Use of Long-term Auctions for Network Investment

Tanga McDaniel and Karsten Neuhoff*

University of Cambridge
Department of Applied Economics

August 17, 2002

Abstract

Short-term auctions for access to entry terminals of the British gas-network appear to successfully allocate scarce resources and capture scarcity rent. Now long-term auctions are being introduced to guide future capacity expansion decisions. In our model the fraction of rights issued in the long-term auction turns out to be a crucial design parameter. Even a ‘hypothetically‘ optimal parameter choice can in general only satisfy one of three aims: Unbiased provision of capacity, full revelation of private information and minimisation of distortions from network effects. The results suggest that long-term auctions for transmission capacity are not necessarily preferable to regulatory approved capacity expansion.

JEL; D44, L95, L5, D92.

Keywords: Auctions, Gas, Investment, Networks, Regulation.

---

*Department of Applied Economics, University of Cambridge, Sidgwick Avenue, Cambridge CB3 9DE, UK. We want to thank David Newbery for extensive and helpful discussions, Gert Brunekreeft, Paul Pezanis-Christou, Emanuele Giovannetti, Paul Joskow, Richard Steinburg and seminar participants at the Max-Planck Institute, Jena for their comments. Any remaining errors are our own. We thank Transco Plc., Gottlieb-Daimler Foundation and the Economic and Social Research Council (awards R42200034307 and R000238563) for research support.

1 Introduction

Auctions are a common method of rationing fixed and scarce resources. Their potential use as a means of determining and allocating future demands is a relatively new idea, however. In electricity and gas industries auctions are either already in operation or are being discussed as a means of allocating use of constrained network capacity among energy producers. In the UK auctions have been used since September 1999 to ration entry rights to the national gas transmission system; access to the electricity interconnectors between many European borders (e.g., Belgium-Netherlands, Germany-Netherlands, France-UK, UK-Ireland, and Denmark-Germany) is determined via an auction process, and auctions are often used to allocate access to gas networks in the US. In many cases, auctions are replacing regulated and negotiated charges for access to essential facilities in utility industries. On the surface this makes perfect sense, and indeed, auctions eliminated the overbooking of constrained entry terminals on the UK gas network and allowed the network owner to captured and redistribute scarcity rent which was previously retained by traders. This leads to the following question: just how much can auctions revolutionize the way essential facilities are used- in particular, can they reveal unbiased demands and willingness to pay for network investments (i.e., future capacity).

In both electricity and gas there is discussion of and planning towards the use of auctions for guiding capacity investments. We argue that widening the use of auctions to determine demand for investments is not the logical extension of current auctions of existing capacity, and using the UK gas industry as a reference we show that, in the presence of market power, unbiased revelation of willingness to pay for investments cannot be achieved. Although this paper is motivated by the UK gas auctions of network capacity and the proposal by the regulator to use auctions as a means of guiding future investment decisions (we subsequently refer to this use of auctions as "long-term" auctions), the results generalize to other network markets where there is some market power, network constraints and competition among bidders.

McDaniel and Neuhoff (2002) discuss changes in the access regime to the national gas transmission system (NTS) in the UK and the use of short-term auctions for entry capacity.[1] They conclude that the short-term auctions have so far been successful with respect to a number of metrics including: anticipation of spot prices, reduction of con-

---

[1] A good summary of the early evolution is given by Armstrong, Cowan and Vickers (1994) .

straint alleviation costs, and rent capture. In this paper our focus will be on the long run aspects of the auction approach. Investment decisions in vertically disintegrated network industries are based on imperfect decentralized information. An objective of the auction would be to aggregate the individual demands and private information of bidders so that the network owner (in this case, Transco) can make better predictions about the need for capacity upgrades to the network. At the same time, there remains the objective of ensuring sufficient competition in gas spot markets. Our results show that these objectives interact with the product being auctioned in such a way that both cannot simultaneously be achieved. The results can be directly transferred to questions of capacity expansion in electricity networks, which were previously performed by regulated monopolies, potentially based on market signals as suggested by Rivier (1991) or Leautier (2000). Specific to electricity networks is that some investments can reduce overall performance of the network, however, Bushnell and Stoft (1996) show that in the case of full transmission contract coverage such detrimental investment will not be profitable for any party. Our analysis suggests that for a non-meshed network market power can significantly distort capacity investment. This is empirically supported by Abdala and Chambouleyron (1999) and Anderson (1999), who show that in spite of the positive framework no significant investment in transmission networks had been performed in Argentina, to our knowledge the only country that had implemented private grid capacity expansion by 1999.

This remainder of this paper is organized as follows: section two provides a description of the UK gas network and entry terminals; in section three we outline the assumptions and challenges for the auction and for the model that follows in section four. Section five is the heart of the paper; here we derive the fraction of entry capacity rights which would be auctioned long-term to meet three different objectives: eliminating bias resulting from market power, revealing private information about upstream production or removing distortions from downstream production. Additionally, we show that these objectives cannot be met simultaneously. Section six concludes.

2 The gas pipeline network

Figure 1 illustrates the main gas pipeline network in Northern Europe. Most underwater pipelines start from gas fields and transport gas of different consistencies that has to be processed at the beach before it can be inserted to the National Transmission System

(NTS). The UK is responsible for approximately 55% percent of North Sea gas production that can be roughly classified as wet and dry gas fields. Wet-gas is produced in the Northern fields that are interconnected to St. Fergus, and is a by-product of crude oil production. Producers of wet-gas are thus reluctant to adjust their output to match gas demand. The other fields are dry-gas fields which only produce natural gas implying that output can be more easily adjusted to accommodate seasonal variations in gas demand.

The Frigg pipeline was initially constructed to allow gas from the UK-Norwegian Frigg field to be transported to the UK. The Frigg Treaty of 1997 allowed use of the pipeline to import gas into the UK from additional Norwegian gas fields by interconnecting it with other pipelines and using it for new gas exploration.

The UK-Belgium interconnector, opened in October 1998, was initially planned to allow for exports of UK gas to the continent, but is also used on so-called reverse flows for imports into the UK during winter peak demand. Upgrades of compression facilities are planned for 2002 to increase the reverse flow capacity. Two further interconnectors are used for exports to Ireland. Given the level of abstraction of the current study, we simply classify these as additional demand on the NTS.

There are six major beach terminals in Great Britain where gas is put into the NTS: St. Fergus, Teeside, Easington, Theddlethorpe and Bacton on the east-coast and Barrow on the west-coast. St. Fergus in Scotland and Bacton in the south-east are the most active entry terminals on the network. The high demand for entry rights at St. Fergus can be seen by observing the number of gas pipelines connecting it to fields in the North Sea. Bacton is likewise connected to a number of major pipelines, but more importantly, it is the closest terminal to the interconnector linking Great Britain to the continent via Zeebrugge in Belgium. The first auction of entry capacity rights included only these six beach terminals; subsequent auctions also included a number of onshore fields, storage and constrained LNG facilities.

The NTS in the UK connects the gas landing facilities and storage facilities to gas customers. Demand for transmission services is volatile over the year and capacity is capital intensive making it inefficient to provide for a network that can satisfy all transmission requests. Over the last years the St. Fergus terminal in Scotland was the most constrained, with currently binding constraints in Scotland at Aberdeen, Moffat & Woller and Kirriemiur.

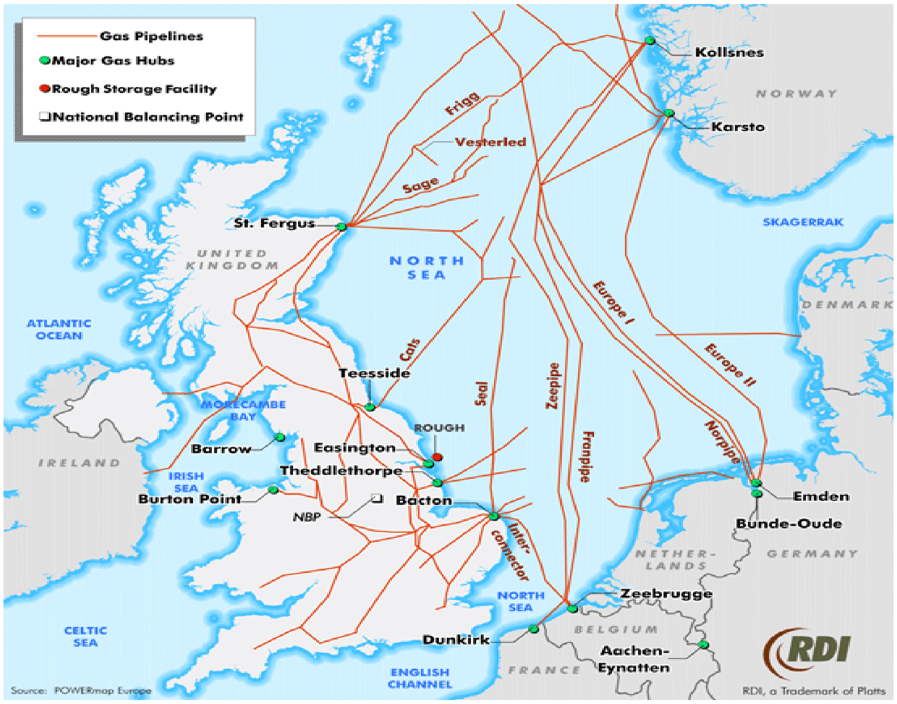

Figure 1: Gas Pipelines Northern Europe (Copyright Platts, 2001)

3 Model assumptions

3.1 Market power

As illustrated by Figure 2 the overall concentration of gas production for the UK market is not high, but several terminals on the network are only used by a small number of producers (the extreme case being at Barrow where there is essentially only one producer buying capacity rights). A consultation document by Transco, the network owner/operator, shows 5-firm concentration ratios between 65-100 percent from July 1998 to June 1999.[2]

The concern about the effect of market power in the upstream market is mirrored in a recent consultation document by the Department of Trade and Industry. The first issue to be addressed was whether "upstream mergers have resulted in over-concentration of gas ownership." (DTI 2001) Given these concerns, our model assumes that there is some market power in production.

---

[2] Transco Revised Consultation Report on PC48, Methodology for determining floor prices for auctions of monthly entry capacity, Transco Plc. September 1999.

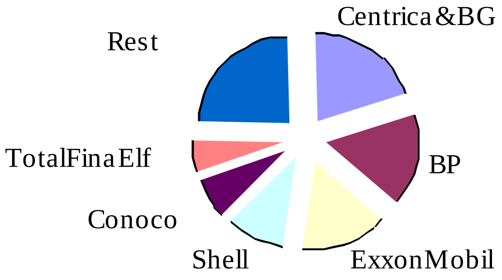

Figure 2: Share of UK gas production (Source: Leading UK Gas Producers, Platts 1998)

3.2 Capacity allocated in long-term auction and market entry

We assume that a proportion of transmission capacity is to be withheld from the long-term auction and allocated in spot markets. The initial purpose of retaining capacity rights for the spot market is the creation of a liquid short-term market and to ensure that entrants can obtain access rights at the market clearing price. Entry requires spot markets because few entrants would have funds to endure the time between the long-term auctions and the date at which they can deliver the first gas. Analysis of competition in the electricity industry by Newbery (1998) showed that entry and the threat of entry are essential to prevent high prices. In the long-term auction this would imply that additional firms will register to participate if they anticipate that the value of the capacity contracts they obtain will be above the spot price. In a world with perfect information, no uncertainty and without transaction costs this process would mitigate market power and reduce the inefficiency of the auction signal.

Ofgem's proposals have been that Transco provide sufficient capacity such that 20-25 percent of access rights will be auctioned in the spot market (2001a). We will refer to annual, monthly and daily auctions as spot markets in contrast to the long-term auction with a suggested five year horizon. When there is market power or private information about production decisions our model shows that the proportion of capacity reserved for the spot-market has substantial implications for the level of investment indicated by the long-term auction. Threat of entry might reduce inefficiencies resulting from such externalities, but entrants face two obstacles. First, entry is difficult if a five-year horizon is required before the first payback on investments can be expected. This difficulty will be reflected in high capital costs or in difficulty ensuring the guarantees required when signing long-term contracts. Second, entrants have less information about the market situation than incumbents. They have less information about which capacity rights are profitable to obtain and which are not. We assume there is a fixed cost required for any participant to acquire information and maintain the trading capabilities to participate in long-term auctions. This effectively limits the number of shippers using the network and prevents only a theoretically feasible perfect arbitrage.[3]

The assumption of capacity allocation in the spot market makes possible a liquid spot market for transmission rights allowing any shipper to obtain transmission rights at the market-clearing price. All shippers will value the rights they purchased in the long-term market at the price they could obtain in the spot market. Figure 3 shows that prices in the monthly auctions (auctioned in 6-monthly tranches twice per year) are a good indicator for spot price differences between the beach price at St. Fergus- where gas is landed before entering the NTS in Scotland- and the National Balancing Point- a fictitious or notional point on the network where spot trading and balancing occur. Deviations can be explained by information revealed after the six months auction. Industry sources suggest that daily spot prices are in line with the other two indicators shown in the figure.

Shippers with long-term contracts are more detached from capacity spot prices; however, if significant trading volume is performed in the spot market, then all shippers will set prices in the downstream market corresponding to spot prices irrespective of their forward contracts. Hence all shippers will include transmission at the spot market clearing price into the resale price. A similar situation can be observed in the international oil market. "Transnationals" like BP-Amoco and Mobil (though not Exxon) are known to hedge prices of both their crude supplies and petroleum products. The system enables petroleum companies to predict and ensure refinery margins for the year ahead[4]. Irrespective of hedging strategies the firms will trade petroleum products corresponding to the spot market price.

---

[3] A shipper is anyone who has a license to put gas into the network; also, any producer who lands gas at one of the nodes on the network.

[4] Madhumita Chakraborty: "Expert group signals foray into oil futures", *Financial Express*, Tuesday, March 21, 2000, see also Phillips and Weiner (1994) .

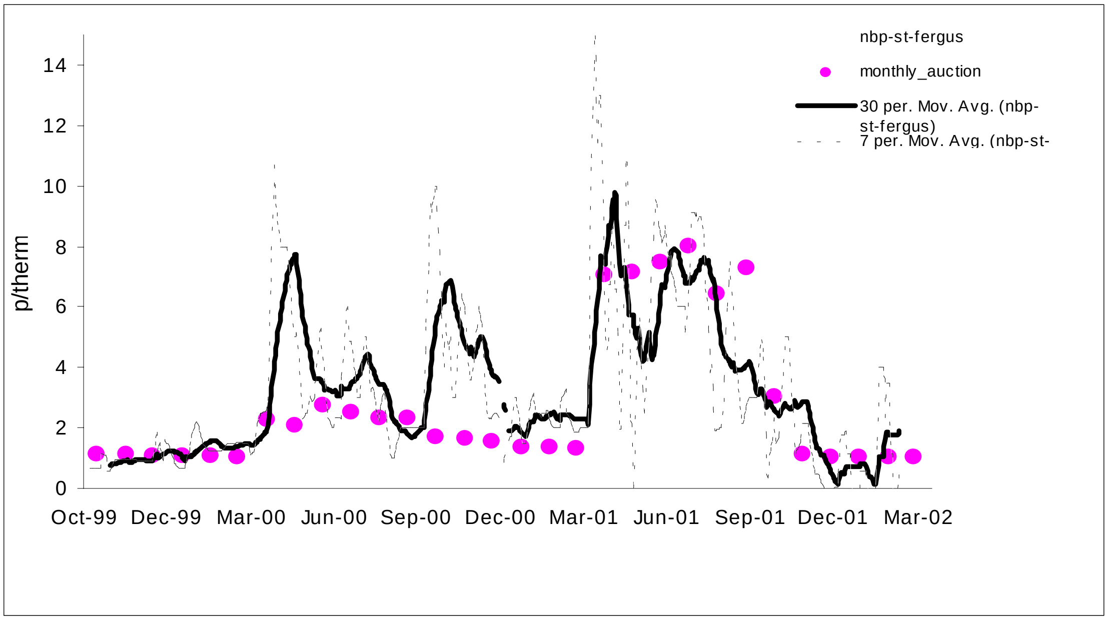

Figure 3: Monthly averaged price differences between day-ahead spot market for gas at St. Fergus and National Balancing Point and weighted average prices paid in auction for monthly entry rights.

3.3 Capacity expansion

We assume the transmission operator and the regulator jointly determine the bidding procedure and that the regulator can use incentive schemes to motivate the regulated monopolist to implement any procedure. For the initial model the procedure is characterized by the parameter $s-$ the fraction of total capacity allocated in the forward auction $-$ and the reserve price r which is set to a fraction of the marginal cost of network expansion, $0.8c$. We assume that additional capacity is available at constant costs c per unit of capacity expansion; in reality scale effects usually imply that investment is only performed if a significant amount of extra capacity is required. The cost c can be thought of as the long run marginal cost (LRMC) of expanding the network to meet expected demand growth.[5]

One proposal by Ofgem for the long-term auction envisages selling bundled strips of

---

[5] Prior to the introduction of capacity auctions shippers paid NTS use of system charges consisting of commodity and capacity fees. The commodity fee was a flat unit rate; the capacity fees varied depending on the entry and offtake nodes on the network and were calculated by Transco on the basis of the LRMC of accommodating a sustained increase in demand between system nodes. (See Transco's *Ten year Statement 1998* for a description of the LRMC calculation: http://www.transco.uk.com)

5 year capacity or unbundled strips of 1 year series of capacity.[6] A short time horizon has the disadvantage that shippers can bid for high quantities so that excess capacity will exist and subsequent auction prices will be low. A longer time horizon as proposed by some respondents to the consultation process preferably corresponding to the life time of the investment, could prevent such behavior but would create rigidity in the system. If one producer anticipated high output during the initial years and a second producer only assumed higher production in subsequent years then their needs would not be matched in the long-term auction. One could imagine scenarios where both bid for capacity resulting in excessive investment or alternatively where neither bids resulting in under-investment.

3.4 Auction design challenge

Within the context of auction theory the right for network entry capacity is a multi-unit product for which bidders have multi-unit demands and multi-dimensional, affiliated values. In addition to these complexities, auctions for access to the gas network deviate from a standard single unit auction with affiliated values in five significant ways: first, multiple units of access rights are offered for each terminal. Second, access rights for several terminals are auctioned concurrently and the value attributed to the rights by a shipper at one terminal depends on the price to be paid at other terminals.[7] Third, the number of access rights issued for a terminal depends on the quantity required at other terminals because most capacity constraints are not at the terminal but in the network; therefore, the auctioneer (Transco in this case) has some flexibility as to which terminal to allocate the capacity. Fourth, it is proposed that long-term auction results will determine investment in capacity expansion− knowing there will be sufficient capacity would give a shipper the flexibility to expand future output beyond the level he contracted in the long-term market. Fifth, the auction designers (in this case Ofgem in conjunction with government) are not primarily interested in maximizing auction revenue (as the auctioneer is a regulated monopolist), but instead care about competition in production and supply,

---

[6] Ofgem, *Transco's National Transmission System System Operator incentives 2002-2007, Final Proposals*, December 2001

[7] In FCC auctions for radio spectrum companies value spectrum based on whether they obtain spectrum in neighboring regions or whether technology applied by provider in neighboring region is compatible with own technology. Entry terminals are not complementary in this way. Some are substitutes in the long run since entry prices influence where producers build pipelines.

security of supply and allocative efficiency.

Subsets of these deviations from a simple auction typically suffice to ensure that the auction will be inefficient. Regarding point two Jehiel and Moldovanu (2001) show that if signals for bidders are multi-dimensional (e.g., private information about expected production at different possibly multiple terminals) then full efficiency is unlikely to be achieved. Moreover, efficiency and revenue maximization do not often coincide in such complex environments. Dasgupta and Maskin (2000) derive strict conditions under which efficient allocations can occur in multi-unit common value auctions if one allows bids to be contingent on the bids of others. However, Jehiel and Moldovanu show that efficient multi-object auctions with common values in general do not exist.

McCabe et al. (1989) anticipate the notion that auctions might successfully allocate rights to future network access, but do not discuss the interaction of long-term and short-term auctions and the strategic effect of this interaction on bidders' incentives.

Our analysis of long-term auctions is simplified by the fact that a significant proportion of access rights are allocated in the short-term market and that rights are defined as use-it-or-lose-it (i.e., if the owner of the rights does not indicate an intention to use them by a pre-specified time, the rights can be re-auctioned). This make a liquid spot market possible and prevents withholding of capacity to influence market outcomes in the spot market. All companies will therefore value their rights based on the spot market values and any difference between the spot market prices and the price of long-term contracts represent a sunk cost with little impact on the competition.[8]

Two open ended auction designs were initially proposed for the UK by the regulator Ofgem (2001a). The first design is a pay-as-bid auction where all bids are accepted which are either supported by existing capacity or for which the lowest bid is still high enough to pay for the corresponding capacity expansion. The second design is an iterative approach whereby Transco announces prices that are increased until the capacity, which shippers bid for at the announced price, coincides with the existing capacity. If more than the existing capacity is required at price c then it is assumed that Transco will expand the network to accommodate demand.

We do not explicitly replicate the suggested auction mechanism, but use the Cournot

---

[8] The 3G auctions in Europe show that auction fees which appear to be sunk costs nevertheless can influence subsequent decisions. We indirectly incorporate these effects by assuming a fixed cost c_i of participating in the long-term auction, which reduces competitiveness of the long-term market.

approximation. Fortunately, this approximation is exact in our setting because the expected auction price in a situation with network expansion will always be the marginal cost of network expansion c. Therefore it suffices for bidders to specify the quantity they want to obtain since the price is already given. Our model is simplified in that it does not capture the discrete nature of capacity expansion. In a situation with discrete capacity expansion the marginal bid can be above c if insufficient bids are available to allow for a further step of capacity expansion.

4 The Model

We will use the British gas market to describe the model underlying our results. Many of the issues involved in an auction for entry rights to the NTS in Britain can to our understanding be captured in a two-node setting. Node one represents the beachhead at St. Fergus where gas is landed before entering the network; node two represents the National Balancing Point (NBP). Entry rights correspond to transmission capacity between St. Fergus and the NBP.

The capacity available for inserting gas or electricity into a network is generally a function of the net-flows at the remaining nodes. However, gas-flow patterns in the UK are predictable and the current short-term capacity allocation mechanism rather successfully separated the allocation of entry rights from the allocation of exit rights. We follow this concept in the subsequent analysis which allows us to focus the model on entry rights and the role of producers.[9]

We focus on a scenario where constraints exist so that capacity expansion is required to fully accommodate demand. The results of the long-term auction determine the transmission capacity made available in five years time. We model the allocation and investment process in four steps. At step zero the regulator or transmission operator decides on the fraction of capacity to allocate in the long-term auction. In the first step access rights are auctioned in the long-auction. In the second step the transmission operator decides how much to invest in capacity expansion and in the third step the remaining capacity is allocated in the short term auctions. This approach appears to reflect the initial thinking of

---

[9] In a recent discussion of transmission rights in the electricity markets a similar separation of entry and exit rights were suggested (Ofgem 2001b). We believe that the volatility of electricity flow patterns makes such an approach infeasible.

Ofgem regarding the auction's implementation (Ofgem 2001a). Later documents (Ofgem 2002) discuss auctioning a fixed fraction of existing capacity and reserving a fixed amount of this same capacity for short-term auctions. The difference in designs produces a subtle change in our results but the qualitative message remains the same. The alternative design is discussed in the Appendix.

As is common in models with a number of stages we use backward induction to find the solution. We begin by finding a solution for step 3, use this solution to determine optimal actions for step 2, and finally, by knowing agents' preferred actions in subsequent rounds, we can determine the solution for step 1.

4.1 Period three

Changes of available transmission capacity in five years time have a twofold effect. Additional capacity permits additional gas to flow into the network and therefore reduces prices at the NBP. At the same time additional capacity from St. Fergus to the NBP results in higher demand for gas at St. Fergus and will thereby increase spot prices at the beachhead. We identify three categories of shippers which are identified with different strategies. The first category are local gas producers, l, who land all their gas for the UK at St. Fergus. Second are national gas producers, n, landing at St. Fergus and other UK terminals. As we assume that other terminals are unconstrained in our model all non-St. Fergus gas is delivered to the NBP. The third category consists of trading companies, t, owning shares of transmission capacity. This setup is illustrated in Figure 4.

We assume a competitive short-term market for gas. This assumption is supported by the observation that scarcity prices of entry capacity rights at St. Fergus are continuously high. In a non-competitive market producers landing at St. Fergus would reduce their output in order to capture the scarcity rent. High scarcity prices would then only be observed at times when Transco has to buy back entry capacity rights, but not in the monthly auctions.

Total expected production Q_u at St. Fergus (upstream) equals the total production of n_l symmetric local producers (q_l) and n_n symmetric national producers (q_n). Higher prices upstream, p_u, (i.e., prices on the beach before the gas enters the network) motivate producers to increase their production by the factor $\frac{\alpha}{Q}$. Aggregate production is a function

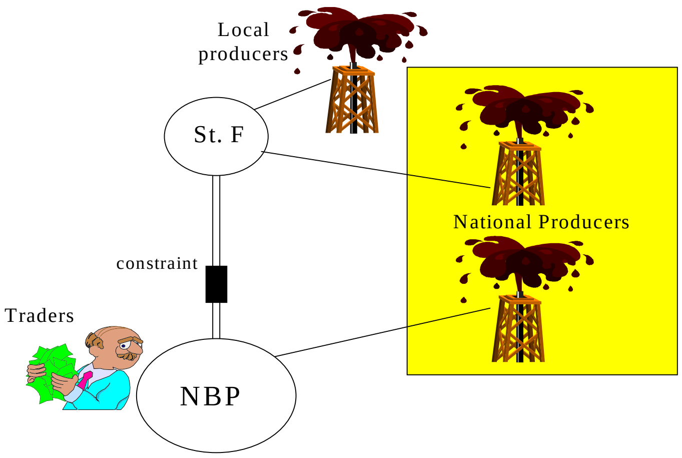

Figure 4: We model local producers, national producers and traders in a two node network.

of aggregate intercept $Q = n_l q_l + n_n q_n$ and aggregate slope θ, with $\theta = (n_l + n_n)\,\alpha$

$$Q_u = n_l\,(q_l + \alpha p_u) + n_n\,(q_n + \alpha p_u) = Q + \theta p_u. \tag{1}$$

Each national producer is furthermore assumed to land q_o units of gas at the NBP. For simplicity we assume that this quantity does not change with the price level at the NBP. We solve for the upstream spot price using (1) and our assumption that the supply of transmission capacity K is scarce:

$$p_u = \frac{K - Q}{\theta}. \tag{2}$$

The downstream price at the NBP, p_d, results from market clearing of net demand $D - \frac{\theta}{\gamma} p_d$ (total demand at NBP minus landing at terminals other than St. Fergus) with gas delivered from St. Fergus:

$$p_d = \frac{D - K}{\frac{\theta}{\gamma}}, \tag{3}$$

where $\frac{\theta}{\gamma}$ is the slop of downstream demand curve and satisfies $0 < \gamma \leq 1$, $\frac{\theta}{\gamma} \geq \theta$.

4.2 Period two

Transmission capacity is expanded such that the total auctioned capacity Y equals the announced fraction of total capacity, sK. The total auctioned capacity is the sum of bids at or above long term marginal cost of expansion c of all shippers $Y = \sum_{i \in \{l,n,t\}} n_i y_i$.[10]

$$K = \frac{Y}{s} = \frac{\sum_{i \in \{l,n,t\}} n_i y_i}{s}. \tag{4}$$

For example, if the sum of bids is 80 and 80 percent of capacity was auctioned long-term then total capacity must be expanded to $\frac{80}{0.8} = 100$ so that (1-s) is available for the short-term auction.

In the discussion we address the question whether the auctioneer or the regulator can adapt s to adjust for distortions due to market power. In the appendix we present a second design option: Instead of requiring Transco to offer a fixed proportion of total installed capacity in the short term market we assess the impact of requiring Transco to offer a fixed amount K_s of capacity in the short term market. The results are qualitatively similar but provide for less flexibility for the regulator to balance the goals of revelation of private information and mitigating market power based on public information.

4.3 Period one

In the auction all shippers choose the quantity of long term rights y_i in order to maximize expected profit.[11] The profit function for a national producer equals the number of rights obtained y_n in the long term auction times their value in the spot market. This value equals the price difference in the spot markets $p_d - p_u$ minus the price c to be paid for the rights. The national producer furthermore sells q_n in the upstream market and q_0 in the downstream market.

$$\pi_n = y_n (p_d - p_u - c) + (q_n + \alpha p_u) p_u + q_0 p_d. \tag{5}$$

---

[10] The currently proposed auction design sets a reserve price of 0.8 times long term marginal cost c. This creates an additional incentive to understate capacity requirements. If in 'reality' a small expansion would be required and therefore the market clearing price in the auction would be c, then bidders with market power will reduce their bidding volume to push the long-term auction price to $0.8c$ and retain profits of $0.2c$ when the real scarcity value realises in period three. However, the current analysis is restricted to a situation where capacity expansion occurs.

[11] When modelling markets with a homogeneous good like the access rights, the basic approaches are either Bertrand or Cournot models. In a Bertrand model firms are believed to set a price for the good they are selling and subsequently customers buy the cheapest good while a Cournot approach assumes that price evolves until supply matches demand. When there are transmission constraints shippers will jointly increase prices (through their quantity choices) until demand for transmission has reduced to the available capacity. The choice variable of companies is therefore the capacity y_i to provide for shipping.

The FOC with respect to y gives the optimal quantity to be obtained in the auction. Note that Y is the sum of all y_i. We keep Y at the right hand side to simplify the subsequent calculation.

$$y_n = \frac{\left(s - 2\frac{\alpha}{\theta}\right) Q + \gamma s D - s\theta c - \gamma q_0 + q_n}{1+\gamma} + \left(\frac{2\alpha}{s\theta\,(1+\gamma)} - 1\right) Y. \tag{6}$$

A local producer does not sell gas at the NBP, therefore we set $q_0 = 0$ and obtain from (6)

$$y_l = \frac{\left(s - 2\frac{\alpha}{\theta}\right) Q + \gamma s D - s\theta c + q_l}{1+\gamma} + \left(\frac{2\alpha}{s\theta\,(1+\gamma)} - 1\right) Y \tag{7}$$

Finally we assess trading companies that do not produce any gas. Setting $q_n = q_0 = \alpha = 0$ in (6) gives the quantity traders bid for in the auction:

$$y_t = \frac{sQ + \gamma s D - s\theta c}{1+\gamma} - Y. \tag{8}$$

4.4 Total capacity provided

We can now calculate total capacity requested in the auction. We use the definition of total auctioned capacity $Y = \sum_{i\in\{n,l,t\}} n_i y_i$ and substitute y_i's from equations (6), (7) and (8). Then we use $Q = n_n q_n + n_l q_l$ according to (1) and set $n_n + n_l + n_t = N$ to obtain

$$Y_{auction} = \frac{1}{1 + N - \frac{2}{s(1+\gamma)}} \frac{N\left(sQ + \gamma s D - s\theta c\right) - \gamma n_n q_0 - Q}{1+\gamma}. \tag{9}$$

The boundary conditions require that all shippers submit positive bids. A rough approximation of the values of s which satisfy this requirement can be obtained by calculating the s for which aggregate bidding volume (9) is positive, $s > \frac{2}{(1+N)(1+\gamma)}$. The exact calculation for national producers gives a slightly higher value of s. Either way the value is far below what is being considered and thus not restrictive for our purpose.

To allow for comparison we need to know the quantity of transmission capacity provided for by a social welfare planner. He provides for sufficient capacity such that the marginal value of additional transmission capacity $p_d - p_u$ equals unit expansion costs c. This gives

$$Y_{opt} = \frac{sQ + s\gamma D - sc\theta}{1+\gamma}. \tag{10}$$

Comparing $Y_{auction}$ and Y_{opt} we obtain

$$Y_{auction} - Y_{opt} = \frac{Y_{opt}\left(\frac{2}{s} - (1+\gamma)\right) - \gamma n_n q_0 - Q}{(1+N)(1+\gamma) - \frac{2}{s}}. \tag{11}$$

It follows that insufficient capacity is provided for ($Y_{auction} - Y_{opt} < 0$) if national gas producers' output at the national balancing point (or other unconstrained terminals) relative to total output at the constrained terminal (St. Fergus) is bigger than the following value:

$$\frac{n_n q_o}{Q} > \frac{1}{\gamma}\left[\frac{Y_{opt}}{Q}\left(\frac{2}{s} - (1+\gamma)\right) - 1\right] \tag{12}$$

If $\frac{Y_{opt}}{Q} \leq \frac{1}{\frac{2}{s}-(1+\gamma)}$ then we obtain insufficient investment ($Y_{auction} < Y_{opt}$) even for $q_0 = 0$, which implies that we do not even need national producers for underinvestment to occur. Local producers under-contract in the long term auction in order to reduce available capacity towards NBP and increase NBP prices and therefore the value of their remaining long-term access rights.

The number of traders n_t does not change the qualitative result. However, in equation (11) more traders reduces the difference between $Y_{auction} - Y_{opt}$ and thereby increase the match between the auction result and social planner's decision.

4.5 Entry cost for traders

An increase in the number of traders reduces the profit to be made by each trader in two ways. First, it reduces the difference between auctioned capacity and optimal capacity, thereby reducing the profits to be made on each unit of capacity. Second, it reduces the market share of each trader. For a given number of traders we can calculate the profit each trader obtains: from (5) set $q_0 = q_n = 0$; substitute y_t from (8); substitute p_d and p_u from (3) and (2); substitute K from (4), and set $Y = Y_{auction}$ from (9):

$$\pi_t(n_t) = \frac{s}{\theta(1+\gamma)}\left(\frac{\left(1-\frac{2}{s(1+\gamma)}\right)(sQ + \gamma sD - s\theta c) + \gamma n_n \frac{q_0}{s} + \frac{Q}{s}}{1 + N - \frac{2}{s(1+\gamma)}}\right)^2 \tag{13}$$

The equilibrium number of traders n_t is achieved if all traders make positive profit while any additional trader would not be able to cover fixed entry costs c_i:

$$\pi_t(n_t+1) < c_i \leq \pi_t(n_t). \tag{14}$$

From equation (13) it follows for n_t that $\pi_t(n_t)$ grow with $\left(\frac{1}{1+n_n+n_l+n_t}\right)^2$ and using (14) gives for the equilibrium number of traders $1 + n_n + n_l + n_t$ which is proportional to $\sqrt{\frac{1}{c_i}}$. The total number of market participants increases only with the root of the reduction in costs. Looking at equation (11) this shows that for a reduction of factor two of the mismatch between auctioned capacity and optimal capacity to be auctioned, c_i has to be reduced by the factor of four. As c_i does never approach 0, unless traders are subsidized, traders will not provide for perfect arbitrage.

5 Discussion

In the previous section we developed a model to illustrate the effect of strategic behavior of bidders if the auction results are used to decide on transmission capacity expansion. The only parameter to be chosen by the regulator or transmission operator was the fraction s of capacity rights to be allocated in the long-term auction. In the next three sections we will assume that the transmission operator uses all publicly available information to choose the optimal s in step zero in order to achieve the best match between transmission capacity provided and transmission capacity required.

We show that a unique unbiased s that is plausible for the industry does not exist because of the competing objectives of the auction: A different s must be chosen to satisfy each of three desirable criteria. In section 5.1 we show that with full information s_{full} will provide for the correct amount of investment. That is, setting $s = s_{full}$ removes the distortion in the auction outcome resulting from market power. However, shippers may also have private information about their upstream production decisions. In this case, as shown in section 5.2, s_{pri} which in general differs from s_{full} should be chosen to reveal private information. Section 5.3 shows that a third value, s_{net}, should be chosen if the goal is to minimize network interactions due to private information of national producers about their production in other parts of the country.

In section 5.4 we show that all three objectives cannot be simultaneously achieved and discuss the merits of an approach to change s during the procedure. This would allow the auctioneer to achieve two out of the three previous goals, but changing s will destroy the reputation of the auctioneer and therefore interfere with future auctions. Finally, in section 5.5 we analyze whether deviations of Cournot equilibrium are feasible.

5.1 Avoiding biased capacity provision, full information $\mathbf{s_{full}}$

Equation (11) suggests that we can choose s in order to match $Y_{auction}$ and Y_{opt}. This would involve setting

$$s_{full} = \frac{1}{1+\gamma}\left(2 - \frac{Q + \gamma n_n q_0}{K_{opt}}\right). \tag{15}$$

In order to make comparisons between our three values for s we first find numerical approximations under plausible assumptions. We then make analytical comparisons under the assumption that, in the long run equilibrium $K_{opt} \sim Q$ (i.e., the optimal amount of capacity between St. Fergus and the NBP is equal to upstream production). For numerical approximations we assume that the output of national producers at the NBP equals total production at St. Fergus $n_n q_0 = Q$, and the price elasticity at St. Fergus is one-third of the price elasticity at the NBP (i.e., $\gamma = 1/3$). We thus obtain $s_{full} \sim \frac{1}{2}$. Only if half the fraction of total capacity is offered in the long-term auction then the distortions of individual bidders cancel each other and in the presence of full information the appropriate amount of capacity is provided by the long-term auction.

5.2 Revelation of private information, $\mathbf{s_{pri}}$

In the previous section we analyzed the effect of s on the future investment assuming that all information was publicly shared. Now we incorporate the effect that producers have additionally with their private information. The purpose of the auction is to reveal such information in order to provide for the optimal amount of capacity. However, producers only focus on their individual profit. The calculation shows that the result is that they usually do not perfectly reveal their private information. Rewriting (6) to ensure that y_n only appears on the left hand side we obtain:

$$y_n = \frac{\left(s - \frac{2}{n_l+n_n}\right)Q + \gamma s D - s\theta c - \gamma q_0 + q_n}{2\left(1+\gamma\right) - \frac{2}{s(n_l+n_n)}} + \frac{\frac{2}{s(n_l+n_n)} - \left(1+\gamma\right)}{2\left(1+\gamma\right) - \frac{2}{s(n_l+n_n)}}\left(Y - y_n\right) \tag{16}$$

Please note, that Y is the sum over all y_i and therefore $Y - y_n$ does not contain the y_n we are calculating.

We want to know by how much a national producer changes her bid in the long term auction, if her private signal changes while all other players retain their signal. Differentiating (16) with respect to q_n we obtain

$$\frac{\partial y_n}{\partial q_n} = \frac{s - \frac{2}{n_l+n_n} + 1}{2\left(1+\gamma\right) - \frac{2}{s(n_l+n_n)}} \tag{17}$$

The auctioneer anticipates how shippers change their bids based on their private information q_n and intends to choose the optimal s_{pri} such that the provided capacity matches the additional/reduced requirements. Using the investment condition in equation (4) we calculate the expected effect of private information on the final allocation:

$$\frac{\partial K}{\partial q_n} = \frac{1}{s}\frac{\partial y_n}{\partial q_n} = \frac{s - \frac{2}{n_l+n_n} + 1}{2s\left(1+\gamma\right) - \frac{2}{n_l+n_n}} \tag{18}$$

In the optimal scenario the system operator wants to ensure that shippers bidding according to their private information results in the same capacity expansion as would have been suggested by the optimal planning condition (10). $\frac{\partial K}{\partial q_n} = \frac{1}{1+\gamma}$ and choose

$$s_{pri} = 1 - \frac{2\gamma}{\left(n_n + n_l\right)\left(1+\gamma\right)}$$

If we assume that two national and two local producers dominate production at St. Fergus then we obtain the optimal $s_{pri} = 0.875$ as illustrated in Figure (5).

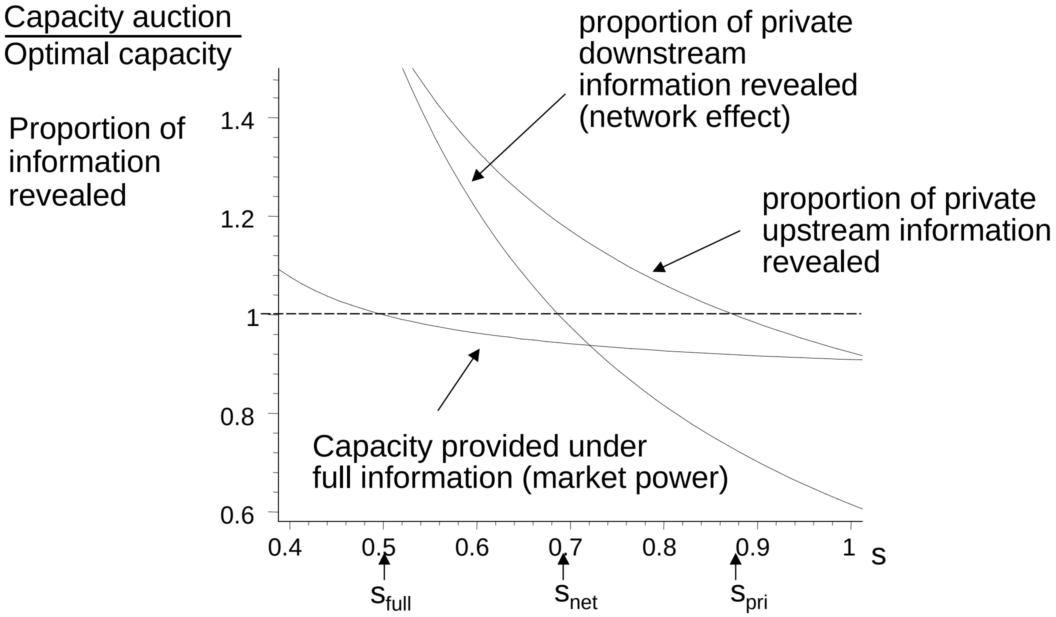

Figure 5: The proportion of rights allocated long-term s is optimal dependent on whether expected bias is to be eliminated s_{full}, truthful revelation of additional information is to be achieved s_{pri} or interference due to the network is to be minimised s_{net}.

5.3 Minimizing distortions through network effects, $\mathbf{s_{net}}$

The auction result is furthermore distorted by changes in expected output of national producers q_0 at terminals other than the terminal we are concerned about. According to (16) we obtain

$$\frac{\partial K}{\partial q_0} = \frac{1}{s}\frac{\partial y_n}{\partial q_0} = \frac{-\gamma}{2s\left(1+\gamma\right) - \frac{2}{\left(n_n+n_l\right)}} \tag{19}$$

Once again we require that the capacity change in the auction equals the capacity change implemented by a informed regulator, and obtain according to (10):

$$\frac{\partial K}{\partial q_0} \equiv \frac{\partial K_{opt}}{\partial q_0} = -\frac{\partial K_{opt}}{\partial D} = -\frac{\gamma}{1+\gamma} \tag{20}$$

Combining (19) and (20) we obtain an the equation for the optimal s_{net}:

$$s_{net} = \frac{1}{2} + \frac{1}{\left(1+\gamma\right)\left(n_n+n_l\right)} \tag{21}$$

Using the previous parameter values gives $s_{net} = 0.69$. The higher the output of national producers is upstream, the higher can s be. If $s < s_{net}$ then national producers' private information about changes of their future downstream output results in excessive capacity expansion, and $s > s_{net}$ implies too little revelation of private information (i.e., too little capacity relative to the social planner's decision).

5.4 Can all objectives be achieved using one s?

In this section we first ask if a unique s exists to meet our three objectives simultaneously; then we discuss why s cannot be strategically changed by the auctioneer in step in step 2 of the auction procedure.

A value for s which removes distortions from market power and privately held upstream and downstream information would have to satisfy $s_{full} = s_{pri} = s_{net}$. We now show that not even any two pairs of the equality are generally satisfied (the entire equality is never satisfied). Maintaining the assumption that in a long run equilibrium, $K_{opt} = Q$ (i.e., the amount of capacity that a social planner would choose equals total upstream production) the solutions to equations (22) and (23) depends on the magnitude of downstream production, $n_n q_0$, relative to upstream production, Q. Letting $n_n q_0 = xQ$, then $s_{full} = s_{pri}$ gives:

$$\frac{1}{1+\gamma}\left(2 - \frac{Q+\gamma x Q}{Q}\right) = 1 - \frac{2\gamma}{N\left(1+\gamma\right)} \tag{22}$$

This has one solution at $\gamma = -\frac{N}{N-2}$ which is infeasible for $N > 1$. Second, if $s_{full} = s_{net}$ then:

$$\frac{1}{1+\gamma}\left(2 - \frac{Q+\gamma x Q}{Q}\right) = \frac{1}{2} + \frac{1}{(1+\gamma)\,N} \tag{23}$$

which is solved when $\gamma = \frac{N-2}{N(2x+1)}$. In the UK total supply at non-St. Fergus terminals is approximately 1.8 times the supply from St. Fergus,[12] thus $s_{full} = s_{net}$ when $\gamma \backsim \frac{N-2}{3.6(N+1)}$. Finally, $s_{pri} = s_{net}$ when:

$$1 - \frac{2\gamma}{N\,(1+\gamma)} = \frac{1}{2} + \frac{1}{(1+\gamma)\,N} \tag{24}$$

This occurs when $\gamma = -\frac{N-2}{N-4}$ and is only feasible for $N = 3$.

Instead of choosing one optimal s to satisfy all criteria it would be tempting for the auctioneer to change the s throughout the process. That is, he might initially sell a fraction $s_1 = s_{pri}$ of total access rights to ensure full revelation of private information and correct the market power distortions in step two by applying an s_2 that differs from the s_1. Alternatively high $s_1 = s_{net}$ could be initially chosen to fully capture private information from national producers about changes in output downstream and systematic bias from market power corrected for at step 2.

However, the change of s_1 towards s_2 in step two would not be welcomed by the market, and would not be feasible in any repeated game as shown by experience from inflation targeting of central banks. Central Banks like to increase the amount of money circulating in the economy in order to stimulate the economy: More money allows agents to buy more services, which results in more production etc. But if agents anticipate additional money to be circulated in the economy then they will increase prices and wages. In equilibrium the additional money issued by the Central Bank is matched by higher prices such that the amount of services and products bought stays constant. The only result of the economic ambitions of the Central Bank is inflation. Therefore most Central Banks that are headed by conservative bankers are believed to have little interest in stimulating the economy but significant interest in maintaining low inflation. Such Central Bankers will only increase the volume of money issued as a result of events that are unanticipated by all players. If a Central Banker will increase the money volume more than previously announced in order to stimulate the economy he and the bank loses the credibility as a conservative banker. In the future markets will anticipate similar behavior and future inflation will be higher.

---

[12] National Grid Company, *Seven Year Statement*

This experience corresponds to the auctioneer's decision process. Transco announces the factor s_1 to inform shippers about the link between auction results and capacity expansion. Shippers bid in the auction based on their beliefs about subsequently capacity investments. The auctioneer can deviate once from the announced s_1 but in all subsequent years shippers will anticipate such behavior and include it in the bidding strategy.

5.5 Danger of foreclosure

Can shippers reserve excessive capacity in the long-term market such that competitors cannot obtain sufficient capacity in the spot market? Faced with a shortage of transmission capacity in the spot market competitors would lack growth potential or even have to default on existing contracts. If such a scenario were realistic it would imply that all shippers amply contract in the long-term auction to ensure sufficient capacity will be available for their own needs or to foreclose competitors. We believe that such a scenario is unlikely for the following three reasons.

First, withholding transmission capacity is difficult. For a producer such as a generator withholding output is feasible because competition authorities have problems attributing such behavior to intentional market manipulation.[13] However, for the owner of a transmission network withholding output (i.e., capacity rights) is more difficult since this behavior can be observed and verified by the competition authorities.

Second, we mentioned at the beginning that we assume that the transmission operator will make a significant fraction $(1-s)$ of transmission capacity available in the short-term time frame of a year or less - the main motivation being the support of potential entrants, but furthermore as a means of preventing foreclosure. This additional capacity makes foreclosure in the long-term market counter-productive since over contracting signals the need for more investment which makes more (not less) capacity available in short term markets.

A third argument is related to our previous model. We analyzed shippers' strategies with a Cournot model to ensure that small unilateral deviations are not profitable. But would a large deviation by shipper, requesting a large quantity in the forward market, be profitable? This shipper could then try to foreclose competitors in the spot market.

---

[13] Experience in the California electricity market indicates that it is hard to differentiate between electricity generators withholding capacity and planned outages for revision or breakdowns (Joskow and Kahn 2001).

Such a deviation seems unlikely. We mentioned above the difficulties of foreclosure in an easily controllable market; in addition to this competitors would observe the behavior of the deviating shipper for example by analyzing the aggregate capacity bids in the long-term auction. If competitors were worried about being a victim of such a foreclosure in the future they would reveal their information to the auctioneer, the regulator or the competition authority. Based on this information the auctioneer could re-evaluate and re-decide on the investment and allocation strategy.

6 Conclusion

Short-term auctions for access to terminals of the British gas-network have been used since September 1999 and appear to successfully allocate scarce resources and capture scarcity rent. Now long-term auctions are being introduced to guide future capacity expansion decisions.

It is important for competition that some access rights be made available in spot markets. In our model the fraction of total rights issued in the long-term auction turns out to be a crucial design parameter. Even a 'hypothetically' optimal parameter choice can in general only satisfy one of three competing aims: unbiased provision of capacity, full revelation of private information, and minimization of distortions from network effects. Gas industries are characterized by asymmetric agents who produce and sell at different points on the network. In this setting, private information about production can give incentives for over or under investment depending on the proportion of capacity reserved for spot markets.

One alternative to long-term auctions is a regulatory approved decision about capacity expansion by the transmission owner. This decision would be based on the same publicly available information as the decision about the optimal s, but would not be influenced by privately held information and would consequently be less prone to error caused by information about production at other entry terminals. Producers would be more willing to reveal private information about expected output growth because additional capacity would increase the value of their output and they would not face the 'artificial' incentive to push up the value of their long-term entry rights by withholding information. However, shippers might overstate capacity requirements to reduce risk of congestion, in order to increase the expected value of their gas.

Our simple model does not allow for a comprehensive analysis of the trade-off between regulatory approved capacity expansion and expansion based on auction results. However, it suggests that investment bias and withholding of private information can be significant drawbacks of long-term auctions.

References

Abdala, M. A. and A. Chambouleyron (1999). Transmission investment in competitve power systems. Privatesector - Worldbank.

Anderson, K. P. and A. McCarthy (1999). Transmission prcing and expansion methodology: lessons from argentina. *Utilities Policy 8*, 199–211.

Armstrong, M., S. Cowan, and J. Vickers (1994). *Regulatory Reform, Economic Analysis and British Experience.* Cambridge Massachusetts.

Bushnell, J. B. and S. Stoft (1996). Electric grid investment under a contract regime. *Journal of Regulatory Economics 10*, 61–79.

Dasgupta, P. and E. S. Maskin (2000). Efficient auctions. *Quarterly Journal of Economics*, 341–88.

DTI (2001). Gas: A consultation on concerns about gas prices and possible improvements to market efficiency.

Jehiel, P. and B. Moldovanu (2001). Efficient design with interdependent valuations. *Econometrica 69(5)*, 1237–59.

Joskow, P. and E. Kahn (2001). A quantitative analysis of pricing behavior in california's wholesale electricity market during summer 2000. *Working paper*.

Leautier, T.-O. (2000). Regulation of an electricity power transmission company. *The Energy Journal Vol. 23, No. 4*, 61–91.

McCabe, K., S. Rassenti, and V. Smith (1989). Designing smart computer assisted markets. *European Journal of Political Economy 5.*

McDaniel, T. and K. Neuhoff (2002). Auctions to gas transmission access: The british experience. *Working Paper*.

Newbery, D. M. (1998). Competition, contracts, and entry in the electricity spot market. *RAND Journal of Economics 29 (4)*, 726–749.

Ofgem (2001a). Long term signals and incentives for investment intransmission capacity on transco's national transmission system. *March.*

Ofgem (2001b). Ngc system operator incentive scheme from april 2002 initial proposals. *December.*

Ofgem (2002). Transco price control and nts so incentives 2002-2007: Explanatory notes to acompany the section 23 notice of proposed modifications to transco's transporter licence. *April.*

Phillips, G. M. and R. J. Weiner (1994). Information and normal backwardation as determinants of trading performance: Evidence from north sea oil forward market. *The Economic Journal 104*, 76–95.

Rivier, M. and I. J. Perez-Arriaga (1991). Cost allocation of transmission services. *Power Industry Computer Applications Conference Baltimore.*

A Short term capacity independent of investment

The previous analysis assumed a constant fraction $1-s$ of total installed capacity is made available in the short term market. Alternatively a fixed amount of pre-auction, existing capacity K_S which is independent of the total post-auction installed capacity could be made available in the short term market. The expansion rules for transmission capacity (4) change to:

$$K = K_S + \sum_{i \in \{l,n,t\}} n_i y_i. \tag{25}$$

This changes prices in the profit function for national producers (5) and the subsequent FOC (6) for the determine the bid volume:

$$y_n = \frac{\left(1 - \frac{2\alpha}{\theta}\right) Q + \gamma D - \theta c - \gamma q_0 + q_n}{\gamma + 1} + \left(\frac{2\alpha}{\theta\left(\gamma+1\right)} - 1\right)\left(K_S + Y\right). \tag{26}$$

The bid function for local producers, previously (7), now follows from setting $q_0 = 0$ in (26) and the previous bid function for traders (8) is replaced by (26) with $\alpha = 0$ and $q_n = 0$. Aggregating these individual bid functions total capacity requested in the auction is

$$Y_{auct} = \frac{1}{1 + N - \frac{2}{1+\gamma}} \frac{N\left(Q + \gamma D - \theta c\right) - \gamma n_n q_0 - Q + \left(\gamma+1\right) K_S}{1+\gamma} - K_S, \tag{27}$$

while the socially optimal bid volume, previously (10), now becomes:

$$Y_{opt} = \frac{Q + \gamma D - c\theta}{1+\gamma} - K_S. \tag{28}$$

Comparing (27) and (28) it follows that insufficient investment is provided iff:

$$\frac{n_n q_o}{Q} > \frac{1}{\gamma}\left[\frac{Y_{opt}}{Q}(1-\gamma) + 2\frac{K_S}{Q} - 1\right]. \tag{29}$$

If $\frac{Y_{opt}}{Q} < \frac{1-2\frac{K_S}{Q}}{1-\gamma}$ then investment is insufficient ($Y_{auction} < Y_{opt}$) even for $q_0 = 0$.

Moving on to the policy implications we can calculate the optimal K_S, instead of previously s_{full}, to avoid biased capacity provision due to market power for the case of complete and symmetric information:

$$K_S = \frac{2\gamma Q - (1-\gamma)\gamma D + (1-\gamma)c\theta}{(1+\gamma)^2} \tag{30}$$

To calculate the effect of private information about future up- and downstream production quantities we rearrange (26) to ensure y_n only appears on the left hand side.

Differentiating this re-arranged equation with respect to q_n gives the change of national producers' bid as a function of their private information on upstream production quantities

$$\frac{\partial K}{\partial q_n} = \frac{\partial y_n}{\partial q_n} = \frac{1 - \frac{1}{n_n+n_l}}{1 - \frac{1}{n_n+n_l} + \gamma} \tag{31}$$

To evaluate (31) we compare it to how much optimal capacity (30) changes when the amount of upstream production q_n changes: $\frac{\partial K_{opt}}{\partial q_n} = \frac{1}{1+\gamma}$. The auction (31) with a finite number of shippers $n_n + n_l \leq N < \infty$ only provides for complete revelation of private information on upstream production if downstream price is independent of imports ($\gamma \rightarrow 0$).

The effect of private information of future downstream production quantities q_0 of national producers on their bid follows from differentiating the re-arranged (26) with respect to :

$$\frac{\partial K}{\partial q_0} = \frac{\partial y_n}{\partial q_0} = -\frac{1}{2}\frac{\gamma}{1+\gamma-\frac{1}{n_l+n_n}} \tag{32}$$

Comparing the result to the capacity change implemented by a well informed regulator (20) $\frac{\partial K}{\partial q_0} = -\frac{\gamma}{1+\gamma}$ shows that both results will only coincide if $\gamma = \frac{2}{n_n+n_l} - 1$. The market with a finite number of shippers only provides the appropriate capacity if either downstream price slope equals upstream price slope and only one strategic producer exists that is national or if two strategic producers exist and downstream price is price independent (γ=0).

Choosing the 'right' quantity of transmission capacity K_s to be allocated short term can remove biased bids based on public information. However, any private information is only revealed incompletely. Deciding on the absolute amount K_s rather than on the fraction of total installed capacity $1 - s$ to be allocated short term eliminates the option for regulators to chose between unbiased provision of public information and revelation of different types of private information. Apart from this difference neither design can simultaneously provide for unbiased use of public information in the presence of market power and unbiased revelation of private information on up- and downstream production quantities.