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European natural gas markets: resource constraints and market power[a]

Gijsbert T.J. Zwart[b]

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[b] Netherlands Bureau for Economic Policy Analysis, CPB, PO Box 80510, 2508 GM The Hague, The Netherlands, and TILEC, Tilburg University; e-mail: g.t.j.zwart@cpb.nl

CPB Netherlands Bureau for Economic Policy Analysis
Van Stolkweg 14
P.O. Box 80510
2508 GM The Hague, the Netherlands

Telephone	+31 70 338 33 80
Telefax	+31 70 338 33 50
Internet	www.cpb.nl

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Abstract in English

The European natural gas market is characterized by declining indigenous resources, particularly in the UK and the Netherlands, and a growing dependence on a small number of large exporters who, as a consequence, see their market power increasing.
In this paper we analyze long-run scenarios for the European natural gas markets in a model, NATGAS, that explicitly includes both factors, resource constraints and producers' market power.
We analyze the impact of conditions on the global LNG market on market shares of pipeline gas suppliers, as well as on the speed of depletion of indigenous European resources. We focus on how shadow prices of resource constraints affect substitution patterns in the various scenarios.

Keywords: European natural gas market, complementarity model, market power, resource rent.

JEL classification: C61, L13, Q31.

Abstract in Dutch

Europa wordt geconfronteerd met afnemende eigen aardgasvoorraden, met name in de van oudsher grote producenten het Verenigd Koninkrijk en Nederland. De Europese afhankelijkheid van een beperkt aantal grote aardgasleveranciers zal toenemen. Daarmee groeit ook de marktmacht van deze producerende landen.
We bestuderen een aantal langetermijnscenario's voor de Europese gasmarkt met een simulatiemodel, NATGAS, dat zowel de beperkte eigen gasvoorraden als de marktmacht van gasproducenten beschrijft. We bekijken de invloed van de beschikbaarheid van vloeibaar aardgas, LNG, op de marktaandelen van producenten en de snelheid van uitputting van Europese voorraden. We bestuderen in het bijzonder hoe in de verschilende scenario's de schaduwprijzen van eindige voorraden de productiebeslissingen beïnvloeden.

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Summary

The European natural gas market is characterized by declining indigenous resources, particularly in the UK and the Netherlands, and a growing dependence on a small number of large exporters who, as a consequence, see their market power increasing.

An important potential competing source of supplies will be imports of liquefied natural gas, LNG. LNG suppliers increasingly compete on a global market, shipping their production to the highest price bidders. Conditions in other consumer markets will therefore set prices for LNG imports, and such prices will largely be exogenous to regional European developments.

We analyze the relations between market power, resource depletion and LNG imports in Europe in a simulation model, NATGAS, that includes both the effects of resource constraints and of market power at the production level. Finite resources lead to interdependencies of current production decisions and future opportunities. Depletion decisions in turn interact with the potential for large producers to set market prices above marginal costs, where these costs themselves should be interpreted to include opportunity costs associated with conserving resources for future production. Apart from modelling producers' market power, the NATGAS model allows for endogenous investment decisions for producers and for price-taking infrastructure providers.

Within this framework we study the impact of different assumptions on the availability of LNG. In the face of varying LNG imports, what substitution patterns do we observe from indigenous production, external pipeline supplies and demand? One key observation is that although total available indigenous resources are fixed and finite, the changing long-run price perspectives will lead resource constrained European producers to shift their production profiles over time. At any given moment, these intertemporal constraints may cause a player's production to function either as a complement or as a substitute to contemporaneous LNG imports. If the effect of higher current prices dominates, more output is shifted to the present, whereas anticipation of higher future prices may lead producers to conserve their resources for future production, reducing immediate output.

We next illustrate how the degree of market power affects depletion decisions in the model. As EU producers are assumed more competitive, EU production peaks at an earlier moment: competition tends to shift more production to the present. If Europe's main suppliers behave more competitively, too, this effect is slightly reversed, as more Norwegian gas flows into the EU market. The effect of more intense supplier competition is furthermore to postpone the growth in LNG imports.

1 Introduction

Two main factors governing the policy debate on the European natural gas market are the decline of indigenous resources, combined with the growing dependence for a large share of gas supplies on a few foreign gas exporters, and the market power this may confer. In one to several decades, gas resources of major EU producers UK and the Netherlands are forecast to dry up. To meet growing demand, three large exporters to Europe – Russia, Norway and Algeria – will see their roles, and perhaps the associated pricing power, enhanced.

An important potential competing source of supplies will be imports of liquefied natural gas, LNG. LNG suppliers increasingly compete on a global market, shipping their production to the highest price bidders. Conditions in other consumer markets will therefore set prices for LNG imports, and such prices will largely be exogenous to regional European developments.

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The NATGAS model is a mixed complementarity model of Cournot producers in a network setting. It builds on a sequence of earlier simulation models of the EU energy markets. Golombek et al. (1995, 1998) used a Cournot model of the European gas market to assess the impact of liberalization on prices in Europe, while Mathiesen et al. (1987) compared Cournot, competitive and collusive equilibria in the European market. Haurie et al. (1987) studied an application to a market with stochastic demand[1]. In Boots et al. (2004), the impact of traders in a conjectural variations production market is investigated. More recent contributions focussing on producer market power in the European gas market include Egging and Gabriel (2006), Holz et al. (2008), Egging et al. (2008), Lise et al. (2008), and Zwart and Mulder (2006). Related recent Nash-Cournot models of the US market are studied, for example, in Gabriel et al. (2005a,b).

[1] See also Gabriel and Smeers (2006) for an overview of the earlier literature.

Modelling of (endogenous) longer-term dynamics in network models of natural gas markets is still underexplored. An early discussion on how Cournot network models could be applied to the European natural gas market was provided in Flåm and Zaccour (1989), though here the idea was not yet implemented in practice. Dynamic investment in electricity market models was addressed by Denis et al. (2002), Pineau and Murto (2003) and Murphy and Smeers (2005). These authors all focus on investment in production capacity. In NATGAS, we combine this approach to investment with the finiteness of resources (see e.g. Withagen, 1999, for an overview of literature on oligopoly power with exhaustible resources). An application of intertemporal optimization under Cournot competition in energy markets is given in Bushnell (2003), in a complementarity model of electricity markets including hydropower generation.

The structure of this paper is as follows. We first sketch the structure of the EU natural gas market and its suppliers. We then briefly describe the key characteristics of the NATGAS model. In section 4 we analyze the patterns of production and imports in various scenarios on LNG costs and market power. We close with some concluding remarks.

2 Gas supplies to Europe

Currently, the major EU producers are the UK and the Netherlands. Denmark, Germany, Italy, Poland and Romania play smaller roles, both in terms of production and reserves. By the end of 2006, total indigenous remaining reserves were approximately equal to 2800 bcm (billion cubic meters, BP, 2008), or less than six times annual EU consumption. Total annual EU production was slightly over 200 bcm in 2006 (IEA, 2007), and EU consumers depend to a large extent on pipeline imports of natural gas from, in particular, Russia, Norway and Algeria.

Even though the corresponding reserves to production ratio suggests that in about 14 years the EU will entirely depend on imports, the situation is slightly less gloomy if one takes into account the additions to reserves from gas exploration activity. Indeed, as Stern (2002) points out, proven reserves in the EU stayed more or less constant over the years 1981-2001, in spite of continuous production: new reserves were added at a similar pace. More important is the quantity of total resources, including those too expensive to exploit at current prices and technology, and those currently yet undiscovered. Though by their nature such resource estimates are substantially more uncertain than figures for proven reserves, both known but undeveloped finds and surveys of suitable geological structures do allow for some indications of their magnitudes. For example, the Department of Business, Enterprise and Regulatory Reform (BERR, 2007) provides a central estimate of total remaining UK resources of 1313 bcm of natural gas, compared to a proven reserves figure of 684 bcm and past cumulative production of just over 2000 bcm of natural gas. And similarly, the midpoint estimate for resources in the Dutch Continental Shelf small fields equals about twice their proven reserves (EZ, 2008). Seeliger (2004) lists values for other European producers.

Even with these figures of remaining resources, EU production is widely expected to decline substantially in the coming decades, in particular for the two major producers, the UK and the Netherlands. Because of still growing demand for natural gas, the need for increased imports from outside the EU is apparent. Fortunately, reserves and estimates for remaining resources in the EU's suppliers are huge: for instance, remaining Norwegian resources are estimated at almost 5000 bcm (NPD, 2008), and Russian proven reserves alone equal about ten times this figure (IEA, 2007). For the EU, a more pressing question is at what price these resources will be made available. Since the 2007 Norwegian Statoil - Norsk Hydro merger, state controlled monopolists have dominated production in all three major gas exporters to the EU: Norwegian StatoilHydro, Sonatrach for Algeria and Gazprom for Russia. It is natural to assume that these firms will, to some extent, use the market power they are endowed with. Also within Europe, entry into the producing sector is typically restricted, and producers are not necessarily price takers, though levels of competition in the various countries will differ. In this paper we will indeed assume that production can be described by an oligopoly model.

As indigenous resources dwindle, will the European gas market essentially become a triopoly, perhaps complemented by smaller pipeline supplies from other North-African or former Soviet Union states? Not necessarily: supplies from elsewhere in the form of liquefied natural gas, LNG, may contest this market, depending on prices in Europe and other consumer regions. The global market for LNG has experienced substantial growth over the past decade, with annual growth rates of over 7% (Elkins, 2008). Currently, LNG only caters for a small share of total gas demand in the European market, around 50 bcm out of total gas demand of over 500 bcm. Although this share is expected to increase, LNG consultant Jensen Associates (2007b) indicates that projections of LNG growth are very uncertain, and estimates a range for the global LNG market in 2020 of 400 bcm to 600 bcm (compared to some 190 bcm in 2005). His estimate for the share going to Europe displays even greater uncertainty, ranging from hardly any growth (if pipeline imports continue to be relatively cheap) to 170 bcm in the most positive scenario.

LNG is more flexible in destination than pipeline gas. Liquefaction facilities in source countries make up the larger part of costs in the LNG chain, while on the other hand, regasification terminals in destination countries account for a much smaller share of the costs in the chain. Indeed, in this latter segment there is overcapacity. Global regasification capacity is roughly twice as large as global liquefaction capacity.

Differences in shipping costs of LNG to various demand centers (Europe, the US, and the Far East) are, at one to a few cents per cubic meter, relatively minor compared to gas prices. Therefore, a producer such as Qatar or Nigeria may choose a destination for its gas based on the highest net-back price. As a result, provided LNG prices are competitive with costs of piped gas, LNG could give rise to arbitrage between these various global regions. Although currently, the LNG market is still dominated by relatively inflexible long-term contracts allowing little scope for interim renegotiation of the cargo’s destination, the market for flexible LNG is growing. As Jensen Associates (2007b) documents, flexibility of destination might grow as spot markets for LNG grow in importance, but also as more and more LNG contractors become themselves active in multiple downstream markets, and can arbitrage within their own portfolios. Jensen Associates (2007a) estimates current flexible volumes in the Atlantic Basin LNG market at some 30% of total volumes.

3 The NATGAS model

In view of the importance of producer market power and finiteness of resources in describing the European gas market, we set out to create a model capturing both characteristics, NATGAS, and see how they interact. In this section we give a brief overview of the structure of the model. For details we refer to Zwart and Mulder (2006).

3.1 Geographical and temporal dimensions

We model gas production and consumption in Europe, aggregating data into a limited set of markets. We distinguish production centers inside the EU (the most important ones being the UK and the Netherlands), as well as Europe's pipeline suppliers Norway, Russia and North Africa. We treat exports to Europe in the form of LNG as one single source. Available LNG supplies vary with market prices. We aggregate European demand into nodal demand centers, tied together through a simplified transmission network of links between these nodes. Table 3.1 lists the various supply and demand nodes included.

In the time dimension the model is discretized into ten sets of five years each, starting from the first period 2007-2011 to, finally, 2052-2056. The period studied consists of the first thirty years.

Table 3.1 Groups of countries represented as supply or demand nodes.

Suppliers	
Russia	including transits from other former Soviet Union
Netherlands	separately considers Groningen field and small fields
Norway	including Denmark
UK	
North-Africa	including pipeline gas from Algeria and Libya
Eastern Europe	mainly Romania and Poland
Germany	including Switzerland and Austria
Italy	
LNG market	
Demand	
The Netherlands	distinguishing low- and high-calorific markets
Belgium	as above
Germany	including Switzerland and Austria, as above
UK	including Ireland
France	
Italy	
Iberian Peninsula	
Eastern Europe	

3.2 Producer market power

Producers are located in each of the supply regions, and compete in selling output to the various consumer regions. Decision variables for each producer are quantities of natural gas sold to each consumer region (in each five-year period), and investment in new production capacity (for each five year period). Clearly, the aggregate quantities produced in any period cannot exceed available production capacity built up in previous periods.

Oligopoly behavior is described as the equilibrium of a non-cooperative game in which all producers simultaneously choose capacities and output. In solving for this equilibrium, we make the Cournot assumption on producers: each producer maximizes the present value of his profits taking the decisions of his competitors as given. The intensity of competition in this Cournot game is determined by the number of producers in each region: as the number of Cournot players in each supply region grows, the Cournot solution will converge to the perfect competition outcome. In the model analysis we will compare low competition scenarios, where every supply node is populated with a single monopolist, to situations in which the production market in some nodes will be shared by symmetric competitors.

The oligopoly game describes producers' investment and production decisions over time, and therefore producers' strategies are functions of time. In the NATGAS model we consider the so-called open-loop solution concept for dynamic games, where strategies are functions of time only[2]. Essentially, producers simultaneously and non-cooperatively choose an entire investment and depletion path for the resources they are endowed with.

3.3 Incorporating the resource constraint

Gas producers dispose of a finite marketable quantity of natural gas and face the choice at what point in time to produce this quantity. As is well known (Hotelling, 1931; Stiglitz, 1976), in equilibrium production will be such that each producer will be indifferent between producing now and postponing production until tomorrow: marginal profits rise at the rate of discounting.

In the NATGAS model, this relation between production quantities at various points in time is realized by explicitly adding the constraint that total production over time be constrained by an exogenous total resource quantity (the sum of reserves, estimated potential and undiscovered resources). The shadow price of this constraint is known as the resource rent. This rent is an opportunity cost of producing in any period, and links behavior across periods. Consequently, current production decisions will be affected by expectations of future prices. The expected structure of the market, and its competitiveness, ten years from now will have an effect on the

[2] The alternative would be a closed-loop solution, where players' strategies are allowed to depend on decisions of their competitors in previous periods. Sometimes the two coincide, see e.g. Flåm and Zaccour (1989).

resource rent, and hence the choice of depletion paths now.

3.4 The LNG market

We model the global LNG market as a competitive fringe: LNG is available to Europe at costs determined by an exogenous supply function. The threshold price at which LNG-imports become available to Europe should be set by the opportunity costs for LNG suppliers of supplying to alternative destinations (corrected for differences in shipping costs). If European gas prices determined by pipeline competition remain below gas prices in the US or the Far East, LNG would be diverted to those regions, while as European prices exceed those prices, more LNG will be made available to Europe. In the model simulations we will analyze the effects of different assumptions on these opportunity costs.

Clearly, even if market prices exceed prices at which LNG will be available, LNG terminal capacity is required in Europe to accommodate any imports. In NATGAS, investment in LNG import capacity is treated as endogenous. Independent, price taking players are assumed to choose capacities and to purchase LNG deliveries constrained by those capacities. In the investment equilibrium, such price takers will make zero net profits in the long run[3].

3.5 Other players included in the model

Besides the Cournot producers and price taking LNG importers, several other players are included in NATGAS, all of which we model as profit maximizing price takers:

- regulated investors in transport capacity between the various demand and supply nodes
- traders arbitraging between different demand nodes, making sure that prices equalize as long as spare transport capacity is available
- storage owners arbitraging price differences between high demand winter and low demand summer seasons

Finally, in each region, consumers are represented by an exogenously specified time dependent aggregate demand function.

[3] The assumption of perfect competition for these players seems consistent with the currently observed wave of new entrants investing in such terminals in various European countries.

4 Patterns of substitution

LNG supplies are likely to play an increasingly large role in global natural gas markets. However, the pace of growth of LNG supplies to European natural gas markets remains highly uncertain. Firstly, global growth of LNG production remains unpredictable. Despite abundant resources worldwide, development of new liquefaction capacity on the longer run may be affected by, for instance, sharp cost inflation (with liquefaction costs doubled over the last few years, see Jensen Associates, 2007c), by political tensions (with large available resources in e.g. Iran, Venezuela, Nigeria), or by steps by producers to coordinate production decisions in an OPEC-like cartel.

Secondly, different consuming regions compete for supplies. Increasing price responsiveness of LNG shipments causes cargoes to be delivered where prices are highest. As a result, a surge in Far Eastern gas demands (e.g. because of Japanese nuclear power station outages) draws LNG to the Far East even from the Atlantic basin. As long as LNG is scarce compared to demand, prices remain set by the highest priced region. If Europe's alternative of pipeline gas remains cheaper, LNG will, at least initially, not play a big role, as emphasized by Jensen Associates (2007b)

We investigate the effects of differing assumptions on LNG costs in the NATGAS model. In a scenario where LNG availability is lower (or LNG is only available at higher costs), we expect lower imports of LNG. How will the market cope with this shortage? What sources will substitute for the gap in imports? In response to higher prices, we may anticipate both demand response and larger incentives for production, and we explore the relative importance of these various sources of gas.

We will be particularly interested in the extent of shifting production patterns in time. Resource constrained producers cannot just increase production: higher production now means lower production in the future. How do changing expectations in LNG costs alter the balance of depletion schedules, in particular for tightly constrained producers such as the UK? Here we note two opposing effects: higher LNG costs may raise current revenues and make production more attractive, but higher future expected costs cast their shadows into the present as well: they raise the resource rents and make production more costly. As we will see, in some cases the second effect dominates and lower LNG imports in those cases go together with lower current production from indigenous producers.

Apart from LNG availability, also producer market power will influence production decisions, although again here any effects of increased competition may be muted by the resource constraints. In our baseline simulations we make the 'worst' assumption on market power and assume that in each country, one Cournot producer is active. We then evaluate the effects of increased competition among producers.

4.1 The baseline

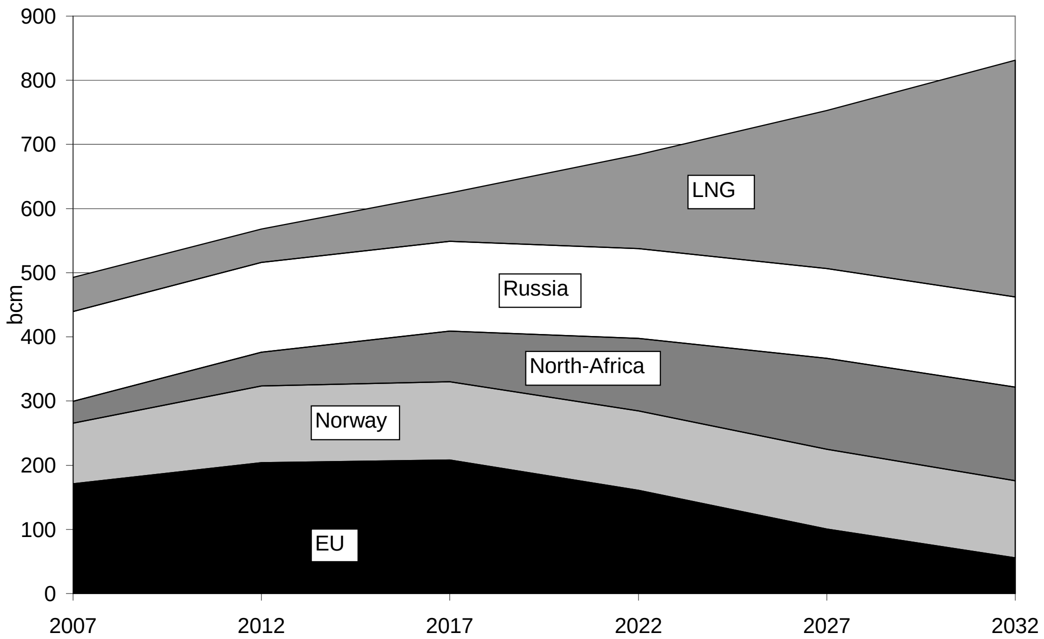
In the baseline scenario we assume LNG costs of 29 cents per cubic meter (ct/m^3) in winter, and 25 ct/m^3 in summer, and keep these constant for the entire simulation period. These prices correspond roughly to prices currently observed in the market and equal around $ 11 to 13 per MMBTU, for comparison with US units. The seasonal spread in costs of 4 ct/m^3 is of the same order of magnitude as long run average costs of seasonal storage. As to market power, in the baseline we make the relatively bleak assumption that a single producer, exploiting its full Cournot market power, dominates each producer region. We will explore the impact of changing the level of LNG costs and degree of market power in various scenario analyses.

Data on production and infrastructure costs and current capacities are based on Zwart and Mulder (2006) and sources cited there, but where possible updated with more recent data from IEA (2007), and with information on cost inflation in the sector as documented by IEA. We keep these data the same for all scenarios. Russian production costs are highest (but still lower than our baseline LNG costs), production from the Dutch giant onshore Groningen field is cheapest. Initial production costs for other European and Norwegian gas are all similar in magnitudes. For all regions, costs are assumed to increase as resources are depleted. We include some additional exogenous bounds on production. Firstly, we exogenously limit future capacity from the Groningen field (in line with expectations on the field's physical possibilities); secondly, we do not allow any region's production capacity to increase by more than 50% in any five-year period; and finally, we assume Russian exports to Europe will not drop below current values, reflecting the sunk character of large part of the infrastructure, a constraint which at least initially binds.

We plot the baseline estimates in figure 4.1. Within the thirty years horizon under study, a large part of indigenous EU resources are depleted: the Dutch small fields and the UK, Eastern Europe and Italy. Only some German production and a modest rate of production from the Groningen field remain. Initial significant growth of output comes mainly from Norway, North-Africa and, within the EU, Eastern Europe. For Russian supplies, the lower bound on exports to Europe is equal to current exports. This constraint binds throughout the study period in this scenario. We note that in this baseline scenario, LNG imports first increase at a relatively modest pace, growing to around 75 bcm (billion cubic meters) per year around 2020, with initial large imports mainly in Spain. Only when EU resources are in rapid decline do LNG imports pick up, with import terminal capacity growing fastest in the UK.

Our main interest does not lie in the absolute values of imports from various sources, but rather in the sensitivity of the depletion and import patterns to assumptions on LNG costs and market power. We explore these issues next.

Figure 4.1 Baseline EU supplies



4.2 Changes in LNG availability

We consider three alternative scenarios for LNG costs, to obtain some insights into the mechanisms governing the relations between current prices, price expectations and depletion decisions in the EU gas market. We will look at one lower costs scenario, with winter and summer LNG costs 5 cents lower (24 and 20 ct/m^3, or average 22 ct/m^3), LNG22 for short, and two higher ones, with costs 34 (30) ct/m^3 in winter (summer) and 39 (35) ct/m^3, LNG32 and LNG37 respectively.

The main effect of these changing assumptions on levels of LNG imports is to shift their growth pattern in time: at higher LNG costs, growth of LNG imports does not start until in a later period. In the LNG37 scenario, LNG will not appear on the market at all for the first 15 years. Eventually though, LNG imports do increase. In LNG22, LNG is relatively cheap compared to pipeline gas and growth is much faster, already reaching 150 bcm per year in 2020. Given that the market clears in all scenarios, how are these large differences compensated for by changes in other sources of supply and demand? We first analyze the substitution patterns at a single point in time, the third period in the model simulation. Then we focus on intertemporal shifts in production: how do producers shift their depletion schedules in response to the various LNG scenarios?

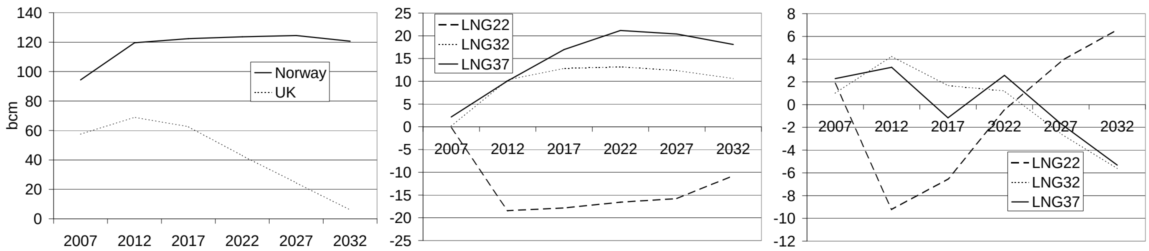
Table 4.1 plots the changes in third-period supply and demand for each LNG scenario, relative to the baseline scenario. The first thing we note is that the large differences in LNG imports across the various scenarios are predominantly matched by large changes in demand. As a result of changing LNG import costs, market prices are affected and these expand or restrict demand. Clearly, price effects are largest in those regions where LNG imports set the margin, in particular Spain and the UK. Average prices in other regions are affected, too. This happens through spill over effects such as arbitrage over available pipeline connections, or rerouting of supplies from the continent to the UK by Norway. The bulk of the remaining compensation is from Norwegian production, with also some contribution from the UK, the Netherlands and North Africa.

Table 4.1 Changes from baseline scenario results, in third period (2017-2022) supply and demand, by LNG scenario (in bcm)

	LNG	Demand	Norway	UK	Netherlands	North-Africa	Other
LNG22	82	43	−18	−7	−4	−4	−6
LNG32	−53	−35	13	2	2	0	1
LNG37	−75	−54	17	−1	2	0	4

As pointed out, changes in a country's production in one period must be accompanied by compensating changes in another, if the resource constraint is binding. Rather than looking at effects of the LNG scenarios in a single period, we now turn to the effects on depletion schedules over time. In doing so we focus on two countries, the UK and Norway. The former faces tighter constraints, and consequently a higher resource rent, than the latter. For the UK, in the baseline the shadow price of the resource constraint equals over 7 ct/m^3, a value comparable in magnitude to physical production costs. For Norway, the resource rent is over three times smaller. Figure 4.2 shows the UK's and Norway's production schedules in the baseline scenario (left-hand panel) as well as deviations from these schedules (Norway centre panel, UK right-hand panel) under the alternative LNG prices.

Figure 4.2 Baseline Norwegian and UK production (left panel) and differences in per period production levels (in bcm) in the scenarios (Norway centre, UK right)



Norwegian imports are projected to grow in the first ten years and to remain stable afterwards during the thirty-year study period[4]. The level of this plateau varies with the scenario in an intuitive way: higher LNG costs (and lower LNG imports) straightforwardly lead to substitution by Norwegian production.

The situation is different for the UK. Here we observe the trade-off between taking immediate advantage of higher current prices, and saving gas in response to higher future expected prices. In comparing the baseline with slightly higher prices in the LNG32 scenario, it is the immediate effect that dominates: the UK's production schedule is shifted to the present as a whole, leading to lower remaining production in the tail end, the last two periods. However, when comparing LNG32 with even higher LNG costs, LNG37, we see a reversal: in response to a further decline in LNG imports, UK production in the second and third periods drops as well, in favour of higher volumes compared to LNG32 in the latter 15 years of the study period. The resource rent leads to conservation of gas in anticipation of higher future prices. In case of cheaper and more plentiful LNG imports, the LNG22 scenario, we see the resource effect mainly in the first period. In conjunction with higher first period LNG imports compared to the baseline, also UK production is increased: production and LNG imports act as complements rather than substitutes for this shift. As a consequence of the lower LNG costs in the future, the UK resource rent goes down and saving gas is less attractive.

4.3 Changes in market power

In the baseline scenario, we assume that each country fully exploits its full Cournot market power. We now evaluate the effect of more aggressive competition. Within the EU, currently the production market is often shared by a larger number of competing firms, particularly in the UK. EU pressure on liberalizing the gas sector and promoting intra-EU competition is primarily directed at the wholesale (or midstream) market[5], rather than at upstream production. Still, it is conceivable that a more liquid and transparent internal wholesale market will reduce entry barriers for EU producers and cause the EU upstream market to be more competitive in the study period. The case is different for outside producers, but here, too, competition might be more aggressive than pure monopoly under the threat of new pipeline imports from e.g. Libya, Iran or Turkmenistan.

We study the effects of such increased competition on the role of LNG in Europe and on production schedules across the study period of resource-constrained producers. For this we introduce two competition scenarios: EUduopoly, where we assume each producer region within

[4] Norwegian production starts to go down at the end of this period. Simulations were done for a significantly longer period of fifty years, to avoid introducing artifacts related to the choice of finite study period duration.

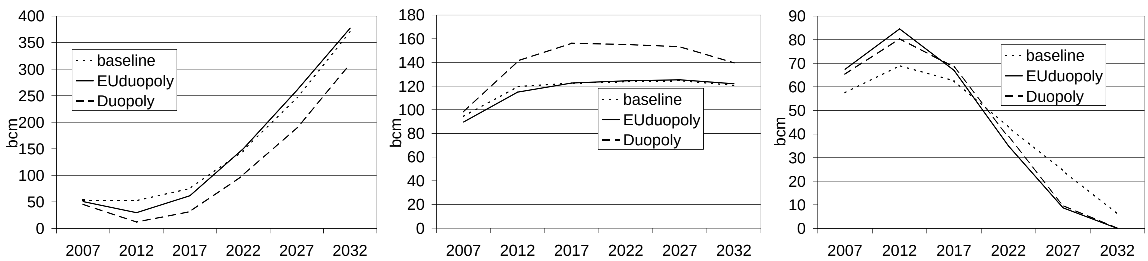
[5] We do not explicitly model this segment of the market here. Models analyzing market power of European wholesalers include those of Egging et al. (2008) and Lise et al. (2008)

the EU to be operated by two (independent) firms, and Duopoly, where also the Norwegian, North-African and Former Soviet Union supplies are Cournot duopolies. We keep LNG costs at the baseline levels, 29 ct/m^3 for winters and 25 ct/m^3 in summers.

As Stiglitz (1976) observes, in the presence of resource constraints the relation between competition and output is less clear-cut than in unconstrained industries. A monopolist with zero production costs, facing constant elasticity residual demand, will not behave differently from a price taker. When these assumptions are relaxed, however, increased competition will usually lead to a shift of production to the present[6]. This is indeed what we observe in the simulation results, figure 4.3: in both cases, LNG, with its fixed supply function, is initially kept at lower levels by the increased production from pipeline producers. In the EUduopoly scenario, this is reversed later, when indigenous resources are depleted. The effect of higher competition is mainly to reduce prices slightly initially, with exporter market power taking over at a later stage (but still kept in check by the LNG fringe supply curve). When also the major exporters to Europe behave more competitively, in the Duopoly scenario, we see a larger increase in demand, and lower LNG imports all over the study period.

This is reflected in the production profiles of the UK and Norway: in the EUduopoly scenario, there is a sharp increase in UK production, partially balanced by lower Norwegian exports to the EU (and lower LNG imports). In the Duopoly scenario, also Norway shifts its production forward in time, and achieves a higher plateau rate; the UK's gain from earlier production is slightly reduced and the production peak is somewhat lowered.

Figure 4.3 LNG imports (left), Norwegian production (centre), and UK production (right) (in bcm) under the market power scenarios



[6] Captured by Solow (1974)'s "A monopolist is the conservationist's friend."

5 Concluding remarks

We have used the NATGAS model to study how equilibrium supplies to the European natural gas market respond to changing conditions in the world LNG market, as well as to changes in assumptions on producer market power. The main feature that distinguishes the NATGAS model from various other approaches is the focus on long-term dynamics, incorporating both the resource constraints and the market power that play an important role in the real world. We highlighted the interaction between short and long-term production decisions relevant in particular for the more tightly resource constrained producers, such as the UK. We observed how, because of these intertemporal links, constraints on LNG availability may lead to short-term reductions in output by competing suppliers, who conserve gas in response to a more favorable outlook on long-term prices. The analysis of market power and depletion patterns demonstrates that increased competition leads to slightly faster depletion of indigenous resources; the main welfare benefit is therefore to reduce current prices, at the expense of higher future prices.

The scenarios illustrate how shadow costs, in particular the resource rent, affect production decisions under changing circumstances: these costs may be comparable in size to real production costs. One direction for further research is to analyze more extensively the impact of competition on the shadow costs of production, including other ones beside the resource rent. Another aspect that could deserve future attention is the relation between European markets and the global LNG market. In the current study, we treated the LNG market as exogenous. Clearly, providing a global modelling framework that allows linking the LNG market endogenously to conditions in both European and other regional markets would be desirable. Steps in this direction are reported in Egging et al. (2009), Aune et al. (2009) and Hartley and Medlock (2009).

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