Regulating investments in vertically related industries*

Dominik Ruderer†

May 2010

PRELIMINARY. COMMENTS WELCOME.

Abstract

This paper studies how investment outcomes in a vertically related industry with a regulated monopolist and downstream competition are affected by diverse regulation imposed investment regimes and the nature of product market competition. We analyze the situation when the regulator determines which segment of the industry, the upstream monopolist or the downstream competitors, is in charge of the investment. With imperfect regulation of the industry, we show that investment outcomes vary substantially with the investment regime. The nature of competition (Cournot vs. Bertrand competition) has significant influence on the welfare maximizing investment regime. While under Cournot competition the downstream investment regime always provides the strongest investment incentives, under Bertrand competition the upstream investment regime provides relatively strong incentives to invest. Hence, a range of parameters exists where under different modes of competition different investment regimes are superior.

JEL classification: L51, L43, L90, D43, K23

Keywords: Regulation, Vertical relations, Investment Incentives, Cournot-Bertrand Competition, Network Industries

---

*The author would like to thank Monika Schnitzer for helpful discussions as well as Klaus Schmidt, Markus Reisinger and Michal Masika for useful suggestions. We also appreciate the comments supplied by participants of presentations at the University of Munich, the University of Gießen, the MPI for Intellectual Property, Competition and Tax Law as well as at the CCPR Workshop 2010. Financial support from the German Science Foundation (DFG) through GRK 801 is gratefully acknowledged.

†International Max Planck Research School for Competition and Innovation (IMPRS-CI), Marstallplatz 1, 80539 Munich, Germany and Munich Graduate School of Economics (MGSE), Ludwig Maximilians University Munich, Kaulbachstr. 45, 80539 Munich, Germany, E-mail: druderer@gmail.com

1 Introduction

Vertically related monopolistic industries such as network utilities are often under broad regulatory supervision in order to avoid anticompetitive effects resulting from a monopolistic upstream segment.[1] Apart from regulation of the monopolist's wholesale prices, regulatory authorities may also require (partial) vertical separation of the industry. Under vertical separation the monopolistic upstream component is not allowed to be active on the competitive downstream market. If new technological opportunities arise in such an industry, it is often not clear which segment of the industry (upstream monopolist or downstream competitors) should conduct the investment on these new technologies. In such situations the regulator decides who should be responsible for the investment.

This paper compares two different investment regimes in order to determine which regime provides the best possible investment incentives from a welfare perspective. Under an *upstream investment regime* the monopolist is responsible for a specific investment in the industry, while under a *downstream investment regime* the investment is 'liberalised' and the downstream firms may invest in the respective technology. We focus on how investment incentives in the different regimes are influenced by the nature of downstream competition (price- vs. quantity-setting).

An example for such an investment scenario is the recently emerging smart meter technology in electricity distribution networks. Metering technology is needed by electricity and gas suppliers to measure their customers' consumption in order to bill them. Traditional electricity metering technology can only measure the delivered quantity over a specified period of time. With the newly emerging (smart) metering technology it has become possible to obtain a much higher functionality and accuracy, as compared to traditional technologies.[2] Responsibility for investment in this new metering technology is per se not linked to a distinct segment in the vertically related electricity industry. Studies show that the biggest benefits from installing smart meters do not arise at the (upstream) network segment, but at the (downstream) production and retail segment.[3] National regulators have chosen different approaches regarding investment in new meter technology.[4,5]

[1]The most prominent network utilities are electricity, gas, telecommunications and the railway industry.

[2]E.g., in Italy, a nationwide roll-out of new meters allowing for two-way communication over power lines and the mobile phone network took place. This new system allows the use of flexible retail tariffs, makes estimated readings and bills due to remote reading superfluous, avoids the need for profile estimation and improves information on network losses. See, e.g., Frontier Economics (2006).

[3]A study by Frontier Economics estimates the benefits from modern meter technology for the downstream segment at GBP 8.2bn and for the upstream segment at GBP 0.3bn (for the UK). Moreover, there is an undetermined externality on the environment. See, e.g., Frontier Economics (2009).

[4]While in most of continental Europe the network owner is responsible for the investment (e.g. Italy), in the UK and Germany this responsibility falls on the downstream segment or is liberalized, i.e. anybody except the network owner is allowed to invest. In this analysis we focus on the first and omit the latter case.

[5]Among regulators, the fear was expressed that a lock-in effect from investment in smart meter technology might exist resulting in the fragmentation of the downstream electricity market. This would render regulation of the access to meter equipment necessary. We abstract in our model from such effects. See, for example, Dow Jones Energy Weekly, 19, 2008, p.7-8.

The formal model analyzes a vertically related industry where the upstream good is provided by a regulated monopolist. For downstream firms the upstream good is an essential input to offer products to customers. These products are offered by a differentiated duopoly that competes either in quantities or in prices. Throughout the main part of the paper, the upstream monopolist is not allowed to be active on the downstream market. As an extension, we consider the case where the monopolist is partially integrated into the downstream market. Before competition takes place, an investment possibility arises that solely lowers marginal costs of the downstream firms.[6] As the investment may possibly be conducted by both sectors of the industry, it is ultimately the regulator who decides which segment is responsible for the investment.[7,8] The actual investment decision is taken after the regulator determines the investment regime as well as the optimal wholesale price, but before firms supply products competitively to consumers.[9] We only consider linear wholesale prices. This is due to the fact that regulators typically do not allow for two-part tariffs as access price schemes as these may provide scope for misuse by the regulated monopolist.[10]

Our main results are the following: First, we show that investment outcomes substantially vary with the investment regime, as different investors face different incentives to invest, though the investment characteristics are the same. Moreover, the nature (quantity vs. price setting) and intensity (expressed by the degree of product differentiation) of product market competition play a crucial role in determining the optimal investment regime. As is well known in the literature, the nature of competition has great influence on investment incentives. We illustrate that the investment incentives work in different directions for the upstream monopolist and the downstream firms among different modes of competition. While under Cournot competition the downstream investment regime is always superior from a welfare perspective, under Bertrand competition different regimes might be superior depending on the specific market characteristics.

Second, we find that under Bertrand competition tougher competition at the downstream market (expressed by a low degree of product differentiation) always decreases investment incentives of the downstream firms, but may increase investment incentives of the upstream monopolist.

[6] Our model is tailored towards deterministic investment technologies, i.e. the cost and result of the investment are well known in advance.

[7] It is assumed here that the two sectors cannot coordinate on conducting the investment jointly. We believe that this assumption is realistic as negotiations between the upstream monopolist and the downstream competitors might result in coordination failure.

[8] We are abstracting from the question, which industry segment actually wants to conduct the investment. This might arise when the investment is associated with high enough fixed costs, so that only one of the two segments is willing to invest. As we assume a convex investment cost function, in our model any segment would invest at least a bit when allowed to do so.

[9] Alternatively we can say, that the investment is non-verifiable, i.e., the wholesale prices cannot be conditioned on the investment.

[10] Non-linear tariffs are under suspicion to make discrimination of the downstream competitors possible. See, e.g., European Commission, Energy Sector Inquiry, Competition report on energy sector inquiry (2007, Jan. 10), part 1, p. 58.

Under Cournot competition, tougher competition may increase investment incentives of the downstream competitors.

An increase in the competitiveness of an industry always increases the reactiveness of a competitor on its rival's actions. As the reaction of a firm influences its rival's investment behavior, differing investment outcomes are quite natural.

Third, the regulator can use the regulated wholesale price as an instrument to achieve an investment outcome closer to the first-best. Increasing the wholesale price aggravates upstream investment and dampens downstream investment. The effects of a decrease are vice versa. This comes at the potential cost of distorting downstream competition and hence welfare. We find that using the wholesale price to incentivize competition may be worthwhile under the upstream investment regime but never under the downstream investment regime.

Finally, we show in a short extension that the optimal investment regime may depend on the vertical structure of the industry. While under partial vertical integration, the downstream investment regime is always superior, under vertical separation the optimal investment regime depends on the market characteristics. Thus, when deciding upon the investment regime, the specific vertical structure should be taken into account.

Our results have significant implications for policy making. They justify sector-specific approaches to regulatory decisions regarding the treatment of investments in network industries. Besides considering the specific characteristics of the investment, in relation to its cost-structure and where the effects of investment finally occur, the nature and intensity of competition should also be taken into account when the regulator determines the investment regime. These findings are particularly relevant for industries that are undergoing rapid technological changes, as is witnessed in the electricity industry.[11]

It has become a common notion in the literature to interpret different natures of competition as a manifestation of the importance of capacity constraints.[12] Industries where capacity matters can be interpreted as being more similar to Cournot industries, while industries where capacity constraints are inconsequential can be characterized as being more similar to Bertrand industries. The nature of competition may not only differ among industries, but also over different jurisdictions as regulatory regimes affecting industry capacities might vary. Moreover, the nature of competition might also change over time, when the regulatory regime changes.[13] Thus, the regulator should be careful when identifying the nature of competition.

[11] An extensive report on new technological opportunities in the electricity industry can be found in The Economist, Oct. 8th 2009.

[12] As Tirole (1988), p. 219, points out, "[...] what we mean by quantity competition is really a choice of scale that determines the firm's cost functions and thus determines the conditions of price competition. This choice of scale can be a capacity decision, [...]". Another reference is Kreps and Scheinkman (1983).

[13] E.g., European network industries like electricity were under cost-plus regulation for quite a long time. Cost-plus regulation gives the regulated firm strong incentives to invest in capacity. When these industries were liberalized and deregulated firms suffered from huge overcapacities resulting in a ruinous price competition. Over time a stark reduction in capacity took place. This had a strong influence on the way competition is working in the market.

A fairly large amount of literature exists on the economics of vertical structures.[14] Our model deals with a more specific form of vertical structure as we assume the upstream component to be monopolistic. The most prominent example for industries like these are network utilities.[15] The unique characteristics of different network utilities have resulted in a tendency towards an industry perspective in the literature.[16] Though our main application is to the electricity industry, we believe that the problem discussed in our article is of a more general nature. Therefore we will focus on some results of the literature that are generally applicable and related to this work.

Surprisingly, the literature on the linkage between price regulation and investment incentives is quite small. Bender (2008) and Vareda (2007) study the interrelation between price regulation and different kinds of investment under different vertical structures. They both find that strict access price regulation is appropriate for investment in cost-reduction and loose price regulation for investment in quality. While the second result is in line with our findings, the first result is in contrast to our paper. This is due to the fact that they assume a different kind of investment: Cost-reduction of upstream marginal costs, while we focus on cost-reduction of downstream marginal costs. Biglaiser and Ma (1999) study investment incentives of a regulated incumbent during a deregulation process when the regulator cannot commit to a specific policy. We instead focus on an industry that is under regulation all the time and where the regulator is endowed with commitment power. Buehler (2005) and Buehler et al. (2004, 2006) explore the issue of potential underinvestment in infrastructure more explicitely. They investigate the effects of partial vertical integration as well as vertical separation on investment. Though our main focus is on vertical separation, we also investigate the case of vertical integration as an extension. A new strand of literature studies the effect of legal unbundling as an intermediate structure between vertical integration and vertical separation. Cremer et al. (2006) and Höffler and Kranz (2007a, 2007b) study if legal unbundling can deliver a superior investment performance through combining the benefits of both vertical structures. They find a weakly positive impact on investments. Valletti and Cambini (2005) consider the influence of access pricing in competing networks on investment in network quality. They show that even in a symmetric model with two-part pricing underinvestment might occur. All of these models solely investigate the effect of upstream investment activity. We instead compare investment incentives by the upstream monopolist and by the downstream competitors given the identical investment technology.

Moreover, this paper relates to the literature on the nature of competition. Singh and Vives (1984) are the first to compare market outcomes of Bertrand and Cournot competition in a duopoly. In our study, we use a framework similar to theirs to model downstream competition. Bester and Petrakis (1993) and Qui (1997) also use similar frameworks to model investments in

[14] Good comprehensive references are Perry (1989), Rey and Tirole (2003) and Motta (2004).

[15] A detailed survey on regulation of natural monopolies is Armstrong and Sappington (2007).

[16] A good description of several network industries can be found in Newbery (2000).

cost-reduction and derive welfare comparisons among the different modes of competition. But their analysis does not consider a vertically related market.[17]

Mandy and Sappington (2007) and Arya et al. (2008) are closer to our paper as they model different modes of competition in a vertical structure with an upstream monopoly. Arya et al. (2008) investigate the price setting behavior of a vertically integrated monopolist owning the source of an essential input good with downstream competition. They partly contradict the findings of Singh and Vives (1984). But they do not consider pre-competition investments as we do. Mandy and Sappington (2007) model the incentives of a vertically-integrated monopolist to sabotage downstream competitors by providing an inferior quality or raising their costs under different modes of competition.[18] Although these actions harm economic efficiency whereas investments improve it, the underlying incentives resemble those considered in our paper. Moreover, both models solely consider partially integrated industry segments, while we mainly consider a vertically separated industry structure.

In the next section we present our model. In section 3 we derive our results for a vertically separated industry under Cournot competition and in section 4 the corresponding results under Bertrand competition. In section 5 we present as an extension the case, where one of the downstream firms is owned by the upstream monopolist (partial vertical integration). In section 6 we provide our concluding remarks.

2 The Model

We consider an industry that consists of an upstream monopolist and a competitive downstream segment. The monopolist U provides a good, which is an essential input required for producing the final product downstream. Downstream firms use a fixed proportions technology, i.e. they transform one unit of the input good into one unit of the output good.[19] The provision of the upstream good involves a fixed cost F, which is incurred whenever the monopolist decides to produce. In addition, each unit of the input good comes at a constant marginal cost, which we normalize to be 0 to simplify our expressions. The upstream industry thus exhibits economies of scale which explains the monopolistic industry structure.

The monopolist is price regulated, i.e. all units that are demanded have to be served at the regulated linear access price $w > 0$. As the upstream marginal cost is normalized to 0, the wholesale price w also represents the upstream margin. Price regulation is needed to avoid anticompetitive effects resulting from the monopolistic nature of the upstream sector. The assumption of linear access prices is crucial for the results of our study. This is also realistic,

[17] Another interesting contribution is Reisinger and Ressner (2009). They model a duopoly game under uncertainty in which firms are free to choose their strategy variables before competition takes place.

[18] More on sabotage can be found in Economides (1998), Beard et al. (2001) and Sibley and Weisman (1998).

[19] This specification is not important for our results, but useful for tractability of the model. Moreover, it fits our leading example of the electricity industry.

as it resembles the situation in network utilities. The regulator determines the wholesale price before investment or competition takes place.[20] We assume that the regulator's objective function is to maximize social welfare, given by the sum of consumer surplus and firm profits net of fixed and investment costs $W = CS + \pi^U + \sum_{i=1,2} \left(\pi_i^D - K(\Delta_i)\right) - F$ under the constraint that the monopolist breaks even. For our analysis it is not necessary to derive the optimal w. Depending on the fixed cost F, the optimal wholesale price is somewhere between 0 and the monopolistic wholesale price w_M.

We restrict attention to two downstream firms $i = 1, 2, i \neq j$. These firms offer their products directly to consumers but require the upstream good as an input. The final product is differentiated and firms compete either in quantities q_i or prices p_i. Hence, the downstream segment has oligopolistic features, where firms have some market power. The marginal cost of providing the downstream service is ex-ante c for both firms. Following Singh and Vives (1984), we assume representative consumers with preferences described by the quadratic utility function $U(q_1, q_2) = \alpha(q_1 + q_2) - 1/2(q_1^2 + 2\gamma q_1 q_2 + q_2^2)$, where $\alpha > 0$ is the maximum willingness to pay, and $\gamma \epsilon (0, 1)$ is the degree of product differentiation, which decreases in γ. As γ approaches 0, the products of the two retail providers become independent. As γ approaches 1, the products of the firms become completely homogeneous. In the remainder we will sometimes refer to a market with rather homogenous goods as a market with tough competition. The resulting inverse market demands are linear and given by $P_i(q_i, q_j) = \alpha - q_i - \gamma q_j$, $i, j = 1, 2, i \neq j$. While some results generalize to other types of demand functions, the linear case is more tractable and needed to derive closed form solutions. This allows us to better investigate implications for welfare. Moreover, this demand specifications allows us to relate our model to the existing models on the comparison of different modes of competition, where this linear demand is widely used.

The downstream competitors have ex-ante symmetric constant marginal costs of production denoted by c. In our model, an investment possibility affecting the downstream firms' technology exists. We restrict our analysis to investment into downstream cost-reduction Δ_i to lower the perceived marginal cost of providing the downstream product from $w + c$ to $w + c_i$ with $c_i = c - \Delta_i$.

This investment can either be conducted by the downstream firms or by the upstream monopolist. The regulator decides ex-ante which sector is responsible for the investment. Therefore, our analysis distinguishes between two cases. In the first case, the upstream firm undertakes the investment. In the second case, the two downstream firms invest themselves. Regardless of which sector is undertaking the investment, it has to be done for each downstream firm sepa-

[20]The same approach is used by Valletti and Cambini (2005). Though the assumption on the timing of the regulator's decision making might seem strong, the wholesale price set by the regulators provides some commitment. Valletti (2003) stresses the need, when implementing a regulatory policy, that regulators are endowed with some commitment power over time. A discussion on the commitment value of a regulator's decision can be found in Guthrie (2006) and Spiller (2005), p. 627-630.

rately. Hence, both industry segments have the same cost structure in investing. For the case of the upstream investment regime, we impose a non-discrimination clause, i.e. the monopolist has to treat every firm equally, $\Delta_i = \Delta_j = \Delta$. This reflects the regulatory situation in most countries.[21] We assume quadratic cost functions $\frac{K}{2}\Delta_i^2$ per downstream firm for the investment, where K is the marginal cost parameter. This assumption is needed to ensure that the cost of investment is identical among both investment regimes. I.e., otherwise the upstream monopolist would suffer diseconomies of scale in investment compared to the downstream firms. Moreover, it is assumed that the investment is not verifiable. Hence, the regulator cannot condition the regulated wholesale price w on the investment.

The timing is as follows: At stage 1 the regulator determines the investment regime and the regulated wholesale price w. Then, at stage 2 the respective investor(s) take(s) the investment decision. Finally, at stage 3 competition in quantities or prices takes place.

The model is solved through backward induction and we restrict the analysis to symmetric equilibria.

3 Cournot competition

In this section, we investigate the differences in investment activity among the two different institutional regimes (upstream vs. downstream investment) under *Cournot competition*. In the final competition stage, we take the firms' marginal costs c_i as given. The investment stage, where c_i is endogenous, is analyzed subsequently for the two different investment regimes.

3.1 Competition Stage

At stage 3, two firms with differentiated products compete downstream in quantities taking the investment decision in stage 2, Δ_i, as well as the regulated access price, w, as given. Except for the firms' individual marginal cost c_i, depending on the previous investment in cost-reduction Δ_i competition will be identical across investment regimes.[22]

Both downstream firms face symmetric objective functions of the form

$$\pi_i = (P_i(q_i, q_j) - w - (c - \Delta_i)) \cdot q_i.$$

The term in brackets represents firm i's margin which depends on $P_i(q_i, q_j)$, the regulated whosesale price w, the ex-ante symmetric marginal costs c and the firm-specific investment Δ_i. The optimality condition with respect to i's quantity thus requires:

[21] E.g. the German Energy Industry Act demands that network operators handle their business in a non-discriminatory fashion, §11(1) EnWG.

[22] Note that we denote firm specific investment levels with subscript i, though under the upstream investment regime investments will be identical over firms due to a non-discrimination rule.

$$\frac{\partial \pi_i}{\partial q_i} = (P_i(q_i, q_j) - w - (c - \Delta_i)) + \frac{\partial P_i(q_i,q_j)}{\partial q_i} \cdot q_i = 0.$$

A Nash-Equilibrium in quantities exists in which each downstream firm produces an output of $q_i^* := arg\,\underset{q_i}{max}\, \pi_i$. For the reference case of linear demand, this becomes

$$q_i^C = \frac{(\alpha - c - w)(2-\gamma) + 2\Delta_i - \gamma\Delta_j}{4-\gamma^2}.$$ [23]

Note that the effect of the degree of product differentiation γ on firm and industry output is negative. Hence, tougher competition in the market expressed by a smaller degree of product differentiation lowers industry output. Under Cournot competition, firms' choice variables (quantities) are *strategic substitutes*. When one firm acts aggressively by increasing its output, the optimal reaction of the rival firm is to respond accomodatingly and slightly reduce its own output. This reaction is stronger, the tougher the competition in the market is. Intuitively, decreasing the degree of product differentiation in a market makes competition for firms tougher. This makes firms react as in the case when its competitors act aggressively and lower their output themselves. As all firms will behave in the same way, industry output will decrease with tougher competition.

3.2 Investment Stage

At stage 2, the investor decides on investment in cost-reduction. The setting differs depending on the investment regime the regulator has chosen at stage 1. While under the upstream investment regime the monopolist invests, under the downstream investment regime the two downstream competitors are responsible for investment. In this section, we distinguish between these two cases, taking the equilibrium quantities of stage 3 as given.

3.2.1 Upstream Investment Regime

Under the upstream investment regime the monopolist chooses how much to invest in the cost-reduction of the downstream firms. It anticipates downstream industry demand Q^C and takes the wholesale price w as given. We assume that the regulator enforces a non-disrimination rule so that the monopolist has to invest the same amount into the cost structure of each downstream competitor, $\Delta_i = \Delta_j$, $i \neq j$. The upstream monopolist maximizes:

$$\pi^U = w \cdot Q^C(\Delta_i, \Delta_j) - \left(\frac{K}{2} \cdot \Delta_i^2 + \frac{K}{2} \cdot \Delta_j^2\right) - F.$$

The first term consists of the regulated wholesale price, which also represents the monopolist's margin, multiplied by total industry output. As the wholesale price is regulated and identical

[23] The respective equilibrium prices are given by $p_i^C = \left((2-\gamma)(\alpha+(1+\gamma)(c+w)) - (2-\gamma^2)\Delta_i - \gamma\Delta_j\right)/(4-\gamma^2)$ and total output is $Q^C = (2(\alpha-c-w)(2-\gamma)+(2-\gamma)(\Delta_i+\Delta_j))/(4-\gamma^2)$.

over all downstream firms, the monopolist only considers overall industry output, regardless of the actual downstream producer. The second term constitutes the cost of investment. Finally, the monopolist has to incur a fixed cost.

The first order condition yields the following optimality condition:

$$\frac{\partial \pi^U}{\partial \Delta_i} = w \cdot \frac{\partial Q^C(\Delta_i,\Delta_j)}{\partial \Delta_i} - \frac{\partial K(\Delta_i)}{\partial \Delta_i} = 0.$$

Why should the monopolist invest when the investment does not affect its own cost structure? The answer is given by the first term of the optimality condition: Though the monopolist does not directly gain from investment, it gains indirectly. Investment will lower the marginal cost of the downstream firms and thus will increase market output.[24] As long as the wholesale margin is positive ($w > 0$), an output increase is profitable for the monopolist.

For our reference case of linear demand, the investment level is given by

$$\Delta_U^C = \frac{w}{K(2+\gamma)}.$$ [25]

From the derivatives of the equilibrium investment, we can easily derive the comparative statics of interest

$$\frac{\partial \Delta_U^C}{\partial w} > 0, \quad \frac{\partial \Delta_U^C}{\partial K} < 0, \quad \frac{\partial \Delta_U^C}{\partial \gamma} < 0 \ .$$

Result 1 *Under Cournot competition and with the upstream investment regime, investments are (i) increasing in the regulated wholesale price w and (ii) decreasing in the marginal investment cost K as well as (iii) in the intensity of competition, expressed through the product differentiation parameter γ.*

(*i*) A higher wholesale price w increases the monopolist's margin. This again increases the marginal benefit of an additional unit of output and a higher investment level becomes optimal. (*ii*) Increasing the marginal cost of investment, K, has the opposite effect on the investment incentive. As investment becomes more expensive, incentives to invest are reduced and a smaller investment level becomes optimal. (*iii*) Finally, the investment level will be lower the tougher the competition is (expressed via a higher γ). As pointed out before, when product differentiation is weak in the market, firms respond strongly to their competitors' behavior. When the monopolist lowers the downstream firms' marginal costs through investment, they increase their output. But as the firms' response on their competitors' output rise is negative, the overall output increase will be relatively modest. With tougher competition, this second (negative) effect will become stronger and the overall output increase from the investment smaller.

[24] In our reference case, this output increase is given by $\partial Q^C / \partial \Delta = 2/2+\gamma > 0$.

[25] The SOC is fulfilled for any $K > 0$.

Therefore, investment becomes less profitable for the monopolist with tougher competition.[26] From comparison of the derivatives of the monopolist's profit π^U and welfare W with respect to the investment Δ we find that, whatever the wholesale price set by the regulator, the monopolist will never invest efficiently.

Proposition 1 *Under Cournot competition, with the upstream investment regime and for a given wholesale price, investment by the upstream monopolist is always too low from a social welfare point of view.*

Proof. See Appendix. ■

Investment by the monopolist will always be below the socially optimal level. This is not surprising as the monopolist's sole incentive to invest comes from industry output increases induced by the investment. In contrast, a welfare maximizing regulator takes into account the investment effect on the whole economy, including the upstream as well as downstream firm's profit and consumer surplus.

3.2.2 Downstream Investment Regime

Under the downstream investment regime, the downstream firms choose how much to invest into reduction of their own marginal costs. They take the access price w as given and anticipate their future demand q_i and q_j. The downstream competitors non-cooperatively maximize

$$\pi_i^D = \left(P_i\left(q_i^*\left(\Delta_i, \Delta_j\right), q_j^*\left(\Delta_j, \Delta_i\right)\right) - \left(w + c - \Delta_i\right)\right) \cdot q_i^*\left(\Delta_i, \Delta_j\right) - \tfrac{K}{2}\Delta_i^2.$$

In contrast to the monopolist, downstream firms do not consider the effect of investment on the industry output level, but on their own total (inframarginal) output and prices. Therefore, the analysis is more elaborate.

Maximization with respect to the investment Δ_i yields the following optimality condition

$$\tfrac{\partial \pi_i^D}{\partial \Delta_i} = \left(\underbrace{\frac{\partial P_i(q_i^*, q_j^*)}{\partial q_i}}_{=0} \tfrac{\partial q_i}{\partial \Delta_i} + \underbrace{\frac{\partial P_i(q_i^*, q_j^*)}{\partial q_j} \frac{\partial q_j}{\partial \Delta_i}}_{strategic\, effect} \right) \cdot q_i^* + \underbrace{q_i^*}_{quantity\, effect} - \underbrace{K\Delta_i}_{cost\, effect}.$$

In the investment decision of a single downstream firm, we can distinguish between the following different effects: (i) Investment comes at a cost (*cost effect*). (ii) As the investment lowers the unit cost of production, the firm has a positive effect of investment on every unit of output

[26] Note that the negative effect of the intensity of competition on industry output mentioned before does not play a direct role for the monopolists investment incentives. As the investment only affects the cost structure of the downstream competitors, the monopolist gains through output changes through investment and not through a cost decrease on the inframarginal output. In other words, not the total industry output, but the output change through investment matters for the monopolist's investment incentives.

(*quantity effect*). Hence, the larger the firm's output, the bigger is this effect. This is in contrast to the result under the upstream investment regime, where the monopolist only considers output changes, but not the cost reduction on the inframarginal output. (*iii*) Finally, a *strategic effect* from investment exists. As pointed out before, under Cournot competition the firms' output decisions are strategic substitutes. I.e. when a firm acts aggressively in the market by increasing its output, the rival firm will react in an accomodating way and reduce its own sales. Hence, a firm gains from investment as it induces an output reduction of the rival firm.[27]

The corresponding optimal investment level per firm with linear demand is

$$\Delta_i^C = \frac{4(\alpha - w - c)}{K(2+\gamma)(4-\gamma^2)-4}$$ [28]

and overall industry investment (with symmetry) is given by

$$\Delta_D^C = \frac{8(\alpha - w - c)}{K(2+\gamma)(4-\gamma^2)-4}.$$

Again, from the derivatives of the equlibrium investment we find

$$\frac{\partial \Delta_D^C}{\partial w} < 0, \quad \frac{\partial \Delta_D^C}{\partial K} < 0, \quad \frac{\partial \Delta_D^C}{\partial \gamma} < 0\, for\, \gamma < \tfrac{2}{3}\ .$$

Result 2 *Under Cournot competition and with the downstream investment regime, firm and industry investments are decreasing* (*i*) *in the regulated wholesale price* w, (*ii*) *in the marginal investment cost* K *and* (*iii*) *in the intensity of competition - expressed by the product differentiation parameter* γ *- as long as product differentiation is ratherstrong.*

(*i*) The wholesale price w has a negative effect on the investment activity of the downstream firms. To understand this, consider that w and Δ_i have diametrical effects on the downstream firm i's cost structure. While w increases the firm's marginal cost of production, Δ_i lowers it. As a firm with lower marginal costs will have a higher output, the quantity effect of investing becomes larger and a bigger Δ_i optimal as the benefit of investment can be materialized over a larger quantity.[29] (*ii*) Increasing the marginal cost of investment K has the identical effect as in the upstream investment regime. Investment becomes more expensive and thus a smaller investment level optimal. (*iii*) The influence of product differentiation on investment is twofold. While an increase in γ has a positive impact on the strategic effect of investment, the impact on the quantity effect is negative. When competition becomes tougher, the rival's responsiveness on the firm's output changes becomes stronger. Thus, under Cournot competition an investment becomes more attractive as the firm's competitive position is improving. On the contrary, an increase in product homogeneity decreases individual sales (as well as industry sales) and

[27] The effect of the investment on the investing firm's own price can be ignored as it is only of second order.

[28] Note that the SOC is fulfilled if $K > 8/(4-\gamma^2)^2$.

[29] More technically, as downstream profits π_i are convex in a firm's marginal cost, given by $(w + c - \Delta_i)$, a higher w always reduces investment incentives.

hence the quantity effect. Whereas the latter effect dominates for low levels of competitiveness ($\gamma < 2/3$), the first effect is stronger when the competition is already sufficiently tough ($\gamma > 2/3$). Again, from the derivatives of the competitors' profits and welfare w.r.t. the investment we find that, whatever the wholesale price set by the regulator, the competitors will never invest efficiently.

Proposition 2 *Under Cournot competition, with the downstream investment regime as well as for a given wholesale price, investment by the downstream competitors is too low from a social welfare point of view.*

Proof. See Appendix. ■

The result for investment under the downstream investment regime is more interesting than under the upstream investment regime. Though, downstream firms consider a strategic effect in their investment decision and the resulting investment levels are relatively high, investment is still below the socially optimal level.

3.2.3 Comparison of Upstream and Downstream Investment Regimes

Now we can compare the investment outcomes among the two different institutional regimes. The industry investment levels are given by

$$\Delta_U^C = \frac{w}{K(2+\gamma)}, \quad \Delta_D^C = \frac{8(\alpha-w-c)}{K(2+\gamma)(4-\gamma^2)-4} .$$

Comparing the investments and using the results in Proposition 1 and Proposition 2, we can state our main result under Cournot competition:

Proposition 3 *Under Cournot competition, the overall investment level is larger in the downstream investment regime relative to the upstream investment regime, $\Delta^*_{Downstream} > \Delta^*_{Upstream}$. Moreover, the downstream investment regime is always superior in welfare terms compared to the upstream investment regime.*

Proof. See Appendix. ■

The proposition formalizes that under Cournot competition the investment activity in the downstream investment regime is larger than in the upstream investment regime. Furthermore, as both investment regimes fall short of the socially optimal investment outcome, the investment regime that provides stronger investment incentives is better for welfare, and hence, should be chosen by the regulator. The intuition of the first part of the proposition is a bit elaborate as different effects are at work among the different investment regimes. As indicated above, under Cournot competition downstream firms have relatively strong investment incentives, while the upstream monopolist has relatively weak incentives to invest.

When downstream firms are responsible for investment, a firm's marginal investment effect consists of three different elements as mentioned before: (*i*) The quantity effect captures the cost reduction over the firm's sales and grows with the size of the firm, (*ii*) the cost effect captures the marginal cost of investment, and (*iii*) a positive strategic investment effect, as firms compete in strategic substitutes.

In contrast, when the upstream monopolist invests, it only considers the overall output increase of its investment activity.[30] Therefore, it ignores the strategic as well as the quantity effect on a single firm's output. Hence, as downstream competition works in an accomodating way, a general decrease in the downstream marginal cost due to an investment is followed by a relatively modest increase in overall quantity. Thus, investment incentives for the upstream firm are relatively small under Cournot competition.

The higher w, the smaller is the difference between investment among the two regimes. We can observe the reverse outcome, when w is above the price a monopolist would set.[31] This result will never occur, even without price regulation.

3.3 Price Regulation

At stage 1 the regulator determines the regulated wholesale price w as well as the investment regime. In order to sustain the monopoly network infrastructure, a positive wholesale price $w > 0$ is needed to cover the upstream fixed costs F as well as potential investment costs. As long as the regulator does not fix the wholesale price at the upstream marginal cost, competitive distortions arise at the downstream level. In this section, we will analyze how the regulator should set the wholesale price in order to achieve a good investment performance.

We conduct the analysis only for the downstream investment regime, as it is superior from a welfare perspective.[32]

Downstream Investment Regime

The regulator faces the following effects when increasing the wholesale price w above the monopolist's marginal cost. A higher wholesale price stifles investment incentives of the downstream competitors and downstream competition will be distorted as a wholesale price above marginal cost creates a double marginalization problem. For determining the optimal wholesale price an evaluation of these effects is necessary. The social welfare measure is given by the sum of consumer and producer surplus.

$$W = CS + \pi^U + 2 \cdot \pi^D$$

$$W = \frac{3+\gamma}{(2+\gamma)^2}\left(\alpha - c - w + \frac{8(\alpha-w-c)}{K(2+\gamma)(4-\gamma^2)-4}\right)^2 + \frac{2w}{2+\gamma}\left(\alpha - c - w + \frac{8(\alpha-w-c)}{K(2+\gamma)(4-\gamma^2)-4}\right) - K\left(\frac{8(\alpha-w-c)}{K(2+\gamma)(4-\gamma^2)-4}\right)^2$$

[30] As pointed out before this is not identical to the output effect of the downstream firms.

[31] A monopolist would always set a price equal to $w^* = (2(\alpha-c)+\Delta_i+\Delta_j)/4$.

[32] The analysis for the upstream investment regime is provided in the appendix.

Proposition 4 *Under Cournot competition and with the downstream investment regime, welfare, consumer surplus, and downstream profits always decrease in the regulated wholesale price w. Thus, a welfare maximizing regulator should choose the smallest possible positive mark-up over the upstream margin, so that the monopolist can just meet its reservation profits.*

Proof. See Appendix. ■

As downstream investment is always below the socially efficient level and a wholesale price above upstream marginal cost $w > 0$ stifles investment incentives and distorts downstream competition, increasing w is always detrimental for welfare. Hence, under the downstream investment regime the smallest possible wholesale price should be chosen to maximize investment incentives.

4 Bertrand competition

Now we consider a setting that is analogous to the setting analyzed in section 3 except for the fact that the downstream firms engage in Bertrand (price-setting) competition rather than Cournot (quantity-setting) competition. As before, in the final competition stage we take the firms' marginal costs c_i as given. The investment stage, where c_i is endogenous, is analyzed subsequently.

4.1 Competition Stage

At stage 3 two firms with differentiated products compete downstream in prices taking the investment decision Δ_i as well as the regulated wholesale price w as given. Except for the firms' individual marginal cost c_i, depending on the previous investment in cost-reduction Δ_i, competition will be identical across investment regimes. Both downstream firms face symmetric profit functions of the form

$$\pi_i = (p_i - w - (c - \Delta_i)) \cdot q_i (p_i, p_j),$$

where p_i is firm i's price and p_j is the price of the rival firm j. The demand for firm i's product is given by $q_i (p_i, p_j)$. The term in brackets represents firm i's margin which depends on p_i , the regulated whosesale price w, the ex-ante symmetric marginal costs c and the firm-specific investment Δ_i. The optimality condition with respect to the price thus requires

$$\frac{\partial \pi_i}{\partial p_i} = (p_i - w - (c - \Delta_i)) \cdot \frac{\partial q_i (p_i, p_j)}{\partial p_i} + q_i (p_i, p_j) = 0.$$

A Nash-Equilibrium exists in which each downstream firm sells at price $p_i^B := arg \max_{p_i} \pi_i$. For the reference case of linear demand, the firm's quantity becomes

$$q_i^B = \frac{(1-\gamma)(2+\gamma)(\alpha-c-w)+\left(2-\gamma^2\right)\Delta_i-\gamma\Delta_j}{(1-\gamma^2)(4-\gamma^2)}.$$[33]

Note that the effect of the degree of product differentiation γ on industry output is different from that before. While under Cournot competition this effect was always negative, under Bertrand competition the effect is negative if product differentiation is already strong ($\gamma < 1/2$), while it is positive when product differentiation is weak ($\gamma > 1/2$).

This result is due to two countervailing effects. Altering the degree of product differentiation has a direct effect on industry quantity as it changes the representative consumer's demand for each product. Decreasing the degree of product differentiation increases the substitutability of the two products. This in turn decreases the consumers' demand as less variety is available in the market. This effect dominates for $\gamma < 1/2$. Moreover, increasing γ makes competition tougher. With tougher competition firms' reactions to their rivals' behavior will become stronger. Downstream firms' choice variables (prices) are strategic complements under Bertrand competition. When one firms acts aggressively by lowering its price, the optimal reaction of the rival firm is also to respond aggressively and lower its own price. This reaction gets stronger the more competitive the market becomes. As market prices lower with more competition, consumer demand and industry output increase. This interesting indirect effect dominates for $\gamma > 1/2$.[34]

4.2 Investment Stage

As before at stage 2, the investor decides on investment. The setting differs depending on the investment regime the regulator has chosen.

4.2.1 Upstream Investment Regime

The upstream infrastructure provider maximizes with respect to the non-discrimination rule $\Delta_i = \Delta_j$, $i \neq j$

$$\pi_B^U = w \cdot Q^B\left(p_i, p_j\right) - \tfrac{K}{2}\left(\Delta_i^2 + \Delta_j^2\right) - F.$$

The interpretation of the objective function is identical to that under Cournot competition, only equilibrium quantities differ.

The first derivative w.r.t. Δ_i yields the following optimality condition:

$$\frac{\partial \pi_B^U}{\partial \Delta_i} = w \cdot \frac{\partial Q^B(\Delta_i,\Delta_j)}{\partial \Delta_i} - \frac{\partial K(\Delta_i)}{\partial \Delta_i} = 0.$$

For our reference case of linear demand, the corresponding optimal investment level is

[33] In the case of linear demand we find symmetric Bertrand prices of $p_i^B = \left(((1-\gamma)\alpha+c+w)(2+\gamma)-2\Delta_i-\gamma\Delta_j\right)/\left(4-\gamma^2\right)$. Total output is given by $Q^B = \left(2(\alpha-c-w)+\Delta_i+\Delta_j\right)/\left((1+\gamma)(2-\gamma)\right)$.

[34] A more thorough explanation of the interplay of these two effects can be found in the appendix A.1.

$$\Delta_U^B = \frac{w}{K(2-\gamma)(1+\gamma)}.$$ [35]

Now, we can derive comparative statics with respect to w, K and γ.

$$\frac{\partial \Delta_U^B}{\partial w} > 0, \quad \frac{\partial \Delta_U^B}{\partial K} < 0, \quad \frac{\partial \Delta_U^B}{\partial \gamma} > 0 \;\; for\, \gamma > \tfrac{1}{2}.$$

Result 3 *Under Bertrand competition and with the upstream investment regime, investments are (i) increasing in the regulated wholesale price w, (ii) decreasing in the marginal cost of investment K and (iii) increasing in the intensity of the competition, expressed through the product differentiation parameter γ, for markets with rather tough competition $\left(\gamma > \frac{1}{2}\right)$.*

Though the comparative statics with respect to w and K are qualitatively identical to the Cournot case, the quantitive effects of w and K on the investment are stronger under Bertrand competition. This is due to the fact that Bertrand competition is more aggressive and therefore more responsive to changes to the environment than Cournot competition. The derivative with respect to γ is even qualitatively different from that under Cournot competition. It is positive for rather competitive markets and negative otherwise. (For comparison: Under Cournot competition it was always negative.) This result is in line with the effect of product differentiation on total market demand, which was explained in subsection 4.1.

Again, from the derivatives of the monopolist's profit and welfare, we find that whatever the wholesale price set by the regulator, the monopolist will never invest socially efficient.

Proposition 5 *Under Bertrand competition, with the upstream investment regime and for a given wholesale price, investment by the upstream monopolist is always too low from a social welfare point of view.*

Proof. See Appendix. ■

Though upstream investment may be more profitable under Bertrand competition compared to Cournot competition, the monopolist's investment incentives still fall short of the socially optimal investment.

4.2.2 Downstream Investment Regime

Under the downstream investment regime, firms choose how much to invest. They take the access price w as given and anticipate their realized market prices p_i and p_j. The firms non-cooperatively maximize

$$\pi_i^D = \left(p_i^*\left(\Delta_i, \Delta_j\right) - w - \left(c - \Delta_i\right)\right) \cdot q_i\left(p_i^*\left(\Delta_i, \Delta_j\right), p_j^*\left(\Delta_j, \Delta_i\right)\right) - \frac{K}{2}\Delta_i^2.$$

Maximization with respect to their investment, Δ_i, yields the following optimality condition

[35] The SOC is again fulfilled for any $K > 0$.

$$\frac{\partial \pi_i^D}{\partial \Delta_i} = (p_i^* - w - (c - \Delta_i)) \cdot \left(\underbrace{\frac{\partial Q_i\left(p_i^*, p_j^*\right)}{\partial p_i^*}}_{=0} \frac{\partial p_i^*}{\partial \Delta_i} + \underbrace{\frac{\partial Q_i\left(p_i^*, p_j^*\right)}{\partial p_j^*} \frac{\partial p_j^*}{\partial \Delta_i}}_{strategic\, effect} \right) + \underbrace{q_i\left(p_i^*, p_j^*\right)}_{quantity\, effect} - \underbrace{K\Delta_i}_{cost\, effect} .$$

Again, we can distinguish between different effects in the investment decision. The cost effect is identical to the Cournot case. The quantity effect has the same sign as before, but as quantities are usually higher under Bertrand competition, its size may also be bigger. However, now a negative strategic effect exists. When a firm invests into a decrease of its own marginal costs it causes more aggressive competition in the market and hurts its own profits, resulting in a disincentive to invest.

The corresponding optimal investment level for the case of linear demand is

$$\Delta_i^B = \frac{2\left(2-\gamma^2\right)(\alpha - w - c)}{K(1+\gamma)(2-\gamma)(4-\gamma^2) - 2(2-\gamma^2)}$$ [36]

Overall (industry) investment (with symmetry)

$$\Delta_D^B = \frac{4\left(2-\gamma^2\right)(\alpha - w - c)}{K(1+\gamma)(2-\gamma)(4-\gamma^2) - 2(2-\gamma^2)}.$$

Again, we derive comparative statics with respect to w, K and γ.

$$\frac{\partial \Delta_D^B}{\partial w} < 0, \quad \frac{\partial \Delta_D^B}{\partial K} < 0, \quad \frac{\partial \Delta_D^B}{\partial \gamma} < 0\, for\, \gamma > 3/5\ .$$

Result 4 *Under Bertrand competition and with the downstream investment regime, investments are decreasing (i) in the regulated wholesale price w, (ii) in the marginal cost of investment K and (iii) the degree of product differentiation γ as long as product differentiation is not too strong.*

Again, the qualitative effects of w and K on the equilibirum investment are again identical to the Cournot case. As under the upstream investment regime, the effects are quantitatively stronger under Bertrand competition due to the higher responsiveness to changes in the environment.

The effect of an increase in the competitiveness on the investment is qualitatively different and therefore of even higher interest to us. When increasing the competitiveness, both the quantity as well as the strategic effect are affected.

A larger γ increases the firms' output and thus, the whole industry output for $\gamma > 1/2$. The quantity effect of investment becomes larger as the lower cost from investment can be spread over a larger output, which affects investment positively. For $\gamma < 1/2$ the effect of a larger γ on industry output is negative and hence also the quantity effect decreases in the competitiveness.[37]

[36] Note that the SOC is fulfilled if $K > 2\left(2-\gamma^2\right)^2 / (1-\gamma^2)(4-\gamma^2)^2$. It ensures that K is large enough in order to ensure an interior solution of optimal investment spending. Suppose that K is small, i.e., that investing is not too costly. Then, a large investment can always create a cost advantage which suffices to win the price war. Hence, K must be large to avoid such a corner solution.

[37] A more elaborate analysis of this phenomenon can be found in Subsection 4.1.

In addition, a larger γ also makes the strategic effect more important. As this effect is always negative under Bertrand competition, having more homogeneous goods increases the (negative) strategic effect and therefore affects investment negatively. As is shown by the comparative static, the investment dampening effects are larger than the investment enhancing effect in a rather competitive environment ($\gamma > 3/5$).

From the derivatives of the competitors' profits and welfare we find that, whatever the wholesale price set by the regulator, the competitors will never invest socially efficient.

Proposition 6 *Under Bertrand competition and with the downstream investment regime as well as for a given wholesale price, investment by the downstream competitors is too low from a social welfare point of view.*

Proof. See Appendix. ■

As firms include a negative strategic effect in their investment decision the resulting investment levels will be relatively low. Thus, under Bertrand competition the downstream investment behavior will always fall short of the socially optimal investment level.

4.2.3 Comparison of Upstream and Downstream Investment Regimes

Finally, we compare the investment outcomes among the two different institutional regimes in order to derive possible policy implications for the regulator. The industry-wide investment levels are given by

$$\Delta_U^B = \frac{w}{K(2-\gamma)(1+\gamma)}, \quad \Delta_D^B = \frac{4\left(2-\gamma^2\right)(\alpha-w-c)}{K(1+\gamma)(2-\gamma)(4-\gamma^2)-2(2-\gamma^2)},$$

From comparison of the investments we get the following proposition

Proposition 7 *Under Bertrand competition, the overall investment level is larger in the downstream investment regime relative to the upstream investment regime, $\Delta^*_{Downstream} > \Delta^*_{Uptream}$, whenever w is below a threshold $w < \hat{w}_B = \frac{2-\gamma^2}{4-\gamma^2}(\alpha - c)$. Moreover, the downstream investment regime is superior in welfare terms compared to the upstream investment regime as long as $w < \hat{w}_B$.*

Proof. See Appendix. ■

The proposition formalizes that, under Bertrand competition, the investment activity under the downstream investment regime is larger - and closer to the social optimum - than under the upstream investment regime, as long as the upstream margin is not relatively large.

This result is in contrast to what we have seen under Cournot competition, where the upstream investment regime was always inferior compared to the downstream investment regime, [38].

[38] The threshold on the wholesale price is always below the price a monopolist would set, $\hat{w}_C < w_C^M = (2(\alpha-c)+\Delta_i+\Delta_j)/4$.

This stems from two effects. On the one hand, as under Bertrand competition firms compete in strategic complements, investing makes downstream competition tougher and hence, gives downstream firms a disincentive to invest.[39] On the other hand, the monopolist profits from aggressive downstream competition, as a general decrease in downstream marginal costs is followed by a relatively large increase in overall quantity.[40] Thus, investment incentives for the upstream monopolist are relatively large when compared to the Cournot case and upstream investment exceeds downstream investment for a comparatively lower upstream margin.

As a result of the different effects at work, wholesale prices exist where upstream investment will be larger and hence, superior from a welfare perspective, than downstream investment under Bertrand competition and the opposite would hold true under Cournot competition. This is due to the fact that upstream investment under Bertrand competition is more effective than under Cournot competititon and for downstream investment, it is vice versa.

We formalize this main result of our paper in the next proposition

Proposition 8 *A range of wholesale prices* $w\epsilon \left[\hat{w}_B, w_C^M\right]$ *exists, where with linear demand and under Bertrand competition the upstream investment regime yields a superior outcome from a welfare perspective compared to the downstream investment regime, while under Cournot competition the downstream investment regime is better from a welfare perspective.*

Proof. See Appendix. ■

Hence, the welfare maximizing regulator should always consider in what mode the competition works at the downstream stage while determining a specific investment regime.

In addition, we have the following finding of the degree of competition on the investment outcome.

Corollary 1 *Under Bertrand competition and for large upstream margins, the investment incentives of the downstream investment regime decrease relative to the upstream investment regime when competition is tougher.*

Proof. See Appendix. ■

This proposition states that tougher competition is enhancing investment incentives of the upstream monopolist and stifling investment incentives of the downstream competitors. The reason for this result is that the investment incentive of the upstream monopolist increases in the intensity of competition if it is already high, while tougher competition stifles the downstream firms' investment incentives, when the market is not competitive. The two effects in detail: On the one hand, increasing the competitiveness of the downstream sector increases the upstream

[39] In comparison to the Cournot case under Bertrand competition market output is larger, what increases the quantity effect of investment and counteracts the negative strategic effect to some extent.

[40] Formally, $\partial q_i^B / \partial \Delta_i = (2-\gamma^2)/(1-\gamma^2)(4-\gamma^2) > 0$

investment activity, if product differentiation is not too strong. As products become more homogeneous, the strategic effect in marginally increasing a firm's output is increasing, i.e., a firm's responsiveness of a change in the rival's output (due to a decrease in their costs) increases and both (relatively) become more reactive to cost-decreases.[41]

On the other hand, an increase in the competitiveness of the downstream sector decreases the investment activity of the downstream firms for a rather competitive market $\gamma > 3/5$. With a decrease in the degree of product differentiation, firms become more aggressive and the reaction on marginal cost decrease will be larger. Thus, investment becomes less profitable and firms will invest less. The result under Cournot competition is the opposite as the strategic effect has the reverse sign.

4.3 Price Regulation

At stage 1 the regulator determines the regulated wholesale price w as well as the investment regime. In this section, we will analyze how the regulator should set the wholesale price in order to achieve a good investment performance. As no clear prediction regarding the optimal investment regime exists, we will consider the optimal price regulation strategy for both regimes now.

4.3.1 Upstream Investment Regime

As before, for determining the optimal wholesale price we have to explore the effect on overall welfare. The social welfare measure is given by the sum of consumer and producer surplus:

$$W = CS + \pi^U + 2 \cdot \pi^D$$

$$W = (1+\gamma)(3-2\gamma)\left(\frac{(\alpha-c-w)+\frac{w}{K(2-\gamma)(1+\gamma)}}{(1+\gamma)(2-\gamma)}\right)^2 + 2\cdot w \cdot \frac{\alpha-c-w+\frac{w}{K(2-\gamma)(1+\gamma)}}{(1+\gamma)(2-\gamma)} - 2\cdot\frac{K}{2}\left(\frac{w}{K(2-\gamma)(1+\gamma)}\right)^2$$

Proposition 9 *Under Bertrand competition and with the upstream investment regime, welfare and consumer surplus are increasing in the regulated wholesale price w for $w > 0$ and rather cost-effective investment technology. Thus, a welfare maximizing regulator may choose a mark-up over marginal cost even if this is not required to meet reservation profits of the monopolist.*

Proof. See Appendix. ■

The proof shows that for rather cost effective investments the former effect may outweigh the latter and increasing the wholesale price over the monopolist's marginal cost may be welfare increasing. Moreover, it is also shown that for very cost efficient investments, the incentive effect is so strong that an increase in the wholesale price may result in a decrease of perceived downstream marginal cost, i.e., downstream competition will not be distorted, but intensified. Hence, for very cost-effective investments, increasing the wholesale price may also increase consumer surplus as well as the downstream firms' profits.

[41] A detailed explanaition of this effect can be found in the appendix.

4.3.2 Downstream Investment Regime

Under the downstream investment regime, the social welfare function is given by

$$W = CS + \pi^U + 2 \cdot \pi^D$$

$$W = \frac{(3-2\gamma)(\alpha-c-w)}{(1+\gamma)(2-\gamma)^2} \cdot \left(\frac{K(1+\gamma)(2-\gamma)\left(4-\gamma^2\right)+2\left(2-\gamma^2\right)}{K(1+\gamma)(2-\gamma)(4-\gamma^2)-2(2-\gamma^2)} \right)^2 + \frac{2 \cdot w \cdot (\alpha-c-w)}{(1+\gamma)(2-\gamma)} \cdot \frac{K(1+\gamma)(2-\gamma)\left(4-\gamma^2\right)+2\left(2-\gamma^2\right)}{K(1+\gamma)(2-\gamma)(4-\gamma^2)-2(2-\gamma^2)}$$

$$-K \left(\frac{4\left(2-\gamma^2\right)(\alpha-w-c)}{K(1+\gamma)(2-\gamma)(4-\gamma^2)-2(2-\gamma^2)} \right)^2$$

Proposition 10 *Under the downstream investment regime and Bertrand competition, welfare and consumer surplus are always decreasing in the regulated wholesale price w. Thus, a welfare maximizing regulator may choose the smallest possible wholesale price so that the monopolist can just recover its reservation profits.*

Proof. See Appendix. ■

As before, increasing w above its smallest possible value so that the monopolist can recover its fixed costs is always detrimental for welfare as $w > 0$ stifles investment incentives and distorts downstream competition.

Hence, the wholesale price is only an efficient instrument to incentivize investors under the upstream investment regime, but never under the downstream investment regime regardless of the mode of competition.

5 Extension: Partial vertical integration

A broad discussion among researchers as well as regulators on the optimal vertical structure in network industries (partial integration vs. separation) has recently emerged.[42,43] In this section, we shortly investigate the influence of the vertical structure on the superiority of a specific investment regime. Therefore, we study the case, where the upstream monopolist is vertically integrated into the downstream market, i.e. one of the downstream firms is owned by the upstream monopolist, and compare these findings to our results above. We denote - without loss of generality - the integrated monopolist with 1 and the independent downstream firm with 2. While the independent downstream firm only maximizes, as before, its downstream profits, π_2^D, the integrated firm maximizes the sum of upstream and downstream profits, $\pi_1 = \pi^U + \pi_1^D$.

[42] A good overview is provided by Motta (2004). Some recent literature discusses different vertical structures explicitely, Cremer et al. (2006) and Höffler and Kranz (2007a, 2007b).

[43] The discussion reached at its peak with the European Commission forcing the German company E.On to sell its German electricity transmission grid.

5.1 Cournot Game

5.1.1 Competition Stage

At stage 3, two firms with differentiated products compete downstream in quantities taking the investment decision as well as the regulated access price as given. Except for the firms' individual marginal cost, competition will be identical across investment regimes. The integrated monopolist faces the following objective function

$$\pi_1 = w \cdot q_2 + (P_1(q_1, q_2) - c_1) \cdot q_1 = w \cdot q_2 + (P_1(q_1, q_2) - (c - \Delta_1)) \cdot q_1$$

and the independent downstream competitors

$$\pi_2 = (P_2(q_2, q_1) - w - c_2) \cdot q_2 = (P_2(q_2, q_1) - (w + c - \Delta_2)) \cdot q_2.$$

A Nash-Equilibrium in quantities exists in which each downstream firm produces an output of $q_i^* := arg\,\underset{q_i}{max}\,\pi_i$. For the reference case of linear demand, this becomes

$$q_1^* = \frac{(2-\gamma)\cdot(\alpha-c)+\gamma\cdot w+2\cdot\Delta_1-\gamma\cdot\Delta_2}{4-\gamma^2} \quad and \quad q_2^* = \frac{(2-\gamma)\cdot(\alpha-c)-2\cdot w+2\cdot\Delta_2-\gamma\cdot\Delta_1}{4-\gamma^2}.$$ [44]

Note that the higher the upstream margin w the bigger are the distortions on the downstream market. While the integrated firm sells a higher quantity, the independent firm's sales decrease.

5.1.2 Investment Stage

As before at stage 2, the respective investor decides on investment in the downstream firms' marginal costs. The setting differs depending on the investment regime the regulator has chosen.

Upstream Investment Regime The upstream firm maximizes with respect to the non-discrimination rule $\Delta_1 = \Delta_2 = \Delta$.

$$\pi_1 = w \cdot q_2^*(\Delta_2, \Delta_1) + (P_1(q_1^*(\Delta_1, \Delta_2)) - (c - \Delta_1)) \cdot q_1^*(\Delta_1, \Delta_2) - 2 \cdot \frac{K}{2} \cdot \Delta_i^2,\ i = 1, 2.$$ [45]

Downstream Investment Regime The downstream firms maximize

$$\pi_1 = w \cdot q_2^*(\Delta_2, \Delta_1) + (P_1(q_1^*(\Delta_1, \Delta_2)) - (c - \Delta_1)) \cdot q_1^*(\Delta_1, \Delta_2) - \frac{K}{2} \cdot \Delta_1^2$$

[44] Total industry output is $Q^* = \left(2\cdot(2-\gamma)\cdot(\alpha-c)-(2-\gamma)\cdot w+(2-\gamma)\cdot(\Delta_1-\Delta_2)\right)/\left(4-\gamma^2\right)$ and market prices are $p_1^* = \left((2-\gamma)(\alpha+(1+\gamma)\cdot c)+\gamma\cdot w-\left(2-\gamma^2\right)\Delta_1-\gamma\Delta_2\right)/\left(4-\gamma^2\right)$ and $p_2^* = \left((2-\gamma)(\alpha+(1+\gamma)\cdot c)+\left(2-\gamma^2\right)\cdot w-\left(2-\gamma^2\right)\Delta_1-\gamma\Delta_2\right)/\left(4-\gamma^2\right)$.

[45] The equlibrium investment level is $\Delta^* = \left(w(2-\gamma)\left(4-\gamma^2+2\gamma\right)+2(2-\gamma)^2\cdot(\alpha-c)\right)/2\left(\left(4-\gamma^2\right)^2K-(2-\gamma)^2\right)$.

$$\pi_2 = \left(P_2\left(q_2^*\left(\Delta_2, \Delta_1\right)\right) - \left(w + c - \Delta_2\right)\right) \cdot q_2^*\left(\Delta_2, \Delta_1\right) - \tfrac{K}{2} \cdot \Delta_2^2,^{46}$$

5.2 Bertrand Game

5.2.1 Competition Stage

At stage 3, two firms with differentiated products compete downstream in prices taking the investment decision in stage 2, Δ_i, as well as the regulated access price, w, as given. Except for the firms' individual marginal cost c_i, depending on the previous investment in cost-reduction Δ_i competition will be identical across investment regimes.

The firms face the same objective functions as before.

A Nash-Equilibrium in prices exists in which each downstream firm produces an output of $q_i^* := arg\,\underset{p_i}{max}\,\pi_i$. For the reference case of linear demand, this becomes

$$q_1^* = \frac{(1-\gamma)(2+\gamma)\cdot(\alpha-c)+\gamma\cdot\left(1-\gamma^2\right)\cdot w+\left(2-\gamma^2\right)\cdot\Delta_1-\gamma\cdot\Delta_2}{(1-\gamma^2)(4-\gamma^2)}$$

for the integrated monopolist and

$$q_2^* = \frac{(1-\gamma)(2+\gamma)\cdot(\alpha-c)-2\cdot\left(1-\gamma^2\right)\cdot w+\left(2-\gamma^2\right)\cdot\Delta_2-\gamma\cdot\Delta_1}{(1-\gamma^2)(4-\gamma^2)}$$

for the independent competitor.[47]

5.2.2 Investment Stage

As before at stage 2, the investor decides on investment. The setting differs depending on the investment regime the regulator has chosen.

Upstream Investment Regime The upstream firm maximizes with respect to the non-discrimination rule $\Delta_1 = \Delta_2 = \Delta$

$$\pi_1^U = w \cdot q_2\left(p_2^*\left(\Delta_2, \Delta_1\right), p_1^*\left(\Delta_1, \Delta_2\right)\right) + \left(p_1^*\left(\Delta_1, \Delta_2\right) - \left(c - \Delta_1\right)\right) \cdot q_1\left(p_1^*\left(\Delta_1, \Delta_2\right), p_2^*\left(\Delta_2, \Delta_1\right)\right) - 2 \cdot \tfrac{K}{2} \cdot \Delta^{2\,,48}$$

[46]The equlibrium investment levels are $\Delta_1^* = \left(4\cdot(2-\gamma)\cdot(\alpha-c)\left(\left(4-\gamma^2\right)^2\cdot K-8-4\cdot\gamma\right)+\gamma\cdot\left(\left(\left(4-\gamma^2\right)^2\cdot K-8\right)\gamma+32\right)\cdot w\right)/\left(\left(\left(4-\gamma^2\right)^2\cdot K-8\right)^2-(4\cdot\gamma)^2\right)$ and $\Delta_2^* = \left(4\cdot(2-\gamma)\cdot(\alpha-c)\cdot\left(\left(4-\gamma^2\right)^2\cdot K-8-4\cdot\gamma\right)-4\cdot\left(\left(\left(4-\gamma^2\right)^2\cdot K-8\right)2-\gamma^3\right)\cdot w\right)/\left(\left(\left(4-\gamma^2\right)^2\cdot K-8\right)^2-(4\cdot\gamma)^2\right)$. Note that the investment level of the integrated firm is always higher than of the independent firm, $\Delta_1^* > \Delta_2^*$, as the vertically integrated firm has lower marginal costs.

[47]Total industry output is $Q^* = \left(2\cdot(1-\gamma)(2+\gamma)\cdot(\alpha-c)-(2-\gamma)\cdot\left(1-\gamma^2\right)\cdot w+(1-\gamma)(2+\gamma)\cdot(\Delta_1+\Delta_2)\right)/\left(1-\gamma^2\right)\left(4-\gamma^2\right)$ and market prices are $p_1^* = ((2+\gamma)((1-\gamma)\alpha+c)-2\Delta_1-\gamma\Delta_2+3\gamma w)/\left(4-\gamma^2\right)$ and $p_2^* = \left((2+\gamma)((1-\gamma)\alpha+c)-2\Delta_2-\gamma\Delta_1+\left(2+\gamma^2\right)w\right)/\left(4-\gamma^2\right)$.

[48]The equlibrium investment level is $\Delta^* = \left((1-\gamma)(2+\gamma)\cdot(\alpha-c)+\left(2+2\gamma-\gamma^2\right)w\right)/\left(\left((1+\gamma)(2-\gamma)^2K-(1-\gamma)\right)(2+\gamma)\right)$.

Downstream Investment Regime The downstream firms maximize

$$\pi_1^U = w \cdot q_2\left(p_2^*(\Delta_2,\Delta_1), p_1^*(\Delta_1,\Delta_2)\right) + \left(p_1^*(\Delta_1,\Delta_2) - (c-\Delta_1)\right) \cdot q_1\left(p_1^*(\Delta_1,\Delta_2), p_2^*(\Delta_2,\Delta_1)\right) - \tfrac{K}{2}\cdot\Delta_1^2,$$

$$\pi_2 = \left(p_2^*(\Delta_2,\Delta_1) - w - (c-\Delta_2)\right) \cdot q_2\left(p_2^*(\Delta_2,\Delta_1), p_1^*(\Delta_1,\Delta_2)\right) - \tfrac{K}{2}\cdot\Delta_2^2$$

5.3 Comparison of investment regimes

Comparing the investment incentives, we get the following result:

Proposition 11 *Under vertical integration, the overall investment level is always larger in the downstream investment regime relative to the upstream investment regime, regardless of the mode of competition.*

Proof. See Appendix. ■

This result is in contrast to the setting with a vertically separated industry, where we have found that different investment regimes are superior under different modes and intensities of competition. However, when the upstream monopolist is vertically integrated, the regulator should always choose the downstream investment regime. The intuition behind this result is as follows: The investment incentives for the integrated firm in its own downstream marginal costs are identical among investment regimes. Hence, we can focus on the incentives to invest in the independent firm's marginal costs. The independent firm faces similar incentives as in our analysis before. The integrated firm faces two diametrical effects when investing: It benefits from investment as this increases sales (to the rival) on the wholesale market. But investment now also hurts the monopolist's downstream affiliates profits as it makes downstream competition tougher. Hence, the integrated firm always has relatively modest incentives to invest. As under the upstream investment regime investment levels have to be equal across downstream competitors, overall investment will be lower. Therefore, the downstream investment regime yields greater investment outcomes relative to the upstream investment regime.

Finally, we can compare the different investment regimes under different vertical structures. The results are summerized in the following proposition:

Proposition 12 *Under Cournot competition the downstream investment regime under vertical integration is always welfare optimal. Under Bertrand competition, three cases have to be distinguished: The upstream investment regime under vertical separation is optimal whenever* $w > {}^{(2-\gamma^2)}/_{(4-\gamma^2)} \cdot (\alpha - c)$ *and* $w > {}^{8(1+\gamma)}/_{(2+\gamma)(12+5\gamma-3\gamma^2)} \cdot (\alpha - c)$*. The downstream investment regime under vertical integration is optimal whenever* $w < {}^{8(1+\gamma)}/_{(2+\gamma)(12+5\gamma-3\gamma^2)} \cdot (\alpha - c)$ *and* $\gamma > {}^{9}/_{10}$*. The downstream investment regime under vertical separation is optimal for* $\gamma < {}^{9}/_{10}$ *and* $w < {}^{(2-\gamma^2)}/_{(4-\gamma^2)} \cdot (\alpha - c)$*.*

Proof. See Appendix. ■

Under Cournot competition the downstream investment regime under vertical integration is always welfare optimal. Under Bertrand competition, we get three cases, where different combinations are optimal from a welfare perspective. Here, we only provide a short graphical illustration for the more interesting Bertrand case. A more thourough, technical illustration is provided in Appendix A.3.

The upstream investment regime under vertical integration is never optimal. The upstream investment regime under vertical separation is optimal for all w/γ-combinations in area (A). That is under high levels of w. The downstream investment regime and vertical integration is optimal for w/γ-combinations in area (B) and the downstream investment regime and vertical separation is optimal for w/γ-combinations in area (C).

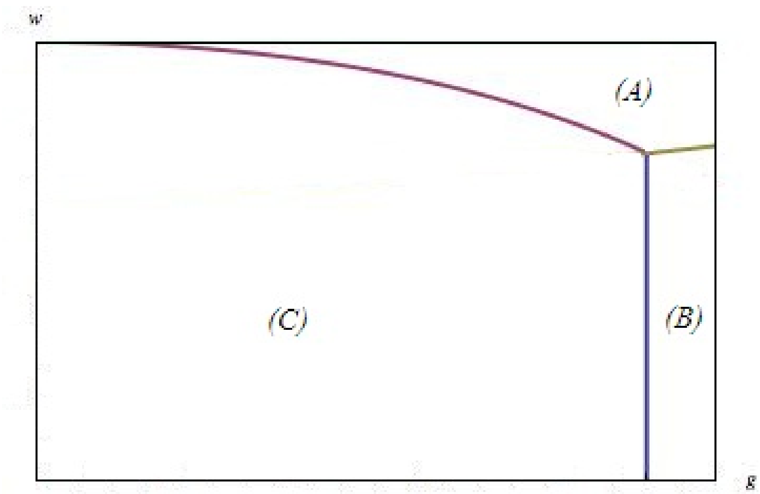

Figure 1: Welfare optimal combinations of investment regime and vertical structure under Bertrand competition

While the upstream investment regime is superior for relatively high levels of w, the downstream investment regime is so for lower levels. Whereas the upstream investment regime should only be chosen together with vertical separation, under the downstream investment regime the optimal vertical structure depends on the degree of competition. Though for most of the parameter range vertical separation is optimal, for very competitive markets vertical integration yields better investment outcomes. Investment by the integrated firm in its own affiliate's cost structure triggers tougher competition on the downstream market and hence, might increase sales on the wholesale market. This gives the integrated firm an additional incentive to invest. The tougher competition becomes, the stronger is this effect.

6 Conclusion

In this paper, we developed a framework to explore the performance of different regulation imposed investment regimes in a vertically related industry. We compared investments in the implementation of a new technology by a regulated upstream monopolist to investments by downstream competitors. We have shown that a welfare maximizing regulator should always consider the nature of downstream competition when determining an investment regime, as different regulatory approaches may be optimal under different modes of competition.

In our model a vertically related monopolistic industry is confronted with a new technological opportunity making available new investment possibilities. As the investment is not directly linked to one of the vertically related segments, it is the regulator who ultimately decides which segment should be responsible for investment. Though the investment possibility is the same in all investment regimes, the incentives to invest differ among these regimes as the regulated upstream monopolist and the (unregulated) downstream firms face different objective functions. More specifically, the investment objective functions are crucially shaped by the nature of downstream competition. We found that, under Cournot competition downstream investment incentives are relatively strong, while under Bertrand competition upstream investment incentives are relatively strong. As all of the investment regimes fall short of the socially optimal investment level, the regulator should always choose the regime providing the strongest incentives to invest. Therefore, in a vertically separated industry under Cournot competition the downstream investment regime is always superior from a welfare point of view, while under Bertrand competition, market environments exist, where the upstream investment regime provides superior investment incentives. Moreover, we found that in a vertically integrated industry, the downstream investment regime always provides the best possible investment incentives.

Furthermore, we showed that the regulator can use the regulated wholesale price as an instrument to achieve an investment outcome closer to the first-best. Increasing the wholesale price enhances upstream investment and dampens downstream investment. This comes at the potential cost of distorting downstream competition and hence welfare. While under the upstream investment regime a wholesale price above cost may be welfare enhancing, under the downstream investment regime the regulator should always choose the smallest possible wholesale price so that the monopolist can just cover its fixed as well as potential investment costs. This result holds under Cournot as well as under Bertrand competition.

Our results have important implications for regulatory policy making and justify sector-specific approaches. Besides considering the specific characteristics of the investment as its cost-structure or where the effects of investment finally occur, the nature and intensity of competition should also be taken into account when the regulator determines the investment regime. These findings are in particular relevant for industries that undergo rapid technological change as is visible in the electricity industry.

As pointed out before, it is a common notion in the literature to interpret different natures of competition as a manifestation of the importance of capacity constraints. This interpretation allows us to derive the following tentative implications for regulatory policy:

In sectors where capacity constraints play an important role on the downstream market, the regulator should opt for the downstream investment regime, as it provides the most efficient investment incentives. This should be accompanied with relatively tough price regulation of the upstream monopolist, as this further improves investment incentives.
In contrast, when capacity constraints are inconsequential and upstream fixed costs in an industry are high (which is often the case in industries where investment has taken place recently) the regulator should opt for the upstream investment regime, as this would provide the most efficient investment regime. This should be accompanied with rather loose price regulation. A similar setting is often given just after cost-plus regulation has been abandoned in an industry.

A Appendix

A.1 Product differentiation and competition

Under Bertrand competition the effect of the degree of product differentiation γ on industry output is negative if product differentiation is already strong ($\gamma < 1/2$), while it is positive when product differentiation is weak ($\gamma > 1/2$). This result is due to two countervailing effects. It can be explained by looking at the equilibrium outputs along the equilibrium prices ($p_i = p_j = p$) depending on γ. We define the equilibrium output as $q(\gamma, p(\gamma)) = a(\gamma) - ((b(\gamma) - c(\gamma))\, p(\gamma))$, where $a(\gamma) = \alpha/1{+}\gamma$, $b(\gamma) = 1/1{-}\gamma^2$ and $c(\gamma) = \gamma/1{-}\gamma^2$. Total differentiation of this expressions gets us get $dq/d\gamma\,(\gamma, p(\gamma)) = da/d\gamma - (db/d\gamma - dc/d\gamma)\, p(\gamma) - (b - c)\, dp/d\gamma$. The first two terms describe the direct effect of increasing the product differentiation. This can also seen by differentiating the demand $q_i = \alpha/1{+}\gamma - 1/1{-}\gamma^2 p + \gamma/1{-}\gamma^2 p$, what gives $\partial q_i/\partial\gamma = \partial/\partial\gamma\,((1-\gamma)\alpha/1{-}\gamma^2 - 1{-}\gamma/1{-}\gamma^2 p) = 1/\gamma{+}1\,(p-1) < 0$ captures the reduced demand of good i through decreasing the degree of product differentiation and is clearly negative. Moreover, a second, for us more interesting, (indirect) effect which works through the market mechanism is at work. Decreasing the degree of product differentiation makes competition tougher, decreases the market price and therefor results in a higher quantity: $-(b-c)\, d/d\gamma\,(1{-}\gamma/2{-}\gamma) > 0$. Expressed in a rather intuitive way this means that with an increasing γ the demand for both products decreases (direct effect), but as prices also decrease (indirect effect) demand also increases. For a rather high degree of product differentiation, $\gamma = 1/2$, the direct effect dominates the indirect effect, but if products are already homogeneous the indirect effect is larger than the direct effect and quantity increases, although valuation for the product decreases.

A.2 Price regulation under Cournot competition

The regulator faces a trade-off when increasing the wholesale price w above the monopolist's marginal cost. While a higher wholesale price strengthens the monopolist's investment incentive, downstream competition will be distorted as a wholesale price above marginal cost creates a double marginalization problem. For determining the optimal wholesale price a comparison of these effects is necessary. The social welfare measure is given by the sum of consumer and producer surplus:

$$W = CS + \pi^U + 2 \cdot \pi^D$$

$$W = (3+\gamma)\left(\frac{\alpha - c - w + \frac{w}{K(2+\gamma)}}{2+\gamma}\right)^2 + 2 \cdot w \cdot \frac{\alpha - c - w + \frac{w}{K(2+\gamma)}}{2+\gamma} - K\left(\frac{w}{K(2+\gamma)}\right)^2$$

We get the following finding: Under Cournot competition, with the upstream investment regime and linear demand, welfare, consumer surplus, and downstream firms' profits may be increasing in the regulated wholesale price w for $w > 0$ and a very cost-effective investment technology (expressed by a low K). Thus, a welfare maximizing regulator should choose a mark-up over marginal cost even if this is not required to meet reservation profits of the monopolist.

Proof.

A marginal increase in the regulated access margin increases the upstream profit

$$\frac{\partial \pi^U}{\partial w} = 2 \cdot \frac{\alpha - c - w\frac{K(2+\gamma)-1}{K(2+\gamma)}}{2+\gamma} + w \cdot \frac{1 - 2K(2+\gamma)}{K(2+\gamma)^2} > 0$$

A marginal increase in the regulated access margin increases consumer surplus as well as downstream profits for $K < \bar{K}_C = \frac{1}{2+\gamma}$:

$$\frac{\partial CS}{\partial w} = 2 \cdot \frac{1+\gamma}{(2+\gamma)^2} \cdot \frac{1 - K(2+\gamma)}{K(2+\gamma)} \cdot \left((\alpha - c)\frac{K(2+\gamma)}{1 - K(2+\gamma)} + w\right) > 0$$

$$\frac{\partial\left(2\cdot\pi_i^D\right)}{\partial w} = 4\cdot\left(\frac{\alpha-c-w\frac{K(2+\gamma)-1}{K(2+\gamma)}}{(2+\gamma)^2}\right)\frac{K(2+\gamma)-1}{K(2+\gamma)} > 0$$

Welfare my also increase for values of K slightly above $\frac{1}{2+\gamma}$, though consumer surplus would not.

■

The proof shows that for rather cost effective investments the former effect may outweigh the latter and increasing the wholesale price over the monopolist's marginal cost may be welfare increasing. Moreover, it is also shown that for very cost efficient investments, the incentive effect is so strong that an increase in the wholesale price may result in a decrease of perceived downstream marginal cost, i.e., downstream competition will not be distorted, but intensified. Hence, for very cost-effective investments, increasing the wholesale price may also increase consumer surplus as well as the downstream firms' profits.

A.3 Investment regimes under different vertical structures

In this section we compare the different investment regimes under different vertical structures. Under Bertrand competition, we get three cases, where different combinations are optimal from a welfare perspective.

(a) Upstream investment regime

As shown in Proposition 11 a combination of the upstream investment regime and vertical integration is never optimal. The upstream investment regime under vertical separation is optimal whenever w is sufficiently high. The thresholds are given by $w > {(2-\gamma^2)}/{(4-\gamma^2)}\cdot(\alpha-c)$ and $w > {8(1+\gamma)}/{(2+\gamma)(12+5\gamma-3\gamma^2)}\cdot(\alpha-c)$. The first restriction ensures that the upstream investment regime is superior to the downstream investment regime under vertical separation. The latter restriction ensures that the upstream investment regime under vertical separation is superior to the downstream investment regime under vertical integration.

(c) Downstream investment regime

The downstream investment regime under vertical integration is optimal whenever w is sufficiently low and γ is sufficiently large. The respective thresholds are given by $w < {(2-\gamma^2)}/{(4-\gamma^2)}\cdot(\alpha-c)$ or $w < {8(1+\gamma)}/{(2+\gamma)(12+5\gamma-3\gamma^2)}\cdot(\alpha-c)$ for w and $\gamma > 9/10$ for γ.[49] The first restriction ensures that vertical integration is superior to vertical separation. The second restriction ensures that the downstream investment regime is superior to the upstream investment regime under vertical separation and the last restriction that the downstream investment regime under vertical integration is superior to the upstream investment regime under vertical separation. The downstream investment regime and vertical separation is optimal for $\gamma < 9/10$ and $w < {(2-\gamma^2)}/{(4-\gamma^2)}\cdot(\alpha-c)$. The first restriction ensures that vertical separation is superior to vertical integration. The latter that the downstream investment regime is superior to the upstream investment regime under vertical separation. The proof can be found in appendix A.4, Proof of Proposition 12.

A.4 Proofs

Proof of Proposition 1

We find that for any (w,Δ)

$\frac{\partial W^C}{\partial\Delta_i} - \frac{\partial\pi_U^C}{\partial\Delta_i} = \frac{12+3\gamma-4\gamma^2}{4-\gamma^2}\frac{\alpha-c-w+\Delta}{2+\gamma} > 0$, for $\Delta_i = \Delta_j = \Delta\ \forall i,j$.

[49] The threshold on γ characterizes the singularity arising from the following restriction on $w < \left(2(2-\gamma)(1+\gamma)-(2+\gamma)\left(2-\gamma^2\right)\right)/\left((2-\gamma)(1+\gamma)((2+\gamma)\cdot\gamma+4)-4(2+\gamma)\left(2-\gamma^2\right)\right)$, which ensures that the downstream investment regime under vertical integration is superior to the downstream investment regime under vertical separation.

Hence, investment by the upstream monopolist is below the investment level a welfare maximizing regulator would choose.

Proof of Proposition 2

We find that for any (Δ, w)

$\frac{\partial W^C}{\partial \Delta_i} - \frac{\partial \pi_i}{\partial \Delta_i} = 4\frac{(1+\gamma)(2-\gamma)}{2+\gamma}\frac{\alpha-c-w+\Delta}{4-\gamma^2} - \frac{\gamma}{2+\gamma}\frac{\alpha-2(c+w-\Delta)}{4-\gamma^2} + \frac{w}{2+\gamma} > 0$ for $\Delta_i = \Delta_j = \Delta\ \forall i,j$.

The first and the third term are positive, while the second term is positive or negative, but never larger than the first. Hence, the differential is clearly positive.

Hence, the sum of investments by the downstream competitor is below the investment level a welfare maximizing regulator would choose.

Proof of Proposition 3

The difference in marginal profits through investment between the upstream monopolist and a downstream competitor is given by

$\frac{\partial \pi^U}{\partial \Delta_i} - \frac{\partial \pi_i}{\partial \Delta_i} = \frac{w}{2+\gamma} - K\Delta - \left(\frac{4((2-\gamma)(\alpha-c-w)+(2-\gamma)\Delta)}{(4-\gamma^2)^2} - K\Delta\right)$, for $\Delta_i = \Delta_j = \Delta\ \forall i,j$

$\Leftrightarrow \frac{\partial \pi^U}{\partial \Delta_i} - \frac{\partial \pi_i}{\partial \Delta_i} = \frac{\left(4-\gamma^2\right)w - 4(\alpha-c-w+\Delta)}{(2+\gamma)(4-\gamma^2)}$, for $\Delta_i = \Delta_j = \Delta\ \forall i,j$

Hence, we find that for any Δ, whenever $w < \hat{w}_C = (\alpha - c)\,\frac{4}{8-\gamma^2}$

$\frac{\partial \pi^U}{\partial \Delta_i} - \frac{\partial \pi^D}{\partial \Delta_i} = \frac{\left(8-\gamma^2\right)w - 4(\alpha-c+\Delta)}{(4-\gamma^2)(2+\gamma)} < 0$, for $\Delta_i = \Delta_j = \Delta\ \forall i,j$.

The maximum price a regulator would potentially set, is the price a monopolist would choose in order to maximize its profits, $w_M^* = \frac{\alpha-c}{2}$. As the monopolistic price is smaller than the threshold from above, $w_M^* < \hat{w}_C$, the downstream investment regime will always be superior over the upstream investment regime.

Proof of Proposition 4

We know from the proof of Proposition 2 that investment by the downstream competitors is always suboptimal from a welfare point of view. Moreover, it can be easily shown that increasing w (i) dampens the investment activity of the downstream firms and (ii) distorts downstream competition, i.e., lowers market market quantity.

(i) $\frac{\partial \Delta_D^B}{\partial w} = \frac{-8}{K(2+\gamma)(4-\gamma^2)-4} < 0$

(ii) $\frac{\partial Q^C}{\partial w} = -\frac{2}{2+\gamma} < 0$

Therefore, it can never be optimal from a welfare point of view to increase the wholesale price, w, above the value that secures that the monopolist can recoup its fixed as well as its investment costs.

Proof of Proposition 5

For any $(w, \Delta)$the difference of marginal increase in welfare and marginal increase in upstream profits through investment between is given by

$\frac{\partial W}{\partial \Delta i} - \frac{\partial \pi^U}{\partial \Delta i} = \frac{w}{(1+\gamma)(2-\gamma)} + 4\,(1+\gamma)\,\frac{\alpha-c-w+\Delta}{((1+\gamma)(2-\gamma))^2} + 2\cdot\left(1-\gamma^2\right)\cdot\frac{\alpha-c-w+\Delta}{((1+\gamma)(2-\gamma))^2}$, for $\Delta_i = \Delta_j = \Delta\ \forall i,j$

$\Leftrightarrow \frac{\partial W}{\partial \Delta i} - \frac{\partial \pi^U}{\partial \Delta i} = \frac{w}{(1+\gamma)(2-\gamma)} + (1+\gamma)\,(6-2\gamma)\,\frac{\alpha-c-w+\Delta}{((1+\gamma)(2-\gamma))^2}$, for $\Delta_i = \Delta_j = \Delta\ \forall i,j$

As all the terms are positive, the whole expression is positive.

$\frac{\partial W}{\partial \Delta i} - \frac{\partial \pi^U}{\partial \Delta i} = \frac{w}{(1+\gamma)(2-\gamma)} + (1+\gamma)\,(6-2\gamma)\,\frac{\alpha-c-w+\Delta}{((1+\gamma)(2-\gamma))^2} > 0$, for $\Delta_i = \Delta_j = \Delta\ \forall i,j$.

Hence, investment by the upstream monopolist is below the investment level a welfare maximizing regulator would choose.

Proof of Proposition 6

For any (w, Δ) the difference of marginal increase in welfare and marginal increase in downstream profits through investment between is given by

$\frac{\partial W^B}{\partial \Delta_i} - \frac{\partial \pi_i^B}{\partial \Delta_i} = \frac{1}{(1+\gamma)(2-\gamma)} \cdot w + 4\left(1+\gamma\right) \frac{\alpha - w - c + \Delta}{((1+\gamma)(2-\gamma))^2} - 2\gamma\left(1-\gamma^2\right) \frac{\alpha - w - c + \Delta}{(1+\gamma)(2-\gamma)(1-\gamma^2)(4-\gamma^2)}$, for $\Delta_i = \Delta_j = \Delta$ $\forall i, j$.

$\Leftrightarrow \frac{\partial W^B}{\partial \Delta_i} - \frac{\partial \pi_i^B}{\partial \Delta_i} = \frac{1}{(1+\gamma)(2-\gamma)} \cdot w + \frac{\alpha - w - c + \Delta}{(1+\gamma)(2-\gamma)} \frac{2(4+\gamma)}{4-\gamma^2} > 0$, for $\Delta_i = \Delta_j = \Delta$ $\forall i, j$.

Hence, the sum of investments by the downstream competitor is below the investment level a welfare maximizing regulator would choose.

Proof of Proposition 7

The difference of a marginal increase in welfare and a marginal increase in downstream profits through investment between is given by

$\frac{\partial \pi^U}{\partial \Delta_i} - \frac{\partial \pi_i^D}{\partial \Delta_i} = \frac{w\left(4-\gamma^2\right)}{(2-\gamma)(1+\gamma)(4-\gamma^2)} - 2\left(2-\gamma^2\right) \frac{\alpha - c - w + \Delta}{(2-\gamma)(1+\gamma)(4-\gamma^2)}$, for $\Delta_i = \Delta_j = \Delta$ $\forall i, j$

We find that for any Δ, whenever $w < \hat{w}_B = \frac{2-\gamma^2}{4-\gamma^2}\left(\alpha - c\right)$

$\frac{\partial \pi^U}{\partial \Delta_i} - \frac{\partial \pi_i^D}{\partial \Delta_i} = \frac{w\left(8-2\gamma^2\right) - \left(4-2\gamma^2\right)(\alpha - c + \Delta)}{(2-\gamma)(1+\gamma)(4-\gamma^2)} < 0$, for $\Delta_i = \Delta_j = \Delta$ $\forall i, j$.

Hence, the upstream investment regime is superior relative to the downstream investment regime, whenever the regulator sets a price below $\hat{w}_B$.

Proof of Proposition 8

The result can be easily derived from comparison of w_C^M and $\hat{w}_B$. w_C^M is the monopoly price and hence, the maximum price a regulator would ever choose. $\hat{w}_B$ is the threshold derived in the proof of proposition **7**.

$\hat{w}_B - w_C^M = (\alpha - c)\frac{-\gamma^2}{4-\gamma^2} < 0$

Hence, some wholesale prices exist, where different investment regimes are optimal.

Proof of Corollary 1

The threshold on the wholesale price $\hat{w}_B = \frac{2-\gamma^2}{4-\gamma^2}\left(\alpha - c\right)$ decreases in γ for any Δ

$\frac{\partial\left(\frac{2-\gamma^2}{4-\gamma^2}(\alpha - c)\right)}{\partial \gamma} = -\frac{4\gamma\left(1+\gamma^2\right)}{\left(4-\gamma^2\right)^2}\left(\alpha - c\right) < 0$

Hence, for a given w the investment level under the downstream investment regime is is relatively smaller relative to that under the upstream investment regime when γ becomes larger.

Proof of Proposition 9

In this proof, we investigate the influence of increasing the regulated wholesale price w on profits (up- and downstream), consumer surplus and total welfare.

A marginal increase in the regulated access margin increases the upstream profit:

$\frac{\partial\left(\pi^U - K(\Delta)\right)}{\partial w} = \alpha - c - w \cdot \frac{2K(2-\gamma)(1+\gamma)-1}{K(2-\gamma)(1+\gamma)} > 0.$

A marginal increase in the regulated access margin increases consumer surplus and downstream profits for $K < \bar{K}_B = \frac{1}{(1+\gamma)(2-\gamma)}$:

$\frac{\partial CS}{\partial w} = 2\left(1+\gamma\right)\frac{\alpha-c-w+\frac{w}{K(2-\gamma)(1+\gamma)}}{((1+\gamma)(2-\gamma))^2}\left(\frac{1-K(2-\gamma)(1+\gamma)}{K(2-\gamma)(1+\gamma)}\right) > 0$

$\frac{\partial\left(2\cdot\pi^D\right)}{\partial w} = 4\cdot\left(1-\gamma^2\right)\cdot\frac{\alpha-c-w+\frac{w}{K(2-\gamma)(1+\gamma)}}{((1+\gamma)(2-\gamma))^2}\left(\frac{1-K(2-\gamma)(1+\gamma)}{K(2-\gamma)(1+\gamma)}\right) > 0$

A marginal increase in the regulated access margin increases total welfare for $K < \bar{K}_B = \frac{3-2\gamma}{(2-\gamma)(1-\gamma^2)}$:

$\frac{\partial W}{\partial w} = \left(2\frac{(1+\gamma)(3-2\gamma)}{((1+\gamma)(2-\gamma))^2}\frac{1-K(2-\gamma)(1+\gamma)}{K(2-\gamma)(1+\gamma)} + \frac{2}{(1+\gamma)(2-\gamma)}\right)\left(\alpha-c+w\frac{1-K(2-\gamma)(1+\gamma)}{K(2-\gamma)(1+\gamma)}\right) - \frac{2w}{K(2-\gamma)(1+\gamma)} > 0\, for\, K < \frac{3-2\gamma}{(2-\gamma)(1-\gamma^2)}$

Hence, as long as the cost of investment K is below a certain threshold, raising w increases total welfare.

Proof of Proposition 10

We know from the proof of Proposition 6 that investment by the downstream competitors is always suboptimal from a welfare point of view. Moreover, it can be easily shown that increasing w (i) dampens the investment activity of the downstream firms further and (ii) distorts downstream competition.

(i) $\frac{\partial\Delta_D^B}{\partial w} = -\frac{4\left(2-\gamma^2\right)}{K(1+\gamma)(2-\gamma)(4-\gamma^2)-2(2-\gamma^2)} < 0$

(ii) $\frac{\partial Q^B}{\partial w} = \frac{-2}{(1+\gamma)(2-\gamma)} < 0$

Hence, it can never be optimal from a welfare point of view to increase w the value that secures that the monopolist can recoup its fixed as well as its investment costs.

Proof of Proposition 11

We find that for any (w, Δ)

(i) under Cournot competition

$\frac{\partial\pi_1}{\partial\Delta_1} - \frac{\partial\pi_1}{\partial\Delta_1} = 0,\, for\, \Delta_1 = \Delta_2 = \Delta\forall 1,2$

Hence, investment incentives for the integrated firm are identical across investment regimes.

$\frac{\partial\pi_1}{\partial\Delta_2} - \frac{\partial\pi_2}{\partial\Delta_2} = -\frac{2}{4-\gamma^2}\cdot\left(\alpha-c-2\cdot\frac{1-\gamma}{2-\gamma}\cdot w+\Delta\right) < 0,\, for\Delta_1 = \Delta_2 = \Delta\forall 1,2$

Investment in firm 2's cost structure are larger under the downstream investment regime.

Hence, as investment across firms has to be equal under the upstream investment regime, it will be lower than under the downstream investment regime. The analysis for Bertrand competition works in the same manner:

(ii) under Bertrand competition

$\frac{\partial\pi_1}{\partial\Delta_1} - \frac{\partial\pi_1}{\partial\Delta_1} = 0,\, for\, \Delta_1 = \Delta_2 = \Delta,\, for\, \Delta_1 = \Delta_2 = \Delta,\, \forall 1,2$

$\frac{\partial\pi_1}{\partial\Delta_2} - \frac{\partial\pi_2}{\partial\Delta_2} = -\left(\alpha-c-2w+\Delta\right) < 0,\, for\, \Delta_1 = \Delta_2 = \Delta,\, \forall 1,2$

Hence, the downstream investment regime always performs better in welfare terms compared to the upstream investment regime. This holds true for both modes of competition.

Proof of Proposition 12

In this proof, we compare the investment incentives among the two different vertical structures. Under Cournot competition, we restrict our analysis to the comparison of the downstream investment incentives. I.e., we compare investment incentives of the downstream firms under vertical integration to the investment incentives of the downstream firms under vertical separation. Under Bertrand competition, we conduct the analysis for both investment regimes under vertical separation and the downstream investment regime under vertical integration for the respective wholesale prices w.

(i) Cournot competition

We find that for any (w, Δ)

$$\frac{\partial\pi_1}{\partial\Delta_1} - \frac{\partial\pi_i}{\partial\Delta_i} - \left(\frac{\partial\pi_i}{\partial\Delta_i} - \frac{\partial\pi_2}{\partial\Delta_2}\right) = -w \cdot \frac{\gamma}{4-\gamma^2} + 2\left(\frac{(2-\gamma)\cdot(\alpha-c)+\gamma\cdot w+(2-\gamma)\cdot\Delta}{4-\gamma^2}\right) \cdot \frac{2}{4-\gamma^2} - K \cdot \Delta + \left(2 \cdot \left(\frac{(2-\gamma)\cdot(\alpha-c)-2\cdot w+(2-\gamma)\cdot\Delta}{4-\gamma^2}\right) \cdot \frac{2}{4-\gamma^2} \cdot\right.$$

$$2\frac{4((2-\gamma)(\alpha-c-w\Delta))}{(4-\gamma^2)^2} - 2K\Delta$$

$$\Leftrightarrow \frac{\partial\pi_1}{\partial\Delta_1} - \frac{\partial\pi_i}{\partial\Delta_i} - \left(\frac{\partial\pi_i}{\partial\Delta_i} - \frac{\partial\pi_2}{\partial\Delta_2}\right) = -w \cdot \frac{\gamma}{4-\gamma^2} + w\frac{4(2-\gamma)}{(4-\gamma^2)^2} = w \cdot \frac{8-8\gamma+\gamma^3}{(4-\gamma^2)^2} > 0$$

Hence, investment under vertical integration is always higher.

(ii) Bertrand competition

(a) Upstream investment regime

We compare the upstream investment regime under vertical separation with the downstream investment regime under vertical integration.

We find that for any (w, Δ)

$$\frac{\partial\pi_1}{\partial\Delta_1} - \frac{\partial\pi^U}{\partial\Delta_i} - \left(\frac{\partial\pi^U}{\partial\Delta_i} - \frac{\partial\pi_2}{\partial\Delta_2}\right) = -w \cdot \frac{\gamma}{4-\gamma^2} + 4\left(\frac{2\cdot(2-\gamma)\cdot(\alpha-c+\Delta)-(2-\gamma)\cdot w}{(4-\gamma^2)^2}\right) - 2K \cdot \Delta - \left(\frac{2w}{(1+\gamma)(2-\gamma)} - 2K\Delta\right)$$

$$\Leftrightarrow -w \cdot \frac{\gamma}{4-\gamma^2} + 4\frac{2\cdot(2-\gamma)\cdot(\alpha-c+\Delta)-(2-\gamma)\cdot w}{(4-\gamma^2)^2} - \frac{2w}{(1+\gamma)(2-\gamma)} = (\alpha - c + \Delta)\frac{8}{(4-\gamma^2)(2+\gamma)} - w\frac{12+5\gamma-3\gamma^2}{(1+\gamma)(4-\gamma^2)} > 0 \text{ for}$$

$$w < (\alpha - c + \Delta)\frac{8(1+\gamma)}{(2+\gamma)(12+5\gamma-3\gamma^2)}$$

(b) Downstream investment regime

We compare the downstream investment regime under vertical separation with the downstream investment regime under vertical integration.

We find that for any (w, Δ)

$$\frac{\partial\pi_1}{\partial\Delta_1} - \frac{\partial\pi_i}{\partial\Delta_i} - \left(\frac{\partial\pi_i}{\partial\Delta_i} - \frac{\partial\pi_2}{\partial\Delta_2}\right) = (\alpha - c) \cdot 4 \cdot \frac{2(2-\gamma)(1+\gamma)-(2+\gamma)(1-\gamma)\left(2-\gamma^2\right)}{(4-\gamma^2)^2(1+\gamma)} - w \cdot \frac{(2-\gamma)(1+\gamma)((2+\gamma)\cdot\gamma+4)-4(2+\gamma)\left(2-\gamma^2\right)}{(4-\gamma^2)^2(1+\gamma)} >$$

$0,\ for\, w < 4(\alpha - c + \Delta)\frac{2(2-\gamma)(1+\gamma)-(2+\gamma)\left(2-\gamma^2\right)}{(2-\gamma)(1+\gamma)((2+\gamma)\cdot\gamma+4)-4(2+\gamma)(2-\gamma^2)}$. This is fulfilled for all w when $\gamma > 9/10$. If γ is smaller than the reverse holds true.

Hence, investment under vertical integration is higher, whenever γ is large enough.

References

Armstrong, M., and D. E. M. Sappington (2007): *Handbook of Industrial Organization*chap. Recent Developments in the Theory of Regulation,, pp. 1557–1700. Elsevier North-Holland.

Arya, A., B. Mittendorf, and D. E. M. Sappington (2008): "Outsourcing, vertical integration, and price vs. quantity competition," *International Journal of Industrial Organization*, 26, 1–16.

Beard, T. R., D. L. Kaserman, and J. W. Mayo (2001): "Regulation, Vertical Integration and Sabotage," *Journal of Industrial Economics*, 49, 319–333.

Bender, J.-P. (2008): "Three Essays on Network Economics - Incentives for Compatibility Choice, Standard Setting and Infrastructure Investment," Ph.D. thesis, University of Munich.

Bester, H., and E. Petrakis (1993): "The incentives for cost reduction in a differentiated duopoly," *International Journal of Industrial Organization*, 11, 519–534.

Biglaiser, G., and C.-T. A. Ma (1999): "Investment Incentives of a Regulated Dominant Firm," *Journal of Regulatory Economics*, 16, 215–235.

Buehler, S. (2005): "The Promise and Pitfalls of Restructuring Network Industries," *German Economic Review*, 6, 205–228.

Buehler, S., D. Gärtner, and D. Halbheer (2006): "Deregulating network industries: dealing with price-quality tradeoffs," *Journal of Regulatory Economics*, 30, 99–115.

Buehler, S., A. Schmutzler, and M.-A. Benz (2004): "Infrastructure quality in deregulated industries: is there an underinvestment problem?," *International Journal of Industrial Organization*, 22, 253–267.

Cremer, H., J. Crémer, and P. D. Donder (2006): "Legal Vs. Ownership Unbundling in Network Industries," *CEPR Discussion Paper*, 5767.

Economides, N. (1998): "The incentive for non-price discrimination by an input monopolist," *International Journal of Industrial Organization*, 16, 271–284.

Frontier Economics (2006): "Current prices, anybody? - The costs and benefits of "smart" electricity meters," *Frontier Economics Bulletin*.

——— (2009): "Smart metering - A report prepared for Centrica," *Frontier Economics*.

Guthrie, G. (2006): "Regulating Infrastructure: The Impact on Risk and Investment," *Journal of Economic Literature*, 44, 925–972.

Höffler, F., and S. Kranz (2007a): "Imperfect Legal Unbundling of Monopolistic Bottlenecks," *Bonn Econ Discussion Paper*, 16.

——— (2007b): "Legal Unbundling can be a Golden Mean between Vertical Integration and Separation," *Bonn Econ Discussion Paper*, 15.

Kreps, D. M., and J. A. Scheinkman (1983): "Quantity Precommitment and Bertrand Competition Yield Cournot Outcomes," *BELL Journal of Economics*, 14(2), 326–337.

Mandy, D. M., and D. E. M. Sappington (2007): "Incentives for sabotage in vertically related industries," *Journal of Regulatory Economics*, 31, 235–260.

Motta, M. (2004): *Competition Policy: Theory and Practice*. Cambridge University Press, Cambridge, UK.

Newbery, D. (2000): *Privatization, Restructuring, and Regulation of Network Utilities*. MIT Press, Cambridge, USA.

Perry, M. K. (1989): *Handbook of Industrial Organization, Volume I*chap. Vertical Integration: Determinants and Effects, pp. 183–255. Elsevier Science Publishers B.V.

Qui, L. D. (1997): "On the Dynamic Efficiency of Bertrand and Cournot Equilibria," *Journal of Economic Theory*, 75, 213–229.

Reisinger, M., and L. Ressner (2009): "The choice of prices versus quantities under uncertainty," *Journal of Economics and Management Strategy*, 18(4), 1155–1177.

Rey, P., and J. Tirole (2003): *Handbook of Industrial Organization*chap. A Primer on Foreclosure, pp. 2145–2220. Elsevier North-Holland.

Sibley, D. S., and D. L. Weisman (1998): "Raising rivals' costs: The entry of an upstream monopolist into downstream markets," *Information Economics and Policy*, 10, 451–470.

Singh, N., and X. Vives (1984): "Price and Quantity Competition in a Differentiated Duopoly," *The RAND Journal of Economics*, 15, 546–554.

Spiller, P. T. (2005): *Handbook of Telecommunication Economics Vol. 2*chap. Institutional Changes in Emerging Markets: Implications for the Telecommunications Sector,, pp. 622–652. Elsevier North-Holland.

Tirole, J. (1988): *The Theory of Industrial Organization*. MIT Press, Cambridge, USA.

Valletti, T. M. (2003): "The theory of access pricing and its linkage with investment incentive," *Telecommunications Policy*, 27, 659–675.

Valletti, T. M., and C. Cambini (2005): "Investments and Network Competition," *The RAND Journal of Economics*, 36, 446–467.

Vareda, J. (2007): "Unbundling and Incumbent Investment in Quality Upgrades and Cost Reduction," Universidade Nova de Lisboa.