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Corporate Self-Regulation vs. Ex-Ante Regulation of Network Access - A Model of the German Gas Sector

by

Georg Meran and Christian von Hirschhausen*

This paper compares the outcomes of corporate self-regulation and traditional ex-ante regulation of network access to monopolistic bottlenecks. In the model of self-regulation, the domestic gas supplier and network owner and the monopsonistic gas customer fix quantities and the network access price, whereas the competitive fringe of foreign gas producers (third party) and the household customers are excluded from the agreement. The results are then compared with the outcome of traditional ex-ante regulation. We find that while industrial self-regulation leads to an exploitation of households, the effect on the foreign producers is unclear. (JEL: L51, L13, D43, L95).

1 Introduction

The issue of "optimal" regulation of network industries is a recurring one in the literature on institutions and regulation, but it has attracted renewed attention in the course of the debate on the pros and cons of industrial "self-regulation". There is a growing body of literature on the effects of new institutional forms of regulation, that calls into question the benefits of ex-ante regulation (for a discussion see Starkie, 2000, Engel, 2002, Brunekreeft, 2002). This literature compares various forms of *external* regulation by an independent, but generally badly-informed regulator to *internal* regulation by industry itself, or "self-regulation". However, empirical findings on this topic are scarce, thus the regulatory process is assumed to be less efficient based only on stylized facts. New evidence comes from the process of European energy market liberalization, where traditional "UK-style" structural and ex-ante regulation has been complemented by self-regulation through *association agreements*, as used in the German electricity and gas industries. These agreements are cartel-type, private contracts negotiated between the main domestic players in the industry, accompanied by weak ex-post control exercised by

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an anti-monopoly agency (e.g. the German Cartel Office). Until recently, the "German way" was judged by its own proponents, the German energy industry and large parts of the political establishment, as a liberalization success story, whereas outsiders tended to view the self-regulated regime with suspicion. To date there has been no adequate theoretical discussion of the issue. [1]

In this paper, we compare the outcomes of different institutional settings regulating network access to monopolistic bottlenecks. These settings range from self-regulated association agreements with no competition policy, to ex-ante regulation combined with a pro-competition policy. We develop a model of regulatory policies in the German gas industry, where self-regulation was implemented five years ago, and where empirical evidence of its effects is beginning to emerge. In contrast to other network industries such as electricity, railways, and telecommunications, the different regulatory regimes in the gas industry have yet to be analyzed thoroughly. Our hypothesis is that although ex-ante regulation of network access tariffs is superior in terms of social welfare, it does not necessarily improve the situation of all of the parties concerned. Thus, different sets of policies may benefit different interest groups (i.e. incumbent producers, potential market entrants, industrial consumers, household consumers).

Self-regulation has been discussed in the literature with regard as an alternative to external, ex-ante regulation, in particular if it is associated with a credible "regulatory threat".[2] This is a situation where the government threatens to implement a formal regulatory procedure if the results of self-regulation proved unsatisfactory, i.e. access prices beyond a critical level. Thus, Starkie (2000) argues that the (privately owned) British Airport Authority's imposition of a voluntary price cap on two of its airports (Glasgow and Edinburgh) was a self-restraint induced by the threat of severe ex-ante regulation. The German electricity and gas sectors can also be examined fruitfully in this context: Brunekreeft (2002) was the first to analyze the association agreements in the German *electricity* sector, showing that the absolute and relative levels of access charges can be explained by the changing regulatory threats of the German Federal Cartel Office (FCO, *Bundeskartellamt*). Engel (2002) argues that self-regulation may have the advantages of lower transaction costs and better use of technical knowledge; but there is no evidence that this solution is always superior.

In this paper, we apply an IO-approach to comparing different regulatory regimes in the gas industry, taking the German situation as background. The next section presents stylized facts and summarizes the recent policy debate. Section three sketches the players and the setting of the model, and derives the solutions for two extreme market forms: *bilateral monopoly* between the vertically integrated gas producer and the monopsonistic industrial gas consumer, and a *pure competitive market.* Subsequently, we analyze the effects of the self-regulation association agreement in force until recently in the gas industry. Section

[1] Within the European Union, Germany is the only country to have opted for unregulated negotiated third party access (NTPA) to the network, whereas most other countries have chosen regulated TPA with a strong role for regulatory agencies.

[2] "Regulatory threat can be defined as the change of the probability of an intervention upon an agent's behavior by some outside authority as a response to the agent's prior behavior." (Brunekreeft, 2002, 2).

four compares the results from different mixtures of regulation and competition policy. Section five concludes.

2 Institutional Setting

Since the EU Directives 96/92 and 98/30 on electricity and gas liberalization,energy sector reform has been high on the policy agenda throughout the European Union. However, results achieved thus far have been modest, due to numerous problems of implementation, in particular in the gas industry.[3] Vertical unbundling and the introduction of competition in gas production have made only sluggish progress. The slow progress of reform is criticized frequently by the European Commission (2003) in its yearly benchmarking reports. The German solution of self-regulation has been a central focus of the benchmarking reports, and the absence of ex-ante regulation has been interpreted as an explanation for the high gas price level in the country.
The institutional framework of self-regulation in the gas industry thus far is follows: *vertical integration* between gas transmission and the dominant wholesale trader, and no regulation of network access or expansion. Instead, network access is self-regulated between the incumbent monopolist, representatives of industry and large industrial users. The association agreement (so-called *Verbändevereinbarung'* on network access and other key issues was negotiated by the Association of Germany Industry (BDI), the Association of Industrial Energy and Power Users (VIK), the Association of the German Gas and Water Industry (BGW), and the Association of Communal Utilities (VKU). Foreign producers, traders, and non-industrial customers were thus far deliberately excluded from the negotiations. The German Cartel Office exercised only passive ex-post control to prevent the abuse of a dominant position.
Whereas opinions are divided on whether the assocation agreements have worked in electricity, there is a negative assesssment of the agreements in the gas industry, shared by large consumers (VIK), the household consumers, and the Federal Government. Prices have remained high, third party access has been negligible, and competition has emerged for only a few large customers (European Commission, 2003).
The topic has significantly picked up speed with the implementation of the new EU Gas Directive (2003/55/EC, the so-called "Acceleration Directive"), which will oblige Germany to abandon its own *Sonderweg* of self-regulation. The Directive provides that each Member State will have to designate one or more competent bodies to act as regulatory energy authority. Under increasing pressure from European policy and mounting criticism from policy advisors and the research community in Germany, the German government agreed to subordinate the gas industry to the inter-sectoral regulatory agency of network industries in Germany (RegTP) in 2004. Whatever this new regulatory agency will do, the debate over pros and cons of self-regulation will continue, and discussions about a new association agreement to prevent the implementation of the regulatory authority may also

[3]See Newbery (2003) for a survey of electricity sector reform, and Brunekreeft (2002) for an account of the regulatory process and self-regulation in the German electricity sector. Cremer, et al., (2003) define the welfare-optimal access prices to a gas network.

be revived It is therefore crucial to understand the possible implications of the move from self-regulation to ex-ante regulation, to which we now turn.

3 The model

3.1 Players and setting

We begin by defining the players and their behaviour in the gas market. The gas market consists of two groups of suppliers, the cartelized German gas industry (indexed "BGW", the Association of the German Gas and Water Industry), and small foreign gas suppliers we refer to as the third party (indexed "TP"). The demand side is dominated by large industry users, who are represented by the Association of Industrial Energy and Power Users (VIK). Domestic households and small industries generate the residual market demand (indexed "HH").

Let us first describe the behaviour of the competitive fringe, consisting of the third party and domestic households.

Profits of the third party (TP) are[4]

$$\pi_{TP} = (p - a)q_{TP} - C_{TP}(q_{TP}) \tag{1}$$

where $C_{TP}(q_{TP})$ is a convex cost function, p is the gas market price and a the access fee set by the association agreement. Profits π_{TP} are maximized by choosing q_{TP} so as to meet the first order condition:

$$(p - a) = C'_{TP}(q_{TP}) \Rightarrow \hat{q}_{TP}(p - a),\, \hat{q}'_{TP}(p - a) > 0 \tag{2}$$

$\hat{q}_{TP}(p-a)$ is the profit-maximizing supply of the third party and, hence, its monotonically increasing supply function.

A household's demand can be derived in similar fashion.[5]. The households maximize net utility[6]

$$U(q_{HH}) - pq_{HH} \tag{3}$$

which yields the first order condition

$$U'(q_{HH}) - p = 0 \Rightarrow \hat{q}_{HH}(p),\, \hat{q}'_{HH}(p) < 0 \tag{4}$$

where $\hat{q}_{HH}(p)$ is the monotonically decreasing demand function.

To keep the model tractable, we assume the following:

assumption 1 *The household's aggregated demand function $\hat{q}_{HH}(p)$ and the third party's supply function $\hat{q}_{TP}(p-a)$ are linear, i.e. the second derivatives of both functions are zero.*

[4]Without loss of generality we assume that the third party consists of one supplier. The main feature of competitiveness consists in that TP takes the market price as exogenously given.

[5]As for the small supplier, we assume that only one household demands gas.

[6]Without loss of generality we assume that gas is an income-neutral good.

3.2 Bilateral monopoly

In addition to the third party and households, the gas market participants consist of the monopolistic gas supplier offering q_{BGW} (Association of the German Gas and Water Industry) and the monopsonistic demanding q_{VIK} (Association of Industry Energy and Power Users). Notice that in this scenario the domestic gas producer "BGW" also owns the network. The market equilibrium is characterized by the following equation:[7]

$$q_{VIK} + \hat{q}_{HH}(p) = \hat{q}_{TP}(p-a) + q_{BGW} \tag{5}$$

Notice that the equilibrium is achieved by the gas price p. Hence, p is a function of q_{VIK}, q_{BGW} and a. To be more precise

$$p = p(\Delta, a),\ \Delta \equiv q_{VIK} - q_{BGW} \tag{6}$$

where Δ is the net demand of the association (VIK and BGW) in the gas market. This demand must be met by the net supply $\hat{q}_{TP}(p-a) - \hat{q}_{HH}(p)$ which is supplied by the competitive fringe (see (5)).
Comparative static analysis leads to

$$p_{\Delta} = \frac{-1}{\hat{q}'_{HH}(p) - \hat{q}'_{TP}(p-a)} > 0 \tag{7}$$

$$p_a = \frac{-\hat{q}'_{TP}(p-a)}{\hat{q}'_{HH}(p) - \hat{q}'_{TP}(p-a)} = \hat{q}'_{TP}(p-a)p^G_{\Delta} > 0 \tag{8}$$

(7) and (8) show how the equilibrium price depends on the gas quantities demanded by the members of the association agreement (net demand) and on the access fee. The signs conform with the intuition. Rising net demand increases the gas price and higher access fees lead to same result as well.
Both big players, the monopsony (VIK) and the monopoly (BGW) set their quantities in a non-cooperative manner. In fact, they are playing a Nash-Cournot game exploiting the competitive fringe, which is defined by its non-strategic supply and demand functions.
The Nash-Cournot-game can be defined as follows:

$$\max_{q_{BGW}}[p(\Delta, a)q_{BGW} + a\hat{q}_{TP} - C_{BGW}(q_{BGW}) - C_N(q_{BGW} + \hat{q}_{TP})] \tag{9}$$

$$\max_{q_{VIK}}[\pi_{VIK}(q_{VIK}) - p(\Delta, a)q_{VIK}] \tag{10}$$

where C_{BGW} is the convex cost function of BGW's gas production and where C_N are capacity costs of the transportation network. $\pi_{VIK}(q_{VIK})$ is the concave profit function of the industrial energy users VIK. Notice, that $\hat{q}_{TP}$ depends on p as defined in (6). Hence, (9) and (10) depend only on q_{BGW} and q_{VIK}. In the following we apply the:

assumption 2 *The capacity costs of gas transportation are, in the long run, linear, i.e.* $C''_N = 0$. *The third party's marginal costs of gas production are lower than the marginal production costs of BGW, i.e.* $\forall q : C'_{TP}(q) < C'_{BGW}(q)$.

[7] If one neglects leakage within the gas distribution system the market equilibrium condition is equivalent to the mass balance identity.

From the first order conditions we can derive the N-C-equilibrium $\{q^{bi}_{BGW}, q^{bi}_{VIK}\}$ (where q^{bi} stands for bilateral monopoly):

$$\begin{aligned} p^{bi} - q_{BGW} p^{bi}_{\Delta} - a p^{bi}_{\Delta} \hat{q}'_{TP} - C'_{BGW} - C'_N [1 - \hat{q}'_{TP} p^{bi}_{\Delta}] &= 0 \quad (11) \\ \pi'_{VIK} - p^{bi} - q_{VIK} p^{bi}_{\Delta} &= 0 \quad (12) \end{aligned}$$

where $p^{bi} = p(\Delta^{bi}, a), \Delta^{bi} = q^{bi}_{VIK} - q^{bi}_{BGW}$.
To summarize, together with equations (2), (4), and (5), the first order conditions (11) and (12) form the gas market equilibrium if the two big players act strategically. This equilibrium is depicted in Figure 1 with the help of reaction curves[8] derived from the two first order conditions. From (11) we can derive the optimal response of q_{BGW} for a given q_{VIK}, which is denoted by $q_{BGW}(q_{VIK})$. Similar, VIK's reaction curve $q_{VIK}(q_{BGW})$ can be derived from (12). Finally, the associations net demand $\Delta^{bi} = q^{bi}_{VIK} - q^{bi}_{BGW}$ can be measured along the vertical axis by a 45°-line through the equilibrium point BI which makes it possible to read off the price $p(\Delta, a)$ in the left half of the figure.

3.3 A purely competitive market

It is instructive to compare the allocation of the cartelized market with a purely competitive market where all participants take the price as given. This case is relevant if competition policy (ex-post regulation) is effective and can successfully assure an ideal market. In this case, the gas provided by the gas supply association BGW must be derived from the maximization program

$$p q_{BGW} + a q_{TP} - C_{BGW}(q_{BGW}) - C_N(q_{BGW} + q_{TP}) \quad (13)$$

Notice, that BGW takes the supply of the third party as given. The respective first order condition yields

$$p - C'_{BGW} - C'_N = 0 \Rightarrow \hat{q}_{BGW}(p),\ \hat{q}'_{BGW}(p) > 0 \quad (14)$$

Similarly, the demand of VIK can be derived from maximizing its total profits

$$\pi_{VIK}(q_{VIK}) - p q_{VIK} \quad (15)$$

for a given gas price p. The demand can be derived from the first-order condition

$$\pi'_{VIK}(q_{VIK}) - p = 0 \Rightarrow \hat{q}_{VIK}(p),\ \hat{q}'_{VIK}(p) < 0 \quad (16)$$

proposition 1 (More competition does not imply a lower gas price) *Assume that $a \geq C'_N$, i.e. total access fees cover at least the network costs. Then the transition from a cartelized market to a fully competitive market may lead to a higher or lower market price. Total supply may rise or fall. Of course, welfare will increase with more competition.*

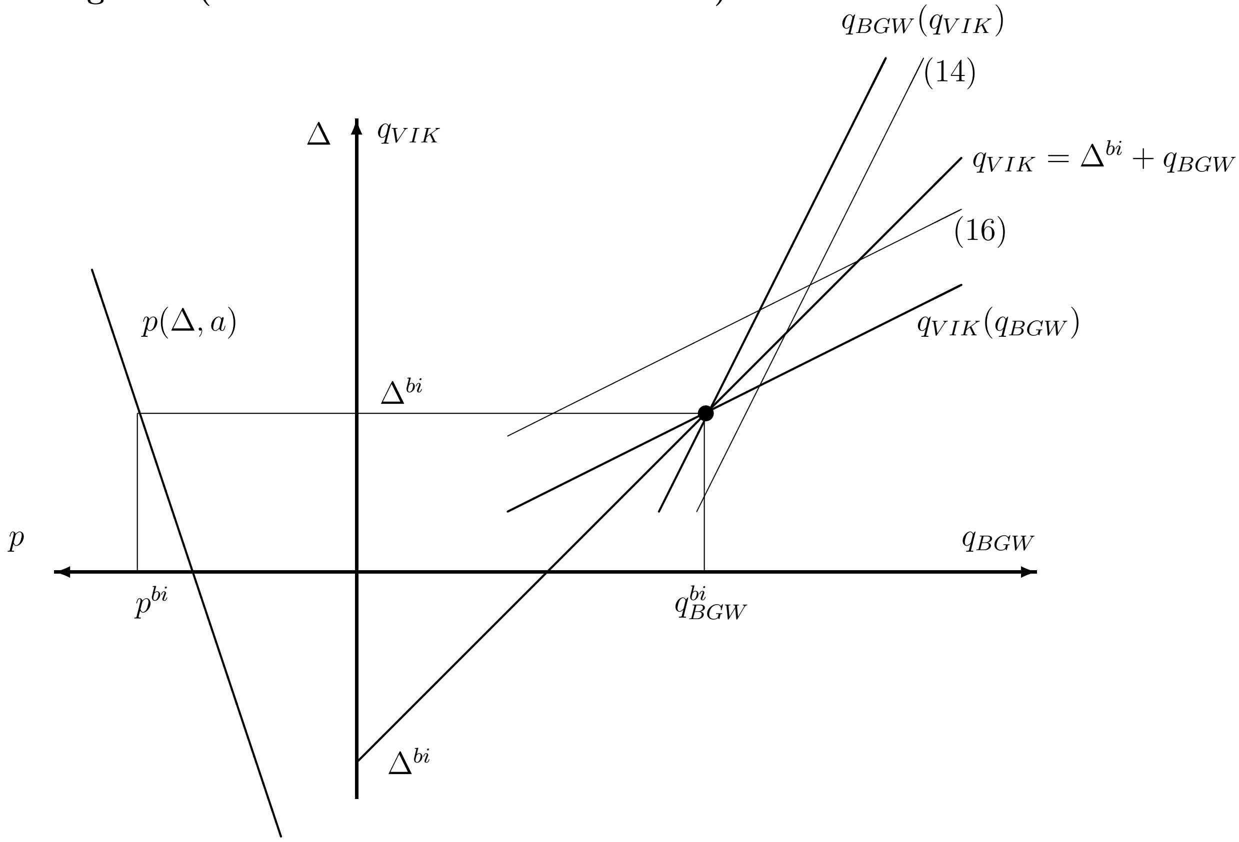
[8]The characteristics of these curves are summarized in the appendix.

Proof: We confine ourselves to a graphical proof[9]. For this purpose we have to consider the optimality conditions (11), (12) and (14) and (16). It can easily be shown that (11) and (12) imply that for the Nash-equilibrium we have

$$
\begin{aligned}
p^{bi} - C'_{BGW}(q^{bi}_{BGW}) - C'_{N} &> 0 \qquad (17)\\
\pi'_{VIK}(q^{bi}_{VIK}) - p^{bi} &> 0 \qquad (18)
\end{aligned}
$$

Due to the assumed properties of the relevant functions (14) must lie to the right of BGW's reaction function. Similarly, (16) is somewhere above VIK's reaction curve. An example is shown in the figure (thin lines). Thus, in a competitive equilibrium both q_{BGW} and q_{VIK} increase, leaving the effect on net demand Δ undetermined. In our example Δ is rising.

Figure 1 (Market structure and allocation)



To summarize: there is no doubt that more competition increases total welfare. Nevertheless, the figure shows that more competition generates both winners and losers. If net demand Δ increases (decreases) in the process of rising competition, the third party (households) is (are) the winner(s).

[9]The formal proof is based on the mean-value theorem for functions with severable variables and can be obtained from the authors upon request.

3.4 Association Agreement

The German association agreement can be modeled within a two-stage time-structure. First, the agreement is settled comprising long-term contracts on gas deliveries between the monopolistic supplier (BGW) and the monopsonistic buyer (VIK) and a stipulated access fee, which applies to all suppliers, the non-discriminatory access.
In the second stage the gas market will unfold as described in subsection 3.2. The market is characterized by two major players: the monopolistic supplier and the monopsonistic buyer. They choose supply and demand strategically, taking into account their reaction (Nash strategies) and the reaction of a competitive fringe consisting of a third party supplying gas and households demanding gas.
The agreement is modelled as a two-stage game to assure self-enforcement. Long-term contracts are legal and hence feasible. Similarly, the German legislation provides for self-regulation, which makes it possible to stipulate an enforceable access fee a. Conversely, future supply and demand decisions in the gas market can not be stipulated ex ante (cartel instability). Hence, these options can only be anticipated. In our deterministic model, this is done by the precise forecast of the second period's Nash equilibrium.
The self-regulation can be modeled by a cooperative Nash bargaining approach[10]. BGW and VIK maximize

$$\begin{aligned} (\pi_{VIK}(q^{bi}_{VIK}) - p^{bi} q^{bi}_{VIK} - T - \bar{\Pi}_{VIK}) \quad \text{x} \\ (p^{bi} q^{bi}_{BGW} + a\hat{q}_{TP} - C_{BGW}(q^{bi}_{BGW}) - C_N(q^{bi}_{BGW} + \hat{q}_{TP}) + T - \bar{\Pi}_{BGW}) \end{aligned} \tag{19}$$

by choosing the access fee a and money transfer T; $\bar{\Pi}_{VIK}$ and $\bar{\Pi}_{BGW}$ are the threat points of the industrial gas consumers and the supplier, respectively. In our deterministic model, T can always be fixed by a long-term contract[11] specifying a certain amount of gas q^0 purchased by VIK and delivered by BGW for a stipulated price p_0. Notice that this delivery does not need to take place physically. In the second period, VIK (BGW) simply buys (sells) q^0 at market price p^{bi} and the contract is settled by a financial close-out of $(p_0 - p^{bi})q_0$. Hence, the long-term contract can be modelled as a simple financial transfer.
Before proceeding, the threat points $\bar{\Pi}_{VIK}$ and $\bar{\Pi}_{BGW}$ need some explanation. The German system of self-regulation is a bargaining process under the threat that the public legislator will introduce an ex-ante regulation scheme if the private players do not reach an appropriate agreement. In this case, the access fee a will be set by a regulatory body. As a result, the respective profits can be anticipated by calculating the non-cooperative Nash equilibrium given the access fee a^{reg} set by a future regulatory authority. This fee will probably be close to marginal transportation costs, i.e. $a^{reg} = C'_N$. Moreover, substituting a public regulatory framework for self-regulation may foster further competition in

[10]In this paper we do not go into details on how the axiomatic bargaining approach models the final outcome of a sequential non-cooperative bargaining process.

[11]In the context of a two period model, this contract is in fact a simple forward contract. Moreover, in the framework of our deterministic two-period model many problems of long term contracts are assumed away (contract length, options, take-or-pay provisions etc.).

the gas market, either through an accompanying competition policy (ex post regulation) or through the signaling effects encouraging potential gas producers to enter the market. Also, the intrinsic cartel instability of the big buyers might intensify competition on the demand side. If this scenario applies, then the threat points refer to profits under full competition (see eqs. (13) and (15)).
In the following, we assume that the threat points are determined by a cartelized market under access-fee regulation ($a^{reg} = C'_N$). From the first-order conditions of (19), one can derive[12] the following rule to fix the access fee a^{aa}:

$$-p_a^{bi}\Delta^{bi} + \hat{q}_{TP} + (a - C'_N)\hat{q}'_{TP}(p_a^{bi} - 1) = 0 \tag{20}$$

proposition 2 (Association Agreement) *The association agreement sets $a^{aa} > C'_N$, which implies the exploitation of households since the gas market price p^{bi} increases with respect to a reference case of a first-best access fee $a = C'_N$. How the net price $p^{bi} - a$ reacts on a depends on the curvatures of the profit function π_{VIK} and the cost function C_{BGW}. As a result, the third party may in fact gain from an association agreement compared to the case of state-run regulation of the cartelized market.*
Proof: See appendix.

4 Policy mix

The recent discussion on deregulation of networks industries differentiates between ex-ante and ex-post regulation. While the former refers to classical price regulation, the latter involves "only" active competition policy. In our model, we take into account both kinds of policy measures. Ex ante regulation is modeled as introducing a price cap which in fact leads to a lower access fee a whereas competition policy results in a more competitive market structure. Here, we assume the textbook case of a competitive market where all participants take the gas price as given.
The following table combines the two policy measures and their joint impact on the gas price.

Figure 2 (Policy mix)

		ex-ante regulation	
		yes	no
competition policy	yes	p^{bi} may rise or fall	p^{bi} may rise or fall
(ex-post regulation)	no	p^{bi} decreases as a is lowered net price $p^{bi} - a$ may rise or fall	association agreements (aa)

We begin from the bottom right corner, the status quo, i.e. the self-regulating cartel of BGW and VIK. From there, one can read off the effects of both policy types. Competition policy without ex-ante regulation (upper right corner) leads to an ambiguous price

[12] See appendix.

movement, p^{bi} may rise or fall (cf. Figure 1). Of course, the welfare impacts are clear-cut as more competition increases total welfare defined as the sum of all profits (minus fixed costs) and consumer surplus. Nevertheless, there are winners and losers depending on the price movement in the process of increasing competition. This is an interesting, counter-intuitive result: self-regulation may benefit the third party when compared with a pro-active competition policy.

Also, ex-ante regulation has its own ambiguities. If the access fee a is lowered, for example by introducing a price cap, then the gas price drops, which in turn leads to an increase of consumer surplus. Whether the third party gains from this price reduction depends on the relative size of the decrease. If p drops faster than a, then the TP will loose and vice versa.

5 Conclusions

In this paper, we have compared different regulatory settings for a network industry, based on a stylized representation of the regulatory process in the German gas industry. The point of inception was self-regulation of the network access price by the incumbent gas production and transmission monopolist (BGW) and the large industrial users (VIK), a situation we have called "bilateral monopoly". This approach to self-regulation has been widely criticized for discriminating against third party gas producers and household consumers. We compare the point of inception with ex-ante regulation, and, alternatively, with no regulation but a pro-active competition policy.

We find that the move from an unregulated bilateral monopoly to a fully competitive market does not necessarily lead to lower market prices, and that total supply may in fact rise or fall. Thus it appears clear that more competition increases welfare. Also, ex-ante regulation of network access prices has an ambiguous effect on the net price so that the welfare position of the third party may or may not be enhanced. When analyzing the self-regulated association agreement, we find that it leads to an exploitation of households, but that the effect on the third party gas producer is unclear. In fact, the latter may even gain from self-regulated access. We conclude that abandoning the association agreements and moving to ex-ante regulation increases welfare, but does not necessarily improve the situation of the third-party producers. Since ex-ante regulation may suffer from inherent information asymmetries (a case that we have not treated here), self-regulation may in fact be a feasible second-best solution for network access regulation.

The results have a couple of interesting policy conclusions. The analysis of a regulatory model needs to be accompanied by an analysis of the prevailing market structure. Self-regulation has a tendency to be welfare-decreasing in the first-best world of regulation; however, it does have certain advantages in a second-best world: transaction costs gains have to be weighted against the potential welfare losses. Instead of prescribing a "one-fits-all" regulatory model, the European Commission, and other governments, might be well-advised to foster a variety of institutional models, from which an appropriate one may emerge in every country or region.

We have left some issues open that merit further analysis. The idealtype model yields a deterministic solution, and does not take into account information asymmetry. Both assumptions might be dropped to render the model more realistic. The topic of regulatory threat, discussed at the outset of this paper, could be investigated fruitfully by looking at additional constellations between the industry player, the Cartel Office, the potential regulator, and the government. An intermediate result of deregulation, i.e. a cartel on the supply side and a larger cartel on the demand side, might also be a more realistic representation of the current situation. We have left aside the contract structure between upstream and downstream market participants, leaving the opportunity for further research to develop a dynamic version of this model. Last but not least, the model can be adapted to the regulatory process in other network industries such as airports, railways, or water.

6 Appendix

6.1 Reaction Curves

To determine the shape of the reaction curves in Figure 1, it is necessary to differentiate the first-order conditions (11) and (12). Thus the price function $p(\Delta, a)$ implicitly defined by (5) and Assumption 1 must be taken into account.
To determine the characteristics of $q_{VIK}(q_{BGW})$ we take q_{BGW} as an exogenous variable and differentiate (12). This yields, after some rearrangements,

$$0 < \frac{dq_{VIK}(q_{BGW})}{dq_{BGW}} = \frac{-p^{bi}_{\Delta}}{\pi''_{VIK} - 2p^{bi}_{\Delta}} < 1 \tag{21}$$

Similarly, the slope of the reaction function $q_{BGW}(q_{VIK})$:

$$0 < \frac{dq_{BGW}(q_{VIK})}{dq_{VIK}} = \frac{-p^{bi}_{\Delta}}{-(C''_{BGW} + 2p^{bi}_{\Delta})} < 1 \tag{22}$$

Notice that the reciprocal value of $\frac{dq_{BGW}(q_{BGW})}{dq_{VIK}}$ exceeds 1.

6.2 Derivation of Equation (20)

BGW and VIK maximize (19) with respect to $\{T, a\}$. Maximizing with respect to T leads to

$$\pi_{VIK}(q^{bi}_{VIK}) - p^{bi} q^{bi}_{VIK} - T - \bar{\Pi}_{VIK}) = (p^{bi} q^{bi}_{BGW} + a\hat{q}_{TP} - C_{BGW}(q^{bi}_{BGW}) - C_N(q^{bi}_{BGW} + \hat{q}_{TP}) + T - \bar{\Pi}_{BGW}) \tag{23}$$

If one utilizes the envelope theorem (i.e. takes into account eqs. (11) and (12)) and (23) it is an easy exercise to show that (20) is the first order condition of (19) with respect to a.

6.3 Proposition 2

To prove the first part insert (2) into (11). This yields

$$(C'_{TP} - C'_{BGW}) + (a^{aa} - C'_N)(1 - \hat{q}'_{TP} p_{\Delta}) - q_{BGW} p_{\Delta} = 0 \tag{24}$$

Notice that all relevant functions are evaluated at the Nash equilibrium $\{q^{bi}_{BGW}, q^{bi}_{VIK}\}$. Assume per contradiction that $a^{vv} \leq C'_N$. From (24) and (8) it follows that $C'_{TP} - C'_{BGW} > 0$ and, by assumption 2, $\hat{q}_{TP} > q^{bi}_{BGW}$. From (20) we can infer that

$$-p^{bi}_a \Delta^{bi} + \hat{q}_{TP} < 0 \;\rightarrow\; -\Delta^{bi} + \hat{q}_{TP} = -q^{bi}_{VIK} + q^{bi}_{BGW} + \hat{q}_{TP} < 0 \tag{25}$$

Inserting (5) into (25) leads to $-\hat{q}_{HH} < 0$ which is not true. Hence, $a^{aa} > C'_N$.
To prove a decrease of the gas price as the access fee is lowered, one has to carry out a comparative static analysis of equations (11) and (12). Differentiating with respect to a and recalling Assumption 1, we arrive at

$$\begin{bmatrix} (\pi''_{VIK} - 2p^{bi}_{\Delta}) & p^{bi}_{\Delta} \\ p^{bi}_{\Delta} & -(C''_{BGW} + 2p^{bi}_{\Delta}) \end{bmatrix} \begin{bmatrix} \frac{dq^{bi}_{VIK}}{da} \\ \frac{dq^{bi}_{BGW}}{da} \end{bmatrix} = \begin{bmatrix} \hat{q}'_{TP} p^{bi}_{\Delta} \\ \hat{q}'_{TP} p^{bi}_{\Delta} \end{bmatrix} \tag{26}$$

Solving this equation system yields

$$\frac{dq^{bi}_{VIK}}{da} = \frac{-\hat{q}'_{TP} p^{bi}_{\Delta}(C''_{BGW} + 3p^{bi}_{\Delta})}{\Sigma} \tag{27}$$

$$\frac{dq^{bi}_{BGW}}{da} = \frac{\hat{q}'_{TP} p^{bi}_{\Delta}(\pi''_{VIK} - 3p^{bi}_{\Delta})}{\Sigma} \tag{28}$$

where Σ is the determinant of the system matrix. It can be shown that Σ is unambiguously positive. Hence, gas demand and gas supply of the big player is decreasing with respect a.
To prove the stated relation between p^{bi} and a, one has to differentiate p^{bi} totally with respect to a. After some calculation one arrives at:

$$\frac{dp^{bi}(\Delta, a)}{da} = p^{bi}_{\Delta}\frac{\Delta^{bi}}{da} + p^{bi}_a = \frac{-3p^{bi}_{\Delta}\pi''_{VIK} + p^{bi}_{\Delta}C''_{BGW} - \pi''_{VIK}C''_{BGW} + 3(p^{bi}_{\Delta})^2}{\Sigma} > 0 \tag{29}$$

The reaction of the net price $p - a$ can be found by differentiating totally and inserting (29). After some calculation, one obtains

$$\frac{dp^{bi}(\Delta, a)}{da} - 1 = \frac{-p^{bi}_{\Delta}(\pi''_{VIK} + C''_{BGW})}{\Sigma} \tag{30}$$

which exhibits an ambiguous sign.

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