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Regulating investments in vertically related industries*

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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. For vertically seperated industries, we find that under Cournot competition downstream process innovation should always be undertaken by the downstream competitors themselves. However, under Bertrand competition investment levels as well as welfare might be higher when the regulated upstream monopolist undertakes the investment. Under vertical integration downstream investment is always closer to the first-best regardless of the mode of competition.

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

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

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1 Introduction

Motivation. 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.[2] 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 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.[3] 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.[4] National regulators have chosen different approaches regarding investment in new meter technology.[5,6]

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

[2] Regulators generally refer to the so-called disaggregated approach to regulation in which only the monopolisitc component of an industry is subject to regulation, while all other components are left unregulated.

[3] 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).

[4] 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).

[5] 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.

[6] 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

Overview. Our 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.[7] 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.[8,9] 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.[10] 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.[11]

Our **main results** are the following: First, we show that 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, 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. 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.

Third, we show in an extension that the optimal investment regime may depend on the vertical structure of the industry. While under partial vertical integration, the downstream investment

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.

[7] Our model only considers deterministic investment technologies, i.e. the cost and result of the investment are well known in advance.

[8] 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.

[9] 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.

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

[11] 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.

regime is always superior, under vertical separation the optimal investment regime depends on the market characteristics.

Our results have 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 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.[12]

It has become a common notion in the literature to interpret different natures of competition as a manifestation of the importance of capacity constraints.[13] 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 (Cournot industries), 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 (Bertrand industries) 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.

Related Literature. Our paper contributes to the literature on investment behavior in vertically related industries. Buehler (2005) and Buehler et al. (2004, 2006) explore the issue of potential underinvestment in infrastructure. 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. Another 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. All of these models solely investigate the effect of upstream investment activity, while we compare investment incentives by the upstream monopolist and by the downstream competitors given the identical investment technology. Buehler and Schmutzler (2008) also consider downstream

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

[13] 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).

investments and how these are affected by different vertical structures. But in their work the downstream firms are always in charge of the investment, while we also let the upstream firm invest.

Moreover, this paper relates to the literature on the nature of competition and its effect on investment behavior. Singh and Vives (1984) are the first to compare market outcomes of Bertrand and Cournot competition in a duopoly with differentiated goods. 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 cost-reduction and derive welfare comparisons among the different modes of competition. But their analysis does not consider a vertically related market.[14]

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. Chen and Sappington (2010) compare the incentives of an upstream monopolist into upstream cost reduction and upstream product design for different vertical structures and modes of competition. They find that under Cournot competiton vertical integration always increases investment incentives, while under Bertrand competition it might lead to a decrease. 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.[15] 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.

Remainder. 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.

[14] 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.

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

2 The Model

Structure. 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.[16] 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.

Access price regulation. 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 resembles the situation in network utilities. We do not consider how the regulator optimally sets the wholesale price, as this is neither part of our analysis, nor particularly insightful. It is only assumed, that the regulator determines the wholesale price before investment or competition takes place.[17] The regulator's pricing policy can be interpreted as 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. Depending on the fixed cost F, the optimal wholesale price is then always somewhere between 0 and the wholesale price set by a monopolist (w_M).

Downstream competition. 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 $\gamma \,\epsilon\, (0, 1)$ can be viewed as a measure of product homogeneity,

[16] 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.

[17] 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.

which increases 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 to relate our model to the existing models on the comparison of different modes of competition, where this specific linear demand is widely used.

Investment and Regulation. 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 separately. 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, $\Delta_1 = \Delta_2 = \Delta$. This reflects the regulatory situation in most countries.[18] 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.

Timing. 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. We restrict the analysis to symmetric equilibria.

[18] E.g. the German Energy Industry Act demands that network operators handle their business in a non-discriminatory fashion, §11(1) EnWG. Nevertheless, some commentators have doubts whether and how this could be enforced.

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' downstream cost reduction Δ_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 (Δ_i) and the regulated access price (w) as given. Except for the firms' individual marginal cost (c_i) competition will be identical across investment regimes.[19] Both downstream firms face symmetric objective functions of the form

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

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

$$q_i^C = {}^{((\alpha-c-w)(2-\gamma)+2\Delta_i-\gamma\Delta_j)}\big/_{\left(4-\gamma^2\right)}.^{20}$$

Note that a firm's output is increasing in own investments $\left({}^{\partial q_i^C}/_{\partial \Delta_i} = {}^{2}/_{\left(4-\gamma^2\right)} > 0\right)$ and decreasing in competitor's investment $\left({}^{\partial q_i^C}/_{\partial \Delta_j} = -{}^{\gamma}/_{\left(4-\gamma^2\right)} < 0\right)$.

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.

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

[19] 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.

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

amount into the cost structure of each downstream competitor, $\Delta_i = \Delta_j$, $i \neq j$. The upstream monopolist maximizes:

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

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 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:

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

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.[21] 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

$$\Delta_U^C = {}^{w}/_{K(2+\gamma)}.^{22}$$

We can easily see that the investment is increasing in w and decreasing in K and γ. Moreover, from comparison of the derivatives of the monopolist's profit π^U and welfare W with respect to the investment Δ_i (Δ_j) we get the following result:

Lemma 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. ■

This is not surprising as the monopolist's incentive to invest comes solely 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 firms' profit and consumer surplus.

[21] In our reference case, this output increase is given by ${}^{\partial Q^C}/_{\partial \Delta} = {}^{2}/_{2+\gamma} > 0$.
[22] The SOC is fulfilled for any $K > 0$.

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

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

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 (*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.[23] The corresponding optimal investment level per firm with linear demand is

$$\Delta_i^C = {}^{4(\alpha-w-c)}\big/\big(K(2+\gamma)\big(4-\gamma^2\big)-4\big)^{24}$$

and overall industry investment (with symmetry) is given by

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

Again, from the derivatives of the equlibrium investment we find that firm as well as industry investment is decreasing in w and K as well as for γ for $\gamma < \frac{2}{3}$.

In addition, from the derivatives of the competitors' profits and welfare w.r.t. the investment we find a qualitatively similar result to the upstream investment case:

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

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

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

Proof. See Appendix. ■

This result 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.

Comparison of Upstream and Downstream Investment Regimes. Comparing the investments, we can state our main result under Cournot competition:

Proposition 1 *Under Cournot competition, the overall investment level is larger in the downstream investment regime relative to the upstream investment regime,* $\Delta^*_{Downstream} > \Delta^*_{Upstream}$.

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. The intuition 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, (*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.[25] 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.[26] This result will never occur, even without price regulation.

Using the results from Lemmas 1 and 2, we can state an additional result under Cournot competition:

Corollary 1 *Welfare is always higher under the downstream investment regime than under the upstream investment regime.*

[25] As pointed out before this is <u>not</u> identical to the output effect of the downstream firms.
[26] A monopolist would always set a price equal to $w^* = {}^{(2(\alpha-c)+\Delta_i+\Delta_j)}/_4$.

Proof. See Appendix. ■

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.

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.[27]

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. In other words, 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. (**Remark 3**; Proof can be found in the appendix.).

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,

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

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

$$p_i^B = {}^{(((1-\gamma)\alpha+c+w)(2+\gamma)-2\Delta_i-\gamma\Delta_j)}/_{(4-\gamma^2)}.^{28}$$

Note that a firm's price is decreasing in own investments $\left({}^{\partial p_i^B}/_{\partial \Delta_i} = -{}^{2}/_{(4-\gamma^2)} < 0\right)$ as well as in competitor's investment $\left({}^{\partial p_i^B}/_{\partial \Delta_j} = -{}^{\gamma}/_{(4-\gamma^2)} < 0\right)$.

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.

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

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

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:

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

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

$$\Delta_U^B = {}^{w}/_{K(2-\gamma)(1+\gamma)}.^{29}$$

The investment is increasing in w, decreasing in K and increasing in γ for $\gamma > \frac{1}{2}$. Again, from the derivatives of the monopolist's profit and welfare w.r.t. the investment, we find the following result

[28] In the case of linear demand we find quantities of $q_i^B = {}^{\left((1-\gamma)(2+\gamma)(\alpha-c-w)+\left(2-\gamma^2\right)\Delta_i-\gamma\Delta_j\right)}/_{\left(1-\gamma^2\right)\left(4-\gamma^2\right)}$. Total output is given by $Q^B = {}^{(2(\alpha-c-w)+\Delta_i+\Delta_j)}/_{((1+\gamma)(2-\gamma))}$.

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

Lemma 3 *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.

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

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

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

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

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

$$\Delta_i^B = {}^{2\left(2-\gamma^2\right)(\alpha-w-c)}\big/{}_{\left(K(1+\gamma)(2-\gamma)\left(4-\gamma^2\right)-2\left(2-\gamma^2\right)\right)}\ {}^{30}$$

and overall (industry) investment (with symmetry) is

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

[30] Note that the SOC is fulfilled if $K > {}^{2\left(2-\gamma^2\right)^2}\big/{}_{(1-\gamma^2)(4-\gamma^2)^2}$. 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.

It can be seen that investment is increasing in w as well as K, while γ has a negative effect for $\gamma > 3/5$ and a positive effect otherwise.[31]

Again, from the derivatives of the competitors' profits and welfare w.r.t. the investment we find that investment is insufficiently high:

Lemma 4 *Under Bertrand competition, with the downstream investment regime and for a given wholesale price, investment by the downstream competitors is always 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.

Comparison of Upstream and Downstream Investment Regimes. From comparison of the equlibrium investments we get the following proposition

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

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, [32]. 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.[33] On the other hand, the monopolist profits from

[31] 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. 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 ($\gamma > 3/5$).

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

[33] 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.

aggressive downstream competition, as a general decrease in downstream marginal costs is followed by a relatively large increase in overall quantity.[34] 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.

Using the results from Lemmas 3 and 4, we can state an additional result under Bertrand competition:

Corollary 2 *Welfare is always higher under the downstream investment regime than under the upstream investment regime, if and only if* $w < \hat{w}_B = \frac{2-\gamma^2}{4-\gamma^2}(\alpha - c)$ *holds.*

Proof. See Appendix. ■

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. 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 3 *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 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.[35]

On the other hand, an increase in the competitiveness of the downstream sector decreases the

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

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

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.

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. We find that, 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. (**Remark 2**; Proof can be found in the appendix.) In the appendix it is shown 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.

Downstream Investment Regime. 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. (**Remark 3**; Proof can be found in the 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 Partial vertical integration

A broad discussion on the optimal vertical structure in network industries (partial integration vs. separation) has recently emerged.[36,37] In this section, we 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. Therefore, we denote 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, $\pi_1 = \pi^U + \pi_1^D$.

5.1 Cournot Game

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 $q_i^* := arg\max_{q_i} \pi_i$. For the reference case of linear demand, this becomes

$$q_1^* = {}^{((2-\gamma)\cdot(\alpha-c)+\gamma\cdot w+2\cdot\Delta_1-\gamma\cdot\Delta_2)}\big/_{(4-\gamma^2)} \quad and \quad q_2^* = {}^{((2-\gamma)\cdot(\alpha-c)-2\cdot w+2\cdot\Delta_2-\gamma\cdot\Delta_1)}\big/_{(4-\gamma^2)}\ .^{38}$$

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.

[36] 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).

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

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

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. Under the upstream investment regime the integrated firm maximizes its profit with respect to the non-discrimination rule $\Delta_1 = \Delta_2 = \Delta$.

$$\pi_1 = w \cdot q_2^* (\Delta_2, \Delta_1) + (P_1 (q_1^* (\Delta_1, \Delta_2)) - (c - \Delta_1)) \cdot q_1^* (\Delta_1, \Delta_2) - 2 \cdot \tfrac{K}{2} \cdot \Delta_i^2,\ i = 1, 2.^{39}$$

While under the downstream investment regime both firms choose their investment level independently:

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

$$\pi_2 = (P_2 (q_2^* (\Delta_2, \Delta_1)) - (w + c - \Delta_2)) \cdot q_2^* (\Delta_2, \Delta_1) - \tfrac{K}{2} \cdot \Delta_2^2,^{40}$$

5.2 Bertrand Game

Competition Stage. Undert Bertrand competition, the competition stage stays the same except for the fact that competition takes place in prices. For the reference case of linear demand, downstream quantities become

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

for the integrated monopolist and

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

for the independent competitor.[41]

Investment Stage. As before at stage 2, the investor decides on investment. The setting differs depending on the investment regime the regulator has chosen. Under the upstream investment regime the integrated firm maximizes with respect to the non-discrimination rule ($\Delta_1 = \Delta_2 = \Delta$)

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

[40] The equlibrium investment levels are $\Delta_1^* = \left(4\cdot(2-\gamma)\cdot(\alpha-c)\left(\left(4-\gamma^2\right)^2\cdot K-8-4\cdot\gamma\right)+\gamma\cdot\left(\left(\left(4-\gamma^2\right)^2\cdot K-8\right)\gamma+32\right)\cdot w\right)\Big/\left(\left(\left(4-\gamma^2\right)^2\cdot K-8\right)^2-(4\cdot\gamma)^2\right)$ and $\Delta_2^* = \left(4\cdot(2-\gamma)\cdot(\alpha-c)\cdot\left(\left(4-\gamma^2\right)^2\cdot K-8-4\cdot\gamma\right)-4\cdot\left(\left(\left(4-\gamma^2\right)^2\cdot K-8\right)2-\gamma^3\right)\cdot w\right)\Big/\left(\left(\left(4-\gamma^2\right)^2\cdot K-8\right)^2-(4\cdot\gamma)^2\right)$. 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.

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

$$\pi_1^U = w \cdot q_2\left(p_2^*\left(\Delta_2, \Delta_1\right), p_1^*\left(\Delta_1, \Delta_2\right)\right) + \left(p_1^*\left(\Delta_1, \Delta_2\right) - \left(c - \Delta_1\right)\right) \cdot q_1\left(p_1^*\left(\Delta_1, \Delta_2\right), p_2^*\left(\Delta_2, \Delta_1\right)\right) - 2 \cdot \tfrac{K}{2} \cdot \Delta^2,$$ [42]

While under the downstream investment regime both firms choose their investment level independently:

$$\pi_1^U = w \cdot q_2\left(p_2^*\left(\Delta_2, \Delta_1\right), p_1^*\left(\Delta_1, \Delta_2\right)\right) + \left(p_1^*\left(\Delta_1, \Delta_2\right) - \left(c - \Delta_1\right)\right) \cdot q_1\left(p_1^*\left(\Delta_1, \Delta_2\right), p_2^*\left(\Delta_2, \Delta_1\right)\right) - \tfrac{K}{2} \cdot \Delta_1^2,$$
$$\pi_2 = \left(p_2^*\left(\Delta_2, \Delta_1\right) - w - \left(c - \Delta_2\right)\right) \cdot q_2\left(p_2^*\left(\Delta_2, \Delta_1\right), p_1^*\left(\Delta_1, \Delta_2\right)\right) - \tfrac{K}{2} \cdot \Delta_2^2$$

5.3 Comparison of investment regimes

Comparing the investment incentives, we get the following result:

Proposition 3 *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 integrated firm faces the same (direct) incentives to invest in its own downstream cost structure regardless of the investment regime as the investment is always conducted within the same firm. Hence, we can focus on the incentives to invest in the independent firm's cost structure: While 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:

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

Proposition 4 ***(a)*** *Under Cournot competition the downstream investment regime under vertical integration yields always a higher welfare than any other combination of investment regime and vertical structure.* ***(b)*** *Under Bertrand competition, three cases have to be distinguished:* ***(i)*** *The upstream investment regime under vertical separation is superior whenever* $w > {}^{(2-\gamma^2)}/_{(4-\gamma^2)} \cdot (\alpha - c)$ *and* $w > {}^{8(1+\gamma)}/_{(2+\gamma)(12+5\gamma-3\gamma^2)} \cdot (\alpha - c)$. ***(ii)*** *The downstream investment regime under vertical integration is superior whenever* $w < {}^{8(1+\gamma)}/_{(2+\gamma)(12+5\gamma-3\gamma^2)} \cdot (\alpha - c)$ *and* $\gamma > {}^{9}/_{10}$. ***(iii)*** *The downstream investment regime under vertical separation is superior 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 yields always the highest welfare. Under Bertrand competition, we get three cases, where different combinations are superior 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 always inferior. The upstream investment regime under vertical separation is superior for all ${}^{w}/_{\gamma}$-combinations in area (A). That is under high levels of w. The downstream investment regime and vertical integration is optimal for ${}^{w}/_{\gamma}$-combinations in area (B) and the downstream investment regime and vertical separation is optimal for ${}^{w}/_{\gamma}$-combinations in area (C).

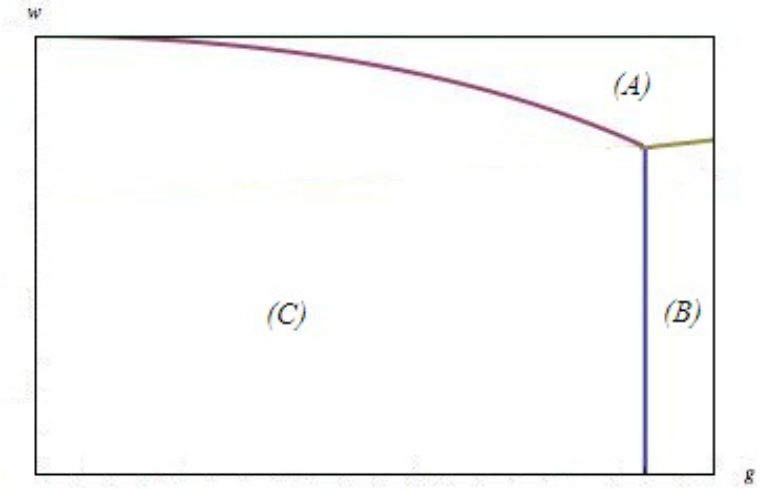

Figure 1: Welfare optimal combinations of investment regime and vertical structure under Bertrand competition

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, what is the main determinant for the optimal investment regime.

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 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.

Extensions of our analysis that would be useful to explore include process innovation, collaborative investment between up- and downstream firms, competition among multiple upstream suppliers, intermediate forms of vertical integration, as well as discrete investment technologies.

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 $K < \bar{K}_C = \frac{1}{2+\gamma}$:

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

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

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 3 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.[43] 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 4.

A.4 Proofs

Proof of Lemma 1

W^C denotes the common welfare function defined as the sum of firm profits and consumer surplus minus investment costs. Under Cournot competition this is $W^C = (1+\gamma)\cdot\left(\frac{2(\alpha-c-w)(2-\gamma)+(2-\gamma)(\Delta_i+\Delta_j)}{4-\gamma^2}.\right)^2 +$

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

$2 \cdot w \cdot \frac{2(\alpha-c-w)(2-\gamma)+(2-\gamma)(\Delta_i+\Delta_j)}{4-\gamma^2} + \left(\frac{(\alpha-c-w)(2-\gamma)+2\Delta_i-\gamma\Delta_j}{4-\gamma^2}\right)^2 - 2 \cdot \frac{K}{2}\Delta^2$. π_U^C constitutes the respective investment objective function of the upstream monopolist under Cournot competition.

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 $\Delta_i = \Delta_j = \Delta \ \forall i, j$.

As all (de)nominators are clearly positive, the whole term is also positive. Hence, investment by the upstream monopolist is below the investment level a welfare maximizing regulator would choose for any wholesale price and investment level.

Proof of Lemma 2

While W^C is defined as above, π_i denotes downstream firm i's investment objective function.

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. (This is easy to see, as $\alpha - (c + w - \Delta) > \alpha - 2(c + w - \Delta)$ and $4(1 + \gamma)(2 - \gamma) > \gamma$.) Hence, the differential is clearly positive.

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

Proof of Proposition 1

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 $\Delta_i = \Delta_j = \Delta \ \forall i, j$. I.e. marginal profits though investment are higher for the downstream firm relative to the upstream monopolist. Hence, the investment incentives and the investment level are higher. Moreover, 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 compared to the upstream investment regime.

Proof of Corollary 1

From Lemmas 1 and 2 we know that first-best investment levels are never reached. Hence, the stronger investment incentives, the closer we reach first-best investment. From Proposition **1** we know that investment levels under the downstream investment regime is always higher. Hence, welfare is also higher under the downstream investment regime.

Proof of Remark 1

The measure for social welfare is given by $W = CS + \pi^U + 2 \cdot \pi^D$. In our Cournot setting this is $W = \frac{3+\gamma}{(2+\gamma)^2}\left(\alpha - c - w + \frac{8(\alpha-w-c)}{K(2+\gamma)(4-\gamma^2)-4}\right)^2 + \frac{2w}{2+\gamma}\left(\alpha - c - w + \frac{8(\alpha-w-c)}{K(2+\gamma)(4-\gamma^2)-4}\right) - K\left(\frac{8(\alpha-w-c)}{K(2+\gamma)(4-\gamma^2)-4}\right)^2$. We know from the proof from Remark 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 Lemma 3

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

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

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

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

$\frac{\partial W}{\partial \Delta i} - \frac{\partial \pi^U}{\partial \Delta i} = \frac{w}{(1+\gamma)(2-\gamma)} + \left(1+\gamma\right)\left(6-2\gamma\right)\frac{\alpha-c-w+\Delta}{((1+\gamma)(2-\gamma))^2} > 0$, 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 Lemma 4

For any (w, Δ) the difference of a marginal increase in welfare and a marginal increase in downstream profits through investment 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 2

The difference of a marginal increase in upstream profits 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 Corollary 2

From Lemmas **3** and **4** we know that first-best investment levels are never reached. Hence, the stronger investment incentives, the closer we reach first-best investment. From Proposition **2** we know that

investment levels under the downstream investment regime are higher relative to the upstream investment regime whenever $w < \hat{w}_B = \frac{2-\gamma^2}{4-\gamma^2}(\alpha - c)$. Hence, welfare is also higher under the downstream investment regime whenever $w < \hat{w}_B = \frac{2-\gamma^2}{4-\gamma^2}(\alpha - c)$.

Proof of Corollary 3

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

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

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 Remark 2

The measure for social welfare is given by $W = CS + \pi^U + 2 \cdot \pi^D$. In our Bertrand setting this is $W = (1+\gamma)(3-2\gamma)\left(\frac{(\alpha-c-w)+\frac{w}{K(2-\gamma)(1+\gamma)}}{(1+\gamma)(2-\gamma)}\right)^2 + 2 \cdot w \cdot \frac{\alpha-c-w+\frac{w}{K(2-\gamma)(1+\gamma)}}{(1+\gamma)(2-\gamma)} - 2 \cdot \frac{K}{2}\left(\frac{w}{K(2-\gamma)(1+\gamma)}\right)^2$. 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 $K < \bar{K}_B = \frac{1}{(1+\gamma)(2-\gamma)}$:

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

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

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 Remark 3

We know from the proof of Lemma **4** 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 3

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 4

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)

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

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

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

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)

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

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

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