upstream and downstream markets are imperfectly competitive and suppliers on both markets exert market power, i.e. their price includes a margin. The downstream oligopoly leads to an additional price distortion and hence to an even less efficient allocation compared to the situation of a single oligopoly (cf. Spengler (1950)).

The equilibrium on each stage is the solution of the non-linear profit optimization of each player. This is in contrast to some energy market models using linear optimization where social welfare or total supply are maximized instead of the profit of the firms (e.g. Perner (2002)). This seems to be an unrealistic abstraction of a market where oligopolistic firms determine supply and prices. Also, linear optimization implicitly assumes a market structure of perfect competition whereas the natural gas market is better represented by an oligopolistic market structure.

On both stages, each player maximizes his profits under certain capacity constraints:

$$\underset{x_{f,r}}{Max.}\Pi\left(x_{f,r}\right)=\left(pe_r-c_f-t_{f,r}\right)*x_{f,r} \qquad (1)$$

$x_{f,r}$ is the supply by exporter f to wholesale trader r, pe_r is the inverse demand function (see below), c_r is the production cost function of producer f, and $t_{f,r}$ his transport costs for delivering to trader r. In line with the literature (e.g. Egging and Gabriel (forthcoming)) we suppose unit production and transport costs. We neglect transport costs within each European country / region because we focus on the international trade relationship.

Taking into account the behavioral assumption of Cournot competition and some standard definitions for own-price elasticity and market share, we derive the first order condition (FOC) of the profit

[9] This seems more suitable in a market where many relations are still based on long-term take-or-pay (ToP) contracts. In ToP contracts the quantities can be chosen in the short run given the demand and price developments; however a minimum quantity must always be paid to the seller. Also, Bertrand competition might yield lower price margins and under some assumptions prices even equal marginal cost (i.e. the perfect competition equilibrium) which would be unrealistic for a highly concentrated market as the natural gas market in Europe.

maximization. In a pure Cournot-Nash equilibrium no player must have an incentive to move; in other words the conjectured variation of the other players must be 0. Thus: $\frac{\partial X_r}{\partial x_{f,r}} = \frac{\partial\left(\sum_f x_{f,r}\right)}{\partial x_{f,r}} = 1$ (2)

Price elasticity σ_r on the market r, and market share $\theta_{f,r}$ of player f on the market r are:

$$\sigma_r = \frac{\partial X_r}{\partial pe_r} \cdot \frac{pe_r}{X_r} \quad (3)$$

$$\theta_{f,r} = \frac{x_{f,r}}{X_r} \quad (4)$$

FOC: $x_{f,r} : pe_r - mc_f - t_{f,r} + pe_r{}' \cdot x_{f,r} = pe_r - mc_{f,r} - t_{f,r} + \frac{\partial pe_r}{\partial x_{f,r}} \cdot \frac{\partial X_r}{\partial X_r} \cdot \frac{pe_r}{pe_r} \cdot \frac{X_r}{X_r} \cdot x_{f,r} = 0$

which yields by taking into account (2), (3), and (4):

$$mc_f + t_{f,r} = pe_r * \left(1 - \frac{\theta_{f,r}}{\sigma_r}\right) \quad (5)$$

where mc_f are marginal costs and $\frac{\theta_{f,r}}{\sigma_r}$ is the price margin obtained by the oligopolistic supplier. In other words, suppliers can exert market power with respect to their competitors. The margin is equal to zero in the case of perfect competition. With this formulation we follow Kemfert and Tol (2000) and Kemfert and Kalashnikov (2004) who use a similar optimization program in a model of the German respectively the European electricity market.

Each player is restricted by capacity limitations such as transport infrastructure constraints (export, import capacities in terms of pipelines and LNG terminals), and production capacities. On the first stage of exports to Europe, gas trade is restricted by the export infrastructure of each producer and the import capacity of each wholesale trader. In addition, the indigenous (domestic) production capacity in each European country is limited. On the second stage, the supply by each trader is restricted by the transport capacity of the pipeline grid between him and each end-user market. We introduce these restrictions of the exports, imports and domestic production with shadow prices (Lagrangian multipliers) in the respective first order conditions. When a shadow price is non-zero the capacity limitation is binding and the shadow price represents the valuation of an additional available capacity unit. Hence, the FOC (5) is enlarged by the shadow prices and for the exporter f, for example, it is equal to:

$$mc_f + t_{f,r} = pe_r * \left(1 - \frac{\theta_{f,r}}{\sigma_r}\right) - \lambda \exp_f - \lambda imp_r \qquad (6)$$

where $\lambda \exp_f$ and λimp_r are the shadow prices for export capacity of the exporter f and the import capacity of importer r, respectively.

Since we consider market relations we do not restrict bilateral trade relations to adjacent countries like for example Egging and Gabriel (forthcoming). An exporter can supply each European region but not more than can physically be transported through the natural gas grid (or via the LNG terminals) connecting them. This way we can represent trade flows as observed in reality where for instance the Czech Republic has imported 2.62 bcm of natural gas from Norway (BP (2005)).

For the natural gas consumption on the end-market m, we assume an iso-elastic demand function of the form:

$$y_m = d0_m \cdot \left[\frac{p_m}{p0_m}\right]^{-\sigma_m} \qquad (7)$$

y_m and p_m are the quantities and prices, $d0_m$ and $p0_m$ are the reference demand and the reference price on the market m in the base year, and σ_m is the price elasticity of the final demand. We prefer an iso-elastic demand function instead of a linear demand function (as suggested by Golombek et al. (1995) and applied for example in Boots et al. (2004), Egging and Gabriel (forthcoming)) because this allows to have a non-negative demand for every price. We assume the demand elasticities σ_r and σ_m to be rather low in absolute terms (-0.85 for all countries, in the absence of detailed data on country level) which reflects a certain inelasticity of the natural gas demand.[10] Shifting from natural gas to another fuel would require changes in the technical installations, which are costly and time-demanding. The right choice of the elasticities is crucial in a model with an iso-elastic demand function; we have carried out (but not reported) several sensitivity analyses which confirm the correctness of our choice.

Equilibrium is reached at the intersection of demand and supply. The demand coming from the downstream (end consumer) market is addressed to the traders who forward it to the exporters. This gives us the following equilibrium model:

FOC upstream:
$$mc_f + t_{f,r} = pe_r * \left(1 - \frac{\theta_{f,r}}{\sigma_r}\right) - \lambda \exp_f - \lambda imp_r \qquad (6)$$

FOC domestic producers:
$$mcdom_r = pe_r * \left(1 - \frac{\theta dom_r}{\sigma_r}\right) - \lambda dom_r \qquad (8)$$

[10] Liu (2004) finds long-run own price elasticities for natural gas between –0.774 and 0.075 for OECD countries. Earlier estimations find higher elasticities (in absolute values), see e.g. Estrada and Fugleberg (1989), Al-Sahlawi (1989). Boots et al. (2004) use elasticities from Pindyck (1979) which are considerably higher (between 1.17 and 2.23).

FOC downstream: $$pe_r + t2_{r,m} = p0_m * \left(1 - \frac{\theta_{r,m}}{\sigma_m}\right) * \sqrt[\sigma_m]{\frac{Y_m}{d0_m}} \quad (9)$$

Market clearance: $$\sum_m y_{r,m} = \sum_f x_{f,r} + domprod_r \quad (10)$$

This model is a square system of equations and variables and is programmed in the MCP (mixed complementarity problem) format. We program it in GAMS and use a standard solver for MCP, PATH.[11]

5 Simulation Results

The model is run for different market scenarios. In addition to the benchmark scenario of double marginalization, we also simulate situations of perfect competition on both markets or of the downstream market only. Here we focus on the results of the scenario of Cournot competition compared to perfect competition on both stages. In addition, we report the results of the scenario of Cournot competition on the upstream market and perfect competition on the downstream market. Indeed, regulators could enforce a competitive market within Europe whereas the upstream market is likely to remain in imperfect competition.

Gasmod in its version presented here is a quasi-static model to the extent that it only regards one time period. This means that we reproduce the base year 2003 and the results must be interpreted as market outcomes if the upstream and downstream markets corresponded perfectly to the theoretical characteristics of a Cournot oligopoly or perfect competition. Thus from the proximity of our results to the original data we can derive conclusions about the actual market structure on the European natural gas market.

5.1 Upstream market: Exports to Europe and Domestic Production

5.1.1 Exports

Table 4 reports the results for the exports on the first stage. Compared to the reference data for 2003 (also see Section 3, Table 1), in the Cournot scenario, exports from some traditional suppliers to Europe (Russia, Algeria) decrease while newly emerging exporters (Middle East, Nigeria) gain market shares. Among the large traditional exporters only Norway, the Netherlands and UK remain at a significant level in this static scenario. Most strikingly, Russia (Former Soviet Union) loses a considerable market share in Europe, partly because of its relatively high production and especially transport costs due to the long distance to the European market. This is also due to the model formulation where large players like Russia have the same strategic "weight" as smaller players like Nigeria, Trinidad etc.[12] In the Cournot scenario, LNG exporters like the Middle East, Nigeria and

[11] For more details about programmation in the MCP format see Rutherford (1995) and Ferris and Munson (2000).

[12] Considering firms instead of countries, including multinational firms which are typical for the global natural gas market, would resolve this uncertainty in the results and we therefore intent to do it.

Trinidad gain some market share. For LNG we may expect an even greater increase of exports to Europe in the future since costs of LNG shipments are projected to decrease further in the coming years.

The comparison with the perfect competition scenario confirms that there is strategic withholding of quantities in the Cournot scenario in order to increase the price above marginal cost levels (also see Section 4.2.2. for the prices). In perfect competition, the greater demand because of lower prices allows market entry and increased market share of higher cost producers such as Russia (FSU) and Egypt. LNG and other non-traditional exporters supply even more natural gas to Europe than in the Cournot scenario. The demand increase compared to the benchmark scenario is such that even higher cost producers are bound by their transport capacity (see Section 4.3.1). Since demand on the markets prefers the lowest-cost supplier, exporters first serve the markets which are the closest to them (in terms of combined production and transport costs); in a context of high demand this explains why the UK and the Netherlands do not export but supply only local traders in the perfect competition scenario.

Table 4: Export quantities and market share (as percentage of total exports to Europe)[13]

Exporter	Cournot Competition		Perfect Competition		Competition2		Reference exports to Europe 2003*	*Reference market share 2003*
	Exports (bcm/year)	*Market share*	Exports (bcm/year)	*Market share*	Exports (bcm/year)	*Market share*		
Algeria	14,7	*4,4%*	66,0	*14,6%*	66,0	*11,9%*	57,77	*17,6%*
Libya	4,8	*1,4%*	14,5	*3,2%*	14,5	*2,6%*	0,75	*0,2%*
Egypt	5,0	*1,5%*	11,9	*2,6%*	11,9	*2,2%*	0	*0,0%*
Iraq	0,0	*0,0%*	0,0	*0,0%*	0,0	*0,0%*	0	*0,0%*
Iran	0,0	*0,0%*	10,0	*2,2%*	10,0	*1,8%*	3,52	*1,1%*
Middle East	13,3	*4,0%*	26,6	*5,9%*	26,6	*4,8%*	2,43	*0,7%*
Russia / FSU	58,8	*17,7%*	196,0	*43,3%*	134,4	*24,3%*	131,77	*40,1%*
Norway	86,0	*25,8%*	86,0	*19,0%*	86,0	*15,6%*	68,37	*20,8%*
Netherlands**	66,6	*20,0%*	0,0	*0,0%*	80,4	*14,6%*	42,17	*12,8%*
UK**	59,4	*17,8%*	0,0	*0,0%*	81,5	*14,7%*	11,5	*3,5%*
Nigeria	12,6	*3,8%*	22,7	*5,0%*	22,7	*4,1%*	10,37	*3,2%*
Trinidad	12,0	*3,6%*	18,7	*4,1%*	18,7	*3,4%*	0	*0,0%*
Venezuela	0,0	*0,0%*	0,0	*0,0%*	0,0	*0,0%*	0	*0,0%*
Total	333,1	*100,0%*	452,4**	*100,0%*	552,6**	*100,0%*	328,65	*100,0%*

*** Source: BP (2004).**
** Excluding own domestic consumption in UK and the Netherlands. If domestic consumption is included, total "exports" are higher in the Perfect Competition than in the Competition " scenario as intuition suggests.

Finally, we see that a perfectly competitive downstream market (scenario "Competition2") would considerably change the outcome. Higher demand on the downstream market because of lower (competitive) prices triggers much higher exports. This strongly contradicts the widespread thesis that an oligopolistic downstream market is the best response to an oligopolistic upstream market. Perfect

[13] The Netherlands and UK are considered as exporters and as importers. In this table we have removed the exports to the traders in the Netherlands and UK. However these quantities are available for re-export (including domestic consumption) on the 2nd stage.

competition on the downstream market with a given Cournot market on the export side also leads to more diversification of supplies.

5.1.2 Profits of the Exporters

In Table 5, one clearly observes the welfare-reducing effect of double marginalization: by twice withholding production capacity, the total sold quantity is lower than it would have been in the case of perfect competition on both stages, thereby also reducing total profits. Oligopolistic Cournot competition on the second stage in addition to the first stage reduces the quantities sold by the exporters even further. With profits being a function of quantities sold, profits can be lower for the exporters in the Cournot than in the perfect competition scenario. By comparing with Table 4, we see that indeed profit increases in the perfect competition case for those producers that can offer more in this scenario: Algeria, Libya, Egypt, Iran, Middle East, Nigeria, and Trinidad. Profits are only slightly different in the Competition 2 scenario from the Perfect competition scenario, again confirming the surplus-reducing effect of double marginalization. Let us recall that the profit maximization rule of zero profits applies for the marginal supplier who sets the price on the market whereas all other exporters (supplying at lower costs) earn a positive producer rent.

Table 5: Profits of Exporters in million US-$

Exporters	Cournot Competition	Perfect Competition	Competition 2
Algeria	689	6258	5678
Libya	161	1339	1176
Egypt	83	589	687
Iraq			
Iran		889	920
Middle East	316	1714	1672
Russia / FSU	5150	15452	10732
Norway	7117	7067	8390
Netherlands*	9749	10154	11079
UK*	6559	10792	12578
Nigeria	261	1392	1392
Trinidad	221	1112	1127
Venezuela			
TOTAL	30306	56757	55430

* This also includes profits earned from “exports” to the trader in the own country.

5.1.3 Domestic Production

Table 6 reports the quantities and market shares of domestic production. We recall that domestic production is endogenously determined by the profit maximizing behavior of the producers. We observe that the higher demand due to lower prices in perfect competition and Competition2 leads to domestic production as part of the natural gas supplies in more countries than in the Cournot competition scenario. This completes the picture of a more diversified supply that we also yield for exports under the perfect competition assumption. In both scenarios with perfect competition, domestic production is generally higher than it was observed in the reference data. Often domestic production serves the demand when trade capacities to a country are congested (see 4.3). This is especially true in the perfect competition scenarios where higher quantities would have been traded if physically possible and where the share of domestic production in the supply is high in many countries.

Table 6: Domestic production quantities and market shares of the domestic producers on the upstream market

Domestic producer	Cournot competition		Perfect competition		Competition 2		Domestic production 2003 in bcm (IEA (2004b))
	Domestic production (bcm/year)	*Part of the supply in the same country*	Domestic production (bcm/year)	*Part of the supply in the same country*	Domestic production (bcm/year)	*Part of the supply in the same country*	
UK*	27,4	*35,9%*	120,0	*100,0%*	38,5	*42,2%*	108,4*
Netherlands*	23,4	*42,1%*	90,0	*80,7%*	9,6	*32,9%*	73,1*
Spain/Port.			0,3	*0,7%*	0,3	*0,7%*	0,2
France			1,9	*3,2%*	1,9	*2,9%*	1,6
Italy/Switz.			16,3	*19,4%*	16,3	*13,4%*	13,6
Belgium/Lux.							0
Germany			13,2	*21,5%*	26,7	*21,1%*	22,2
Denmark	1,0	*44,7%*	8,5	*100,0%*	9,6	*86,4%*	8,0
Swed./Fin.							0
Austria							2,1
Poland	6,0	*27,8%*	6,8	*38,3%*	6,8	*32,7%*	5,6
CSH	3,9	*14,7%*	3,9	*3,5%*	3,9	*15,3%*	3,3
Balkan			4,1	*100,0%*	4,1	*28,9%*	3,4
Rom./Bulg.			17,5	*49,8%*	17,5	*69,3%*	14,6
Baltic							0
Greece					0,03	*0,9%*	0,03
Turkey							0,6

* Here we report exports from the UK or the Netherlands to the trader in the same country.

5.2 Downstream market: Intra-European Market

5.2.1 Intra-European Trade

Although we separate them in the presentation, the first and second stage are solved in parallel. Thus the model is complex and the results on the second stage inherently depend on the first stage and vice versa. Although the results of the first stage for the Cournot scenario may be somewhat surprising, the results of the second stage, and especially the final consumption, indicate a proximity to the real world situation. Indeed, as is shown in Table 7 we generally obtain results for this case that are close to actual final consumption in 2003. Clearly, this gives an indication to consider the Cournot case as the most realistic representation of the today's European natural gas market. Consumption results of the perfect competition and the Competition2 scenario generally are much higher than real world data. The notable exception of the UK can be explained by the observed competitive market structure in this country in contrast to the rest of Europe.

Looking at particular regions, some interesting features can be discovered (Appendix, Tables 11 and 12). For instance, direct exports to Germany (1st stage trade) only come from Northern Europe, especially Norway. This result is confirmed by several sensitivity analyses. However, Germany is still consuming Russian gas, as in reality, but which is indirectly supplied via Eastern European (Czech and Polish) and Austrian traders. Reciprocally, Russia is not directly exporting to Western Europe, but mainly to Eastern Europe. This is due to the production and transport cost structure. Hence, the results in Gasmod are more cost-driven than trade relations are in today's reality where they are often the consequence of geo-political considerations and the existence of destination clauses. However, the results of our model point to an increased diversity of supply which is also a political objective in Europe.

Table 7: Final consumption of natural gas in bcm per year

Markets	Cournot Competition	Perfect Competition	Competition 2	Consumption 2003
UK	49,5	113,3	95,9	95,4
Netherlands	38,9	69,6	56,9	40,3
Spain/Portugal	27,5	39,8	39,4	26,6
France	50,7	60,2	63,3	43,3
Italy/Switzerland	96,0	115,9	121,1	73,6
Belgium/Luxembourg	16,1	21,3	21,4	16,0
Germany	100,7	147,4	138,3	85,5
Denmark	0	6,2	5,7	5,4
Sweden/Finland	2,0	6,3	2,2	5,3
Austria	11,9	15,5	14,6	9,4
Poland	12,6	17,6	16,2	11,2
Czech/Slovak/Hungary	26,3	41,8	36,4	28,8
Balkan	9,7	10,0	10,5	7,7
Bulgaria/Romania	13,3	29,2	28,9	20,9
Baltic	0	3,3	5,7	5,0
Greece	2,3	3,7	3,6	2,3
Turkey	0	33,6	33,1	20,9
TOTAL	457,6	734,7	693,4	497,6

5.2.2 Prices

Table 8 reports the prices on the upstream and the downstream market for both scenarios. One clearly recognizes the effect of market power in the Cournot scenario where strategic withholding of production increases the price. However, the price is not only influenced by the market situation but also by the availability of import capacity for a market. Markets like Sweden/Finland for instance which benefit from the proximity to an exporter (Russia/FSU) on the first stage cannot be deserved on the second stage due to missing infrastructure and therefore have to pay a high-mark-up to their local wholesale trader. This explains the very striking heterogeneity of prices in the Cournot scenario.

The picture is different in two aspects in the scenarios with perfect competition. Prices are distributed homogenously between the countries, and the prices generally are lower. For both scenarios, the premium added on the import price is equal to the transport costs of the marginal trader; very often there is only intra-country trade (Table 12) so that the difference between prices on the upstream and the downstream market equals the assumed intra-country transport costs (2 US-$ per tcm). Although exporters behave strategic in the Competition 2 scenario the prices are considerably lower than in the Cournot scenario and only about 20% higher than in the Perfect competition scenarios. This confirms the finding that enforcing perfect competition on the European market would lead to increased welfare because it allows higher consumption of natural gas combined with lower prices.

Table 8: Prices in US-$ per thousand cubic meters (tcm)

Trader r resp. final market m	Cournot competition		Perfect competition		Competition 2	
	Import price	Endmarket price	Import price	Endmarket price	Import price	Endmarket price
UK	144,8	529,3	160,4	162,4	203,9	205,9
Netherlands	203,0	383,3	165,0	167,0	220,7	222,7
Spain/Portugal	119,2	275,0	165,9	167,9	168,3	170,3
France	123,2	220,7	170,9	172,9	158,6	160,6
Italy/Switzerland	63,6	225,4	170,4	172,4	159,9	161,9
Belgium/Lux	125,6	251,4	165,9	167,9	164,5	166,5
Germany	160,3	290,8	166,7	168,7	182,8	184,8
Denmark	462,1	n.a.	166,7	168,7	191,3	193,3
Sweden/Finland	69,5	816,6	175,5	177,5	701,4	703,4
Austria	157,9	233,3	161,3	161,3	173,3	175,3
Poland	233,1	272,5	160,7	162,7	183,7	185,7
Cz./Slovak/Hung.	224,7	348,4	158,8	160,8	199,7	201,7
Balkan	126,7	174,3	163,9	165,9	152,2	154,2
Romania/Bulgaria	58,9	590,3	156,7	158,7	159,4	161,4
Baltic	66,9	n.a.	168,9	170,9	66,9	68,9
Greece	118,0	278,5	149,7	151,7	154,3	156,3
Turkey	42,8	n.a.	138,9	140,9	142,0	144,0

n.a.: Since there is no final consumption in these markets (Table 7), no price can be computed. The price would in that case have been higher than the willingness to pay. Thus it is more profitable for the local traders and the traders with access to these markets to export elsewhere.

5.3 Infrastructure Capacity Constraints

5.3.1 Upstream Market

On the upstream market, the only transport route which is congested in the Cournot scenario is the Norwegian access to Europe. With Norway being close to high demand markets in Europe (Germany, etc.) and transport costs being relatively low, this is an well-positioned supplier to Europe. Our results are reflected in reality by the stable reserve situation and the increasing production capacity in Norway which make it an important exporter for the coming decades with the need to expand its export infrastructure.

In contrast, in the perfect competition case and very similar in the Competition 2 case, there are many exporters which are bound by their actual export capacities (Table 9), which may be pipelines or LNG liquefaction terminals. Export capacities are taken into account as the existing export infrastructure in 2003. It is striking that even an exporter with large export capacities as Russia (FSU) reaches the bounds of its capacities but it gives an idea of the quantities that would be traded in a fully competitive market without capacity restrictions as compared to the actual natural gas market. This also clearly shows the necessity to take into account infrastructure capacities when modeling a network market as the natural gas market.

Table 9: Export capacity utilization of each exporter[14]

Exporters	Cournot competition	Perfect competition	Competition 2
Algeria	22%	100%	100%
Libya	33%	100%	100%
Egypt	43%	100%	100%
Iraq	n.a.	n.a.	n.a.
Iran	0%	100%	100%
Middle East	50%	100%	100%
Russia / FSU	30%	100%	69%
Norway	100%	100%	100%
Netherlands	74%	0%	89%
UK	50%	0%	68%
Nigeria	55%	100%	100%
Trinidad	64%	100%	100%
Venezuela	n.a.	n.a.	n.a.

Table 10: Congested Intra-European capacity (used at 100 %) in the Cournot competition scenario

From	**To**
Netherlands, Belgium, Germany	UK
UK, Germany, Belgium	Netherlands*
France	Spain / Portugal
Balkan (via Slovenia), France	Italy / Switzerland
Germany	Belgium / Luxemburg
Belgium, Austria*	Germany*
Germany	Poland
Austria	Czech / Slovak Republic / Hungary*
Italy / Switzerland	Balkan
Denmark**	Sweden / Finland**

* Note that these transport routes are also congested in the Competition 2 scenario.
** Only in the Perfect Competition and Competition 2 scenarios.

5.3.2 Downstream Market

In Table 10 we indicate the congested transport routes within Europe. We focus on the Cournot scenario as we have identified this as the most realistic representation of today's European natural gas market. The large number of bilateral transport routes that are listed seems surprising. But there clearly exist only a small number of cross-border natural gas pipelines within Europe, many of them with very

[14] Note that in addition to export capacity restrictions we have also introduced import capacity and bilateral trade restrictions. Whereas import capacity of European traders generally is not binding, bilateral trade capacity quite often is but with a structure similar to the exort capacity utilization.

limited capacity. Several studies have already pointed out that this is an important obstacle to a Single European market of natural gas (EC (2005), Neumann et al. (forthcoming)). Although we find many congestions in two directions, this is not a necessary result since compressor capacity at a cross-border point may be such that more gas can flow in one direction than in the other. As discussed above, we observe in the results that missing transport capacity has a clear effect on prices since the local wholesale trader can benefit from a quasi-monopoly.

6 Conclusions

We have presented a model of the European natural gas market: Gasmod. It is a static model which structures the natural gas market as a two-stage game of successive i) exports to Europe, and ii) trade within Europe. In contrast to other models of the literature (e.g. Boots et al. (2004)) we have applied an unambiguous two-stage structure without simplifications and have incorporated an endogenous determination of domestic production. Infrastructure capacities which are an important characteristic of a network industry and which may be binding are explicitly taken into account in the model. We use Gasmod for numerical simulations with reference data for the base year 2003. We model three different market scenarios: Cournot competition on both the upstream and the downstream market, perfect competition on both markets, and Cournot competition on the upstream market with a downstream market in perfect competition.

We find that the scenario of Cournot competition is the most realistic representation of the European natural gas market with total export and consumption quantities close to the reference data. However, our results present a more diversified picture of supplies to Europe, with newly emerging (LNG) exporters gaining market shares in Europe. This indicates that there are other factors than market drivers influencing the supply relations in real world today (e.g. long-term contracts, destination clauses, etc.). Results in the Cournot competition scenario are strongly influenced by infrastructure capacity since a limited access to a market reduces the number of players which can then exert more market power. With no surprise we find the highest prices, lowest quantities and lowest exporter profits in this scenario, thereby confirming the welfare-reducing effect of double marginalization.

Whereas the scenario of perfect competition is only simulated to benchmark the results of the Cournot scenario, the scenario of perfect competition on the downstream market in the presence of an oligopoly on the upstream market merits a closer attention. Indeed this is a situation which could be enforced by the regulation authorities in Europe. We find that this case has an unambiguous welfare-enhancing effect compared to double marginalization (lower prices, higher quantities on both markets). This strongly contradicts the widespread thesis that an oligopolistic downstream market is the best response to an oligopolistic upstream market. Our results also point to more diversified supplies than in the Cournot scenario, which is another objective of European policy.

The comparison with real world data indicates that the current state of the European natural gas market is best represented by a scenario of Cournot competition. Deviations for some countries suggest that modeling them with competitive behavior might be more appropriate, be it in a competitive fringe for smaller countries or in the case of the UK because of its already successful market liberalization.[15] There are several improvement which should be included in Gasmod. Notably, the infrastructure bottlenecks that we have identified should be the basis for further investigation and for modeling the dynamics of the natural gas market and of investment in its infrastructure.

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[15] See e.g. Egging and Gabriel (forthcoming) for a model with a competitive fringe), and Pavel and Holz (2005) for an application of this specification in the Gasmod model.

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<u>Appendix:</u> Table 11: Intra-European Trade in the Cournot (Double Marginalization) Scenario

	UK	Netherl	Spain/Port	France	Italy/Switz	Belgium/Lux	Germany	Denmark	Swed/Finl	Austria	Poland	CSH	Balkan	Rom/Bulg	Baltic	Greece	Turkey
UK	25,1	10,0	2,2	10,2	7,1	4,4	8,1			2,5	2,2	4,2	0,3				
Netherlands	8,3	12,7	2,2	1,4	2,0	2,0	20,4			0,7	1,8	4,2					
Spain/Port			11,5										1,1				
France			2,2	15,4	7,1												
Italy/Sw					47,7								1,4				
Belgium/Lux	8,3	10,0	2,2	14,1	7,1	5,5	8,1			3,5	2,2	4,2	1,2				
Germany	1,6	1,6	2,2	8,1	7,1	1,6	31,1			2,3	2,2						
Denmark	1,6								0,6								
Swed/Finl									1,4								
Austria	1,6	1,6	1,6	1,6	17,9	1,6	7,1			2,6	2,2	4,2	0,3				
Poland	1,6	1,6	1,2			0,2	11,8				1,1	4,2					
CSH	1,6	1,6	2,0			0,7	14,0			0,2	1,1	5,5					
Balkan					0,2								1,7	6,1			
Rom/Bulg													3,9	7,2		1,3	
Baltic																	
Greece																1,0	
Turkey																	
TOTAL	49,5	38,9	27,5	50,7	96,0	16,1	100,7	0,0	2,0	11,9	12,6	26,3	9,7	13,3	0,0	2,3	

Table 12: Intra-European Trade in the Perfect Competition Scenario

	UK	Netherl	Spain/Port	France	Italy/Switz	Belgium/Lux	Germany	Denmark	Swed/Finl	Austria	Poland	CSH	Balkan	Rom/Bulg	Baltic	Greece	Turkey
UK	113.3					6.7											
Netherlands		69.6				5.0	36.9										
Spain/Port			39.8														
France				59.1													
Italy/Sw					83.9												
Belgium/Lux						9.6											
Germany							61.3										
Denmark								6.2	2.2								
Swed/Finl									4.1								
Austria				1.0	25.0		1.8										
Poland											17.6						
CSH					7.1		47.4			15.5		41.8					
Balkan													4.1				
Rom/Bulg													5.9	29.2			
Baltic															3.3		
Greece																3.7	
Turkey																	33.6
TOTAL	113.3	69.6	39.8	60.2	115.9	21.3	147.4	6.2	6.3	15.5	17.6	41.8	10.0	29.2	3.3	3.7	33.6

Table 13: Intra-European Trade in the Competition 2 Scenario

	UK	Netherl.	Spain/Port	France	Italy/Sw.	Belgium/Lux	Germany	Denmark	Swed/Finl	Austria	Poland	CSH	Balkan	Rom/Bulg.	Baltic	Greece	Turkey
UK	81,3	10,0															
Netherlands		29,1															
Spain/Port.			37,9														
France			1,4	63,3													
Italy/Sw					121,1												
Belgium/Lux	8,3	10,0				21,4	8,1			6,4	2,2	4,2					
Germany	1,6	1,6					123,1										
Denmark	1,6	1,6						5,7	2,2								
Swed/Finl.																	
Austria	1,6	1,6					7,1			8,2	0,6	4,2					
Poland	1,6	1,6									13,4	4,2					
CSH		1,6										24,0					
Balkan													10,5	3,7			
Rom/Bulg.														25,3			
Baltic															5,7		
Greece																3,6	
Turkey																	33,1
TOTAL	95,9	56,9	39,4	63,3	121,1	21,4	138,3	5,7	2,2	14,6	16,2	36,4	10,5	28,9	5,7	3,6	33,1