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Gas models and three difficult objectives

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Gas models and three difficult objectives

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Abstract

Competition, security of supply and sustainability are at the core of EU energy policy. The Commission argues that making the European gas market more competitive (completing the internal gas market) will be instrumental in the pursuit of these objectives. We examine the question through the eyes of existing models of the European gas market. Can model tell us anything on this problem? Do they confirm or infirm the analysis of the Commission appearing in fundamental documents such the Green Paper, the Sector Inquiry or the new legislation package? We argue that results of existing models contradict a fundamental finding (paragraph 77) of the Sector Inquiry. We further elaborate on the basis of the economic assumption underlying the models, that changing the assumptions implicitly contained in paragraph 77 cast doubts on a large part of the reasoning justifying the completion of the internal gas market. We also explain that models could help arriving at a better definition of the relevant market, which is so important in the reasoning of the Commission. Last we also find model results that question the effectiveness of ownership unbundling. As to security of supply, we explain that models can also contribute to assess the value of additional infrastructure in the context of security of supply, but this potential seems largely untapped. Last we note that sustainability has not yet penetrated models of gas markets. We conclude by suggesting other area of immediate concern, possibly of higher technical difficulty, that modellers could address in future research.

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1. INTRODUCTION

Competition, security of supply and sustainability are the three objectives of the energy strategy heralded in the 2006 Green Paper (EC, 2006)) of the European Commission. The Commission, which was then referring to a balance between the three objectives now sees them as helping one another (EC, 2007a). In this view competition is both a goal and an instrument to achieve other goals; it also contributes to the more global objective of competitiveness of the European industry. This new, more proactive, view is confirmed in the third energy package published by the Commission on 19 September 2007. Others (Röller et al., 2007) have maintained that there are tradeoffs between these three objectives. Some in the industry have recently adopted a more vigorous position. They claim that, by focusing on the internal market the Commission might have overlooked the problem of security of supply. Natural gas plays a particular role in these objectives. With electricity, it is one of the two energy sectors that the Commission hopes to make more competitive and contribute to overall competitiveness. Natural gas has a relatively low carbon content and is abundant around Europe. It is therefore also a key contributor to sustainability. But its production is progressively moving outside of the EU/EEA area, causing concerns of security of supply. This paper analyzes the insight that gas models can potentially give on the role of natural gas in the pursuit of the European objectives of the Green paper. It does not address the more specific question of the compatibility of the three European objectives but simply recognizes diverging opinions about it.

We restrict our discussion to six gas models (see Table 1).

Model name	Authors	Reference papers
NATGAS	G. Zwart and M. Mulder	NATGAS. A model of the European natural gas market. CPB Memorendum, 24 February 2006.
GASTALE1	M.G. Boots, F.A.M. Rijkers and B.F. Hobbs	Trading in the downstream European gas market: A successive oligopoly approach. . *Energy Journal,* 25(3), 74-102, 2004.
GASTALE2	R.G. Egging and S. Gabriel	Examining market power in the European natural gas market. *Energy Policy, 34(17),* 2762-2778, 2006.
GASTALE3	W. Lise, B.F. Hobbs and F. van Oostvoorn	Natural gas corridors between the EU and its main suppliers: simulation results with the dynamic GASTALE model
GASMOD	F. Holz, C. von Hirschhausen and C. Kemfert	A strategic model of European gas supply (GASMOD). *Energy Economics,* 2007 (forthcoming).
EUGAS	D. Bothe and A. Seeliger	Forecasting European gas supply. Selected results from EUGAS model and historical verifications. EWI Working Paper 05.01. August 2005.

Table 1: Models, authors and titles

We consider three versions of the GASTALE model developed in ECN in the Netherlands. NATGAS is another Dutch model. GASMOD was developed in DIW, Berlin and EUGAS in EWI, Cologne. Table 1 gives some more information on these models.

The first five models suppose an imperfectly competitive European gas market and hence seem best adapted to investigate the preoccupation of the Commission on competition and competitiveness. The sixth model supposes perfect competition and concentrates on the infrastructure. This makes it particularly suitable for examining questions of investments in relation to security of supply. The assumption of perfect competition in the gas market may seem at odd with reality but we shall argue that it offers several advantages. Because of the central role of competition both in the thinking of the Commission and of the modellers, most of this paper is devoted to this theme. In order to insert our discussion of models as much as possible in the current competition debate, we adopt the language of product and geographic markets throughout the paper.

Section 1 accordingly begins with an analysis of the product and geographic gas markets that summarizes and complements the view of European competition authorities on the subject. Section 2 attempts to map the definition of markets found in the models into those of the Commission. We conclude that some elements are common but many diverge. Section 3, 4 and 5 discuss the representation of competition in gas models. Section 3 surveys different possible models of competition and relate them to the views of the Sector Inquiry (EC, 2007b). We particularize this discussion to our models in Section 4 and concentrate on some model results in Section 5. We then assess the extent to which models comply with, or support some policy recommendations of the Commission in Section 6.

Concerns of security of gas supplies are growing. Energy authorities draw the attention to the increasing share of gas sourced outside the EU/EEA area and flowing into the EU. They express concerns about our increased dependence on these sources. We discuss whether models can shed some light on this question in Section 7. Last we acknowledge in Section 8 that, even though natural gas is crucial in greenhouse gas policies, the gas models covered here are silent on the problem. The paper summarizes our analysis and points to subjects that have been ignored and could usefully be explored.

2. PRODUCT AND GEOGRAPHIC GAS MARKETS

One can describe gas models by listing their sets of variables and constraints together with the functional relations that express the behaviour of economic agents. We avoid this mathematical language and present the models in terms closer to those used by Competition Authorities. The concepts of relevant product and geographic markets pervade competition law both in Europe and the

US. We accordingly describe the gas market in those terms and analyze the extent to which models comply with or depart from the view of the Commission on the product and geographic gas markets.

An economic sector involves activities taking place in spatial markets. Defining the relevant market amounts to identifying the competitive pressure imposed on companies by alternative products or suppliers. This should sound familiar in natural gas: on the one hand, the industry has for a long time argued that natural gas is the only energy form subject to the competition of another fuel in each of its consumer segments. This is an issue of product market. On the other hand, and depending on transportation possibilities, producers exercise pressure on one another, with the result that their prices are reasonably aligned. Whatever the degree of competition that this suggest, this "single price" is a matter of geographic market. The notions of product and geographic markets directly transpose to models as these implicitly or explicitly represent the competition between alternative fuels and suppliers in different products, services and geographic zones.

Market definition paves the way to competition analysis. Authorities use concentration indices and analyze company behaviours (e.g. pricing behaviour) in order to assess the intensity of competition in the different product and geographic markets. They then elaborate remedies to enhance competition when it is not sufficient. Models represent competition by invoking economic assumptions and comparing their implications with real world observation. It is useful to try to relate these two descriptions of competition. The definition of product and geographic markets by the Commission reported here largely relies on Cabau (2005a and 2005b) and considerations found in the Sector Inquiry (EC, 2007).

2.1. Product and geographic markets

- *The product markets*

The gas industry comprises upstream and downstream activities. Exploration, gas production and sales at the producer site, liquefaction and transport whether by pipeline or in LNG form to the European border are upstream activities. Except for the declining, but still important, EU production and the expanding LNG shipping, these upstream activities, even when conducted by Western companies, are mainly under the control of sovereign states on which European competition authorities have little or no direct authority. Downstream activities encompass re-gasification, transportation of natural gas by high and low-pressure pipelines in the European Union, storage, supply (buying and reselling gas) and retail. Companies operating these downstream activities are subject to European law, and hence also the contracts concluded between upstream and downstream companies.

Competition authorities concentrate on the downstream activities. Gas models cover the whole value chain from production to retail. We first summarize the market definition by the Commission and then compare it to the one implicitly adopted in the models.

2.2. Production

- *The product market*

Except for considering exploration and LNG sales as separate markets and for recognizing different qualities of gas, the Commission does not refine the definition of production.

Models generally bundle production and liquefaction (when relevant) into a single product (or activity in modelling terms). They represent this activity by its cost and capacity that they describe with different degrees of detail (Table 2). The simplest representation assumes a single unit cost (e.g. in euro/bcm) and an annual or seasonal sendout capacity (e.g. in bcm/year). The different versions of GASTALE rely on a function that shows production cost increasing with the use of the capacity. Cost data come from Golombeck et al. (1995 and 1998) and OME (2001). These sources may be somewhat outdated today.

GASTALE1	Long term marginal cost – Golombek et al. 1995 ($/kcm)
GASTALE2	Long term marginal cost – Golombek et al. 1995 ($/kcm)
GASTALE3	Long term marginal cost – Golombek et al. 1995, 1998
GASMOD	Long term marginal cost – OME 2001 (US$/kcm)
NATGAS	Investment and variable production costs (ct/cm)
EUGAS	Investment and variable production costs

Table 2: Model description of products

GASTALE 1 and 2 as well as GASMOD do not distinguish short and long run operations and only work with long-term costs. This is questionable. Competitive pressure differs in the short and the long run and hence corresponding market definitions may also differ. This important distinction is recognized in the Commission Notice on the definition of Relevant market for the Purposes of Community Competition Law (EC, 1977): "The different time horizon defined for the same products, depending on whether the Commission is examining a change in the structure of supply, such as a concentration or a cooperative joint venture, or examining issues relating to certain past behaviours" (paragraph 12) . The question is related, but distinct, from whether the definition of markets should take into account the progressive opening of national markets as a result of restructuring (paragraph 32 in EC, 1997). We shall not delve into that question that itself deserves a methodological paper. One shall simply note that modelling competition on the basis of long-term costs, as done in many gas models, sharply contrasts with the predominant analysis of market power in electricity. The whole academic literature of market power in electricity indeed relies on short run marginal costs. The Commission explicitly endorsed the short-term analysis in its presentation (EC, 2007c) of London Economics (2007), where it refers to a world driven by short run marginal costs as the paradigm of a perfectly competitive economy. There is thus a significant discrepancy between the current model

based analysis of competition in gas and electricity. Last one can also contrast the correct association of short run costs and existing capacities found in electricity reasoning (e.g. as in London Economics, 2007) with the more delicate combination of long run costs and existing capacities in gas models. All this deserves further analysis but falls outside the scope of this paper.

- *The geographic market*

Modellers describe production and liquefaction (when relevant) by country but some models also allow a representation by companies. The distinction between production companies and countries is important but it not clear that it can be made operational. Competitive pressure due to geography is different for sovereign states and for global vertically integrated oil and gas companies whose upstream activities are often controlled by those sovereign states. All case studies discussed here (and many consultants analysis) refer to countries as the economic agent in charge of production (and liquefaction when relevant). Most models assume that each country behaves as a single economic entity and rarely distinguish production by individual firms in a country. They represent an aggregate production field with aggregate cost and capacity. NATGAS departs from that practice and allows for a set of identical producers in each country (except fort the Netherlands where it distinguishes high and low cost producers). Consultants such as Wood McKenzie go much deeper in the analysis.

A description of production by country does not imply that the geographic production market is national. According to Cabau (2005b) "the development and production of natural gas probably includes the EEA, Algeria and Russia". This statement does not say much about the geographic market of production. The intriguing paragraph 77 of the Sector Inquiry (EC, 2007b) (hereafter paragraph 77) that will often be quoted in the paper is equally vague "There are a number of global players on the upstream gas producer level. If the market is considered global, the concentration is unlikely to be excessively high". The Commission recognizes that "defining this upstream market is not straightforward". It avoids the question in concentration cases but concludes paragraph 77 on a surprisingly optimistic note on gas supply to Europe. "However, the future development of new infrastructure and LNG sources is likely to provide new economically viable sources of gas to Europe thereby reducing dependence on a few producers and hence reducing concentration, when it exists, at this level of the gas supply chain." This positive view about the forthcoming reduction of concentration is also amazing: the Commission generally insists on immediate and guaranteed effects when looking at concentration downstream (e.g. in Verbond/Energie Allianz (June 2003) "the sought-after results are not certain and immediate enough to justify the conclusion that the relevant geographic market is in fact larger (than national)". But it is here satisfied that "likely future development of new infrastructure and LNG sources" will eliminate most of the concentration on the upstream market. We shall argue later that this complacent view of the upstream market is particularly important when assessing modelling assumptions of competition. Conversely, we shall also argue that

the economic theory underlying the models shed a very particular light on paragraph 77 and on the methodology adopted for analyzing the gas market.

Part of the difficulty of "defining this upstream market" comes from the fact that producers compete against one another through the transmission system. The capability of the transmission system is thus a key element of the definition of the upstream market. This capability implicitly delineates the geographic production market. As we discuss next, models embed a representation of gas transmission that influences the assumed competitive pressure among producers. A thorough analysis of the impact of the explicit representation of transmission on the implicit degree of competition among producers is important, but beyond the scope of this paper. In any case, one should recognize that the modelling of the transportation activity is at the core of any analysis of the geographic production market that tries to go beyond concluding that "defining this upstream market is not straightforward" (Paragraph 77) or that the supply market is national "as a matter of principle" (Cabau , 2005b).

2.3. Transportation

- *The product market*

Transportation of natural gas is subject to different regimes inside and outside the EU/EEA. European law imposes open access to transportation inside the EU and the EEA (EC, 2003 and EC, 2005). National law and Regulators have diversely interpreted this general requirement, which led to a "regulatory gap" now commonly denounced (EC, 2007a and ERGEG, 2007a and 2007b). The Sector Inquiry abundantly documents the restrictive practices induced by current national regulations. The Energy Charter Treaty (see e.g. Annual report 2006 (ECS, 2007)) was intended to introduce some regulation on transportation (articles 6 on transit) and to foster competition (article 7 on competition) outside the EU/EEA. Russia, which is a member of The Energy Charter Conference, never ratified the Treaty. Attempts to agree on transit rules in the context of the Energy Charter Conference also never came to fruition. Neither Regulators in the ERGEG reports (see ERGEG website), nor the Sector Inquiry refer to transportation conditions outside the EU. Transportation is thus balkanized inside the EU and subject to a completely different regime, that many would argue is far from competitive, outside.

Competition authorities do not offer any market definition (product or geographic) of transportation outside the EU. Transportation inside the EU is a separate product market that is further decomposed into high-pressure (transmission) and low-pressure (distribution) pipelines. Some cases (e.g. IV/M.1190-AMOCO/REPSOL/IERDROLA/EMTE VASCO DE LA ENERGIA, 1998) suggest that regasification is also a special product (see also Frontier Economics, 2006)). The industry, Regulators and Competition Authorities sometimes argue about the special rules that apply to transit and

transport. The Commission also sometimes differentiates transport of high and low calorific gas and the associated grids.

Models adopt a much simpler view. They do not differentiate transmission inside and outside the EU/EEA. They also do not separate LNG shipping and re-gasification from transmission in general and do distinguish transport and transit. They generally take High and Low calorific gas as a single product (in terms of high calorific gas equivalent) even if they sometimes separate high and low pressure pipeline. We only refer here to high-pressure pipelines. These activities are represented by their cost and/or capacity and treated alike in the models. As for production, GASTALE 1 and 2 as well as GASMOD only consider full costs that they apply to existing capacities. NATGAS models a gas transmission system in expansion, GASTALE 3 assumes endogenous expansion of corridors of gas transmission capacities and EUGAS is a capacity expansion model of gas infrastructures.

- *The geographic market*

The Commission's jurisprudence is that transmission by high-pressure pipelines inside the EU is no wider than national. The claim looks more like an assumption than the result of an analysis: "it is submitted that each pipeline defines its own geographic market scope –or more precisely each entry point to each exit point" (Cabau, 2005b). The Sector Inquiry confirms that transmission is geographically segmented and refers to the Commission practice in concentration cases for further details. The Sector Inquiry extensively describes various practices used by incumbents to restrict access to the infrastructure. The introduction by GTE (Gas Infrastructure Europe) of the notion of cross-border capacity implicitly suggests a geographically segmented market. Cross border capacities are an unintended by-product of the opening of the market. Merchant companies in the former regulated regime were indeed keen to explain that gas was flowing seamlessly from wellhead to city gate through pipelines operated under different ownership without encountering any cross border capacity. Regulators are currently inquiring about the computation of cross border capacities.

Modellers' views on gas transport differ significantly from those of the Commission. All models assume an institutionally transparent transmission system only limited by physical capacities. They implicitly or explicitly suppose a single operator of the transmission system that gives equal access to all from wellhead to burner tip. The representation of the physical infrastructure differs by model and it is not always clear to identify from available papers what is exactly done in each model (Table 3). EUGAS is an exception: the EDGIS data-base of the model and the accompanying tool TIGER identify more than 1000 infrastructure elements described in physical terms. All other models, adopt an aggregate description of the grid that consists of corridors from production sites to markets and cross border capacities between markets. This requires the ex ante computation of the capacities of aggregate lines. This computation is not documented and hence not transparent for the reader. The lack of transparency in aggregate descriptions of the grid is a common modelling difficulty that

Regulators also note today with GTE's cross border capacities. Different representations imply different modelling problems: constructing capacities of bilateral links from production sites to markets requires more assumptions than computing cross border capacities. The former are less transparent than the latter. This is obviously important to the extent that the modelling of the infrastructure has an impact on the competitive constraints on producers and hence on the geographic market of production implicitly assumed in the model. Making this dependence explicit is an interesting and relevant area for further investigation but is beyond the scope of this paper.

GASTALE1	Transportation from production to market
GASTALE2	Transportation from production to market, and then from market to neighbouring market
GASTALE3	Main corridors from production sites to markets, then from market to neighbouring market
GASMOD	Production costs includes transportation to Europe. One then considers transportation within Europe (from market to market)
NATGAS	From production to markets and from market to market (no netting of flows)
EUGAS	Individual high pressure pipelines

Table 3: Representation of gas transmission (tentative on the basis of available description)

Aside from divergences in the representations of physical transmission capacities, the discrepancy between the institutional views of the transmission market by the modellers and the Commission is striking. The Commission documents a market segmented by the restrictive practices of incumbent transmission companies. Modellers assume a seamless grid. These are two different worlds. Modellers describe the network promised by the internal market. They adopt a forward view of the grid as suggested in paragraph 32 of EC (1997) and contemplate a grid only restricted by physical limitations. The Sector Inquiry and ERGEG's reports document the outcome of European law. The Sector Inquiry argues about the very slow market opening and concludes that transportation is no wider than national. But the discrepancy between the Commission and the modellers' views hides a much deeper problem. We shall later argue in Section 6.2 that modellers would find it extremely difficult to accommodate a representation of the restrictive practices of the incumbents with respect to infrastructure. This implies that the description of transmission adopted in the models is overly optimistic and exaggerates the expanse of the relevant geographic market in both the upstream and downstream market.

2.4. Storage

- *The product market*

The Commission recognizes storage as a particular product market. Storage is an important infrastructure; it smoothes out variations of demand between summer and winter and allows one to accommodate the vagaries of demand in case of extreme weather. It also plays a key role for security of supply. Various types of storage exist that differ by maximal capacity and maximal injection and withdrawal rates. They offer different storage services.

Not all models represent storage. GASMOD and GASTALE1 work with an annual supply and demand and hence do not model storage. GASTALE2 decomposes the year in three seasons that are linked by storage activities. NATGAS adopts a similar representation with two seasons. There is no further distinction of storage services in these latter models. EUGAS/TIGER combines a detailed physical representation of the grid with a physical representing of storage. These different modelling of physical infrastructures correspond to different modelling objectives.

- *The geographic market*

The Commission describes the geographic market as spatially segmented. Countries are endowed with different geological storage possibilities. The Commission sees the storage market as no larger than national. It explains that it is uneconomic to resort to storage services at distances greater than 200 kms (pore storage) or 50 kms (cavern storage) (Cabau, EC2005b). This conclusion maybe surprising: those with limited indigenous storage possibilities have no choice but to rent storage services at their neighbours sites. One should be able to store at distance higher than 200 kms if there is no storage facility closer. This increases the spread between summer and winter prices that arbitrage cannot eliminate; but it does not make this spread economically unjustified. Still the implication is that the geographic expanse of storage is limited as the Commission suggests. The Sector Inquiry adds to this finding by listing practices by incumbents to restrict access to storage. Needless to say, negotiated access to storage facilitates those restrictive practices.

Models that include storage operation suppose a perfectly competitive storage market. The existing physical capacities and the availability of transmission capacities to and from storage facilities are the only limitations; there is no institutional or behavioural barrier. Remarks similar to those made for transmission apply here. Modellers represent the Promised Land, the Sector Inquiry documents the walk through the desert (Oren made this comparison for US electricity restructuring). Again, the dichotomy hides a deeper problem. Modellers are truly limited if they want to represent the restrictive practices to access storage described in the Sector Inquiry.

2.5. Supply

Supply consists in buying and reselling gas on the wholesale and large consumer markets. The product can be bought at the wellhead, EU border or wholesale market. It can be resold on a hub, on a consumer site or to retailers. Supply was before integrated in the merchant companies together with transmission and storage. Its unbundling as a separate activity is seen as the main instrument to enhance competition in the EU/EEA gas market and hence the competitiveness of large industrial gas consumers. It is indeed a major theme of the restructuring process that unbundling supply from transmission (and storage when relevant) facilitates the entry of other undertakings in the supply market and hence makes it more competitive. The major question today is to identify the necessary extent of unbundling.

- *The product market*

Suppliers operate in the EU and are thus subject to EC law. The Commission identifies supply as a separate market distinct from transmission and storage. Supply is modelled implicitly or explicitly. All models considered in this paper contain an implicit representation of a perfectly competitive supply except when it is superseded by an explicit modelling of an imperfectly competitive one. The unrestricted access to transmission and storage at opportunity cost described above indeed implies the unrestricted possibility to move and store gas, provided one pays for the cost of the service. This is equivalent to a perfectly competitive supply activity. NATGAS and GASTALE2 and 3 adopt this philosophy; they do not explicitly represent supply and therefore embed an implicit model of the activity. Models that embrace the view of the Sector Inquiry that market power in supply is the major concern of the European gas market go beyond that simple approach and model supply explicitly. This is the approach of GASTALE1 and GASMOD.

- *The geographic market*

The Commission concludes both in concentration cases (see Cabau, 2005b) and in the Sector Inquiry (EC, 2007b) that the supply market is no wider than national.

Models adopt different paradigms for representing supply. We first note that the implicit representation of supply (e.g. GASTALE2 and NATGAS) implies a global supply market that extends from wellhead to burner tip subject only to the restrictions imposed by physical transmission and storage infrastructures. The implicit representation of supply therefore also implicitly defines a global geographic supply market. In contrast, models that encompass an explicit representation of supply introduce explicit assumptions on its geographic market. GASTALE1 and GASMOD describe different supply markets that both largely comply with the Commission's view. GASTALE1 supposes multinational suppliers that operate through independent national subsidiaries. The model therefore assumes that competition in supply is limited to national boundaries. Suppliers import gas from

different origins but only compete to resell it in their home market: they do not venture into neighbouring markets. GASMOD offers an interesting alternative, probably more realistic. There is one incumbent supplier in each country. This company acquires gas from different sources that it sells on its home market and can resell to other markets. In this latter case, the resold gas is sourced from the incumbent's national market. This implies additional transmission costs to ship the gas to other markets. This organization is akin to the one that emerged after the elimination of the destination clause in long-term contracts. Gas purchased from the producers can now be resold to other parties in Europe but the intricacies of the nomination for transport services make it almost mandatory to first transport the commodity to its initial destination (and to pay for transmission cost) before shipping it again to another party. The explicit modelling of supply in GASMOD does not restrict the geographic expanse of supply to be strictly national but, because of transportation costs, keeps it limited.

The conclusion is that models adopt different representations of supply that have different implications on its geographic market. Needless to say these are crucial, given the view of the Commission that a competitive supply is the key to a competitive gas market. We shall come back to this issue when discussing competitiveness in Section 3.

2.6. The retail market

- *The product market*

The Commission notice on market definition (EC,1997) explains that the Commission determines the relevant product market by examining, among others, the substitution possibilities on the demand side. The idea is formalized in the so-called SSNIP (Small but Significant Non transitory Increase in Price) or Hypothetical Monopolist test (see e.g. Motta, 2004, chapter 3 for an economic analysis of the test). According to the test, the relevant product market of natural gas is determined by the possibilities to substitute this energy form by another product after a non-negligible and non-transient price increase. This fundamental analysis underlies the linkage between gas and oil prices that has pervaded the gas market since its early developments. Neither Cabau (2005a and 2005b) nor the Sector Inquiry mention the test in their analysis of the product or geographic gas markets. One thus finds no explicit definition of the product market of gas based on the SSNIP test that the Commission says it uses. The Commission notes that gas and electricity are separate markets but it does not analyze the substitution with oil products, even though this substitution has been the structuring gas pricing mechanism since almost half a century. In short, the Commission assumes that the product market of gas is limited to natural gas.

Demand functions should answer the questions of the substitutability of natural gas by other product and hence provide an implicit implementation of the SSNIP test in gas models. This is unfortunately not the case. All models rely either on somewhat obsolete information on gas demand function

(GASTALE1) or on more or less arbitrary calibration (GASTALE2, GASMOD). The same lack of solid demand analysis is also found in the electricity sector where the assessment of electricity demand boils downs to stating that electricity demand is rather inelastic in the short run, selecting an arbitrary price elasticity and simply skipping the subject of long run elasticity.

- *The geographic market*

The retail market is logically not geographically larger than the supply market. Retail is thus no wider than national. The market may even be smaller than national as local regulations may modify competition conditions in different parts of a given country.

Models recognize the local character of the retail market. They represent it by sector or global demand functions, always restricted to a single country.

2.7. Summing up

Figure 1 summarizes the discussion by representing the different gas activities in a single graph.

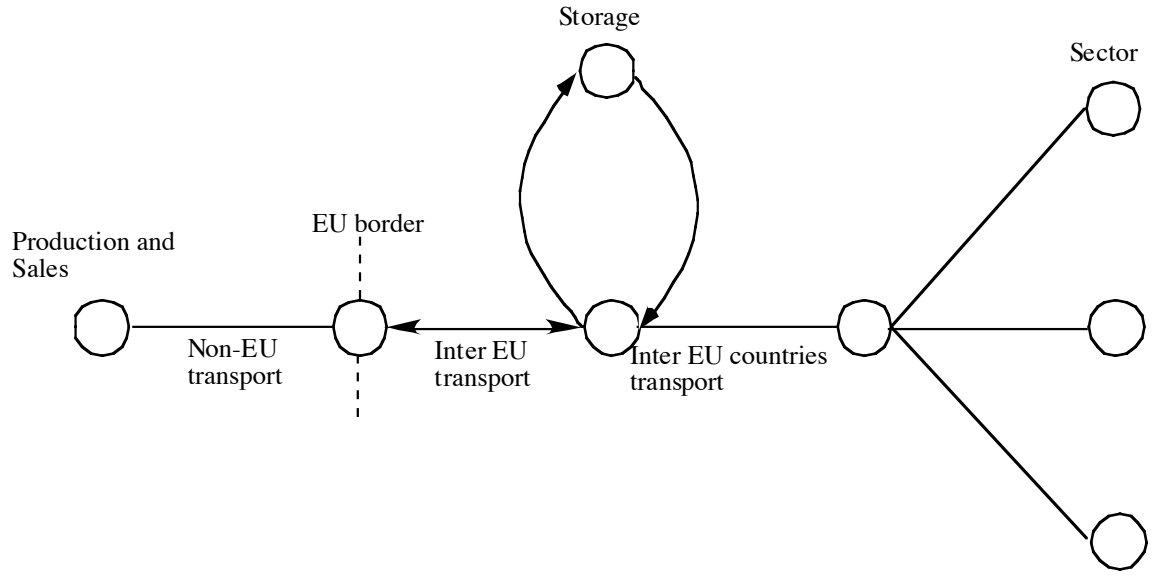

Figure 1: A graphic description of the gas supply chain

The supply chain begins with production and sales. The corresponding node also encompasses gas liquefaction and LNG shipping. Production and sales has both EU/EEA and external components but we only represent the external part. Gas becomes subject to EU energy and competition law at the EU border. It thus makes sense to separate EU and non-EU transport. One can further decompose EU transmission into cross-border and domestic transport in order to reflect the different rules applying to transit and transmission. Storage may or may not be represented depending on the model. Last, the retail market is modelled by a set of demand nodes. The scheme can certainly be made more realistic but it is sufficient for our discussing models and EC law on a common basis.

Figure 1 is in terms of supply chain. It immediately suggests an analysis in terms of value chain. Chevalier and Percebois (2007) offer an example of this analysis. They decompose the price respectively paid by French households and industrial consumers into the (CIF) commodity, transport, distribution and supply components. They find that the commodity account for 54 and 90% of the price respectively paid by the household and the industrial consumers. Supply accounts for 10 and 2% respectively. The rest, the sum of transport and distribution, which are regulated activities, amount to 36 and 8%. In other words, the internal gas market targets respectively 10 and 2% of the price paid by the French consumer. The authors also give a decomposition of the CIF price of Russian gas at the French border. In an observed price of 23euros/Mwh (6.3 euro/GJ), at some unspecified period of time, 14.8 euros/Mwh (4.1 euro/GJ) or 67.2% goes to the margin taken by Gazprom on top of its production transport and transit costs. Chevalier and Percebois only address the French market and do not give the source of their numerical investigation. The following is an attempt to conduct this type of analysis on the basis of published statistics.

Figure 2 is inspired from Figure 1 and decomposes the average wholesale price in Europe into components related to the activities depicted on Figure 1.

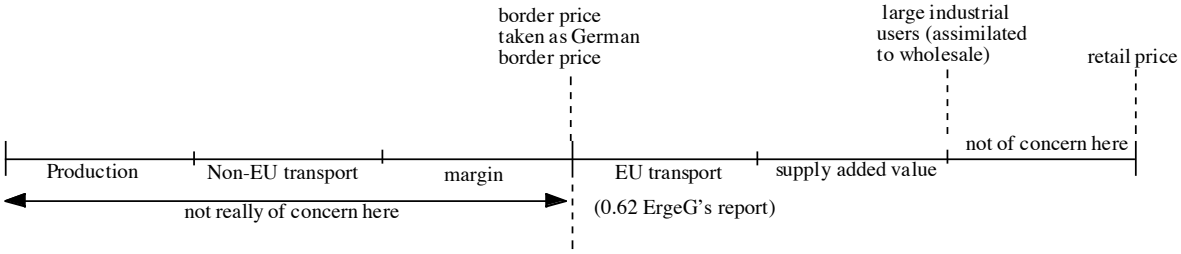

Figure 2: A value chain description of the gas market

As in Chevalier and Percebois (2007) the objective is to show the supply and non-supply components of the wholesale price. Figure 2 is constructed as follows. EUROSTAT of 10 December 2007 gives average yearly gas prices paid by large consumers (load factors 330 days, 8000 hours, 418600 GJ(a), 4186000 GJ(b)). We report 2004 to 2007 prices observed in Germany, France and Belgium where imports make the largest part of the gas market. We do not aggregate industrial consumers but distinguish the large ones (418600 and 4186000 GJ(a)) that we assimilate to the wholesale market. ERGEG report on tariff benchmarking of July 2007 suggests an EU domestic transport cost of 0.62 €/GJ (average transport distance of 1000km). Data on marginal production and transport costs to the EU border can be found in OME (2001) and Van Oostvoorn (2003): 2.5 €/GJ is an illustrative value for these years but should be updated. They are just mentioned for memory. Information on border price in Germany can be found on Bundesministerium for Wirtschaft und Technologie's website. We estimate the added value created by the supply industry as the difference between the large industry price and the sum of the border price and ERGEC domestic transport. We make no claim for the

accuracy of the result. This is all we could do with publicly available data and we are only interested in rough orders of magnitude. We find (see Tables 4 and 5) that the added value of the suppliers in France and Belgium ranges between 0 and 0.5 €/GJ after paying EU domestic transport costs. Profits (on the wholesale markets), that is the remuneration of the capital, can only be smaller than this added value.

	Border of Germany	Germany	France	Belgium	
2004	3.288	5.09 3.5	na na	3.97 na	a b
2005	4.479	6.55 3.81	5.57 na	na na	a b
2006	5.926	8.87 4.72	7.00 na	6.59 na	a b
2007	5.474	8.92 4.8	6.28 na	6.19 5.86	a b

Table 4: Price comparison

	Germany	France	Belgium	
2004	1.2 -0.41 (.4)	na na	0.08 na	a b
2005	1.47 -1.27 (0.1)	0.49 na	na na	a b
2006	2.34 -1.8 (0.27)	0.47 na	0.06 na	a b
2007	2.84 -1.27 (0.8)	0.21 na	0.21 -0.39	a b

Table 5: comparison of added value of supply

Again, these computations make no claim of accuracy. They certainly reveal the poor insight that can be obtained from public statistics. There is no doubt that the data collected by the Sector Inquiry would allow the Commission to produce a more reasonable analysis. But however approximate this computation is, it confirms Chevalier and Percebois' more informed analysis. EU law can only directly act on a small part of supply chain which can be estimated here at less than 0.50 €/GJ. The table shows that this is a comparatively small component of the price paid by the consumer on the wholesale market. The profits (the remuneration of the capital in the added value) can only be smaller than the added value. These profits may still be excessive in the sense that they would be higher than those prevailing in a competitive market. The Sector Inquiry does not provide any evidence of excessive profits though; it indeed only describes restrictive practices and shows prices that, in average when computed over all market segments, differ among countries (e.g. figures 69 and 70).

The Sector Inquiry also does not attempt any comparison with margins that would prevail in a competitive market. The legal instruments available to the Commission for mitigating possibly excessive price therefore only directly bear on less than 10% of the total price using our computations and much less according to Chevalier and Percebois's more informed evaluation. Other effects on the upstream part of the supply chain, if any, can only be indirect. The obvious question is whether action on the margin embedded in supply, that is on less than 10% of the price, for which we have no evidence that it is excessive, is an effective policy. Reducing the part of the excessive profit contained in an added value of 0.5 €/GJ (e.g. France in 2005) may be a legal achievement but will not help large industrial consumers much. Maybe models can help look at that question; maybe they can help compare the margin of the concentrated suppliers with the one that would prevail in a competitive supply market. This is the question that we are turning to now.

3. MODELLING COMPETITION

Competition policy is the founding pillar of European integration. The Lisbon agenda gave it a new impetus by emphasizing the needed competitiveness of European industry. More recently, the Green paper (EC, 2006), the Communication on an Energy Policy for Europe (EC, 2007) and the third package of 19 September 2007 presented competition in the energy market as a central contributor to security of supply, sustainability and global competitiveness of the European industry. Gas and electricity Regulators also acknowledge this dual role of competition being simultaneously a goal and an instrument towards other goals. Competitive energy markets are thus at the core of European energy policy.

The capabilities of current models are much more restricted than those global objectives of Competition and Regulatory Authorities. Competition law addresses four types of problems, agreements between undertakings (article 81), abuses of dominant positions (article 82), State Aids (articles 87 to 89) and reinforcement of dominant position (Regulation 139/2004 of 20 January 2004 on Merger). Regulators of the gas and electricity sectors mainly target dominant positions with a particular attention to excessive and discriminatory prices. Existing gas models concentrate on one of these problems, namely excessive prices resulting from dominant positions. Even in this relatively restricted domain they concentrate on exploitative prices and do not consider exclusionary prices. Models also offer some potential to assess modifications of dominant positions due to concentration or divestiture but existing papers do not offer any example of such study.

3.1. Competition and market power in the upstream and downstream markets

The competitiveness of the European gas market has upstream and downstream sides. Paragraph 77 of the Sector Inquiry offers an unusually reassuring view of upstream competition "If the market is

considered global, the concentration is unlikely to be excessive"; moreover LNG will "reduce … concentration, when it exists, at this level of the gas supply chain". This suggests that concentration in the downstream market is our main concern when it comes to competition. And indeed, except for paragraph 77, the Sector Inquiry does not elaborate on the upstream market. It focuses on the downstream market and finds several shortcomings. Gas and oil prices remain linked by indexation clauses though long-term contracts; hubs and gas-to-gas competition do not develop well. The proposed explanation is that suppliers have too much market power: even though transportation, supply and storage activities are legally separated from supply, they remain under common ownership. Suppliers can thus restrict access to the infrastructure. Further unbundling should solve the problem. All this might be true. It might also be wrong: the Sector Inquiry indeed provides considerable factual information but does not really prove claims. This leaves the question of the upstream competition and its possible impact on the downstream market rather un-explored. We shall explain in Section 7 that views like those expressed in paragraph 77 of the Sector Inquiry directly contradict the rationale of the Commission's concerns about security of gas supply to Europe. The coal market offers a brief, preliminary, illustration of the point. This market indeed demonstrates that the proportion of imports is irrelevant for security of supply when the upstream market is not "excessively concentrated": an un-concentrated market with sufficient resource is secure by the sole fact that it is un-concentrated. By the same token, concerns about security of gas supplies are "unlikely" to be justified if upstream "concentration is unlikely to be excessive". Only the combination of upstream concentration and large imports can endanger security of supply. The growing awareness of a possible dangerous evolution in gas supplies suggests that in contrast with paragraph 77, many, including in the Commission and IEA see the upstream gas market as unusually concentrated. Upstream competition therefore deserves at least as much attention as the downstream one. Can models shed some light on this question that the Sector Inquiry bypasses?

We argued in the preceding section that the bulk of the wholesale price goes to the upstream market. This is compatible with producers exercising market power (for instance if underdeveloped resources have a very high marginal cost) but does not imply it. Chevalier and Percebois (2007) indeed give very high margins with respect to the production cost but do not specify whether it is marginal or average. It is thus worthwhile to question paragraph 77 and to investigate the effect of a possible concentration in the upstream market.

There is also a downstream aspect to the question. The German columns of Tables 4 and 5 show bizarre results. Prices charged to *a* and *b* type consumers are quite different. The tables suggest that the situation varies by country and that gas prices may contain margins that significantly differ in the wholesale and retail markets, at least in some countries. Figures 69 and 70 of the Sector Inquiry confirm these observations. The available information does not allow one to conclude with certainty on anything like excessive margins in the supply market. If anything, it suggests the possibility of

price discrimination in some cases. This suggests targeting the competition and regulatory actions to some parts of the downstream market where the exercise of dominance seems highest. The existing models, because of their poor representation of the demand on the retail market, do not allow for that analysis. It is thus impossible to foresee the gains accruing from action on one or the other part of the retail market. We are limited to analyzing the impact of concentration on the upstream market and on the downstream wholesale markets. The Commission wants to act on the latter: the question is thus whether one can foresee the overall gain for the consumers of actions undertaken on this sole wholesale market. We begin by some preliminary discussion on the relation between the upstream and downstream parts of the market.

3.2. Market power in the upstream and downstream markets

The Sector Inquiry does not elaborate much, at least explicitly, on the relation between the upstream and downstream markets. This is consistent with paragraph 77: “concentration is unlikely to be excessive” and hence the upstream market is "unlikely" to exercise market power. The relation between the two sides of the market is then very simple: producers do not exercise market power; only suppliers do. The difference of reasoning of the Sector Inquiry in the gas and electricity sections confirms this interpretation. The analysis of the electricity sector finds that both generators (seen together with import, as the wholesale or upstream market in the product definition of the Commission) and retail (the downstream in the product definition of the Commission) have market power in the electricity sector. The Inquiry justifies introducing more competition in the downstream electricity market by invoking the theory of "double marginalisation". Paragraph 922 indeed states, "Even if the wholesale trade is highly concentrated, customers can still benefit from the existence of competitive downstream markets. Competition at the retail level prevents double marginalisation, which occurs when downstream firms mark up over their input cost. Hence, thanks to competition on the downstream market, a mark-up on a mark-up, i.e. double marginalisation, is less likely". We briefly recall the principles of the theory of double marginalisation in the following subsection but already note, as appears from paragraph 922, that this theory is only relevant if one assumes upstream market power. Invoking double marginalization in paragraph 922 of the Electricity part of the Sector Inquiry is thus consistent with the finding of the Commission that both generators (the wholesale market or the upstream) and retailers (the downstream) exercise market power in the electricity sector. The analysis is different in natural gas: the upstream market is "unlikely to be excessively concentrated" and hence an exercise of upstream market power is equally unlikely. There is thus no need to invoke double marginalization in the gas section of the Sector Inquiry and indeed, one finds no trace of it. All this is internally consistent. But it may not be consistent with cursory observation of the upstream market and it is certainly not consistent with the assumptions of the modellers. All gas models except EUGAS indeed consider the possibility of a concentrated upstream market. Moreover,

two models, GASTALE1 and GASMOD invoke double marginalization and one, GASMOD explicitly gives quantitative arguments to justify the action of the Commission to reduce downstream market power. All this requires some further discussion. A brief reminder of the principle of double marginalization may be necessary in order to understand the Commission and modellers' reasoning.

- *A reminder of the theory*

Spengler (1950) introduced the theory of double marginalization that we briefly summarize here as follows. Suppose a market with both upstream (producer) and downstream (supplier) monopolies. The producer monopoly (upstream market) sets the price at which it sells to the suppliers. The supplier monopoly (downstream market) in turn sells to final consumers at a price that it fixes unilaterally. The supplier has no negotiating power and cannot influence the price set by the producer; similarly consumers, whether large or small, cannot influence the price decided by the supplier. The monopoly supplier chooses its sale price to maximize its profit, given the price paid to the producer. The monopoly producer selects its sale price in order to maximise its profit knowing the behaviour of the supplier. Spengler showed that the producer and supplier each extract a monopoly margin from the market. He also showed that the total welfare loss due to these two margins is larger than if only one monopoly (whether producer or supplier) had served the whole (production and supply) market. Each agent of the chain (whether producer or supplier) makes a lower profit than if it had controlled the whole chain (production and supply), the other agent (supply or monopoly) behaving perfectly competitively. This analysis has since been extended to oligopolies; its presentation is more complicated but the essence of the results is identical.

- *Double marginalisation, gas models and the European gas market*

The Sector Inquiry does not invoke double marginalization in its analysis of the gas market but the GASTALE1 and GASMOD models that support the action of the Commission on the downstream market do. The following relates the assumption of double marginalisation in these models with the position of the Commission and with observation.

First note that the assumption of double marginalisation is at variance with the description of the upstream gas market of the Sector Inquiry. Because it explains that the upstream market is "unlikely to be excessively concentrated" paragraph 77 implicitly assumes that companies like Gazprom, Sonatrach or Statoil have little power when negotiating long-term contracts with entities such as Eni, GdF or E.ON Rhurgas. Double marginalisation supposes the opposite. It assumes that Eni, GdF or E.ON are powerless with respect to the producers. In other words, double marginalisation supposes that Gazprom set the price and E.ON takes it without any say to it. The common wisdom and the development of Gazprom activity with suppliers among them E.ON and Eni suggest that this is not realistic. Global oil and gas companies may have lost a lot of bargaining power to acquire resources in

Russia and Kazakhstan and some are kicked out of Venezuela; still they retain bargaining power at the EU border when it comes to buying and marketing natural gas.

Double marginalisation therefore assumes that the producers have market power. This complies with the common wisdom: most the current discussion on security of supply is only justified if gas production is concentrated (security of supply also depends on the incentive to invest in the EU but this is almost never discussed). But double marginalisation makes an extreme assumption on the market power of the producers that is also at variance with the anecdotal description of the gas market that has prevailed so far. The traditional view of the European continental gas market is that producers and merchant companies negotiated quantities and prices and shared the rent accruing from the difference between the price to the final consumer on the market and the production, transportation and storage costs. Former regulation on the downstream market guaranteed that a fraction of that rent was passed from the merchant company to the consumer. In contrast with what happens in double marginalisation, this traditional view does not assume that producers and suppliers (which inherited from the merchant activity) exercise market power in sequence. They instead behave simultaneously to extract the whole monopoly profit from the market. Producers and suppliers then share that profit in a way that depends on their bargaining power. Theory tells us that this organisation of the market is superior to the one resulting from double marginalization: it leads to a smaller loss of welfare. The monopoly profit captured in this organisation is smaller than the sum of the monopoly profits accruing from double marginalisation. In short, the traditional view of the gas sector that saw arrangements between producers and suppliers is more favourable for the consumers and for global welfare than the one embedded in double marginalization. Is it more realistic?

The Sector Inquiry offers an indirect support to this traditional view that contradicts double marginalization. The Inquiry finds that incumbent suppliers have today retained quite a lot of market power on access to the infrastructure and that they exercise that market power by withholding both storage and transmission capacities. The Sector inquiry also argues that joint ownership of supply and the infrastructure is the cause of this discriminatory access to infrastructure. In short the Sector Inquiry finds that suppliers control the access to the downstream very much like a concentrated producers control the access to the resources. The control of the access to the infrastructure makes it very unlikely that all the bargaining power is in the hands of the producers. It indirectly support the traditional view that producers and suppliers both have bargaining power when it comes to negotiate prices at the border on the basis of the value at the city gate.

- *Are there alternatives to double marginalization?*

It is thus not clear that the theory of double marginalization that gives all the pricing power to the producer complies with the reality of the market and the findings of the Sector Inquiry. Several authors offer analysis that go in the same direction. They recognize the growing power of the

producers without going as far as admitting that suppliers are powerless in their negotiation with producers. Stern (2006, 2007) recognizes the market power of both the producers and the suppliers. He describes a situation where upstream and downstream firms tend to cooperate and even integrate activities. Tönjes and de Jong (2007) also recognize the market power of the producers. They welcome the increasing concentration of the downstream market both for "increasing the robustness of European energy markets to external disturbances" and to "assure producers of reasonably and profitable sales market". Last Chevalier and Percebois (2007) argue that it is essential that suppliers retain some bargaining power with respect to producers. None of these views confirms double marginalisation.

Hubert and his co-authors (2003a, 2003b and 2004) offer a particularly interesting modelling analysis of a related problem of market power in the European gas market. These authors study the relations between producers and transporters, a problem that had been examined before by some of the authors of GASMOD using the theory of double marginalisation (Chollet et al., 2001). Hubert and his co-authors first note the arbitrariness of assuming that all the market power resides with the producers; they then contest the use of double marginalisation on the production and transit markets using an argument that we briefly summarize as follows. They argue that the development of the transportation infrastructure from Russia to Europe can only be interpreted in terms of concentrated production and transmission markets. As an example, the Yamal pipeline that goes through Belarus and Poland was much more expensive to construct than renovating and expanding the lines through Ukraine (Hubert and Ikonnikova, 2003a). Using arguments of game theory, the authors explain that the justification of that new pipeline is entirely in terms of Gazprom counteracting the market power of Ukraine as transit country. Stern, 2006 argues the same by referring to the history of events. The pipeline cannot be justified on ordinary economic terms but by gaming considerations that the authors quantify in two successive papers (Hubert and Ikonnikova, 2003b and 2004). Needless to say gaming considerations only make sense in concentrated markets. The same applies to the NordStream pipeline that shall be constructed in order to bypass Poland and Belarus as transit countries. This second pipeline is more expansive than the Yamal's line and thus also more expansive than renovating and expanding the Ukrainian corridor. The justification is again in strategic terms (that the authors quantify). It is rooted in the desire of both producers and suppliers not to depend on the market power of transit countries. All this reasoning is conducted in terms of coalitions in a cooperative game and thus in terms of a few players acting in a concentrated market. The cooperative gaming argument of the paper suggests that both the upstream and transmission markets are concentrated. But there is a more immediate implication for the current discussion of the third package of the Commission: the papers show that controlling pipelines (as Ukraine does) can give considerable market power with respect to the producers (in this particular case Gazprom). This certainly implies that double marginalization is not the right assumption for describing the relation between the upstream and the downstream markets. It

also implies that we one can at least question the policy of ownership unbundling that removes the market power of the suppliers with respect to the producers. More generally one can question the usefulness of removing the market power of the suppliers when one cannot mitigate the one of the producers.

- *Are there computable alternative to double marginalization?*

Hubert and his co-authors mention but do not develop a crucial argument against double marginalisation. These authors note that double marginalisation assumes linear prices, that is, unit prices expressed in euros/GJ. They also note that gas contracts are in quantities and prices. These take the form of the well known Take or Pay clauses. In other words contracts are expressed with nonlinear prices, a fact that double marginalisation completely neglects (see Tirole, 1998, Chapter 4 for a textbook discussion of these effects). Ehrenmann and Smeers (2008) show that it is possible to cast non linear prices contracts in a computable form to come up with models that are much more in line with the realities of the gas market where producers and suppliers both share a single monopoly profit. They do not model the sharing that obviously depends on the negotiating power of the partners. Note here that the reasoning of the Sector Inquiry implicitly dismisses any danger of transferring all the negotiating power to the producers.

Gabzewicz at al. (2007) recently offered an alternative way to model the relation between producers and consumers that better accounts for the duality of prices and quantities in gas contracts. They retain the sequential nature of the producers and suppliers relation but cast the problem in strategic game where producers decide quantities and suppliers bid the money that they are willing to pay for the quantities. Even though market power is still exercised in the same sequence as in double marginalisation, the fact that suppliers make an offer to producers in terms of willingness to pay make their relation more symmetric. This model is also amenable to computation (Ehremann and Smeers (2008)).

3.3. Models' assumptions of competition

The above discussion suggests that the relation between the upstream and downstream gas markets is a complex issue and that we may not be well equipped to deal with it. This applies as well to non formalized analysis (as the Sector Inquiry, Stern, Chevalier and Percebois or Tönjes and de Jong) and to computable investigations (as in models). We now elaborate on this latter point and discuss the possibilities offered by the models considered in this paper. We refer in the following to four assumptions of market power implemented in the models and relate them to the analysis of the Sector Inquiry. These assumptions are extreme cases in a continuous range of possibilities.

- *Relative upstream and downstream market power*

One can first assume that both the upstream and downstream parts of the market are not excessively concentrated and hence that the whole market is reasonable competitive. All models can accommodate this assumption. It is at variance with the finding of the Sector Inquiry but we shall see that it offers a reference to which other situations can be compared. An alternative is to suppose that the upstream market is not excessively concentrated but there is downstream market power. This is the implicit assumption of the Sector Inquiry. The absence of market power of the producers differs so much from the common wisdom that the modellers do not report any result on this view of the gas market! Another assumption is to suppose that the upstream market is concentrated while there is no downstream market power. The authors of GASTALE1 and GASMOD see this as the final outcome of the actions of the Commission, after elimination of downstream market power. We refer in the following to this case with no downstream market power (neither in supply, nor transmission and storage) as to the internal gas market scenario. All models but EUGAS can simulate a mix of upstream market power and internal gas market and report results. Last GASTALE1 and GASMOD also consider the case of double marginalisation that they compare to the current situation in the European gas market. We now discuss how all this can be made operational.

- *Technicalities: Cournot and perfect competition*

The models considered in this paper, and the four classes of assumptions listed above, rely on two standard micro economic paradigms namely perfect and Cournot competition. Perfect competition is the reference paradigm; it assumes away all dominant positions and supposes that agents are price takers. Agents foresee the outcome of the market but cannot influence it. EUGAS only models perfect competition that it examines using a quite detailed representation of the infrastructure. The other models adopt a coarse description of the grid but allow for both perfect competition and different mixes of Cournot competition.

Cournot competition assumes that agents modify market prices by acting on the quantities that they sell on the market. This is referred to as strategic withholding. A Cournot agent tries to optimize its profit by restricting its sales in order to raise price. It optimizes the balance between higher prices and lower output. The Cournot equilibrium is also a Nash equilibrium: every agent acts to optimize his position, assuming that the actions of the other agents are fixed. The introduction of Cournot competition in gas models (and in market simulation models in general) goes back to the seminal work of Mathiesen (1985) on the computation of economic equilibrium and of Mathiesen et al. (1987) on the European gas market. This work took place before the restructuring of the gas market and the authors empirically justified their use of the Cournot paradigm. They found a significant upstream market power.

Market simulation models relying on the Cournot assumption have flourished in the electricity sector. That work revealed that models could apply different competition paradigms to different submarkets leading to a wide range of models that are sometimes difficult to interpret. The same evolution did not (yet) take place in natural gas. Gas models remain comparatively simple and mix perfect and Cournot competition on the production and supply sides. They suppose that all other markets are perfectly competitive. The findings of the Sector Inquiry suggest constructing more complex models that should consider the exercise of market power in the transmission and storage markets. We shall argue later that this seems technically impossible today and that the difficulty of interpreting the results would only cloud the discussion. The deep reason is that models of imperfect competition quickly become un-identifiable: one cannot select among possible models on the basis of existing data and theory. The Sector Inquiry here uncovers problems that we are unable to handle.

Using this general background, we now specialize the discussion and describe the assumptions of competition adopted in the different activities of our models. We also briefly mention alternative, more complex combinations of competition assumptions.

4. MODELLING COMPETITION IN THE PRODUCT MARKETS

4.1. Production

Except for the rather optimistic view expressed in paragraph 77 of the Sector Inquiry, the Commission does not comment on the competitiveness of the upstream market. In contrast modellers devote considerable attention to that part of the market.

- *The product market*

Models do not differentiate gas of different qualities. There is one type of gas measured in standard bcm for which models introduce two different assumptions of competition.

- *Perfect competition*

All models accommodate perfectly competitive producers. Various methodological arguments justify assuming perfect competition in the upstream market, and this independently of the real intensity of competition in that market. Perfect competition, by modelling price-taking agents, indeed offers an unambiguous paradigm. Perfect competition also maximises welfare and hence provides a reference to which other structures can be compared. In contrast, imperfect competition is inherently ambiguous: different behaviours are possible and except for special cases, there is no theoretical or empirical basis for selecting a particular one of them. It may come to a surprise that a perfect competition model also offers a technically easy and transparent way to represent market power: it suffices to add a mark-up to the pure competition price. An exogenous mark-up may seem arbitrary, but is no more so than a conjectural variation or a conjectured response such as implemented in NATGAS or GASTALE1 and

2. Mark-ups are easy to interpret and to compare to market observations. They are also trivial to accommodate computationally. Last, we mention in passing that perfect competition models can be used to define the relevant geographic market in cases of market dominance (but not in concentration cases). This property seems unexploited and will be discussed in a further paper.

- *Cournot competition*

Cournot is the imperfect competition paradigm most often found in market simulations studies. All models considered in this paper except EUGAS accommodate Cournot competition among producers. GASTALE1 and GASTALE2 can additionally resort to conjectured supply function (Day et al, 2002). This possibility is essentially equivalent to conjectural variations, a technique largely discredited by economists today. In practice, conjectured supply functions offer the possibility to select any competition intensity ranging between Cournot and perfect competition. As indicated before, assuming conjectured supply functions is no more general than assuming mark-up but it is more difficult to calibrate and interpret on the basis of market data.

An extension of existing models would have been to combine dominant producers and a competitive fringe. This is frequently done in electricity models but not in gas. GASMOD assumes domestic Cournot producers at the same level as large producers. Modelling them as a competitive fringe that cannot exercise market power may have been more adequate.

- *Competition in the geographic market*

Production is national (see section 2) except in NATGAS which allows for several producers in a single country. Producers are represented by their investment and operation cost or by an aggregate production cost and capacity in the other models. Perfect competition models do not need to distinguish whether producers are companies, fields or countries as all these assumptions lead to the same result. In contrast the distinction is important in Cournot models. Note that competition among producers does not take place at the wellhead but in the downstream market after using the transmission and possibly the storage systems. The result of the Cournot competition therefore depends on the assumptions made on the competitiveness on transmission and storage. This is the question to which we now turn.

4.2. Transmission and storage markets

- *The product market*

The Sector Inquiry sees considerable barriers to entry in the current organisation of transmission and storage. It claims that the residual ownership of gas transmission and storage facilities by suppliers is at the origin of these barriers.

Models overlook this important question of vertical integration. They assume perfect separation of supply, transmission and storage and suppose perfectly competitive transmission and storage markets. There is no barrier for accessing infrastructure and capacities are priced at congestion rent, possibly with the addition of a cost or access charge. This general principle is adapted to the particular representation of the infrastructure in the model. Pipelines are charged congestion rents in EUGAS (an objective of EUGAS is to identify bottlenecks in the grid). Corridors between producers and consumers of GASMOD are similarly priced at congestion rent plus some transmission cost. They are charged at full cost in GASTALE1. Cross border transmission capacities are charged at congestion rent in NATGAS and GASTALE2. None of the models represent the entry exit system currently implemented in the EU. A similar story applies to storage. EUGAS, NATGAS and GASTALE2 all price storage capacities at congestion cost. GASTALE1 and GASMOD do not represent storage. In short models behave as if transmission and storage capacities from wellhead to burner tip were sold through a European wide fully coordinated auction. This drastically diverges from the Sector Inquiry's findings. Except possibly for underestimating transmission and storage possibilities through the computation of corridors and cross border capacities (something that the reader cannot verify), the models therefore give an optimistic view of transmission that makes the market look more competitive than it really is.

- *The geographic market*

As indicated in section 2, the models do not recognize the geographic segmentation of transmission and storage found by the Sector Inquiry. The corridor and cross border capacities explicitly introduced in the model, together with transmission costs are thus the implicitly determinant of the geographic market. The same is true for the storage market (that may further modify the geographic market) after taking transmission cost into account. As already mentioned a few times in the paper, it would be interesting to use models to investigate how to move from this implicit to an explicit definition of the relevant geographic market. This will be discussed in a further paper.

4.3. Supply

Together with the alleged insufficient unbundling of the supply, transmission and storage functions, the concentration of the supply market is the area that attracts most of the attention of the Commission and of the Regulators. The two questions are quite different though. A better access to the infrastructure as a result of an improved regulation enables competition but does not induce it (except if these activities can themselves be made competitive, which is not the dominant view in Europe). In contrast supply is by essence a competitive activity in the spirit of the internal energy market and hence the driving force of the restructuring of the gas market. The Sector Inquiry recognizes that progress on this aspect is limited. The Sector Inquiry finds a very concentrated supply market that it claims incumbents maintain by withholding capacities from the transmission and storage markets. It

argues that the common ownership of these activities facilitates this practice. It concludes that this hinders entry and limits competition in supply. These are the principles: infringements procedures might eventually give more detail.

As discussed in Section 2, GASTALE2, GASTALE3 and NATGAS do not explicitly model supply. They implicitly suppose that it is competitive or alternatively that the mark-up taken by suppliers is insignificant. The same is true of EUGAS with represent all activities as perfectly competitive. In contrast, GASTALE1 and GASMOD explicitly model supply and allow for both Cournot and perfectly competitive supply markets. GASTALE1 and GASMOD representation of supply differ in several aspects, illustrating on this particularly important product market the ambiguity that immediately arises when departing from the perfect competition paradigm. The following discussion overlaps to some extent with some of Section 2. We justify this repetition by the important claims on the supply market made by GASTALE1 and especially GASMOD authors.

GASTALE1 supposes identical Cournot suppliers in each national market. In other words the relevant geographic market of supply is national; this complies with the view of the Commission. Identical suppliers render Cournot competition plausible but are a far cry from observation. This view of supply can be interpreted in two ways. One is a supply market where the incumbent has been split into several, identical, smaller suppliers in order to decrease the concentration on the market. This is akin to a very harsh competition remedy. Those who today oppose ownership unbundling are unlikely to later agree on such dramatic divestitures in supply without requiring a very strong proof of the "proportionality" of the remedy. It is unlikely that models, or competition authorities for the matter, can deliver such a proof (which does not mean that competition authorities could not decide such a remedy as allowed by article 7 of Regulation 1/2003 (EC, 2003). But reasons quite different from modelling remedies may have motivated GASTALE1 approach. The real reason for making suppliers identical is technical: it permits drastic computational simplifications in a model that is otherwise numerically untractable. A discussion of computational matters is beyond the scope of this paper; Ehrenmann and Smeers 2008 take up the matter in more detail.

GASMOD adopts an altogether different view on supply: it assumes a dominant incumbent in each national market that can resell part of the imported gas to other national markets. The idea of a dominant national supplier is also in line with the highly concentrated supply market found by the Sector Inquiry. We already explained in Section 2.5 that the reselling of imported gas is also a good description of the current situation after the elimination of destination clauses from long-term contracts. Gas imported by one supplier can be resold but transmission rules require that the exporter and the importer nominate the same volume on each transmission link. This makes it almost mandatory to first transport the gas (and pay the transmission) to the importer's node before reshipping. This is what GASMOD represents. This drastically stretches the idea of Cournot

competition: incumbent and entrants are unlikely to behave à la Cournot in this model: they are of too different sizes. But there is a more intriguing aspect to this model. In contrast with GASTALE1 that does away with the technical difficulties inherent in double marginalisation by assuming identical suppliers in each national market, GASMOD does not make such modelling simplification. GASMOD therefore faces the complexity of a full treatment of double marginalisation and all its technical difficulties (an Equilibrium Problem subject to Equilibrium Constraints (EPEC) in technical jargon). GASMOD bypasses these difficulties by implicitly modifying the standard assumptions of double marginalisation with the result that GASMOD in fact adopts an unknown paradigm of competition. Because this paper is not about computational matters, we do not elaborate on the matter but give a brief additional discussion of the question in the appendix.

This discussion suggests that the modelling of imperfect competition in the supply market is not transparent, possibly ad hoc, and even possibly computationally erroneous in some cases. Authors represent competition in supply on the basis of a mix of computational and modelling considerations whose real motivations and interactions are not clearly stated. Concentration of the supply market provides a rationale for a Cournot assumption in GASTALE1 and GASMOD. By this is as far as the justification goes. The modelling of reselling possibilities is realistic in GASMOD but makes the Cournot assumption more difficult to accept. In contrast Cournot fits very well in GASTALE1 but at the cost of an unrealistic representation of reselling. As we have already mentioned and will later discuss again, computational choices made in GASMOD also cast doubts on the results of the models. Last, and because of state of the art limitations, no model can account for the practice of withdrawing transmission and storage capacities identified in the Sector Inquiry and attributed to insufficient unbundling of supply and infrastructure. Needless to say, models as well as the Commission analysis in concentration cases are limited by the state of the art. One cannot ask what is not possible but the limitations of some modelling choices and of the state of the art should probably be better explained.

4.4. Retail

Retail competition is another concern of the Sector Inquiry and other Commission's papers on the state of the internal market. These documents note the low level of switching and conclude to insufficient competition. The observation of retail prices in Eurostat suggests that problems, when they exist, are concentrated in some parts of the retail market. None of the models explicitly represent retail except for very rough sector demand functions. This implies that models implicitly assume that the retail market is perfectly competitive but very imprecisely known. The models therefore offer no insight on retail competition.

4.5. Summing up

Models differ by their representation of the infrastructure and their assumptions of competition. These give them different capabilities and make them suitable to address different problems. EUGAS endeavours to offer a particular good representation of the infrastructure. GASMOD2 and NATGAS have some representation of storage; all models have some representation of transmission from wellhead to burner tip. Transmission and storage are perfectly competitive in all models. All can accommodate perfect competition in production and supply. All but EUGAS can accommodate Cournot competition in production. GASTALE1 and GASMOD are the only ones to also address the problems raised by a concentrated supply market. The next question is whether notwithstanding the limitations discussed so far, models can still tell us something about the gas market. We shall see that they indeed convey quite important messages and that these messages are not always in line with these of the Sector Inquiry.

5. MODEL RESULTS

5.1. On upstream market power

The Sector Inquiry sees the upstream market as un-concentrated and focuses on downstream market power; it also finds barriers to access transmission and storage facilities. All models overlook these barriers and several of them (GASTALE2, GASTALE3, NATGAS and EUGAS) assume fully competitive supply markets. All models except EUGAS also have provision to accommodate a concentrated upstream market modelled à la Cournot. At first sight, models and the Sector Inquiry seem to operate in two different worlds. We shall argue that, notwithstanding these differences, models can truly help assess the claim of paragraph 77 about the lack of concentration in the upstream market. Competitive supply, and unrestricted access to transmission and storage are indeed the goals of the Commission in the internal gas market. One can thus assess whether, in this internal gas market, Europeans would be subject to a possible exercise of upstream market power, or in other words, whether the upstream market would not be excessively concentrated and exploit the European internal gas market.

- *Numerical results*

GASTALE 1, 2 and 3 as well as NATGAS come to the same conclusion: the upstream market is sufficiently concentrated for producers behaving à la Cournot to exercise considerable market power in the European internal gas market, that is, in a downstream market where supply is perfectly competitive and transmission and storage accessible at a perfectly competitive price. GASTALE1 reports that a market with dominant producers and competitive suppliers best matches the benchmark. "In general, for most countries, actual 1995 prices are closest to simulated prices under oligopolistic

producers and competitive traders". GASTALE2 also reports a significant market power. "When producers are able to exercise market power from a Cournot perspective, they dramatically change the market". GASTALE3 needs to introduce long term contracts to mitigate the exercise of the market power and make it more in line with observed prices (see the conclusion). Last NATGAS also concludes that the concentration of the upstream market, under Cournot competition has a significant impact. In contrast with all these results GASMOD concludes that "in the EU liberalization scenario, we find a welfare close to the overall perfect competition". This EU liberalization scenario in GASMOD is the combination of Cournot producers and an internal gas market. GASMOD therefore fully complies with the views of the Commission: the downstream market is the key to a competitive gas market.

- *Conclusion*

This conclusion of the three GASTALE models and of NATGAS is not really surprising. Except for paragraph 77 and GASMOD results, the common wisdom is that the upstream market is concentrated, whether producers take advantage of this concentration or not. The growing concern for security of supply further suggests that this concentration is increasing. The conditional "if one assumes that market is global" used by the Commission in paragraph 77 to conclude that the upstream market is "unlikely to be excessively concentrated" is irrelevant if the market is not global. GASMOD is an outlier. But we signalled before that there might be computational problems with that model. At this stage we cannot conclude otherwise than with the conjecture that the upstream market is sufficiently concentrated to cause worries. The question is thus whether concluding that the upstream market is excessively concentrated would have had an impact on the rest of the reasoning of the Commission. It is to this question that we now turn.

5.2 On downstream market power

Acknowledging that the upstream market that is (un)"likely to be excessively concentrated" would not change the restrictive practices of the suppliers identified in the Sector Inquiry. Could it change its policy conclusions, namely that making the downstream market more competitive is beneficial for Europe? Intuition strongly suggests that Europeans cannot do much to mitigate upstream market power, "when it exists". The only possibility is to act on the downstream market power. Eliminating downstream market power therefore seems to make considerable sense. The Commission submitted this argument in relation to electricity in paragraph 922 of the Sector Inquiry; it then invoked double marginalization. But one finds no similar statement for gas. Two models, GASTALE1 and GASMOD invoke double marginalisation and conclude to gains accruing from making the downstream market fully competitive, that is from implementing the internal gas market scenario. This supports, albeit by a different reasoning, the Commission's policy. We briefly summarize their findings after a short reminder of the discussion of Section 3.2.

GASTALE1 and GASMOD assume double marginalisation to model upstream and downstream market power. This theory, when adapted to oligopolies, explains that an oligopoly of producers that extracts margins from perfectly competitive downstream suppliers causes less economic damage than if suppliers can also extract margins on the downstream market. This single statement suffices, if one accepts the theory, to justify the internal gas market viewed by the Commission. This is the argument of paragraph 922 for electricity in the Sector Inquiry. Models can certainly provide further insight on this objective by assessing the gains accruing from the elimination of downstream market power. But models cannot discover these gains; they are embedded in the assumption of double marginalisation. Can GASTALE1 and GASMOD offer a good assessment of these gains? These models assume a perfectly transmission market in the EU (they do not represent storage) which is part of the internal gas market. GASTALE1 and GASMOD run with the sole upstream market power will thus give, if we neglect transmission imperfections outside the EU, an assessment of the outcome of the internal gas market. This is one side of the picture. Because we cannot represent the current barriers to transmission in the models, we may not be able to assess today's market, which is the other side of the picture. But one can argue that GASTALE1 and GASMOD, by assuming perfect transmission, offer an optimistic view of the current market that can only perform worse (in terms of total and consumer's welfare) under imperfect transmission. In this reasoning, going from the current gas market to the internal gas market can only generate more gain than what the models effectively determine. The gains accruing from the internal gas market can thus only be higher than what the models determine.

- *Numerical results*

GASTALE1 conclusions are in line with the theory, and this at different levels. First, GASTALE tests double marginalisation. Boots et al. (2004) run the model with increased degree of competition in the supply market (that is by increasing the number of suppliers in each country). Their findings comply with the theory: total welfare increases with the number of suppliers in the market; suppliers see profits decreasing to the benefit of producers; consumers benefit when producers solely have market power. The interpretation of the results is straightforward: in a market where suppliers have lost their bargaining power with respect to producers that practice linear prices by selling on a hub, it is a good policy to also eliminate the market power of the suppliers with respect to the consumers. One obvious question is whether it is good policy to reduce the market power of suppliers with respect to producers that do not sell on a hub. GASTALE 1 provides further insight.

The theory of double marginalisation raises the question of why producers that have all the market power would give up part of it by selling on a hub (through linear prices). Theory suggests that their interest is to try to resort to two-part prices to increase their profits (see e.g. Tirole, 1988, Chapter 4 for a textbook discussion). This is what GASTALE1 implicitly finds in its benchmark exercise "In general, for most countries, actual 1995 prices are closest to simulated prices under oligopolistic producers and competitive traders". Note that GASTALE 1 only models linear prices; but the theory

also tells us that the solution of the two-part and one part prices are identical when the downstream market is perfectly competitive (which is what GASTALE1 models in its benchmark). The benchmarking exercise of GASTALE1 is thus compatible with the result of a two-part pricing assumption. Can we find supporting evidence in the real world? It is common knowledge that producers resort to Take or Pay clauses; they impose a minimal volume that is paid for in any case, and a linear price on any additional take. These are two-part prices. Note that the benchmark of GASTALE1, even though compatible with the assumption of producers having all the market power, does not prove this to be the only possible explanation: other assumptions like a shared market power would give the same result if producers and suppliers negotiate. GASTALE1 findings are thus well in line with what theory would allow one to deduce from the casual observation of the gas market.

GASMOD is much more assertive in its support of actions for a competitive downstream market. The model finds that eliminating downstream market power makes the result close to a perfectly competitive market with un-concentrated producers and downstream market "… in the EU liberalization scenario we find a welfare close to the case of overall perfect competition. Both welfare results are unsurprisingly higher than in the double marginalization". The authors conclude "This contradicts the widespread thesis that an oligopolistic downstream market is the best response to an oligopolistic upstream market" . But the overall results are surprising. If GASMOD effectively implements double marginalization, then GASMOD effectively supports paragraph 77 and concludes that the market power of the producers is inconsequential. The reasoning is the following. Double marginalization argues that a competitive downstream market improves the welfare of the consumers when suppliers have lost all bargaining power with respect to the producers. But it is impossible, in double marginalisation, to bypass the market power of the upstream oligopoly. Whatever the competitiveness of the downstream market, the upstream oligopoly continues to exercise its market power. GASMOD finding of a close to perfect competition of the internal gas market scenario therefore implies that the market power of the producers is indeed limited. This is quite different from the findings of the other models. An alterative explanation is that GASMOD, in contrast with the claims of its authors, does not implement double marginalization! We already pointed out before that GASMOD bypasses the numerical difficulties (non convexities inherent to equilibrium models subject to equilibrium constraints) arising in double marginalisation by implicitly adopting another, unknown, economic paradigm. We briefly explain in the appendix that GASMOD implicitly makes two assumptions that depart from the theory of double marginalization, with the result that the model enters uncharted waters. This suggests taking the support of GASMOD to the internal gas market resulting from the Commission's policy with utmost care.

All this is irrelevant if, as stated in paragraph 77, the upstream market is "unlikely to be excessively concentrated" as has long been the case in the US (before the country started to depend more on LNG imports). This is extremely relevant otherwise. Models that implement double marginalisation offer no

insight on the origin of Take or Pay clauses except if they find, as GASTALE1, that observations are compatible with a competitive downstream market. They are also internally inconsistent as soon as the market allows for two part tariffs.

- *Conclusion*

Double marginalisation justifies the structural remedies recommended by the Commission. But nothing justifies double marginalisation. It is one among several possible assumptions about the market. We did argue in Section 3.2 that it fits neither the factual findings of the Sector Inquiry, nor the observation of the gas market and the gas contracts. We just saw that GASTALE1, which implements double marginalization, does not conclude that this assumption offers a good description of its benchmark year (1995). This suggests questioning the results of double marginalization models. And there are theoretical reasons to do so. In contrast with what is sometimes claimed, economic theory does not tell us that a competitive downstream market improves on a pair of oligopolistic upstream and downstream markets. Double marginalization comes to that conclusion after making the additional crucial assumption that these oligopolies operate in sequence: producers have full power on suppliers, which have no say to the negotiation of the price. Double marginalization makes an additional, bizarre, assumption: producers that have all the power do not fully exploit it. They sell at linear prices and hence deliberately give up the take or pay clauses prevailing in current gas contracts even though these give them the capability to capture the whole monopoly rent. Other assumptions more in line with the observation of the market and other theories, not implemented in computable form so far, may have led to different results. Barring the unrealistic assumption of double marginalisation, our models therefore offer today no argument supporting the Commission's internal gas market policy. They would even suggest the opposite: if producers have full market power when setting the price to suppliers, they will use a mix of upfront payment (the minimal take of take or pay clauses) and linear price in such a way that the suppliers loose all their market power with respect to the consumers. In other words, the internal gas market will be automatically realized, but at no gain for European consumers. This contrasts with a situation that keeps both producers and suppliers in control of the market and manages to pass part of the monopoly profits (a fraction of 0,5€/GJ!) to the consumers through regulation.

The ambiguities caused by the unrealistic theory of double marginalisation and the politically very incorrect conclusion that the internal gas market is useless disappear if the upstream market is "unlikely to be excessively concentrated". The internal logic of the Commission is incontestable: paragraph 77, if correct implies that there are gains in making the downstream market competitive and hence in the internal gas market. But all but one model that test the upstream market under an internal gas market scenario (perfectly competitive supply and no barrier to access the infrastructure) conclude that it is effectively (un)"likely to be excessively concentrated". Barring the assertion of paragraph 77,

the reasoning of the Sector Inquiry therefore also offers no argument supporting the Commission's internal gas market policy.

5.3. Infrastructure issues

The Sector Inquiry uncovers practices that limit the access to gas transmission and storage infrastructure. It argues that these practices segment the supply market and therefore make it less competitive. The models analysed in this paper suppose unconstrained access to transportation and storage facilities at competitive prices; they are thus unsuitable to analyse the impact of the organizational barriers discovered by the Commission on the use of the infrastructure. Such an analysis would require modelling the microstructure of these markets, something that does not seem to have been done today. But models can be used, at least in principle, to assess the impact of exogenously given limitations of the infrastructure. These can be physical limitations (a saturated pipeline, storage or injection capacity) or result from the restrictive practices identified by the Commission (e.g. an unused capacity that cannot be justified by operational or security reasons). The argument developed in section 5.2 implies that we are unable today to assess the impact of limited infrastructure (whether physical or artificial) on the competitiveness of the supply market, except under the unrealistic assumption of double marginalization. But limited infrastructures also have an impact on the market power of the producers. Limited transmission capacities modify the relevant geographic market of the producers and hence their market power. Similarly, limited storage capacities modify the product market by restricting intertemporal substitutions. We know from electricity that these limitations can exacerbate market power. As argued by Hubert and his co-authors limited international transmission capacities also have an impact on the market power of the transit countries, which in turn reflects on the market power of the producers. These are very complex issues that models that assume perfect transmission and storage cannot take up (and it is unclear that any model can today cope with these issues). The rest of the section will thus concentrate on the impact of modification of infrastructure capacity on the market power of the producers.

- *Upstream competition from downstream of transmission*

GASTALE2 only considers market power on the producer side. All other markets (transmission, storage, supply and retail) are perfectly competitive. It concludes, as expected, that the upstream market power degrades total welfare in general and consumer welfare in particular. GASTALE2 also offers an interesting illustration of how additional transmission capacities can mitigate the market power of the producers.

GASTALE2 represents the transmission system through a set of corridors from production to markets and cross border transmission capacities between markets. It then considers scenarios of additional capacities in some lines (Norway to the UK, the Netherlands to the UK and Denmark to the

Netherlands) and compares the market power of the producers before and after these capacities come on stream. Note that GASDTALE2 does not model these capacities as endogenous investments but through exogenous scenarios. As argued in Section 2.3, changing the transmission system modifies the relevant geographic market of the producers by increasing substitution possibilities. In this particular case study, the additional capacities in the above lines increase the competitive pressure on the producers delivering to the UK. The results of GASTALE2 reveal dramatic price decreases to the different consumer segments.

This case study points to an interesting but controversial result that the paper does not develop much. The value of the additional pipeline essentially derives from a reduction of the market power of the producers. A more concentrated upstream market implies a higher value of the pipeline. For given demand and production facilities (that is in a static market) producers therefore loose from investing in an infrastructure that decreases their market power. They are thus unlikely to invest. Interestingly, the owner of the infrastructure also looses from the operation, and hence will also not invest. The reason is more intricate: infrastructure owners in a competitive transmission market (the internal gas market scenario) derive their revenue from arbitraging between regions (transmission) or periods (storage). The market power of the producers increases price discrimination and hence makes these arbitrage operations more lucrative. Reducing the market power of the producers may increase the volume of arbitrages (by increasing flows) but it will make each of them less lucrative. The end result may be a loss of profit of transmission owners (as is this case study). Therefore transmission owners may not be induced to invest. Consumers are the true beneficiaries of the new capacity. But consumers are also unlikely to invest in the pipelines except if public authorities do so for them. The question is then who is going to take the initiative of building the new capacity. Note that the downstream market in this model again satisfies the assumptions of the internal gas market at least in the short run: competitive supply and unhindered access to transmission and storage infrastructure at competitive prices. But transmission owners may exercise market power in the long run, whether unbundled or not. Transmission owners may indeed refrain from investing because they realize that they benefit from an externality, namely the price discrimination induced by the market power of the producers. They do not create that externality but also do not want to sacrifice the benefit that they get from it. Note that this very indirect exercise of market power disappears if paragraph 77 hold. In contrast with the view of paragraph 77, GASTALE2 concludes that the upstream market is concentrated, that this concentration leads to spatially discriminatory prices and that transmission owners take advantage of these discriminatory prices without having done anything to contribute to it. An interesting question is whether the Commission would consider an internal e-mail of the transmission owner giving this reason for not investing as an indication of strategic withholding of investment. The case study suggests a more general policy conclusion: it is by no means obvious that ownership unbundling will

favour investment in transmission if producers have market power. There would be no problem if paragraph 77 were right. But what if it is wrong?

The problem of finding the right incentives for investing in the grid has often been mentioned in electricity and remains so far unsolved (see paragraph 67 of the Sector Inquiry for an example of a non solution). The problem is twofold. One first needs to identify who gains from the new capacities; models can help on this point. One then needs to assemble those who benefit from the project and induce them to pay. This is difficult when the beneficiaries are not the investors; further difficulties add up when there is, as when consumers benefit, a free rider effect. This is a policy question that goes much beyond what models can offer.

Last, possibly not least, and at the cost of repetition, it may be noteworthy to pinpoint once again that the gains accruing from the new pipeline capacity in GASTALE2 case study result from the enlargement of the relevant geographic market. Investing in transmission broadens the relevant market, which in turn increases the competitive pressure on the gas producers and hence improves welfare. This remark has now become a recurring theme of the paper: models embed an implicit definition of the relevant market. We elaborate on this important property in a forthcoming paper.

- *Competition through storage*

GASTALE2 and NATGAS contain both a representation of the market power of the producers and a description of storage. As models can be used to assess the reduction of market power resulting from new transmission capacity, they can be also be used to assess the impact of new storage capacities to decrease market power. GASTALE2 offers an illustration in the same spirit as the case study on pipeline capacity. This can again be interpreted in terms of relevant market. By enhancing the substitutability of gas across time periods, storage capacity increases the relevant product market in each period.

- *Conclusion on infrastructure*

All models covered in this survey have a potential for looking at increases of competitiveness accruing from additional transmission or storage capacity. Both reduce upstream market power. This potential derives from a fundamental property of the models: they embed a representation of the geographic market that captures the impact of changing infrastructure.

6. SUMMING UP ON COMPETITIVENESS

Cases of competition law begin with the definition of the product and geographic markets. We did repeat again and again that models embed a representation of the geographic market that goes much beyond the role based analysis revealed by Cabau (2005a and 2005b). The next step is to assess the

degree of competition in the relevant market. A common practice is to rely on concentration indices. Electricity has revealed that standard indices are often inadequate. Non-storability is the key reason of this inadequacy in electricity, but the network also plays an essential role. The network and the strategic and operational role of storage may determine that gas is also a special commodity for which concentration indices may turn out to be a convenient but meaningless computational trick. Can models go beyond concentration indices to assess dominance? Having found dominance or a potential for it, competition law then proceeds to two types of problems. It assesses possible abuses of dominant positions of dominant firms; it also explores the consequences of concentration on competition. What can model do about these different problems?

6.1. The relevant market

Reading about market definitions in concentration cases is not a very rewarding occupation. The Court gave a clear definition of the notion of dominance. The "Commission notice on the definition of relevant market" (EC, 1997) announced the application of a well-defined test namely the SSNIP. Concentration cases reveal a plethora of criteria whose relation with the fundamental definitions of the Court and the SSNIP is not always obvious. The general impression is that one is not on very solid ground. The interesting question is whether models can be used to return to the more fundamental definitions and tests in market definition. The conjecture is that this is possible: market definition and models are both about the analysis of substitution possibilities.

Models can easily accommodate physical capacities and constraints that determine substitution possibilities. Specifically gas models can embed elaborate descriptions of production, transmission and storage facilities. These will be less detailed than what operations engineers are used to and more akin to the tools of project or planning engineers. In any case they capture much more about the physics of the real world than the reasoning of concentration cases. EUGAS/TIGER with its detailed description of the infrastructure probably offers the best choice for conducting this type of analysis.

The situation is much less clear for regulatory constraints. Both Competition and Regulatory Authorities now recognize that European transmission and storage is balkanized, leading to markets that are often "no wider than national". One finds no trace of institutionally balkanized regulation in the models. Except for physical capacity limitations, transmission and storage markets are assumed unregulated and perfectly competitive. The absence of any modelling of regulation, and of balkanized regulation for the matter, is a serious drawback; but it can be overcome. This requires two conditions: one is to get a clean description of the various regulations that apply throughout Europe; the other is to cast this description in mathematical form. Getting the clean description is probably the more difficult part of the exercise.

6.2 Models of competition can quickly become quite complex

Suppose that one is able to cast the description of the physical and institutional constraints that segment the markets in the model. Alternatively, assume that one only considers physical constraints in transmission and storage to shape the relevant product and geographic markets. Can models help assess the degree of competition? Models do not reveal factual information. In this sense they will never substitute the data collection that underlies investigations like the Sector Inquiry. The question is whether they can help improve on the reasoning conducted on those data. Model based analysis of competition are so far (but this can change) limited to studying exploitative prices. A considerable amount of the electricity literature focuses on this subject with the view of measuring the potential to exercise market power through excessive prices. These models in fact propose true substitutes of the standard concentration techniques. In this sense, all surveyed models but EUGAS can measure (collective) dominance in the upstream market in the sense that they assess the potential from the upstream market to move price above competitive levels. Only two of these models GASTALE1 and GASMOD also claim to be able to assess dominance in supply. One may wonder whether all this is reliable. A first, quick, common and positive answer is that these economic models augment simplified physical models with the necessary theories of competition and hence are taking the best of two worlds. This should do the job. We already expressed doubts about the realism of theories like double marginalization. The recent study of electricity prices conducted in relation to the Sector Inquiry (London Economics, 2007) suggests that we might have to doubt more. London Economics has its own proprietary economic model but it did not use it. The study instead resorts to an (true industry standard) engineering model of the power sector. This model does not embed any theory of competition; it only describes technical characteristics of plants and solves a unit commitment problem. Is there more economic theory in the analysis? London Economics study begins by assuming national geographic markets; it then assesses dominance on the sole basis of standard and electricity specific concentration indices. It further proceeds with an analysis of exploitative prices that it studies by comparing observed prices to costs or prices that would prevail in a competitive environment. Except for these cost computations, the analysis contains no economic theory; it embeds an engineering model in an otherwise purely legal methodology (the comparison of observed prices to costs or prices that would prevail in a competitive environments are two criteria of the jurisprudence). It is remarkable that three academic economists, well known for constructing economically strong but engineering light models, supported this purely engineering oriented method. This raises the question of whether the authors of the study and their academic advisors, had enough faith in economic theory for assessing dominance and exploitative prices in the electricity sector. The same question can be raised for gas. We briefly give our analysis of the problem. Needless to say this is only our own, particular view.

Models commonly resort to two competition paradigms: perfect and Cournot competition. Suppose in order to simplify the discussion that the exercise of market power can always be assimilated to Cournot competition. Both, perfect and Cournot competition are clearly defined and computationally quite tractable when applied to a single product market. But competition law identifies several product and geographic markets. Even though separated by competition law, we know that these product and geographic markets interact, even if they do not form a single market. The modelling challenge is to introduce a mix of perfect and Cournot competition assumptions in each product and geographic markets and to complete them by assumptions of imperfect competition on the interactions between these markets. In order to illustrate the first point, consider the production, supply, transmission and storage markets. Each of these four product markets can be assumed competitive or à la Cournot. This makes sixteen combinations. Are we sure we know which one to choose? The former discussion of double marginalisation illustrates the second point. Some models implement double marginalization but could have assumed otherwise: the simplest alternative that comes to mind is to suppose suppliers behaving as an oligopoly with respect to consumers and as an oligopsony with respect to buyers. Which one is more realistic? We do not know and are unlikely to know soon. Notwithstanding the extensive factual analysis of the Sector Inquiry on each product market, we are today unable, on that basis, to make assumptions of competition at the inter-market level such as the interaction between production, supply, transmission and storage. We are also reasoning in terms of non-cooperative games while Hubert and his co-authors suggest cooperative game arguments. We thus have a complex mix of assumption to choose from. But suppose that we know what to choose. Have we solved all our problems?

6.3. and hence should be limited to what we can control

Suppose the Sector Inquiry gives us the necessary evidence for selecting the adequate competition assumptions both in each market and in the relations between markets. As an example, the Sector Inquiry points to withholding strategies in transmission and storage; suppose we want to model withholding transmission and storage capacities à la Cournot. The Sector Inquiry finds a concentrated supplier market and an un-concentrated producer market. Suppose we adopt these assumptions: we model producers as perfectly competitive and suppliers à la Cournot. Can we manage this model? Here is a brief summary of the state of the art in these models. Perfect competition in interactive markets is easy to model and solve. Cournot competition is also quite tractable and easily interpretable in a single market. Cournot competition is close to numerically intractable and dubious to interpret in two interactive markets as the discussion of double marginalisation shows. It becomes hopeless if one adds another layer of interaction, for instance, transmission and/or storage. In short, we are unable to operationally model the findings of the Sector Inquiry even if we assimilate imperfect competition to a simple Cournot. Worse! the experience of electricity modelling suggests that these combinations that

we can model already generate a wide range of possible assumptions, that the choice among them is driven more by computational possibilities than by market observation and that results depend on these assumptions. In short, complex models of imperfect competition are unreliable: we get results but cannot trust them. There is obviously no reason to believe that the rules of competitions law are more effective than our models. If economic theory does not know, legal rules do not know either. Both are unreliable: one can apply the rules and run the models but one cannot guarantee the effectiveness of the results.

In conclusion, our capabilities to analyse market power in different interacting markets such as those appearing in gas and electricity are lacking. There are too many possible combinations; we are uncertain which one to select; last but not least we are not sure that we can trust what we can model and solve. This does not mean that we are powerless? We can restrict ourselves to problems that do not involve market interactions at least not imperfectly competitive ones. This, we can model and properly interpret with a certain robustness today. Perfect competition models are easy to interpret and provide useful benchmarks. Cournot competition on a single market is a generalisation of concentration indices. It requires fewer assumptions and hence is an improvement on them. It is tractable and quite easy to interpret. These models may restrict the wide set of possible choices to what we understand and can compute without ad hoc assumptions. They raise considerable data challenge and meeting them would already be a great contribution. As ascertained but not elaborated above, these models can provide significant insight in the important question of the relevant market without too much ambiguity. As we shall see these models can, by the same token, help examine the question of infrastructure in the context of security of supply. This is already quite a lot in the current context.

6.4. Global conclusion

The competitiveness of the gas market is crucial for Europe. The market has both upstream and downstream sides. Except, possibly for global companies, Europeans can barely act on the upstream; authorities therefore concentrate on the downstream. Will this work? Models only offer support for the internal gas market policy under drastic and unrealistic assumptions. They indicate, without making much assumption, that the real problem is upstream. Model can also help, with minimal assumptions, identify actions on the infrastructure that will mitigate upstream market power. For the rest, we should probably refrain from claiming potentially important policy results that we cannot control and justify on serious ground.

7. SECURITY OF SUPPLY

Security of supply, whether of electricity or natural gas, is high on the European agenda. Papers and reports have abundantly documented the "arithmetic of gas security" (Stern 2006): European production is still important, but slowly decreasing. At the gauge of more than 500 bcm of annual EU consumption, indigenous reserves will not last long. Gas has to come from elsewhere and the proportion of this external input is increasing. It is widely acknowledged that the problem is not scarcity of resources. Gas is abundant around Europe. The problem is elsewhere: gas even though abundant may be unavailable. Paragraph 77 of the Sector Inquiry, if taken seriously, suggests that this worry is unjustified: abundant resources in an un-concentrated market should be available. It is certain though that very few would mention security of gas supply if resources were owned by one thousands producers and not reside in a few hands. One would not interpret Russia trying to get market prices (possibly excessive, but in any case non discriminatory) from Ukraine or Belorussia as a political move if Russia were just one small producer among many. It would just be a normal market operation: Ukraine and Belorussia have had to pay Western market price or be cut off. This trivial observation makes it clear that the market power of the producers is the driving theme of most of the discussion of security of supply. Even though LNG increases its market share and can contribute to the liquidity of the market, it remains far from sufficient today and in the likely future. We concentrate on this view of the problem. We discussed competitiveness before; we take up security of supply now.

Besides a general recommendation to diversify sources, one finds remarkably little about how to handle questions of security of supply in Europe. But there are indications that the problem may not lie where the common wisdom believes. Stern (2006) finds Russia curtailing supply for geopolitical purposes very unlikely. But he is concerned about Gazprom concentrating its future developments on the progressively more lucrative Russian market and LNG from the Middle East and Western Africa not being able to compensate. Tönjes and de Jong (2007) do not seem too much worried about Russia using gas for geo-politic purposes either but they also see a possible reluctance of Russia to increase exports to Europe; moreover they are not certain that the pipeline infrastructure will be sufficient if Russia is indeed willing to export more. These analyses are of the political science type. Joskow (2005) offers an economic view. He explains that there is no conflict between competition and security of supply (he does not go as far as saying that the former helps the latter) "There is no inherent conflict between the liberalization of electricity and gas sectors that meet reasonable supply security goals as long as the appropriate market, industry structure, market design, and regulatory institutions are developed and implemented". Joskow also makes it clear that there are conditions to this compatibility between the two objectives "However the effective liberalization of the electricity and gas sectors does create a number of challenges for institution building and governance that must be recognized and addressed for liberalized systems to perform reasonably well from a supply security perspective". Joskow also suggests that getting these conditions in place in Europe might be difficult.

A major question, he argues, is whether "governments in Europe try to capture gas that might otherwise be exported for their own citizens during supply emergencies using out-of-market mechanisms and government induced behaviour that restricts the transportation of gas when it is most valuable". More generally governments may try to meddle with market forces in times of disruption. It is also often suggested that structural remedies, namely investments in infrastructure and a more liquid market should be implemented. Infrastructure and globalization are necessary conditions for making today's market more liquid. Making the market more liquid is thus not a policy but the result of a policy. We therefore concentrate on the question of infrastructure and first try to structure the issue.

7.1. Undistorted market forces?

The reasoning of the Commission on investment and security of supply can be summarized as follows. "Liberalised and competitive markets help security of supply by sending the right investment signals to industry participants" (EC2006, page 8). This short statement contains a major condition: markets should not only be competitive; they should also function well. Investment signals might not come forward in an improperly functioning market, even if free from market power. The question is thus whether a competitive European gas market would function well. We again reason in an internal gas market scenario, that is, for a downstream market where supply is competitive and access to infrastructure unhindered and priced competitively. We shall argue that even then, this market will remain plagued by externalities and is thus unlikely to send “the right investment signals to industry participants". As long as the institutions do not properly master these externalities, market forces will be distorted.

The common wisdom and our models reveal that the upstream market is concentrated. Assume that producers have market power. We saw in Section 5.3 that this concentration creates externalities that induces transmission owners not to invest to reduce the market power of the producers. Benchmarking regulation (that only concentrates on cost reduction) cannot correct this missing incentive. Only a heavy regulation that gets into the investment calculation of the transmission owner can identify those investments that reduce the market power of the producers and hence increase security of supply. It would still remain to find the way to incite transmission owners to undertake these investments. As we saw in Section 5.3 models can help identify those interesting additions of capacity. They cannot go beyond that.

Suppose, for a moment, that the above problem is resolved and assume away all questions of market power, whether at the producers or suppliers side. Would competition give the right signals for investments”? The Green paper suggests that there may be externalities in security of supply: "decisions to rely largely or wholly on natural gas for power generation in any given Member State

have significant effects on the security of supply of its neighbours in the event of gas shortage" (EC2006, page 9). Basic economics tells us that externalities distort prices and hence may possibly interfere with " the right signals for investments". Can one explore the argument further? Joskow (2007)'s analysis of security of supply shed some light on the question. This author argues, among others, that pure market forces in proper markets and institutions can handle resource adequacy if investors are certain that governments of countries affected by the disruption will not confiscate the resource or cap its price in case of disruption. This is far from guaranteed. The gas Directive and the Directive on Security of supply even suggest the opposite: governments managed to retain the possibility to intervene and are unlikely to let markets operate normally in exceptional circumstances. The consequence is that market forces will not induce the investments in infrastructure and individual security of supply if investors foresee that their capacities will be confiscated or that they cannot get market price for the commodity or services in case of disruption. The usual free rider phenomenon will also reduce the incentive to invest: some will count on the investments of the others. The Commission's claim should thus be restated as follows. "Competition will give the right signals for investments and hence enhance security of supply as long as governments can commit not to mangle the market in case of disruption." Needless to say the Commission cannot guarantee the latter condition. Models can help assess the extent of these externalities by measuring the effect of disruption. They are obviously useless to get governments commit not to intervene.

But suppose in order to further simplify the problem that governments credibly commit not to confiscate resource or cap prices in case of disruption. The resource adequacy is then a private good that can be left to market forces. Is this all there is? Electricity suggests that we should be prudent.

7.2. And missing risk markets

Suppose an ideal world where governments do not intervene in case of disruption: they leave competition increase gas price to clear the market and remunerate those who invested in the infrastructure or alternative sources. These are the price signals invoked by the Commission to induce investments. Will they suffice? The experience of electricity teaches to be cautious. The obvious question is whether the problems of resource adequacy now commonly recognized in electricity will not appear in gas, possibly with increased acuity.

- *A brief look at electricity*

Resource adequacy has been discussed at length in US electricity markets. Insufficient investments can be traced to two causes: prices might not be high enough to justify investments. Even if they are, they remain quite unpredictable and make the investment risky. We assumed that prices could increase as necessary to clear the market and hence excluded the first worry. We are left with the risk problem. Will investments related to security of supply not be too risky? Invoking competitive markets becomes

here more technical. Competitive markets can develop very sophisticated instruments to handle delicate risks but they do not necessarily do so. Even when they do, the beautiful sophisticated mathematics that underlies the pricing of financial derivatives should not hide the equally strong assumptions of market liquidity that they require. The example of electricity shows that competitive markets do not spontaneously trade long-term capacity risks with the result that we do not have today in Europe the "right signals for investment" in electricity. The monopoly companies had more leeway. They could aggregate these risks and pass them to customers. They could also conclude contracts with other companies to share these risks. The example of the US shows that regulatory intervention maybe warranted to create the necessary markets alluded to by Joskow (the capacity market or the price add up) to compensate the risks embedded in investments. An analogous problem could happen for gas, possibly with a higher degree of acuity as we briefly discuss now.

Single cycle combustion gas turbine is the equipment of choice for handling resource adequacy in electricity. These plants are relatively capital inexpensive. Most investments in gas turbine are for resource adequacy. But a gas company, whether a producer or a supplier that wishes to secure an alternative source of gas or of delivering infrastructure needs to add a full combination of pipelines, storage, terminal infrastructure, and some additional contracts. These are highly capital intensive, especially when we refer to long distance supplies. And the risk that applies to them is certainly as large as the one borne by a simple gas turbine. A key question (but not the only one) is thus to assess the cost of investments in security of supply. This is where models can play a crucial role.

- *European gas is not European electricity; it is not US gas either*

European gas is indeed different from European electricity or from US gas. Part of the resource adequacy problem arises from resources that have to travel several thousands of kilometers to reach the market. Except for LNG, they may have to cross several countries some of them "difficult". This brings us back to market power and the problem examined by Hubert and his co-authors. Investments of security of supply have to deal not only with normal commercial risk; they are also subject to the possible market power of the producer and transit countries. In other words, the cost of investing in security of supply for European gas may be much higher than what would accommodate weather, technical failure or strike risk. The risk premium embedded in investment of security of supply does not come from trading risk in a liquid financial market. It is rooted in negotiations between a few agents that all have market power and that are not necessary induced to comply with their contracts. As an example, the risk premium that justifies building NordStream has nothing to do with a standard commercial risk. It is a strategic risk that no competitive market will ever reveal. According to Hubert et al. (2003, 2004 and 2005) and Stern (2006), this premium needs to be paid because transit countries cannot credibly commit to remain in compliance. It is not clear what kind of “clear policy on securing and diversifying energy supplies" or "clearly identified properties for the upgrading and construction of new infrastructure necessary for the security of EU energy supplies …" (EC, 2006, p.15) will help

NordStream like projects. But gaming considerations can justify them. Only a careful case by case analysis can signal that a costly redundant infrastructure is profitable because it mitigates the market power of some agents (in this case Poland and Belorussia as transit countries). Can model say something about redundant infrastructure?

7.3. Models for assessing the capital intensity of security of supply

Except for GASTALE3, none of models presented here explicitly addresses the question of security of supply. But all have the potential to contribute to the question.

- *Redundant infrastructure*

Redundancy (in the sense of reliability theory) can accommodate forced outages or weather uncertainty. This is standard in systems reliability. It is the part of security of supply for which one can expect that a sufficiently sophisticated competitive downstream market will send the right investment signal. But economic actors, whether integrated suppliers or infrastructure owners may face degraded incentives to invest. Stern (2006) argues that defaults in delivery have so far mainly occurred because of the downstream market. He also gives the example of insufficient and delayed investments in gas storage in the UK. Withholding is not involved here; simply the market or its regulation may have failed to send the right investment signal. Tönjes and de Jong (2207, page 9) also mention the possible effect of inadequate regulation at the domestic level. But the possible insufficient incentives to invest domestically are not the main concern in today conversations of security of gas supply. The concentration in production and transit outside of the EU/EEA area, in other words, the strategic aspect of problem is the driving concern.

This problem is not new. Similar worries developed during the cold war, when Europeans were wondering about the impact of possible disruption of Russian supplies (at the time Soviet supplies). IEA had developed a methodology for looking at the problem. It considered several scenarios of disruption and verified how the gas system would strive in these scenarios. The work concentrated on quantities: one verified the feasibility of transporting and redistributing available gas, including the one from strategic storage to the affected countries. The question was whether the existing infrastructure and volumes in storage would allow one to sustain an ex ante set of interruptions. Very little modelling was involved. One just checked that quantities matched.

This idea is quite similar to the N-1 constraints in electricity models. One verifies that the system can sustain a set of ex-ante defined contingencies before returning to some new normal situation. Electricity shows that this idea can be embedded in models. As an example security constrained dispatch solves an economic optimization problem subject to N-1 security constraints. The inclusion of this idea in gas market simulation models requires a further step. Gas market simulation models are

equilibrium and not optimization models. The question is thus whether one can introduce N-1 constraints in equilibrium models. The answer is a clear yes for perfect competition models such as EUGAS or the perfect competition versions of the other models. The issue is probably hopeless in double marginalisation models. The more intriguing cases are the versions of GASTALE, NATGAS and GASMOD that implement a concentrated upstream market. Being able to introduce N-1 criteria in market simulation models with an upstream oligopolistic structure and competitive downstream market will not solve the gas security problem but would be a first step towards clarifying the necessary redundancy to build in the infrastructure. None of the models examined in this paper so far handles the redundant infrastructure investment problem. Difficulties are twofold: some are related to the insertion of an N-1 type criterion. The other much more difficult question relates to making investments endogenous when there is market power. A reasonable discussion of these questions goes beyond this paper. This is a full subject for research.

- *What exists*

Besides the case study conducted with GASTALE2 and mentioned in Section 5.3, GASTALE3 has been used to examine investments requirements for insuring security of supply in the Europe gas market. The models adopt a "modelling as usual" view. It considers a set of scenarios of prices and demand and runs the models separately on each of them. We are thus very far from an N-1 type analysis since we are looking at each of the "N-1" cases separately. But the results are already daunting: massive investments in new corridors are necessary. This rejoins the claims of the IEA world outlook about the restructuring of the European energy system. The message may not be big but the amounts involved are. Tönjes and de Jong (2007) are not that worried. They see the forthcoming infrastructure as sufficient. Stern (2006) is more cautious because of the degraded situation in Ukraine and the possible LNG delays in the Middle East and West Africa. The question though is whether this infrastructure, even if fully realized would pass a "N-1" test.

- *Conclusion*

Talks about security of supply are abundant but recommended actions are not clear. The question seems to be totally under researched by modellers, at least as soon as one departs from the repetition of the well-known generalities about our growing dependence on a concentrated market and the need to implement clear policies of security of supply. Explaining that the market is unlikely to be excessively concentrated is simply misleading because it leads one to overlook the issue. Arguing that competition will solve the problem and at the same time proposing "A clear policy on securing and diversifying energy supplies" and "clearly identified properties for the upgrading and construction of new infrastructure necessary for the security of EU energy supplies …" only add to the confusion. Either competition does it or it does not. Business as usual scenarios tell us that investment needs are immense; but we are no longer in business as usual when it comes to understanding incentives to

invest, still less so about incentives to invest in redundant infrastructures for mitigating the market power of producers and transit countries or possibly the inability of the Middle East and West Africa to deliver. Models could help understand some aspects of the problem things. But they should be developed urgently.

8. SUSTAINABILITY

8.1. The reasoning of the Commission

The following quote summarizes the thinking of the Commission about the link between competitiveness of the European industry, sustainability and security of supply: "An effective energy efficiency policy does not mean sacrificing comfort or convenience. Nor does it mean reducing competitiveness. In fact an effective policy in this area means the opposite; making cost-effective investments in order to reduce the waste of energy …" EC(2006, p. 10). The statement is clear even if the underlying reasoning leading to the statement may not be. But there is no point discussing the statement in this paper devoted to gas models. The modelling situation is indeed embarrasly simple.

8.2. Models

None of the gas models explicitly considers the question of sustainability. One can at best argue that it is implicit in the demand functions that represent the retail market: higher gas prices, whether they originate from the link with oil or from increases of CO2 allowance prices decrease the demand for gas. We already lamented that we know very little about the demand functions embedded in our gas models. We therefore also do not know how CO2 and the EU-ETS modify it. It is thus impossible to say how the demand for gas changes as a result of the introduction of the EU-ETS. Sustainability is thus, for all practical purposes, absent from our gas models.

9. CONCLUSION

European Institutions herald a competitive, secure and sustainable energy system. Competition is central to the enterprise. It should contribute to the two other objectives and facilitate a more global goal, namely the competitiveness of the European industry. Energy policy concentrates today on the electricity and gas internal markets. This paper restricts itself to natural gas with the limited objective of discussing the extent to which gas models shed some light on how to achieve these European targets. We discuss six models: three versions of the GASTALE model originate from ECN in the Netherlands; DIW and EWI in Germany are respectively the authors of GASMOD and EUGAS. The Planbureau in The Netherlands produced NATGAS.

Except for EUGAS and GASTALE3, which concentrates on infrastructure, these gas models mainly focus on the oligopolistic character of the European gas market. This emphasis responds to two concerns. First it is commonly (but not universally) admitted that the upstream gas market becomes more and more concentrated. This reduces competitiveness and security of supply, which may in turn limit the recourse to gas in the European quest for sustainability. Second, the Commission and industrial consumers are also worried about concentration in the downstream market. The industry complains that it leads to high prices and hence reduces its competitiveness. The Commission reasons that it also deteriorates security of supply and sustainability. Can gas models tell us something relevant about these questions?

- *On competition*

Models that attempt to capture market power on both the production and supplier sides appear, at first sight, most useful. They encompass the full problem of competitiveness. But nesting two oligopolies in a single model is not a trivial matter. One difficulty is rooted in economic theory: how does one represent the relation between two oligopolies? GASTALE1 and GASMOD invoke the theory of double marginalization for representing the relations between the production and supply markets while supposing that transmission and storage operate as perfectly competitive markets. This is just one of the possible assumptions that one can make about today's gas market. The observation of the market certainly does not justify double marginalisation. A second difficulty is computational; models based on double marginalization require dramatic simplifications to retain good computational properties and these simplifications may invalidate their results. Some of these simplifications may even move the model away from the double marginalization that it claims to embed. In the absence of alternative implemented models of the relations between the upstream and the downstream markets, our conclusion is that we are badly equipped to analyze the global impact of market power on competition in the gas market. Is this important?

The upstream and downstream gas markets are quite different objects. European policy can directly act on concentration in the latter. It cannot change the structure of the former. It is therefore not surprising that European Institutions emphasize actions on the downstream market. They claim that a competitive downstream market will help the competitiveness of the industrial consumers and enhance security of supply and sustainability. This may be true but, barring the recourse to the unrealistic assumption of double marginalisation, we find no element to justify this claim in the models. The analysis of the price in the upstream and downstream gas markets suggests that the bulk of the added value is made upstream. Whatever the share of excessive profits in the downstream market, reducing it by competition will not do much for the competitiveness of the large consumers. It is also not clear why this added competition would increase security of supply or sustainability. In short, downstream action may bring very little gain to Europeans, if any. It is indeed not very difficult to imagine that an un-concentrated downstream gas market would simply permit a concentrated upstream market to

capture all the rent that can be made on European consumers. But even though this might be possible, we also find no quantification of the increased gain for the upstream of a more competitive downstream market. The problem therefore remains to be studied. Would then current models be useless? The analysis of security of supply suggests a response. With abundant gas resources around Europe, few would care about security of supply if production were not concentrated. There is certainly a threat for security of supply in the downstream market because regulatory uncertainty may have reduced incentives to invest. But this does not attract much attention and the upstream concentration is what most people have in mind when they think about security of supply. Can models of the sole upstream market tell us something relevant?

The market power of the producers depends on their relevant market, something that Competition Authorities have so far refrained from studying. More infrastructures, whether in transmission or storage, can increase the geographic or product markets of the producers. Prototype case studies conducted with models that only represent upstream market power show that this is a reality. Additional infrastructure may indeed effectively decrease the market power of the producers. This is not the end of the story. Models also usefully point to some controversial policy questions. Investments that reduce upstream market power may obviously not benefit the producers (it all depends on the trade off between price and quantities), which are thus unlikely to undertake them. But the same applies to transmission and storage owners. These operators are arbitrageurs and additional infrastructure may not benefit arbitrageurs. The reason is simple; arbitrageurs take advantage of high price differential resulting from the exercise of market power of the producers. Their unit profit on each transaction decreases together with the exercise of market power of the producers (but might in certain cases be compensated by an increase of volume). In other words, companies that, after separation from supply, get their sole revenue from transmission may have an incentive not to invest. This certainly contradicts the claim of the Commission and the Regulators that ownership unbundling will enhance the incentive to invest (note that an ISO would not suffer from the problem). This result is obviously too partial to be made a general finding. It is just an interesting question to investigate and models can be used for that purpose.

In conclusion, oligopolistic models that only represent one side of the market power are quite useful. They are more robust and transparent than those that try to capture both the upstream and downstream parts. Economically, they just go one step beyond perfect competition models. They capture the very fundamental and observable existence and exercise of market power of the producers. They also implicitly model relevant markets (as perfect competition models). Last they pose (and hopefully help solve) the problem of financing a project by identifying those who gain from it.

- *On security of supply*

Security of supply should open a vast potential for models, but this potential remains untapped so far. The Commission claims that competition will help solve the question of security of supply by giving the right signals to invest. Good authors suggest a more careful position: competition and security of supply are compatible, but under some conditions that are unlikely to be satisfied in Europe. The main requirement is that agents that invest for reason of security can reap the benefits from their investments when disruption arises and prices skyrocket. Very few will believe that European governments can credibly commit not to intervene and let the market operate in case of serious disruption. But even if this were the case, investing just to reap benefits in case of disruption remains a very risky business in a competitive environment. The restructuring of the electricity market revealed difficulties for inducing investments in low capital cost gas plants. One may reasonably wonder, on the basis of this experience, where getting the incentive to build redundant gas transmission and storage infrastructure will come from. Models can contribute to clarifying the question. At least they can help us assess the costs of these redundant infrastructures and the added system flexibility that they induce. This can be done up to some extent with existing tools. They may also help assess the strategic value of some investments, but this is certainly more difficult. The question of which type of company can undertake investments of high strategic value is posed. We know that Gazprom, E.ON and the like can. We can also believe that a joint Gazprom-E.on project is a credible commitment to supply the market.

- *Sustainability*

None of the models surveyed in this paper considers sustainability question. Still inserting CO2 considerations is something that should be relatively easy if we had good demand functions to represent the substitution of gas with other fuels. We did see that those demand functions are largely missing. This is an important shortcoming. The knowledge of the demand function is equivalent to the knowledge of the product market. Without it, all analysis of competition remain doubtful. We can add that we are also restricted from any serious analysis of sustainability. The absence of solid demand functions is a common weakness in many facets of European energy policy. Its impact ranges from the definition of the relevant product market to the impact of particular GHG policies on the competitiveness of European large industrial consumers.

- *Neglected relevant questions*

An interesting question overlapping both competition and security of supply is whether agreements between companies to build redundant infrastructure for their exclusive use, therefore sharing risk and eliminating free riders in case of disruption, would be allowed. This is a problem of agreement between undertaking and hence a question of competition law. This is also a question of exemption from open access and hence a question of energy law. From an economic point of view, the problem is

whether such agreements would foster the incentive to invest. Models are completely silent on the issue.

The existence of market power does not imply its exercise. GASTALE3 notes that the Cournot counterfactual exaggerates the exercise of market power in comparison with observation. The authors of GASTALE3 then introduce long terms contracts in the model to mitigate the exercise of market power in the upstream market with the view of finding prices more compatible with observation. Long-term contracts raise several interesting questions.

The role of long-term contracts in electricity and gas markets is ambiguous. The literature of computable gas models does not elaborate much on the question except, as in GASTALE3, by assuming exogenous long-term contracts. The economic literature commonly (but not universally) admits that long terms contracts mitigate the exercise of market power by limiting the incentive to raise prices on spot markets. It is to this effect that GASTALE 3 refers to when introducing long-term contracts to mitigate the impact of the Cournot assumption. Competition authorities have an altogether different point of view. They argue that long terms contracts foreclose the market and hence reduce competition: they enhance market power but not necessarily its exercise. The two arguments refer to different phenomena that are simultaneously at work in the market and hence are not contradictory. Computable models, to the best of our knowledge, do not deal with the foreclosure effect. As GASTALE 3 illustrates, they can account for the impact of long term contracts on spot prices. Needless to say, we would like to have models capable of assessing the combination of these phenomena.

A second important question is the role played by long terms contracts in the formation of gas prices. The European gas industry commonly argues that long-term contracts have been instrumental for its development. These contracts were also a corner stone of the US gas market until the restructuring in the eighties. Competition authorities object to long-term contracts by incumbents because they foreclose the market. They see a second, related, problem: long-term contracts prevent the development of liquid exchanges and hence in the view of the Commission hamper the formation of competitive prices. Repeated spot markets where many suppliers and consumers meet obviously correspond to the ideal, textbook, and description of competitive markets. This view is materialized in exchanges like Heny Hub in the US or NBP in the UK. These hubs trade large volumes of gas coming from many relatively close producers. The situation is less clear for Zeebrugge, Baumgarten, the Easter border of the EU or any other location in the EU for that matter. These places lie a few thousand kilometres away from the main forthcoming production sites and are linked to consumption sites through a balkanized transmission system. A liquid market requires a good arbitraging system and European law has so far been unable to produce the enabling organisation of transmission. It is not certain that producers will build 20 or 30 bcm pipelines over a few thousand kilometres, just to get

costly production priced on a volatile exchange. It is also not certain that suppliers will go to the effort of negotiating long-term contracts, just to be told to release the bulk of them on an exchange. In short, there might be several reasons while, as in other commodities, a liquid exchange does not develop, therefore preventing the emergence of the textbook spot market. Contracts are the usual remedy to that situation. This does not imply that they should continue to be linked to oil products (see Stern 2007) but it is also not clear that one can dispense with them. They played an important role in the history of European gas but we find no trace of them in our models.

APPENDIX

GASMOD models both production and supply as oligopolies. Contrary to the claim of the paper, the relations between the upstream and downstream firms are not those assumed in standard double marginalization. A careful reading of the equations of the model reveals that producers and consumers see the same price elasticity, namely the one of the final demand sector. This assumption has definite computational advantages on which we do not elaborate in this non computational paper (in short, the assumption dispenses with the need to derive the demand curve of the supply sector). But it also has serious modelling implications: GASMOD no longer implements double marginalization and we know of no economic paradigm of what it really implements. Specifically, suppliers behave as in the standard double marginalization theory: they take the price of producers as given and exercise market power on the final demand. But producers do not behave as in double marginalization; they do not see the elasticity of demand from the suppliers but use the one of the market. The model therefore implicitly decreases the exercise of market power of the producers.

Another feature phenomena also influences GASMOD results. We explained in Section 2.6 that both market simulation models and definitions of relevant markets generally suffer from a poor understanding of demand. Modellers, whether in gas or electricity, often adopt ad hoc demand functions. GASMOD models demand as a constant price elasticity taken as–0.7 and -0.6 respectively for the Western and Eastern European markets. The justification of this choice given in the paper is essentially technical: this eliminates inequalities, demand never goes to zero. It also has technical consequences: it makes the problem of the suppliers in the second stage non convex. A non-convex downstream problem is incompatible with the theory of double marginalisation. In other words, the use of constant elasticity demand function with elasticities smaller than 1 places the model in a domain where the theory double marginalisation does not apply.

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