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Abstract

In most developed countries, the provision of water is organized at a local level. The costs and tariffs vary significantly, even between adjacent water utilities. Such heterogeneity is an obvious indication of the sector's overall inefficiency and stresses a need for institutional adjustments. We show that cooperation by water trade and the introduction of competition by common carriage between adjacent utilities are valuable alternatives to improve the industry's efficiency, even when mergers are not feasible. Because both approaches require the physical connection of neighboring networks, they may have similar effects. This paper analyzes and compares the relevant welfare gains and shows that production efficiency and retail prices may differ depending on the initial cost differential, the application of regulations and the distribution of bargaining power. Using a theoretical model, we show that at higher initial production cost differentials, welfare is higher under competitive conditions, even in a lowerbound benchmark case without any regulation.

Keywords

Water, Networks, Product-Market Competition, Trade, Bargaining.

JEL Classification

L95, L43, D21, Q25.

1. Introduction

The existing organization of piped water supply in Europe is very heterogeneous. In most countries, water supply is organized at a local level. Historically, the communities are responsible for water supply systems, such as treatment and storage facilities or pipe networks, because water supply industry is widely viewed as a natural monopoly. In addition, local authorities choose the form of organization and the permitted degree of private sector participation. Due to these decentralized structures, water supply in most European countries is characterized by a high number of locally operating monopolies. Hence, there are more than 6,500 local operators in Germany, approximately 8,000 in Italy, 3,000 in Switzerland and 2,000 in Sweden (see EEB 2002, p. 24 - 28). Local operators often face very different marginal production costs due to differences in production scales, the use of different raw water resources, such as surface, ground or spring water, and different conditions of network infrastructure (see Correia and Kraemer 1997). As a result, retail prices vary significantly – even between adjacent water utilities (see Zschille et al. 2009). These cost and price differentials indicate overall production inefficiency for locally organized water supply industries. Hence, regulatory authorities or consumers in high-priced areas may ask for measures that improve productivity of supply. In fact, in 2009, the German Monopoly Commission strongly criticized regional price differentials and inefficiencies in the water supply and claimed institutional adjustments are needed (see Monopolkommission 2009). In its report, the authority proposed regulatory measures that increase the municipality's incentives to merge neighboring water utilities. Moreover, the Monopoly Commission recommended outsourcing and competition to enhance efficiency of water supply.

There are four *prima facie* ways to improve productive efficiency in the water sector: concentration, competition for the market, competition in the market and cooperation (see also Ludin et al., 2000). In fact, there has been a progressive concentration process in countries such as Belgium and the Netherlands. In Belgium, there are 109 waterworks, and 93% of total production is concentrated in the hands of only 10 companies. The Netherlands reduced the number of its government-owned water utilities from 111 to only 24 companies (see EEB 2002, p. 26). However, in many other countries, concentration is not a feasible or preferred opportunity due to political, legal or geographical restrictions. Only a few European countries, such as France, Italy, and UK (England and Wales), introduced some degree of competition in the water sector. France and, more recently, Italy implemented competition by the model of franchise bidding based on the idea of competition *for* the market. Furthermore, the German Monopoly Commission recommended in its report the application of franchise bidding to enhance the efficiency of water supply. However, simultaneously, it pointed to the danger of hold-up problems arising from long-term license contracts within the system of franchise bidding.

Hence, in many cases, mergers and competition *for* the market may not be feasible. However, significant welfare gains can be achieved using the latter of the two alternatives. In a setup with profit-maximizing private companies, we show that welfare gains may be higher in the case of unregulated competition when assuming high efficiency differentials between water utilities. England and Wales have chosen a model of product market competition based on competition *in* the market. One main element of such competition is common carriage. The concept is based on the shared use of networks, similar to telecommunication, electricity or gas: the incumbent company is required to grant its competitors access to the network, which is assumed to be an essential facility. However, due to difficulties in the regulation of access prices and the physical characteristics of water, competition is expected to be weak and mainly local. In fact, competition by common carriage still plays a minor role in the English and Welsh water industries, even when the government tried to increase the relevance of competition by introducing a sector-specific law in 2005. An alternative way to enhance efficiency might be to increase cooperation between neighboring utilities. One main element of such a cooperation model is the exchange of treated water resources based on trade. Because water utilities often have differing qualities of raw water and therefore face different marginal production costs, trade between neighboring suppliers is expected to reduce total costs. In fact, water trade is already practiced in several countries. However, in most cases, trade is only used to balance peaks in demand, as the non-profit-oriented communal water utilities usually try to be as independent as possible. Hence, trade does not happen even when costs vary significantly between neighboring utilities, although a more consequent implementation of trade might induce extensive efficiency and, therefore, welfare gains.

Obviously, such a regime of cross-border trade resembles the regime of competition by common carriage described above. The connection of networks can be used for water trade rather than for competition by common carriage. In both regimes, local and neighboring water suppliers connect their networks and exchange water. Both trade and competition cause the more efficient utilities to increase production volume and the less efficient utilities to reduce volume. One may question whether competition is useful because welfare gains are expected to be small due to the limited degree of competition and the emerging regulation costs. Using a game-theoretic model, we show that competition by common carriage induces stronger production incentives for the inefficient supplier. This implies that not only production efficiency but also the retail price tend to be lower than with cross-border trade. The net effect regarding welfare depends on the efficiency differential. At higher cost differentials, welfare is higher under common carriage, even in a lower-bound benchmark case without regulation of access charges.

There is some literature addressing the issue of competition *in* the market by common carriage applied to the piped water sector. For instance, from economic and regulatory perspectives, Cowan (1993 and 1997), Webb and Erhardt (1998), Grout (2002), Klein (1996), Scheele (2000) and Sawkins (2001) discuss the opportunity for common carriage to be applied to the water sector. Due to technical constraints, regulation difficulties and barriers to entry, most authors indicate that common carriage is *not* a major opportunity to introduce effective rivalry into the water sector. Nevertheless, Sawkins (2001) concludes that common carriage remains the greatest competitive opportunity in the water sector. However, the main challenges are to reduce the regulatory burden and to lower entry barriers. Saal and Parker (2001) empirically analyze the efficiency effects of privatization and liberalization in England and Wales. They conclude that total factor productivity growth has not been improved after privatization. Additionally, privatization raised retail prices and water suppliers' profits. However, Saal and Parker analyze the post privatization period of 1990-1999, when competition by common carriage still played a minor role. Using a game-theoretic model, Foellmi and Meister (2005) analyze potential efficiency gains of common carriage. They argue that competition may increase efficiency even in a "worst case" scenario in which regulation is absent. The effects of different access price regulations were analyzed by Hern (2001). He concluded that the Efficient Component Pricing Rule (ECPR) is a superior approach for the development of efficient competition in the specific circumstances of the UK water industry. The role of regulation in practice was also highlighted by a recent market report from the Office of Water Services (Ofwat), which is the regulator for the English and Welsh water industry. Ofwat, which applies a version of ECPR, recommends accounting separation of the contestable markets from the natural monopoly to improve the efficiency of regulation (Ofwat 2008).

A wide range of literature is related to *trade of water rights.* For instance, Hearne and Easter (1997) describe gains from the trading of water rights in Chile, Rosengrant and Binswanger (1994) present potential efficiency gains in developing countries, Pigram (1993) analyzes property rights and water markets in Australia, and Becker (1995) discusses potential gains from trade in Israel. However, few authors have analyzed trade related to spot water markets. Howitt (1998) shows that spot markets are better than water rights markets for stabilizing water availability. Calatrava and Garrido (2005) consider the risk dimension of water markets under conditions of uncertain water supply. They show that spot water markets may allow farmers to reduce their risk exposure caused by an unstable water supply. Additionally, they show that centralized water markets lead to more efficient allocation and resource use than decentralized markets. Carey and Zilberman (2002) investigate farmers' investments into irrigation technology under conditions of uncertainty and conclude that farmers with access to a spot water market may delay investment. Due to price uncertainty, the option to delay investment has a positive value, and thus, farmers will not invest until the expected present value of investment sufficiently exceeds the cost of investment. There is some literature analyzing bargaining processes and bargaining power in water markets: Kajisa and Sakurai (2000) examine water markets in India, and Meinzen-Dick (1997) examines groundwater markets in Pakistan. However, this literature addresses water trade related to agricultural issues in particular, while our paper rather discusses trade between neighboring water utilities that offer water services to final customers, such as households or industry. Newbery (1999) introduces a model that combines competition and trade in the network industry. Two suppliers compete in a single downstream gas market. Both pay a fee for using the network, which connects the market to the upstream gas producers. Newbery shows that if the suppliers can trade capacity rights amongst each other, they can use the price of these rights to support the joint profit-maximizing downstream price. However, such a setting is not feasible in the piped water market with vertically integrated water utilities. To the best of our knowledge, there is no literature analyzing the comparison of trade and competition between local water utilities.

Section 2 evaluates the reasons for the above-mentioned productivity differentials and discusses the relevant approaches to enhance efficiency. Additionally, the section provides evidence on competition and trade in the European water market. In Section 3, we set up a general model that considers the physical restrictions in the water sector, the difficulties of regulation and varying bargaining power to analyze the effects of competition and trade. We then compare the effects of competition and trade on productive efficiency, retail prices and welfare, and the distribution of profits between firms. In Section 4, we consider an example with linear demand and constant marginal costs. In the same section, we investigate the effects of regulation of access prices on the one hand and regulation of retail prices on the other. In Section 5, we present a simulation of the model. It shows that the result of the linear case holds as well for more general demand and cost functions: welfare tends always to be higher with trade because the productive efficiency effect dominates. Section 6 concludes.

2 Improving efficiency of water supply

2.1 Sources of efficiency differentials

In many countries, costs and tariffs of water supply differ significantly. Renzetti (1992) estimates the marginal costs of waterworks in Vancouver range from \$ 0.53 to \$ 0.85 per cubic meter. Such differences in costs obviously induce price differentials. For example, in France, tariffs varied between 0.42 FF and 10.92 FF per cubic meter (see Correia and Kraemer 1997). Current tariffs in Germany vary between 0.5 and 4 Euros (see von Hirschhausen 2009). The significant cost and price differentials may lead us to believe there is inefficiency in the water supply. Hence, before evaluating approaches that address the increase of water supply efficiency, it is useful to discuss the reason for the vast cost and price differentials. Walter et al. (2009) offer a broad literature overview on the issue of efficiency of the water supply. The *ownership structure* of water utilities does not clearly influence the level of productivity. There is no clear empirical evidence of whether private or public ownership matters for efficiency. Hence, more useful is the analysis of *structural and quality variables* on the one hand and *economies of scale, density and scope* on the other.

Structural variables may be water losses and the quality of the used raw water. One can assume that these two variables strongly stick together, as water losses tend to be more costly when using a more complex and expensive treatment procedure. The use of spring water usually requires no treatment at all and is therefore less expensive than ground or surface water. In particular, the surface water resources need extensive treatment, such as screening, flocculation, clarification, filtration, the addition of chemicals and the use of ultraviolet light. Hence, marginal costs vary significantly between water suppliers, depending on the availability of high- or low-quality raw water resources. The empirical analysis of Zschille et al. (2009) strongly supports such an impact of these two structural variables in the German water market. The result is consistent with an older analysis of Dwr Cymru Welsh Water (1999) that shows water supplier's operative costs to be mainly influenced by the complexity of water treatment, a finding also confirmed by Antonioli and Filippini (2001).

Several studies illustrate the existence of economies of scale and scope. *Economies of scale,* or rising profits with increasing size, are shown by Garcia and Thomas (2001) for France, Garcia et al. (2007) for the US and Filippini et al. (2008) for Slovenia. However, some studies also show diseconomies of scale, e.g., Saal and Parker (2005) for the UK and Mizutani and Urakami (2001) for Japan, implying that the firm size is too large. In fact, even when water utilities costs are mainly fixed, the size of scale economies is rather limited. Mergers of water utilities may induce cost savings in administration, sourcing or water treatment. However, the vast investment and maintenance costs related to the pipe network cannot significantly be reduced. Antonioli and Filippini (2001) show that there is no evidence that a larger service area results in any scale economies in water distribution. They conclude that a merger between two companies with adjacent service areas does not substantially decrease average costs. This is due to the fact that the average network cost is greatly determined by the influence of the population density, as documented by the studies analyzed by Walter et al. (2009). Economies of density measure differences in costs when output or production increase while holding the other variables, such as the supply territory, constant. Strongly related to the concept of economies of scale are economies of *scope*. They measure cost advantages when running the water supply business together with other network services, such as wastewater, electricity, gas and telecommunications. Even though the related literature is limited, there are indications of the existence of economies of scope. The sources of cost savings may be synergies in administration on the one hand and civil works on the other.

The analysis above illustrates that the merger of neighboring water utilities may not be the only and preferred strategy to increase efficiency in the water supply. First, it may hinder local utilities from harvesting the fruits of their multi-utility approaches. By merging neighboring water utilities into supra-regional or even national players, the use of local economies of scope between the communal suppliers of network services can be significantly restricted. Otherwise, the whole set of local water, wastewater and gas suppliers should be merged into one large firm to take advantage of economies of scale and scope. However, in many cases, this would not be realistic or would simply be too complex. Additionally, in many countries where water supply is integrated into the municipalities' organizational structure, political and legal restrictions hinder the merger of neighboring utilities.

Second, there are alternative strategies to increase efficiency in the water supply. As is shown above, the main sources of productivity differences are the use of different quality levels of raw water and the related treatment costs. Clearly, the reduction of these costs requires a physical connection of water utilities' pipe networks: Utilities with higher-quality raw water or more efficient treatment facilities should supply a greater portion of consumers, while the more expensive supplier should reduce its production share. Of course, such an approach would not require any merger between the connected water supply firms. Rather, it may be reached by either competition in the market or cooperation by trade. The following two subsections elaborate in more detail.

2.2 Competition in the Market

Thus far, product market competition, or competition *in* the piped water market, has only been introduced in England and Wales. After the entire privatization of water service companies in 1989, competition *in* the market was established through three basic channels (see Scheele, 2000 or Kurukulasuriya, 2001): inset appointments, cross-border competition and common carriage. Inset appointments – licenses issued by Ofwat – allow new entrants to supply customers in a defined geographical area. However, Ofwat initially limited the permission of inset appointments for sites that were not already connected and that were more than 30 meters away from the local water supplier's pipe network. Today, inset appointments are available for new customers (not yet connected) or major customers (consuming more than 100,000 m3 per year). Moreover, customers at every scale can change their supplier, provided that their previous supplier agrees to the change (see Scheele, 2000, p. 14). Cross-border competition allows customers that are located at the border of a supply area to purchase water from an existing neighboring utility. Finally, common carriage refers to the shared use of assets, as it would be uneconomical for a competitor to duplicate the provision of large assets, such as the pipe network. The competition model allows market entrants with their own water resources and/or treatment facilities to enter the market and use the incumbent's network to supply customers. However, in many cases, market entrance is assumed to be difficult because new water rights are not locally traded and/or investments into new treatment facilities are immense. Alternatively, treated water can be moved between areas through existing or new connections between local networks (see also Ofwat 2008, p. 10 and 66). Then, competition occurs through the interconnection of existing neighboring water supply companies: the former monopolists connect their water networks to allow each other access to their distribution pipes – analogous to well-established network-access regimes in telecommunication, electricity or gas (see BMWi 2001, p. 11-28). Hence, market entrance is assured through (mutual) network access. Providing network access allows a network owner to charge an access fee to its competitor – analogous to the access fees in the telecommunication sector.

Basically, the Competition Act 1998 (which generally determines access to essential facilities) has been a legal basis for the introduction of competition by common carriage. However, the government in England and Wales tried to strengthen the role of common carriage. In 2002, Ofwat issued guidance on the development of access codes. The guidelines defined standards of behavior for the companies and new entrants in their agreements about common carriage and helped companies to avoid breaching the Competition Act. Additionally, in 2005, a sector-specific law (Water Act 2003) came into effect. It was intended to give new momentum to the development of product market competition through common carriage. It introduced a formal regime of water supply licensing (WSL), defined the threshold for contestability (non-household customers with a consumption of more than 50 ML/year) and provided a detailed framework for access. In this context, the act also defines the principles of access price calculation. Based on the law, Ofwat proposed a price formula that is a version of the well-known Efficient Component Pricing Rule (ECPR) (see Conti 2004).

However, in practice, competition still plays a minor role in the water industry of England and Wales (see also Ofwat 2008, p. 3). None of the three mentioned forms of competition has developed much. The regulation of retail prices by price cap and elements of yardstick competition are of higher importance. In fact, due to the specific technical issues in the water sector, product market competition by common carriage is not expected to be as effective as it would be in the telecommunication or electricity industries (see BMWi 2001, p. 24). In contrast to telecommunication or electricity networks, water networks are more local than national because there are limitations to network connection due to specific technical aspects of the water sector. On the one hand, there are limitations to mixing different water qualities, as it raises the possibility of leaching, corrosion of pipes, sedimentation and suspension of particles and affects microbial quality (see Kurukulasauiya 2001, p. 24). On the other hand, there are limitations to transport. In contrast to electricity, the transportation of water causes significant marginal costs due to pumping requirements. Furthermore, transportation over long distances affects the quality of the water in a negative way (see BMWi 2001, p. 24). To sum up, due to these limitations, competition by common carriage tends to occur only at a regional or even local level.

Furthermore, competition in the water sector can be restricted by the market power of incumbents (see also Ofwat 2008, p. 65). They can defend their monopoly positions by charging high access prices; effective regulation of access charges in the water sector is very complex, as the costs of using water pipe networks depend on various technical aspects such as age or material of pipes, pumping requirements and water pressure. In addition, these costs vary significantly between local networks. Hence, the access charges would have to be set in an individual and local manner, which is different from the telecommunications industry. Simon Cowan (1997, p. 91) argues that the regulatory burden of assessing access prices for different companies' networks is large. Indeed, the regulator Ofwat does not explicitly regulate access charges ex ante. It rather defines general terms for the calculation of access prices. On the basis of the guidance, water companies have to publish their specific access codes, including indicative or standard prices for access. Ofwat requires companies not to set indicative prices that are unrealistically high to deter entrants (see Ofwat 2002, p. 20-22). The extensive complexity of regulation is also highlighted by Sawkins (2001), who mentions that the amount of information gathered for monitoring purposes has grown unremittingly as the suite of performance indicators has expanded. Based on these circumstances, the effectiveness of regulation and competition in the market is doubtful. The World Bank even questions whether efficiency gains from competition outweigh the costs (see Webb and Ehrhardt 1998, p. 5). Aside from these provisos against the effectiveness of competition in the market, there is political opposition to the introduction of any kind of competition and privatization in the piped water sector. There is fear that private companies would rather optimize short-term profits than long-term welfare (see, for instance, BMWi 2001). Before 2000, the European Community (EC) excluded the water industry from its competition law – in contrast to other network utilities, such as postal services, gas and electricity. Additionally, the EC defined in its Water Framework Directive (Directive 2000/60/EC): "Water is not a commercial product like any other but, rather, a heritage which must be protected, defended and treated as such (see European Commission 2009)." The Water Framework Directive does not include any guidelines or recommendations about privatization or competition.

2.3 Trade

Cross-border trade between neighboring water suppliers is more common than competition by access. Treated water is exchanged between independent neighboring water utilities or, more commonly, between utilities that are members of partnerships of convenience (PC), which are called Zweckverbaende in Germany. PCs are voluntary associations between independent municipalities that intend to fulfill a certain public task, such as water supply or wastewater disposal, as a collective. Approximately 17% of German water suppliers are organized in PCs (see BGW 1999). According to Ludin et al. (2000), PCs are mainly motivated by insufficient enterprise scales, on the one hand, and technical aspects, such as hydrologic and hydrogeologic conditions, on the other hand. A PC has a self-contained legal form of organization and acts as public corporation. Hence, in most cases, it describes a merger of neighboring water utilities rather than trade between independent water suppliers. However, purer forms of water trade between utilities also exist. German water suppliers with extended treatment capacities, such as Bodenseewasserversorgung, Harzwasserwerke or Gelsenwasser, sell water to neighboring or even distant water utilities. Water trade between utilities is also practiced in other countries, including Switzerland. Switzerland's largest water supplier is the Zurich water utility (WVZ). It provides about 460,000 inhabitants of the Zurich city directly; furthermore, it sells water to contractual partners, represented by 67 communities in the nearer region of Zurich with an additional 420,000 inhabitants. The latter communities have their own local public water suppliers. Such a large number of partners might be surprising because mixing different water qualities usually requires extensive coordination efforts. However, none of the WVZ's partners use complex treatment technologies. They exclusively use spring or ground water and do not need the addition of any chemicals. Mixing their water with the WVZ's treated water is therefore unproblematic and requires only a minimum level of coordination effort.

However, only in the case of demand peaks do they buy treated water from the WVZ that disposes of extended treatment capacities due to the use of surface water. The relevant price is based on costs and is calculated identically for each partner. Approximately 20% of WVZ's total water production is sold to contractual partners (see WVZ 2009). Obviously, the same specific technical issues restrict the extension of trade and product market competition. Limitations of mixing different water qualities, extensive coordination requirements for the exchange of treated water and diseconomies of scales due to pumping requirements and quality losses over long distances limit the exchange of water between utilities significantly.

3 A Model of Competition and Trade

As we explained above both competition and trade are expected to occur on a regional or even local level. The above mentioned specifications in the water industry limit the number of networks that can be connected in order to exchange water. To keep the following analysis simple, we assume a network connection of only two neighbouring utilities. And since favourable raw water resources such as spring and groundwater are limited and the construction of new treatment facilities causes high sunk costs, we exclude the entrance of new water suppliers and focus only existing water utilities. Figure 1 describes the basic setting of the model. By connecting their networks 1 and 2, two suppliers A and B are able to exchange treated water. The vertically integrated suppliers A and B can be asymmetric. Depending on production scale and the quality of raw water resources used, water supplier's marginal costs may differ significantly – even between neighbouring water suppliers (see above). Since water supply is very capital intensive, we assume that utilities choose rather quantities and capacities than prices. Our model is therefore based on a Cournot competition. And since the treated water of both suppliers is mixed within the water pipe system, we assume homogenous goods. Due to water treatment and pumping requirements the production of water causes variable costs $C_j(\bullet), j \in \{A, B\}$. Such variable cost may include additional expenditures related to billing, metering and other administration cost. Fixed costs such as network investment and maintenance costs are omitted since they are irrelevant for the optimisation problem under concern. Without loosing generality we assume the more efficient utility B to have lower marginal treatment costs than utility A.

Figure 1：Connection of two neighbouring water networks

In order to ease the exposition, marginal costs of the (efficient) supplier B are equal to c_B and constant. Instead, supplier A faces increasing marginal costs, $C_A'(0) > c_B$ and $C_A'' \geq 0$. The assumption of increasing marginal costs is appropriate for utilities facing relevant capacity constraints because of the production structure in the water industry. Water supplier's operative costs are mainly influenced by the complexity of water treatment. In order to minimise treatment costs, utilities firstly use raw water resources of high quality such as spring water. To overcome capacity constraints they use further resources with poorer quality and therefore higher treatment requirements such as groundwater or surface water. Due to this reasoning, marginal costs of drinking water production are obviously increasing in output. According to our assumptions, the more efficient utility B does not face relevant capacity constraints due to sufficient availability of high quality raw water resources. The introduction of increasing marginal costs for B does not change the results in network 1 qualitatively. However, the analysis would be more complex since we would have to consider price and quantity changes in both networks 1 and 2 (see also Foellmi and Meister, 2005). Further, we only allow for linear access and trade prices. Of course the analysis could be extended to a non-linear pricing regime. The qualitative predictions of the model remain the same. However, the reader would obtain the well known result that highest possible production efficiency can be achieved (see Foellmi and Meister, 2005). Additionally, we consider two profit-maximising water utilities in both competition and trade. Instead, we could assume that the utilities are welfare-maximising. However, this would not change the results fundamentally. For a broader analysis of common carriage in mixed oligopolies where water utilities maximise profits and/or welfare see Meister (2008).

3.1 Competition

Supplier A with higher marginal costs generates earnings in two different ways: Selling water to customers connected to the own network and levying an access charge. It can be shown (Foellmi and Meister, 2005) that the inefficient supplier will not sell water to customers connected to the low-cost-competitor's network. The profit of a supplier A is given as follows:

$$\Pi_A = p_1(q_{1A} + q_{1B})q_{1A} + a_1 q_{1B} - C_A(q_{1A}) \qquad (1)$$

where p_1 denotes the retail prices in market 1. Q_{1A} stands for the quantity of sold water produced by A to customers connected to network 1, q_{1B} stands for the quantity of sold water produced by B to customers connected to network 1. Utility A levies an access charge which consists of a variable access price a_1. As there is no regulation, A is free to set the access charge. And as Bs marginal costs are constant, its decision problem can be fully described by considering its profit from market 1. Such profit is given as follows:

$$\Pi_B = p_1(q_{1A} + q_{1B})q_{1B} - a_1 q_{1B} - c_B q_{1B} \qquad (2)$$

The model consists of two stages. In a first stage supplier A chooses the access prices a_1. Given the access charge A and B simultaneously set production quantities q_{1A} and q_{1B} in the second stage. Obviously, A would be able to prevent any competition by charging extensive high access charges in the first stage. On the second stage A and B would choose q_{2A} respectively q_{1B} equal to zero – access would not take place. Allowing common carriage would not have any positive welfare effects compared to a situation, where two independent monopolists act in their own markets. However, it can be shown (see Foellmi and Meister, 2005), that the inefficient utility A voluntarily opens its network to the low-cost competitor B. In order to compare welfare between the competition and the trade regime we have to analyse the relevant effects on retail prices and production efficiency. We solve the model by backwards induction. Given a_1, the firms choose their quantities q_{1A} and q_{1B}:

$$\frac{\partial \Pi_A}{\partial q_{1A}} = p_1' q_{1A} + p_1 - C_A' = 0 \qquad (3)$$

$$\frac{\partial \Pi_B}{\partial q_{1B}} = p_1' q_{1B} + p_1 - a_1 - c_B = 0 \qquad (4),$$

where $\partial p_1(\cdot)/\partial q_{1A} = \partial p_1(\cdot)/\partial q_{1B} \equiv p_1'$. In the first stage, monopolist A sets a_1:

$$\frac{\partial \Pi_A}{\partial a_1} = q_{1B} + \frac{dq_{1B}}{da_1}\left(p_1' q_{1A} + a_1\right) = 0 \ . \qquad (5)$$

As usual the optimal access price depends on the quantity reaction of B, captured by the dq_{1B}/da_1 term. Considering the term $p_1' q_{1A}$, A perceives that a reduction of q_{1B} increases prices in the retail market. Note that the quantity reaction of A does not affect marginal profits because of the Envelope theorem. The quantity reaction of B can be determined by differentiation of equations (3) and (4), whereas the former only has to taken into consideration if $q_{1A} > 0$. We get

$$\frac{dq_{1B}}{da_1} = \left[q_{1B} p_1'' + 2p_1' - \frac{\left(q_{1A} p_1'' + p_1'\right)\left(q_{1B} p_1'' + p_1'\right)}{q_{1A} p_1'' + 2p_1' - C_A''} \right]^{-1} \qquad \text{if} \quad q_{1A} > 0 \qquad \text{and}$$

$$\frac{dq_{1B}}{da_1} = \left[q_{1B} p_1'' + 2p_1' \right]^{-1} \qquad \text{if} \quad q_{1A} = 0 \qquad (6).$$

We assume that the reaction curves (in quantities) are falling, so $q_{1j} p_1'' + p_1' < 0$. We note that the absolute value dq_{1B}/da_1 is larger when $q_{1A} > 0$ than for the case $q_{1A} = 0$. The quantity reaction of B is therefore stronger when A produces. This result is due to the strategic complementarity of quantities. An increase in a_1 reduces q_{1B} (direct effect). This leads in turn to an increase in the quantity of the competitor q_{1A}, which induces B to produce even less (indirect effect). We first analyse p_1 under the assumption that utility A still produces a positive amount of water itself. By using equation (6) in (5), solving it for a_1 and inserting the result into (4) we can derive the relevant retail price in market 1.

$$p_1 = -q_1(q_1 p_1'' + 3p_1') + q_{1A}\left[2p_1' + (q_1 + q_{1B})p_1''\right] + q_{1B}\frac{(q_{1A}p_1'' + p_1')(q_{1B}p_1'' + p_1')}{q_{1A}p_1'' + 2p_1' - C_A''} + c_B \qquad (7),$$

if $\quad q_{1A} > 0 \quad$ and where $q_1 = q_{1A} + q_{1B}$.

Equation (7) only holds if $q_{1A} > 0$, or equivalently, the implied value of p_1 is larger than $C_A'(0)$. Considering the regularity assumptions above, an increase in $C_A'(0)$ implies a reduction of q_{1A}. According to equation (3) A *stops* the own production exactly where $p_1 = C_A'(0)$. In this case, A becomes a pure network operator. If marginal costs $C_A'(0)$ increase further it is optimal for A to increase the access fee a_1 such that the retail price p_1 rises (but p_1 increases less than $C_A'(0)$ as our regularity assumptions guarantee uniqueness). Since $q_{1A} = 0$ the above mentioned strategic effect is no longer existent. Hence it is optimal for A to raise a_1 since B will reduce its engagement in market 1 less strongly. Taken together, the retail price p_1 is smaller than or equal to $C_A'(0)$ if $q_{1A} = 0$ and follows directly from (4), (5) and (6):

$$p_1 = \min\left\{C_A'(0),\ -q_{1B}(q_{1B}p_1'' + 3p_1') + c_B\right\} \text{ if } \quad q_{1A} = 0 \qquad (8)$$

In both cases the high-cost utility A reduces own production (if it was not already zero before) and the low-cost utility B increases production, so the differential of A's and Bs marginal costs diminishes and overall efficiency in the water market increases. Due to increasing marginal production costs in market 1 the introduction of competition reduces retail prices and raises sold water volume. Obviously welfare must be higher than in the status quo, where the two utilities act as independent monopolists. However, since A levies a positive linear access price a_1, welfare is negatively affected by a double marginalisation problem. In its decisions about quantities and therefore prices utility B faces relevant marginal costs of (c_B + a_1). Hence B will limit its engagement q_{1B} in market 1 below the socially optimal amount, which would guarantee efficiency of production. In fact if B were a monopolist in market 1, according to the Amoroso Robinson equation he would set $p_1 = -p_1'q_{1B} + c_B$. This is smaller than p_1 in equation (8) since $-p_1'q_{1B} + c_B = p_1 - a_1 < C_A'(0)$ according to equation (4) and since $-p_1'q_{1B} + c_B < -q_{1B}p_1' - q_{1B}(q_{1B}p_1'' + 2p_1') + c_B$ since $q_{1B}p_1'' + 2p_1' < 0$ according to equation (6).

In both cases supplier *A* and *B* share the additional profit resulting from the introduction of competition. In our general analysis we forbear from doing a more detailed analysis regarding the profit distribution between *A* and *B*.

3.2 Trade

We have shown that introducing product market competition between neighbouring water utilities can lead to significant efficiency and therefore welfare gains in the water industry. However, one could argue that similar effects could result from introducing unregulated cross border trade amongst neighbouring utilities. It is obvious that a high cost utility *A* has incentives to buy treated water from the more efficient utility *B* that faces lower marginal costs of water treatment. Buying inexpensive water from *B* allows *A* to reduce own water treatment respectively to reduce the use of inferior raw water resources and therefore cost of production. *B* on the other side can earn additional profit by these trading activities. Due to the constant marginal costs c_B the decision problem of *B* reduces to the analysis of its trading activities. The reduced profit is given by:

$$\Pi_B = q_T(p_T)p_T - c_B q_T(p_T) \qquad (9),$$

where q_T stands for the quantity of water that *B* sells to *A* and p_T describes the trade price. *A* on the other side derives revenues solely from selling water to customers located in network 1. Own production of *A* is now denoted by q_A to avoid confusion with the competition case. *A*'s profit can therefore be defined as follows:

$$\Pi_A = p_1(q_1)(q_A + q_T) - C_A(q_A) - p_T q_T \qquad (10),$$

where $q_1 = q_A + q_T$. Cross border trade implies three different market places: On the one side the retail markets 1 and 2, where the utilities act as monopolists, and on the other side the wholesale market for treated water resources. The latter market is characterised by a *bilateral monopoly*. One seller and one buyer bargain over the trade price and quantity and therefore the allocation of gains from trade (which are positive because marginal costs of *A* are higher than those of *B*). We assume that the equilibrium amount of trade is the outcome of a Nash bargaining between *A* and *B* with exogenously given bargaining power. As our model describes trade between fully informed but unequal players the relevant bargaining power of the two parties can be different. There are several empirical studies addressing the issue of bargaining power in bilateral monopolies (e.g. Chipty and Snyder, 1999, Kauf, 1999, Kajisa and Sakurai, 2000). Kajisa and Sakurai analyse it for water trade in the agrarian sector in India. According to their analysis seller's power is positively correlated with its physical capital respectively total amount of investment into the water production facilities. They also found some empirical evidence in support of a weak sellers' bargaining position in the Indian water market. Social constraints may hinder sellers to enjoy unacceptable amounts of excess profits. In order to make the impact of different bargaining power apparent, we focus in the following analysis the two polar cases, where only the seller respectively the buyer has the entire bargaining power.

3.2.1 Full Bargaining Power of Utility B

We first consider the perhaps more intuitive case where the more efficient utility *B* has the entire bargaining power on the wholesale market. Seller *B* defines the relevant trade price and makes a "take it or leave it" offer to utility *A*. Obviously *B* sets a trade price that maximises its profit from trading activities described by equation (9). Maximization of *B*s trade profit with respect to p_T yields to the following first order condition:

$$\frac{\partial \Pi_B}{\partial p_T} = q_T + (p_T - c_B)\frac{\partial q_T}{\partial p_T} = 0 \qquad (11).$$

In order to define $\partial q_T / \partial p_T$ which describes the slope of *A*'s demand function for treated water on a trading market we need to analyse its profit, which is described by equation (10). Maximization of *A*'s profit with respect to q_A and q_T yields the following first order conditions:

$$\frac{\partial \Pi_A}{\partial q_A} = q_1 p_1' + p_1 - C_A' \leq 0 \qquad (12) \quad \text{and}$$

$$\frac{\partial \Pi_A}{\partial q_T} = q_1 p_1' + p_1 - p_T = 0 \qquad (13).$$

In case- of utility *A* decides to produce itself a positive amount of water ($q_A > 0$) the right hand side of equation (12) is zero. Total differentiation of (12) and (13) and applying Cramer's rule we derive the slope of the demand schedule, dq_T / dp_T.

$$\frac{\partial q_T}{\partial p_T}=\frac{q_1 p_1''+2p_1'-C_A''}{(q_1 p_1''+2p_1')(-C_A'')}=\frac{1-\left[\frac{\partial MR_A}{\partial q_1}\Big/ C_A''\right]}{\frac{\partial MR_A}{\partial q_1}} \qquad (14) \qquad \text{if} \quad q_A>0$$

where $MR_A = \partial \Pi_A / \partial q_1$ denotes *A*'s marginal revenues ($\partial MR_A / \partial q_1 < 0$). Note that the above defined slope of the demand curve is only valid when utility *A* produces water as well ($q_A > 0$). If $C_A'(0)$ exceeds p_T, *A* gives up own production and becomes a pure water broker. In this case *A* purchases the entire amount of water which is necessary to cover demand in market 1. Obviously this can happen when *A* is very inefficient compared to *B*. In order to define now the slope of the demand curve we can neglect equation (12), since $q_A = 0$. Total differentiation of (13) and solving for dq_T / dp_T yields

$$\frac{\partial q_T}{\partial p_T}=\frac{1}{q_1 p_1''+2p_1'}=\frac{1}{\frac{\partial MR_A}{\partial q_1}} \qquad (15) \qquad \text{if} \quad q_A=0\ .$$

The demand curve is less elastic after utility *A* decides to stop own production ($q_A = 0$), since the right hand side of equation (15) is less negative than the right hand side of (15). *A* is therefore more sensitive to changes in p_T when it still produces itself ($q_A > 0$). If *A* still produces own water, an increasing trade price p_T would make *A* expand its own production – *A* would substitute q_T by q_A. A higher C_A'' reduces *A*'s opportunities to substitute q_T by q_A since own water production would be too costly. *A* steeper marginal cost curve reduces therefore price elasticity of demand.

Figure 2: Demand for traded water

A decides to stop own production when $C_A'(0) > p_T$. In this case own production is more expensive than purchasing water from the neighbouring utility *B*. As mentioned above, the demand curve changes its slope depending whether *A* produces a positive amount of water or not (see Figure 2). The relevant bend in the demand curve for traded water must therefore be at a trade price $p_T = C_A'(0)$.

3.2.1.1 Competition versus trade

After defining *A*'s demand curve we are able to compare the trade regime with the competition regime. In order to carry out the comparison for all parameter values, it turns out useful to separate the cases whether – for both regimes – *A* keeps own water production or gives it up completely. The sign of the welfare comparisons may be different depending on whether *A* produces or not. The possible outcomes when comparing trade with competition are given in the following Table 1.

Table 1: Different Marginal Cost Scenarios

To read Table 1 note that we reduce *A*'s marginal costs as we move from case 1 to case 3. We divide case 1 in 1a and 1b to account for the discrete change in dq_{1B}/da_1 which occurs at q_{1A} = 0 (see equation (6)). We divide case 2 in 2a and 2b in order to consider different trade prices due to the bend in the demand curve for traded water (see Figure 2). The equilibrium values for the retail price in market 1 and the trade price on the wholesale market are denoted by $\hat{p}_1$ and $\hat{p}_T$, respectively. Of course, prices depend on C_A' in general. However it is easy to see that the case ordering in Table 1 is still applicable. Let us start in case 1 where $C_A'(0)$ is high. When $C_A'(0)$ decreases, $\hat{p}_1$ remains fixed as long as q_A = q_{1A} = 0. When we enter Case 2a – where $q_{1A} > 0$ – price p_1 begins to fall. However it cannot fall below $C_A'(0)$ again. Otherwise *A* would choose q_{1A} = 0 and p_1 would be equal to that in case 1. But this price is higher than $C_A'(0)$ contradicting our assumption. For case 2b and 3 the argument is analogous.

According to equation (3) in the competition regime, utility *A* produces a positive amount of water if and only if $\hat{p}_1 > C_A'(0)$. With trade, equations (13) and (12) apply; we see that *A* produces only if $\hat{p}_T < \hat{p}_1$ respectively $C_A'(0) < \hat{p}_T$ where $\hat{p}_T < \hat{p}_1$. Because of this double marginalisation argument *A*'s incentives to produce a positive amount of water are stronger in case of competition.

We start analysing case 1a where *A* decides to give up completely its own production. From equation (8) we know that the retail price is given by:

$$p_1 = -q_{1B}(q_{1B}p_1''+3p_1') + c_B \qquad (16)$$

In the trade regime we apply equations (14) and (15) in (11) to get

$$p_1 = -q_T(q_T p_1''+3p_1') + c_B \qquad (17).$$

Proposition 1: *In case 1a retail price, production efficiency and resulting welfare are equal in the trade and competition regime.*

Proof: *Equations (16) and (17) imply* $q_{1B} = q_T$ *since* $q_{1A} = q_A = 0$. *As water is produced within the efficient utility B only, the production costs and thus welfare are equal for both regimes.*

When $C_A'(0)$ equals the retail price p_1 given by (16), we enter case 1b. Now, the retail price is given by $C_A'(0)$ (see equation (8)). Obviously p_1 in the competition regime begins to fall, as $C_A'(0)$ falls further. However, the lower retail price implies a lower access price than in case 1a. This is an interesting result: *A*'s profit declines when he becomes more efficient. The reason is that *A* cannot credibly commit not to produce on his own at the second stage when he would set the access price too high. The thread that *A* will start own production makes *B*s quantity reaction to an access price change more elastic which implies that *A* will set lower access prices in equilibrium. This implies that in case 1b welfare is strictly higher in the competition regime. Prices are lower and production is still efficient since only *B* produces.

Proposition 2: *In case 1b welfare is always higher in the competition regime.*

Proof: *The reduced level of* $C_A'(0)$ *implies a lower retail and access price in the competition regime compared to case 1a. However, since* $q_{1A} = 0$ *production efficiency is the same. In the trade regime nothing changes to case 1a.*

Case 2a compares the competition regime, where *A* keeps (parts of) its own production, to the trade regime, where *A* completely gives up its water production. The formulae for the trade regime are the same for both cases 1 and 2a, so equation (17) still holds. However, in the competition regime the retail price is given by equation (7). It is shown in proposition 3 that the retail price is always lower in the competition regime. The intuition can be grasped as follows: in case of trade only one monopolistic firm is present in market 1 (in case 2). In the access regime the retail price tends to be lower since there are two utilities engaged in Cournot competition and hence do not take the change in their competitor's profits into account when setting their quantities. However, even when prices are lower in the competition regime, welfare could still be higher with trade. The reason is higher production efficiency with trade. In the competition regime the inefficient utility produces a positive amount of water – as a result average production costs must be higher than in the trade regime. Therefore competition tends to work better when *A*'s marginal cost are relatively high – because in such a case *A*'s own production stays small (or equals zero as in case 1b). In fact our simulations in section 5 show that the productive efficiency effect dominates the consumer surplus effect when the marginal cost differential between *A* and *B* is smaller ceteris paribus.

Proposition 3: *For case 2a the welfare comparison is ambiguous. The retail price p_1 is always lower under competition, but production efficiency is higher in the trade regime.*

Proof: *The price in the case 2a is strictly lower for the competition case. The right hand side of (7) is strictly lower than that of (17) because* $q_{1j}p_1''+p_1'<0$.

Obviously, from a consumer's viewpoint competition is always more favourable, since consumer surplus is determined by the level of the retail price p_1.

Since cases 2b and 3 do not raise any qualitatively new issues, we keep their discussion short. The only distinctive feature is that – compared to the competition regime – the relative prices with trade are lower than in cases 1 and 2a. In case 2b the relative difference between $C_A'(0)$ and c_B is small enough such that the marginal costs of *B* cross the marginal revenue curve at the vertical segment (see Figure 2). Hence $p_T = C_A'(0)$. Therefore *A* maximises its profits similar to an independent monopolist facing constant marginal costs p_T. The relevant retail price in the trade regime reads now:

$$p_1 = C_A'(0) - q_T p_1' \qquad (18)$$

Obviously this price lies between the trade price of the trade regime in case 2a and 3. In Case 3 both utilities keep their water production. The demand curve for water on the trade market is now defined by equation (14). Using equations (11), (13) and (14) we derive price p_1 in the trade regime

$$p_1 = -q_1(q_1p_1''+3p_1') + (\mu q_A + (1-\mu)q_1)(q_1p_1''+2p_1') + c_B \qquad (19),$$

where $\mu = C_A''(q_A)/[C_A''(q_A) - (2p_1'+q_1p_1'')] < 1$. Since $q_1 > q_A$ the retail price p_1 in the trade regime tends to be smaller than in cases 1 and 2a. This result induces that the relative performance of the trade regime in case 3 tends to be more advantageous than in 2a. However, it is still not obvious whether p_1 is lower than in the competition regime. The price differential is now determined both by the curvature of the demand and the value of $q_1(1-\mu)+q_A\mu$. To sum up, the trade regime performs "better" in comparison to the competition regime when *A*'s marginal costs are at lower levels. The reason is that the price setting possibilities for *B* are now limited which dampens the double marginalisation effect of trade pricing.

Independent from the curvature of the demand curve, production efficiency in the trade regime is still higher although the inefficient utility *A* produces also in the trade regime when case 3 is relevant. However, and as mentioned above, *A*'s incentives to produce a positive amount of water are always stronger under competition than under trade. The amount of traded water must therefore be higher than the amount of water sold by *B* through access, $q_T > q_{1B}$. This means that the more efficient utility *B* produces in the trade regime a higher part of the entire water quantities sold in market 1 and 2. Total production costs are therefore lower than in the competition regime.

Apart from the effects regarding retail price and efficiency it is worth mentioning the distribution of profits. The roles of *A* and *B* differ fundamentally in the competition and trade regime. In the trade regime the less efficient utility *A* acts as a downstream monopolist while in the competition regime *A* is an upstream monopolist. For most demand functions an upstream monopolist is able to skim the main part of the overall profit – e.g. two thirds in case of a linear demand function.

3.2.2 Full Bargaining Power of Utility A

Let us now analyse the other polar case where less efficient utility *A* has the entire bargaining power on the wholesale market. This means the buyer *A* defines the relevant trade price and makes a "take it or leave it" offer to utility *B*. Having the entire bargaining power utility *A* maximises its own profit represented by equation (9) subject to *B*s participation constraint denoted by $p_T q_T \geq c_B q_T$. Obviously *A* will offer a trade price $p_T = c_B$. Offering a higher trade price would reduce *A*'s profit since it causes higher costs, offering a smaller trade price would violate *B*s participation constraint. In such a setting *B*s marginal cost curve represents the supply curve on the wholesale market for treated water. Of course this is a well-known result which goes back at least to Tintner (1939) and Morgan (1949).

The equilibrium production structure is quickly determined. *A* reduces its own water production q_A until C_A' is equal to $p_T = c_B$. If $C_A'(0)$ exceeds p_T, *A* gives up own production and becomes a pure water broker. Due to the resulting equalisation of marginal costs overall production efficiency in market 1 and 2 is maximised and therefore aggregated profits rise compared to the autarky situation. Purchasing water resources from *B* at price $p_T = c_B$ allows the less efficient utility *A* to extract the full rent of the additional profit induced by the increased efficiency. Similar to the trade regime in cases 1 and 2 of section 3.2.1 highest possible production efficiency can be achieved. However, due to the marginal cost pricing at the wholesale market the problem of double marginalisation can be totally removed. *A* therefore faces exactly the same maximisation problem as an independent monopolist with marginal costs c_B und sets $p_1 = -q_1 p_1' + c_B$. Due to the non-existent double marginalisation the relevant retail price must be lower and welfare higher than in a trade regime where the more efficient utility *B* has some positive bargaining power. However, it is in general not clear whether p_1 is lower than in the competition regime as under trade *A* acts as a monopolist on its home market.

4 Linear Analysis

In order to illustrate the results derived for general demand functions in section 3.2.1 (where *B* has the entire bargaining power in the trade regime) more detailed, we use an example with linear demand and cost functions. However, using linear costs for both utilities excludes case 3 because a less efficient utility *A* would never have any incentives to produce a positive amount of water in a trade regime since *A*'s constant marginal production costs (now denoted by c_A) always exceed c_B. Therefore our linear example analyses and compares competition and trade in cases 1 and 2. We define the inverse demand in market 1 as follows:

$$p_1 = k - bq_1 \qquad (20)$$

Using equations (3), (4), (5), (13), (15), (17) and (20) we obtain explicit expressions for the equilibrium prices and production quantities in the two different regimes. We know from our general analysis that there are three possible states in the competition regime: case 1a and case 1b, where *A* stops own production and case 2, where *A* keeps its own production. The equilibrium will be in case 2 if and only if the resulting retail price p_1 in market 1 exceeds marginal costs c_A

$$q_{1A} > 0 \quad \text{if} \quad p_1 = \frac{3k + c_B}{4} > c_A .$$

As mentioned above, in the trade regime one has to consider only one possible state: *A* does not produce a positive amount of water. However, one has to differentiate case 2b, the bend of the demand curve, from cases 1 and 2a. In case 2b *B*s marginal cost curve cuts its marginal profit curve from trading activities in its vertical range. Hence for $c_A \leq (k + c_B)/2$ it is profit maximising for *B* to set $p_T = c_A$. To derive the relevant equilibrium values in cases 1 and 2a the slope of the demand curve for traded water has to be determined. Using equations (15) and (20) we get $\partial q_T / \partial p_T = -1/(2b)$. Table 2 illustrates the relevant equilibrium values for both the competition and the trade regime. Additionally it shows the equilibrium values for a monopoly regime in order to create a benchmark case.

Table 2: Retail prices, quantities and access respectively trade prices

Figure 3 illustrates and compares the above derived results regarding the retail price. The figure defines retail price p_1 as a function of marginal costs c_A in the monopoly, trade and competition regime.

Figure 3: Retail price in market 1: monopoly, trade and competition

4.1 Trade versus Competition

As mentioned above the roles of *A* and *B* change when moving from competition by access to trade. *A* acts in the trade regime as a downstream company, in the competition regime as an upstream company. For *B* the reverse holds. Figure 4 illustrates this fact.

Figure 4: Market structure: trade versus competition

The linear analysis allows us to extract more intuition of the general result stated in proposition 1. For case 1a we derived the result that p_1 is the same for both the competition and trade regime. However, in the trade regime consumers are exclusively served by the downstream company *A*, in the competition regime by the downstream company *B*. Their relevant marginal costs correspond to the same level since $p_T = a_1 + c_B$. Since both downstream companies face isomorphic profit maximisation problems, in equilibrium p_1 and q_1 and therefore consumer rent correspond to the same level. And since water is only produced by the more efficient utility *B*, aggregate profits must be equal as well. We conclude that the resulting welfare is the same in both regimes. However, the *distribution* of the aggregate profits between *A* and *B* is different. With linear demand, the corresponding upstream monopolist receives two thirds of aggregate profits. Hence, the inefficient utility *A* is better off in the competition regime. In case 1b the retail and the access price in the competition regime are lower than in case 1a. Obviously *A*'s engagement must be higher than in case 1a. Similar to case 1a only the more efficient *B* produces. As stated in proposition 2 we can infer that in case 1b welfare is always higher in the competition regime.

The result may change when moving to case 2. As stated in proposition 3 the retail price p_1 is still lower under competition than under trade. The lower retail price is due to *A*'s engagement in market 1 which implies a higher overall production quantity in market 1 (see Table 2). Again, the lower retail price positively affects welfare in the competition regime.

However, since $c_B < c_A$ average production costs are higher with competition which negatively affects welfare. At high levels of c_A where A's production is still small, the price effect dominates. However, when the neighbouring water utilities' cost differential becomes smaller, the production inefficiency effect becomes relatively more important since the price difference between competition and trade declines (see Figure 3). Our simulations in section 5 show that welfare is higher in the trade regime when c_A is lower. How are profits distributed? With linear demand, the upstream monopolist skims two thirds of the aggregate profits in both regimes. In the trade regime B gets two thirds of aggregate profits. In the competition regime aggregate profits are lower due to lower productive efficiency. Obviously A is able to skim more than two thirds of aggregate profits because A also acts as a producer in the downstream market.

4.2 Shifting the Bargaining Power

The linear analysis can easily be extended to the trade regime in section 3.2.2 where the entire bargaining power is shifted to the less efficient utility A. Now, utility A can buy treated water at a trade price $p_T = c_B$. A stops own production completely and purchases the entire water from B since $c_A > p_T$. A therefore faces exactly the same maximisation problem as an independent monopolist with marginal costs c_B. The retail price is therefore determined as follows: $p_1 = (k + c_B)/2$. Since $k > c_A > c_B$ such retail price must be lower than the relevant retail prices in the competition regime. The relevant quantity q_1 is given by $q_1 = (k - c_B)/2b$. Figure 5 illustrates the relevant retail prices.

Figure 5: Retail price in market 1 (A has the entire bargaining power)

Since the entire water sold in market 1 is produced at marginal costs c_B highest possible production efficiency can be achieved in the trade regime. And since the relevant retail price p_1 is lower than in the competition regime and than in the trade regime where B has the entire bargaining power, welfare can be improved.

4.3 Introducing Price Regulation

In most European countries water supply is provided by public utilities or regulated private companies. In both cases it is assumable that water suppliers' freedom to set prices is restricted. Up to this point the model does not consider any kind of regulation. One might wonder if the above derived results fundamentally change when price regulation is taken into account. Price regulation can basically be applied for access and retail prices. First we examine the effects of an access price regulation and then the effects of a retail price cap.

Traditional regulation theory suggests marginal cost pricing for access in order to maximise welfare. Since such a pricing regime describes a first best solution we use it as a benchmark. In our model we assumed no marginal costs of water transport and allocation. The regulator should therefore set $a_1 = 0$. Again we analyse the effects of Bs entrance in market 1. Since B does not face any marginal costs of using network 1, the problem of double marginalisation is removed. Competition in network 1 can be described as an ordinary Cournot duopoly competition model. The relevant retail price is illustrated in Figure 6:

Figure 6: Retail price in market 1 (with 1st best regulated access price)

The regulation of the access price increases the degree of competition in market 1 and therefore reduces the relevant retail price compared to unregulated competition and trade. Similar to the trade regime the less efficient utility A does not have any production incentives in cases 1a, 1b and 2a because only B produces a positive amount of water when $c_A > (k + c_B)/2$. Welfare is then the highest in the regulated access price regime. However, since A does not charge a variable access price, there is a hazard for inefficient market entry: A would enter market 1 even when $c_B > c_A$). But marginal cost pricing does not allow the incumbent to cover fixed network costs such as costs for investment and maintenance. If the incumbent cannot be compensated by subsidies, access prices are required to consider fixed costs. This can be realised by charging an additional lump sum fee to the market entrant or by charging a mark up over marginal costs. In practice, usually the latter alternative is chosen. In its guidance for the access price calculation the English water regulator Ofwat originally suggested three different methodologies: average accounting costs (AAC), long run marginal costs (LRMC) and the efficient component pricing rule (ECPR) (see Ofwat 2002, p. 22). Based on the Water Act 2003 Ofwat applied a price formula which is a version of ECPR (see Conti 2004, p. 12)

However, introducing a mark up over short run marginal costs reduces the relative performance of the regulated access price regime. When $a_1 > 0$, B faces marginal costs of access and reduces its engagement in market 1. The resulting retail price p_1 would be higher than illustrated in Figure 6. To regulate access prices in practice, sufficient accounting data must be available and physical depreciation must be measured adequately. But due to asymmetric information an incumbent firm may be able to manipulate such data: While an incumbent itself is able to assess costs accurately, the regulator as an outsider cannot observe and verify them properly. In addition the regulation of access prices in the water industry is expected to be very complex and costly (see section 2.2). Henceforth water suppliers' freedom to set access prices is significant and it is difficult to achieve the first best access price. However, as shown in section 3.1 even in a "worst case scenario" where access price regulation is not applied at all, a vertically integrated water supplier opens its network to the competitor that produces with lower marginal costs. It is important to note, that an analogous result could be achieved using access price regulation by the Efficient Component Pricing Rule (ECPR), which is also applied by Ofwat in the English and Welsh water market regulation (see Foellmi and Meister 2005, p. 125). As in our model, market entry only happens if the incumbent's competitor is more efficient. However, under ECPR there is no voluntary motivation to open the network since it indicates revenue neutrality for the incumbent.

Finally, consider the regulation of retail prices. Ex ante retail price regulation by price cap is applied for instance in England and Wales. The regulator fixes the retail price at $\overline{p_1}$. Demand in market 1 is then given by $q_1(\overline{p_1}) = \overline{q_1}$. In order to analyse the potential effects of regulation we assume that $\overline{p_1}$ is below the equilibrium retail prices in both regimes. Using such a price cap implies that consumer surplus must be equal in both regimes. Regulation therefore withdraws the benefit of the competition regime described above. The only source of welfare differences can therefore be due to differences in productive efficiency. Obviously the introduction of the price cap in a trade regime does not change the overall productive efficiency. Again, in the relevant cases 1a, 1b, 2a and 2b only the more efficient utility *B* produces a positive amount of water. In contrast, the introduction of a price cap may change the productive efficiency under competition. Now, the less efficient supplier *A* faces lower production incentives in case 2a and 2b than in an unregulated model, since we assumed $(3k + c_B)/4 > \overline{p_1}$. *A* keeps its own production in the competition regime only when c_A is below the relevant retail price in market 1. A reduction of the retail price due to regulation therefore reduces the less efficient utility's production incentives. Hence the productive efficiency in the competition regime can be improved by the implementation of a price cap. However, as long as $\overline{p_1} > c_A$ the less efficient utility *A* still produces a positive amount of water. Therefore productive efficiency and welfare are still higher (or equal) with trade than with competition.

5 Simulation

In section 4.1 we indicated that welfare is higher in the trade regime when the cost differential between the two firms is small. With larger cost differences, welfare is higher in the unregulated competition regime or equal in both regimes. One may ask whether these results are robust when assuming a more general demand or increasing marginal costs. In this section we simulate the (unregulated) model of section 3 and perform some comparative statics. We allow for non-linear demand and increasing marginal costs of *A*. Demand is defined as $p_1 = k - bq_1^{\eta}$, where η determines the curvature of water demand, and *A*'s marginal costs as

$C_A'(q_A) = c_0 + c_1 q_A$. *B*s marginal costs c_B are assumed to be linear. Since the relative performance of trade is stronger when *A* has the entire bargaining power we restrict our analysis to a situation where the more efficient utility has the bargain power. First we apply comparative statics by varying *A*'s marginal costs (see Table 3). We assume $b = 1$, $\eta = 1$, $k = 12$, $c_1 = 1$ and $c_B = 2$.

Table 3: Varying the cost differential

Note first that for $c_0 \geq 9.5$ *A* decides in both regimes to stop own production and welfare is equal in both regimes (case 1a). For $9.5 > c_0 \geq 9.273$ we are in case 1b. We see that the welfare of the competition case is strictly higher than in the trade regime. As we decrease *A*'s marginal costs further, the welfare advantage of the competition regime begins to shrink because the inefficient utility increases its own production. For c_0 smaller than 8 the productive inefficiency is so high such that welfare is higher under trade.

Table 4: Varying the curvature of the demand curve

Table 4 varies the curvature of the demand curve. We assume $b = 1$, $k = 12$, $c_0 = 8$ $c_1 = 1$, $c_B = 2$ and vary the curvature of the demand curve, which is described by η. In cases 1b and 2 the retail price p_1 is always lower in the competition regime than in the trade regime. The intuition from Ramsey pricing suggests that the positive welfare effect of lower prices should be stronger in the case of a more elastic demand (lower η). As Table 4 shows, this holds true in the numerical simulation. For elastic demand, competition works better whereas in the inelastic case trade prevails.

6 Conclusions

Costs and tariffs of water supply differ significantly, even between adjacent water utilities. Mergers between water firms may be one approach to increasing the efficiency of water services and balancing the regional tariff levels. However, mergers are not always the best strategy. On the one hand, political restrictions on the municipal level might limit fundamental changes in organizational structures and related changes of ownership. On the other hand, they may hinder the use of economies of scope that occur when providing different network services within one local firm. We argued in Section 2.1 that differences in raw water qualities and the related treatment requirements tend to be a main source of cost differentials.

Our model in Section 3 shows that an increase in overall production efficiency can be achieved without merging the organizations. Rather, competition in the market and cooperation by trade may be reached after networks are physically connected. Both competition and trade allow less efficient suppliers to reduce their own production and/or overcome their capacity constraints, while more efficient suppliers enhance production by raising their treatment facilities' rate of capacity utilization. We showed that the increase in combined consumer and producer surplus is higher (lower) in the trade regime compared to competition when the cost differential between utilities is low (high). The optimal choice of the institutional framework, therefore, depends on the initial efficiency differential between neighboring utilities because there is interplay between the productive efficiency and the retail price effect.

One might conjecture that the model of trade would be implemented anyway, as the relevant firms face incentives for trade and both may profit from a higher overall efficiency. However, most water utilities are currently monopolists, and tariffs depend on the relevant costs. Hence, incentives for organizational and structural changes tend to be low. Moreover, our analysis shows that a simple setup of voluntary trade and unregulated competition does not lead to the same results.

Furthermore, it is important to note that both regimes' performances can be improved. The competition model assumes a lower-bound benchmark case in which regulation does not exist. Of course, the regulation of the access price increases the relative performance of the competition regime because it reduces the problem of vertical foreclosure and double marginalization. A further extension is the regulation of retail prices. Introducing a price cap into the model improves the production efficiency in the competition regime (see Section 4.3). The trade regime's relative performance can be improved by enhancing firm A's bargaining power; again, the double marginalization problem of trade pricing is reduced.

Although we designed our model to examine what we view as an important feature in the water industry, our analysis might also be applicable to other industries as well. In general, it applies to market structures (i) that are characterized by geographically separated natural monopolies and (ii) where access to the incumbent's infrastructure by neighboring monopolies is possible. Examples are local network-based services. It is important to note that our model is not applicable to two-way networks such as railroads or industries for which customer utility depends on how many customers are connected to the network. This is the main difference of the present analysis to the existing network models of the telecommunications industry.

Our model analyzed welfare effects of competition and trade in the piped water industry with a pure microeconomic analysis. However, in practice, it may be useful to consider additional political and legal aspects. Obviously, trade between utilities can be implemented much easier in practice than competition by common carriage. Profit-maximizing utilities have incentives to introduce voluntarily cross-border trade, whereas competition may need extensive and complex economic regulation. In contrast to competition, political resistance to trade would be minor. Besides political resistance, there is a wide range of legal barriers for competition in the water sector. In countries such as Germany or Switzerland, the principle of territorial exclusivity (Oertlichkeitsprinzip respectively Territorialprinzip) hinders the introduction of common carriage (see Andersen and Reichhard 2009, p. 29). Of course, trade between neighboring utilities is already practiced by existing water utilities in several countries. However, in most cases, trade is only used to balance peaks in demand; efficient spot water markets usually do not exist. One can infer that trade is particularly applied in the case of *significant* cost differentials. An extension of water trade or even the introduction of common carriage would lead to further welfare gains. However, trade does not occur because local water suppliers are often not profit-oriented, as they are part of the public authority. Furthermore, common carriage is not applied due to the legal framework.

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Figure 1 : Connection of two neighbouring water networks

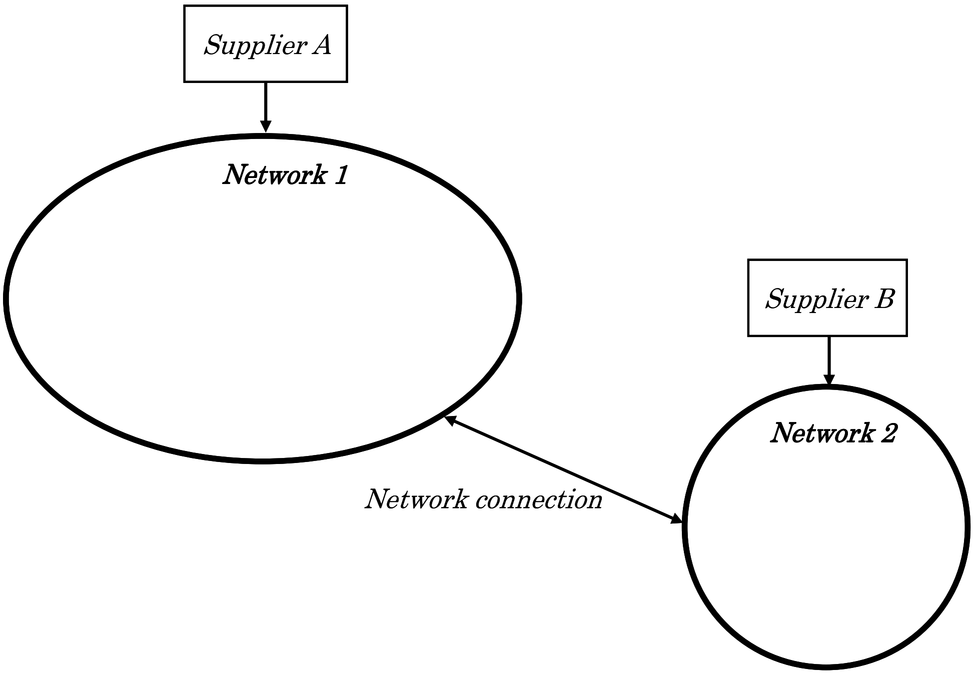

Figure 2: Demand for traded water

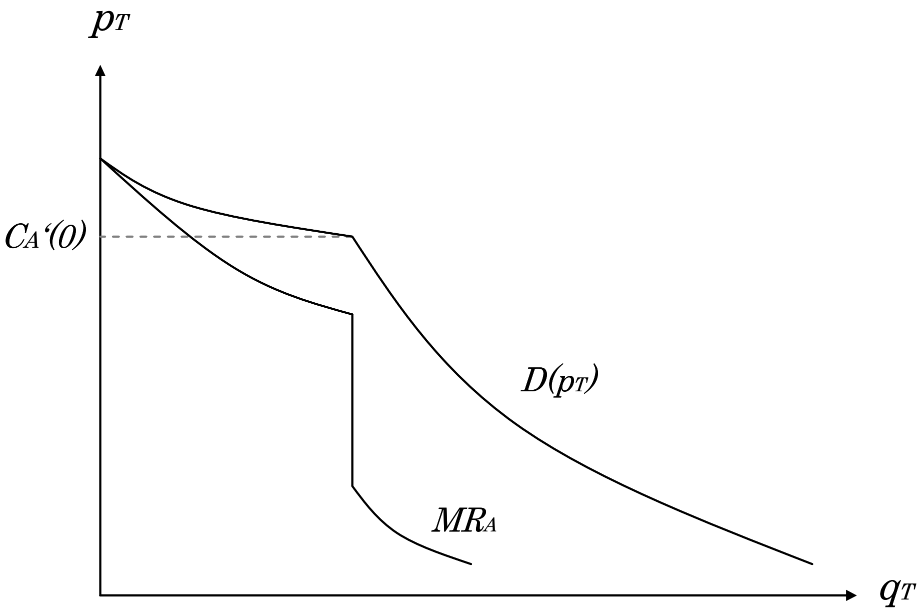

Figure 3: Retail price in market 1: monopoly, trade and competition

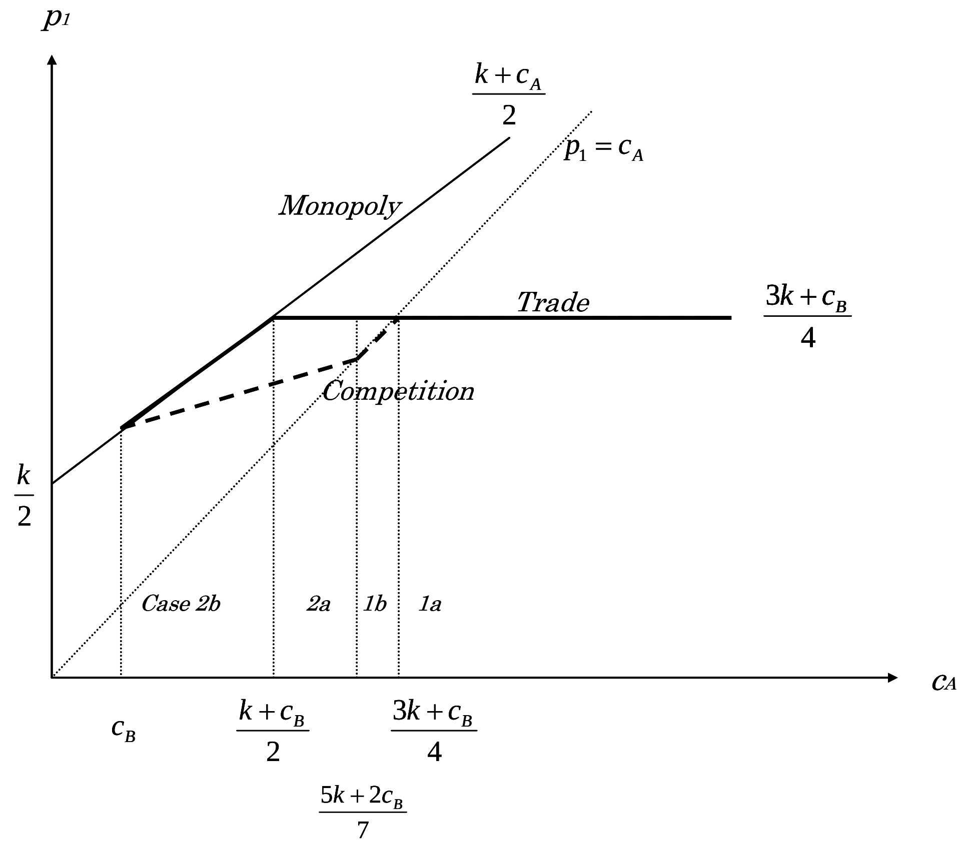

Figure 4: Market structure: trade versus competition

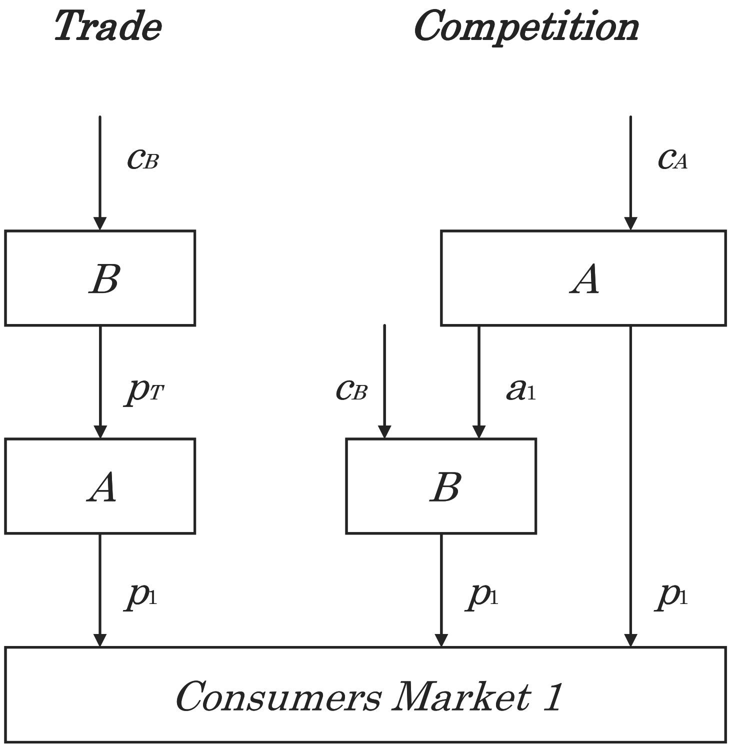

Figure 5: Retail price in market 1 (*A* has the entire bargaining power)

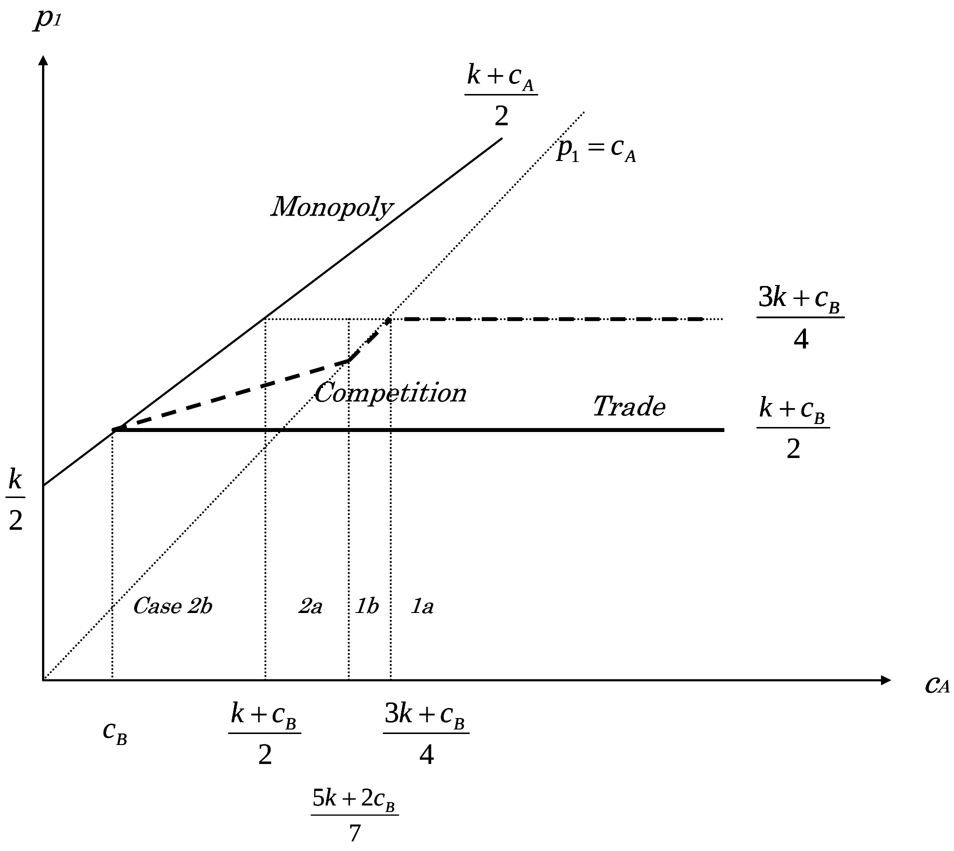

Figure 6: Retail price in market 1 (with 1st best regulated access price)

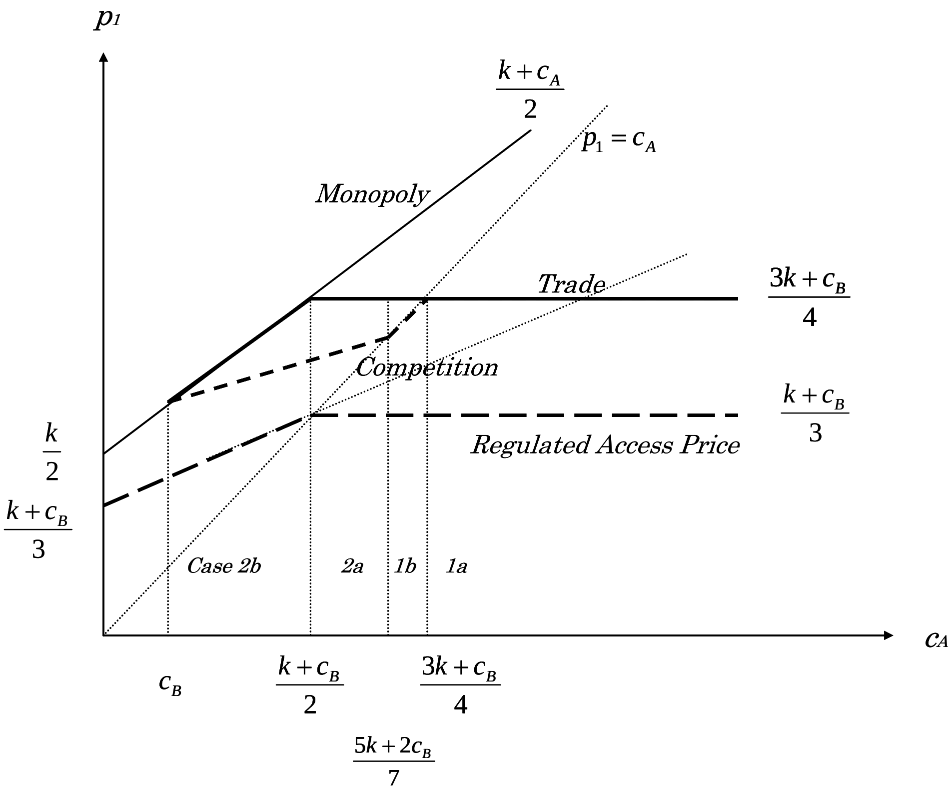

Table 1: Different Marginal Cost Scenarios

	Case 1a $C_A'(0) > \hat{p}_1$	*Case 1b* $C_A'(0) = \hat{p}_1$	*Case 2a* $\hat{p}_1 > C_A'(0) > \hat{p}_T$	*Case 2b* $C_A'(0) = \hat{p}_T$	*Case 3* $C_A'(0) < \hat{p}_T$
Trade	$q_A = 0$		$q_A = 0$		$q_A > 0$
Competition	$q_{1A} = 0$		$q_{1A} > 0$		$q_{1A} > 0$

Table 2: Retail prices, quantities and access respectively trade prices

	P_1	q_1	q_{1A}	q_{1B}	a_1 or p_T
Monopoly	$\frac{k+c_A}{2}$	$\frac{k-c_A}{2b}$	$\frac{k-c_A}{2b}$	-	-
Competition (Case 1a)	$\frac{3k+c_B}{4}$	$\frac{k-c_B}{4b}$	-	$\frac{k-c_B}{4b}$	$a_1=\frac{k-c_B}{2}$
Competition (Case 1b)	c_A	$\frac{k-c_A}{b}$	-	$\frac{k-c_A}{b}$	$a_1=2c_A-k-c_B$
Competition (Cases 2a & 2b)	$\frac{5k+3c_A+2c_B}{10}$	$\frac{5k-3c_A-2c_B}{10b}$	$\frac{5k-7c_A+2c_B}{10b}$	$\frac{2(c_A-c_B)}{5b}$	$a_1=\frac{5k-c_A-4c_B}{10}$
Trade (Cases 1 & 2a)	$\frac{3k+c_B}{4}$	$\frac{k-c_B}{4b}=q_T$	-	$\frac{k-c_B}{4b}$	$p_T=\frac{k+c_B}{2}<c_A$
Trade (Case 2b)	$\frac{k+c_A}{2}$	$\frac{k-c_A}{2b}=q_T$	-	$\frac{k-c_A}{2b}$	$p_T=c_A$

Table 3: Varying the cost differential

	Trade				*Competition*				W^{Comp} (W^{Trade}/100)
c_0	p_1^{Trade}	p_T	q_1^{Trade}	W^{Trade}	p_1^{Comp}	q_{1A}^{Comp}	q_1^{Comp}	W^{Comp}	
7.0	*9.500*	*7.000*	*2.500*	*21.875*	*8.852*	*0.926*	*3.148*	*21.468*	*98.1*
7.5	*9.500*	*7.000*	*2.500*	*21.875*	*8.944*	*0.722*	*3.056*	*21.654*	*99.0*
8.0	*9.500*	*7.000*	*2.500*	*21.875*	*9.037*	*0.519*	*2.963*	*21.994*	*100.5*
8.5	*9.500*	*7.000*	*2.500*	*21.875*	*9.130*	*0.315*	*2.871*	*22.488*	*102.8*
9.0	*9.500*	*7.000*	*2.500*	*21.875*	*9.222*	*0.111*	*2.778*	*23.136*	*105.8*
9.273	*9.500*	*7.000*	*2.500*	*21.875*	*9.273*	*0.000*	*2.727*	*23.554*	*107.8*
9.5	*9.500*	*7.000*	*2.500*	*21.875*	*9.500*	*0.000*	*2.500*	*21.875*	*100.0*

Table 4: Varying the curvature of the demand curve

	Trade				*Competition*				W^{Comp} (W^{Trade}/100)
η	p_1^{Trade}	p_T	q_1^{Trade}	W^{Trade}	p_1^{Comp}	q_{1A}^{Comp}	q_1^{Comp}	W^{Comp}	
0.6	8.094	5.750	9.689	73.233	8.003	0.002	10.068	75.511	103.1
0.7	8.540	6.118	5.890	46.915	8.357	0.254	6.341	48.261	102.9
0.8	8.914	6.444	4.091	33.894	8.631	0.397	4.565	34.646	102.2
0.9	9.230	6.737	3.102	26.499	8.852	0.475	3.576	26.869	101.4
1.0	9.500	7.000	2.500	21.875	9.037	0.519	2.963	21.994	100.5
1.1	9.732	7.238	2.105	18.776	9.196	0.542	2.553	18.725	99.7
1.2	9.934	7.455	1.831	16.588	9.335	0.553	2.263	16.415	99.0
1.3	10.110	7.652	1.632	14.979	9.459	0.559	2.049	14.716	98.2
1.4	10.264	7.833	1.483	13.757	9.571	0.560	1.885	13.424	97.6
1.5	10.400	8.000	1.368	12.804	9.672	0.560	1.756	12.415	97.0