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With Upstream Market Power**

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Downstream Mode of Competition With Upstream Market Power*

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Abstract

In contrast with previous studies we assume no ex-ante commitment over the —price or quantity— type of contract which downstream firms will independently offer consumers in a two-tier oligopoly. Under competing vertical chains, we propose that the downstream mode of competition which in equilibrium emerges is the outcome of independent implicit agreements, between each downstream firm and its exclusive input supplier, in each vertical chain. Our findings suggest that input suppliers may thus act as commitment devices sufficient to endogenously sustain the quantity (Cournot) mode of competition.

JEL Classification: D43; L13; L42

Keywords: Oligopoly; Vertical relations; Wholesale prices; Equilibrium mode of competition

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1. Introduction

The cornerstones of modern oligopoly theory are the models of Cournot-Nash, where rival firms independently adjust their quantities, and Bertrand-Nash, where the firms' strategic variables are their prices. Although these alternative hypotheses deliver highly significant implications to the theory and practice of industrial economics (Vives, 2001), a full understanding of what induces the mode of competition in oligopoly is however still to come.

Singh and Vives (1984) were the first who explored the latter inquiry, in the context of a differentiated product-duopoly, where each firm, facing constant and exogenous marginal cost, offers consumers either a price-contract or a quantity-contract: If a firm chooses the price-contract, then this firm is committed to supply the amount which consumers demand at a predetermined price, independently of its competitor's action. If on the other hand the firm chooses the quantity-contract, then it is committed to supply a predetermined quantity at the market bearing price. Assuming that there are prohibitively high costs associated with changing the type of contract, the dominant strategy for each firm was found to be the quantity (price) contract if goods are substitutes (complements). This seminal paper had subsequently inspired a number of variant studies on the determinants of the different types of imperfect competition (see e.g. Cheng, 1985; Klemperer and Meyer, 1986; Dastidar, 1997; Lambertini, 1997; Qiu, 1997; Häckner 2000; Amir and Jin, 2001). The bulk of that literature was however grounded on the assumption that firms can credibly ex-ante commit to a particular mode of competition, without unraveling any explicit mechanism or device which might reason such an assumption.

The objective of this paper is to endogenously determine the downstream firms' mode of competition, in the context of a two-tier industry, as well as to

investigate whether and how vertical relations can act as a commitment device to a particular mode of competition.

To fulfill this objective, we consider an environment with two upstream and two downstream firms that are locked in exclusive relations.¹ The timing of moves is as follows. At stage one, each upstream-downstream pair, simultaneously and independently from the rival pair, determines its downstream firm's specific input price and the mode of competition that the firm will materialize at the second stage. This specific input price/mode of competition scheme is the result of an *implicit agreement* within each pair obtained as follows: For any ex-ante presumed pair-specific input price/mode of competition configuration in the industry, the downstream firm proposes a unilateral ex-post deviation to an alternative mode of competition, and its input supplier, if agrees, dictates the downstream firm's specific input price corresponding to that deviation. Otherwise, e.g., if the supplier disagrees, the two agents stick to the originally presumed configuration. In the latter instance, the input supplier effectively acts as the downstream firm's commitment device to the presumed mode of competition, deterring the firm from unilaterally shifting ex-post to a different mode. At stage two, downstream firms compete in the product market on the — chosen as above — types of contracts to be offered consumers.

In this environment, each input supplier independently opts for that pair-specific input price/mode of competition scheme which secures the highest profits for its own. Hence, the input supplier, by vetoing the downstream firm's relevant

¹ Lafontaine and Slade (2008) identify a series of industries with vertical chains' exclusive relations. Car equipment suppliers have exclusive contracts with car manufacturers, petroleum firms with gasoline retailers and soft drinks producers with food retailers.

proposal, can block any ex-post unilateral deviation on the downstream firm's part to a mode of competition that does not increase the supplier's profits.

Our contribution to the literature is two-fold.

First, we suggest a plausible solution concept for the downstream mode of competition in vertically related industries. To this end, our starting point of reasoning is that a downstream firm's ex-post deviation, to a mode of competition different from the one according which the input price has ex-ante been struck, is time-consistent with the upstream supplier's objective only so long as the supplier optimally readjusts the downstream firm's-specific input price according to the novel mode of competition. This however in turn entails that the deviant downstream firm will effectively be transformed to a Stackelberg follower in the product market, since its production decision(s) would be taken at a later time than those of its rival firm. It follows that, within each competing vertical chain, the downstream firm has an incentive to — collectively with its input supplier — decide in advance (e.g., at the first stage) about any possible ex-post deviation (during the second, market competition, stage) from the ex-ante, pair-specific, input price/mode of competition scheme. At the first stage, therefore, given any ex-ante input price/mode of competition configuration in the industry, the downstream firm may propose an alternative [e.g., a quantity (price) instead of a price (quantity)] contract to be offered to the downstream firm's clients ex-post, whereas the input supplier may in advance choose an input price contingent upon that novel contract, provided however that (in advance) consents to the proposed deviation. Otherwise, the two parties would ex-post stick to the presumed downstream firm specific wage/mode of competition scheme. Hence, in the latter instance, the input supplier effectively acts as a commitment device of its

own firm to a firm-specific mode of competition, rendering credibility to the type of contract which downstream firms offer consumers in the equilibrium.

Second, we highlight the significance of exclusive input suppliers on the equilibrium downstream mode of competition. In particular, we show that in differentiated (final) goods industries, where each downstream producer is locked in a bilateral monopoly situation with its exclusive input supplier, the symmetric Cournot mode of competition (where downstream firms simultaneously adjust their own quantities) is endogenously sustained as the industry's mode of competition. The reason is that, this particular mode of competition, results in the highest profits for both the input supplier and the final good producer, in each vertical chain. Intuitively, a quantity-setting downstream firm may raise more its price above its marginal cost, compared with a price-setting downstream firm, because the elasticity of a firm's demand when taking the rival firm's quantity as given is lower than the respective one when taking the rival's price as given. The input supplier can thus enjoy a share from a larger pie in the first than in the second instance.

Furthermore, our welfare analysis suggests that the symmetric Cournot (Bertrand) competition results in the highest (lowest) downstream profits and the lowest (highest) consumer surplus. The ranking of the upstream firms' profits in the three configurations depends on the degree of product substitutability. It nonetheless proves that the consumer surplus-effect always dominates the vertical chains' (joint) profits-effect. Hence, the symmetric Bertrand mode of competition always leads to the highest social welfare, the symmetric Cournot mode leads to the lowest, and the asymmetric Cournot–Bertrand mode lies in-between.

A closely related paper to ours is that of Correa-López and Naylor (2004), henceforth LN, who replace the Singh and Vives (1984) assumption for exogenous

unit cost with the outcome of a (first stage) wage bargain between the firm and its labour union. They find that, if unions are relatively powerful in the wage bargain, and attach high relative importance to wages in their objective functions, equilibrium profits under the Bertrand regime may exceed those under the Cournot regime, in case that the firms' products are sufficiently differentiated. Yet, like in the previous literature, this paper assumes that, when firm/union pairs independently bargain over the wage, the type of contract which firms will ex-post offer consumers is credible.

We depart from this paper in at least three dimensions: First, LN postulate that at the second stage both firms simultaneously adjust either their quantities, or their prices. Contrary to them, we investigate also the asymmetric case, where the one downstream firm sets the quantity and the other sets the price, as a candidate equilibrium configuration. Second, and more important, LN implicitly consider multilateral deviations from a benchmark, Bertrand or Cournot regime, according which, when a firm ex-post deviates to a mode of competition different than the ex-ante addressed one, its rival firm also does so, at the same time. Hence, both firms' wages are simultaneously readjusted according to the novel mode of competition. As a consequence, LN implicitly address an equilibrium mode of competition by simply comparing the downstream firms' profits in the symmetric Bertrand regime vs. the respective ones in the Cournot regime. Contrary to them, we consider that, for a particular mode of competition to emerge in the (sub-game perfect) equilibrium, it must render the upstream supplier, as well as the downstream firm, the maximum pay-off ex-post. We therefore investigate all possible unilateral (not multilateral, as in LN) deviations, on the part of any vertical chain, to a different than the ex-ante presumed chain-specific input price/mode of competition scheme and check whether by any of them the deviant chain's pay-offs improve. If not, then (and only then) the

ex-ante scheme is a (sub-game perfect) equilibrium one. Third, LN assume that, when each union at the first stage bargains with its own firm about the firm-specific wage, the firm can credibly commit to a particular mode of competition, to be materialized at the second stage. Yet, in their paper there is no mechanism/devise which might reason such an assumption. We postulate that, given that the firm's decision to deviate will be materialized after the firm-specific wage bargain has been struck according to a particular mode, the union and the firm must (cooperatively) readjust the firm-specific wage according to the novel mode of competition. Hence, we argue that, it is the input supplier who effectively acts as a commitment device of its own downstream firm to a specific mode of competition, rendering credibility to the type of contract which each downstream firm will offer consumers in the equilibrium.

The rest of the paper is organized as follows. In section 2, we present our model. In section 3, we study all candidate equilibria and state our main findings. Section 4 includes the welfare analysis and in Section 5, two extensions of the basic model are briefly discussed. The analytical results and the proofs are relegated to Appendix A.

2. The model

We consider a two-tier industry consisting of two upstream and two downstream firms. One could think of the upstream and the downstream firms as being respectively input producers and final good manufacturers or wholesalers and retailers. There is a one-to-one relation between the products of the upstream and the downstream firms and an exclusive relation between upstream firm i and downstream firm i , with $i = 1, 2$.² The latter can result from various sources. As in

² This is a quite common assumption in the vertical relations literature (see e.g. Horn and Wolinsky, 1988; Ziss, 1995; Lommerud et al., 2005). In Section 5, we relax it and in line with some recent papers

Milliou and Petrakis (2007), “when the upstream firms produce inputs which are tailored for specific final good manufacturers, there may be irreversible R&D investments that create *lock-in* effects and high switching costs”.

Following Singh and Vives (1984), it is assumed that the representative consumer’s preferences are described by the utility function $U(q_i, q_j) = a(q_i + q_j) - (q_i^2 + q_j^2 + 2\gamma q_i q_j) / 2$, where q_i is the quantity of firm i ’s. Then, each downstream firm i faces the following (inverse) demand function:

$$P_i = a - q_i - \gamma q_j, \quad i, j = 1, 2, i \neq j \quad (1)$$

Where, $a > 0$ and $\gamma \in (0, 1]$ measures the substitutability between the products. If $\gamma = 0$, each firm has monopolistic market power, while if $\gamma = 1$, the products are perfect substitutes.³

Downstream firms are endowed with constant returns to scale technologies that transform one unit of input to one unit of output, that is $q_i = L_i; i = 1, 2$; where L_i denotes the downstream firm i ’s-specific input, bought from the upstream firm i .

Each downstream firm faces no other cost than the cost of obtaining the input from its upstream supplier. The latter consists of a per-unit of input price w_i i.e., trading is conducted through a linear wholesale price contract. Each upstream firm faces a normalized to zero marginal cost of production, That is, the upstream firm i ’s objective is to maximize its profits:⁴

(see e.g. de Fontenay and Gans, 2005, 2006; Björnerstedt and Stennek, 2006) we discuss what would happen if we allow for non-exclusive relations.

³ In section 5, we also examine the case where the products are complements.

⁴ The existence of an exclusive relation within each upstream-downstream pair is a natural assumption if input suppliers are trade unions. In this case, we would assume that all workers have identical skills and are organized into two separate firm-level unions. Each union is of the utilitarian type, maximizing the sum of its (risk-neutral) members’ utilities, given fixed union membership (see e.g. Oswald, 1982;

$$\pi_i(w_i, L_i) = w_i L_i \quad (2)$$

In this context, we consider the following two-stage game:

Stage 1:

Each upstream-downstream pair i , simultaneously and independently from pair j , $j \neq i = 1, 2$, determines the downstream firm i 's specific input price and the mode of competition that the downstream firm i will materialize in the second stage. This determination of specific input price/mode of competition scheme is the result of an *implicit agreement* within each pair i , obtained as follows: For any ex-ante presumed downstream firm i 's specific input price/mode of competition configuration in the industry, the downstream firm i proposes a unilateral (e.g., on the part of firm i) ex-post deviation to an alternative mode of competition, and the upstream firm i , if agrees, dictates the downstream firm i 's specific input price corresponding to that deviation. Otherwise, e.g., if the upstream firm i disagrees, the two agents stick to the originally presumed configuration. In the latter instance, the upstream firm i effectively acts as a commitment device for downstream firm i to the presumed mode of competition, deterring the later from unilaterally shifting ex-post to a different mode.

The following clarification is in order: The upstream-downstream pair i 's, as above agreed, mode of competition to be materialized ex-post, is not actually observable by the rival pair j before market competition (e.g., the second stage of the

Booth 1996). That is, union i 's objective is to maximize $U_i(w_i, L_i) = (w_i)^b L_i$. Where, w_i is the wage paid by firm i and captures all short-run marginal costs for the downstream firm i (Correa-López and Naylor, 2004) and $b \in (0, 1]$ can be thought of as the representative member's relative rate of risk aversion, provided that union membership is fixed and all members are identical. Alternatively, b , which in our context is normalized to unity, denotes the representative union member's elasticity of substitution between wages and employment. We have also applied our model for the case of labor unions and our results remain robust.

game) is in place. Still, however, the upstream-downstream pair i 's input price contract (which is observable just after the first stage negotiations are completed in both pairs) provides ex-ante information about the downstream firm i 's mode of competition. Hence, and given that the downstream firm i 's input price would be readjusted without delay to a mode of competition different than the one dictated by the original input price contract, the upstream-downstream pair j can be “surprised” ex-post by a novel input price/mode of competition scheme on the part of the upstream-downstream pair i . This can happen, however, only so long as it —at the first stage— proves to be at both the downstream firm's and its input supplier's best interest to do so. If not, and only then, the ex-ante downstream firm's-specific input price/mode of competition scheme would be credible and thus ex-post sustained.

Stage 2: Downstream firms compete in the product market on the — chosen as above — types of contracts to be offered consumers.

3. Equilibrium mode of competition

3.1 Symmetric Cournot competition

Let first propose, as the candidate equilibrium, the one where both pairs independently reach a —first stage— implicit agreement on the quantity being (e.g., ex-post sustained as) each downstream firm's mode of competition.

Under this scenario, at the second stage, each downstream firm i will choose its output q_i to maximize its profits, $\Pi_i^C(\gamma, w_i, q_i, q_j) = (a - q_i - \gamma q_j - w_i)q_i$. Taking the first order conditions and solving the system of equations, the downstream firm i 's input demand and profits are then given by $L_i^C(\gamma, w_i, w_j)$ and $\Pi_i^C(\gamma, w_i, w_j) = [L_i^C(\gamma, w_i, w_j)]^2$ respectively. At the first stage, each upstream firm i

independently sets the input price w_i so as to maximize its profits, $\pi_i^C(\gamma, w_i, q_i, q_j) = w_i L_i^C(\gamma, w_i, w_j)$. The upstream firm i 's input price reaction function is then given by $w_i^C = w_i^C(\gamma, w_j)$ and, solving the system of the input price reaction functions, we get a unique stable solution for the input price, $w_i^C(\gamma)$. Using $w_i^C(\gamma)$, we subsequently derive the downstream firm i 's quantity $q_i^C(\gamma)$, price $p_i^C(\gamma)$ and profits $\Pi_i^C(\gamma)$, as well as the upstream firm i 's profits, $\pi_i^C(\gamma)$, corresponding to the symmetric Cournot candidate equilibrium mode of competition (see Appendix 1A).

The above results constitute a Nash equilibrium only if no upstream-downstream pair i has an incentive to reach an alternative agreement at the first stage. That is, instead of agreeing on downstream firm i to adjust its own quantity, to agree over adjusting its own price in the continuation of the game (e.g., at the second stage) with the upstream firm i readjusting (without delay) the pair's input price according to the (pair-specific) novel mode of competition. At the same time, of course, pair j sticks to the quantity mode of competition.

Suppose w.l.o.g. that, at the first stage of the game, the upstream-downstream pair $i \equiv 1$ is the one considering the downstream firm i to adjust its own price. In the continuation of the game, such an agreement entails that, while the upstream firm 2 will sustain the downstream firm 2's input price which corresponds to the symmetric Cournot competition, $w_2^C(\gamma)$, the upstream firm 1's optimal response will be given by the input price reaction function corresponding to the configuration where downstream firm 1 choose its price and downstream firm 2 chooses its quantity at the second stage, i.e., $w_1^{PQ} = w_1^{PQ}(\gamma, w_2^C)$. It follows that the upstream firm 1 will (without

delay) readjust the downstream firm 1's input price to $w_{1d}^C(\gamma)$, with $w_{1d}^C(\gamma) < w_1^C(\gamma)$.

The reasoning and consequences of this result are as follows.

The elasticity of input demand for downstream firm i , when firm $i(j)$ sets the price (quantity), is higher than the respective elasticity when both downstream firms set the quantity in the second stage of the game.⁵ Hence, in case of a percentage increase in the input price that the downstream firm i faces, the resulting percentage decrease in its respective demand for input will be higher in the former configuration than in the latter. Therefore, the relatively high marginal cost which the downstream firm 1 faces, for a unit input price increase, pulls down $w_{1d}^C(\gamma)$ at a level lower than the respective in the candidate symmetric Cournot equilibrium. This in turn implies a direct cost saving for downstream firm 1, which decreases the price of its final good

in the second stage of the game, since $\frac{\mathcal{G}p_i^{PQ}(\gamma, w_i, w_j)}{\mathcal{G}w_i} = \frac{2(\gamma^2 - 1)}{3\gamma^2 - 4} > 0$. An immediate

consequence of that will then be the expansion of downstream firm 1's output sold in the downstream market.

However, given $w_{1d}^C(\gamma)$ and $w_2^C(\gamma)$, the ensuing profits for upstream firm 1 is $\pi_{1d}^C(\gamma, w_{1d}^C, w_2^C) = \pi_1^{PQ}(\gamma, w_{1d}^C, w_2^C)$, and, since it proves that $\pi_{1d}^C(\gamma) < \pi_1^C(\gamma)$, $\forall \gamma \in (0, 1]$, it turns out that upstream firm 1 has no incentive for downstream firm 1 to ex-post switch from quantity-setting to price-setting. This is so because the negative input price reduction effect dominates the positive output expansion effect.

⁵ The elasticity of input demand for downstream firm i , when both downstream firms set the quantity is $|\varepsilon_{Li}^C| = \frac{2w_i}{a(2-\gamma) - 2w_i + \gamma w_j}$. The respective elasticity, when downstream firm i sets

the price and firm j sets the quantity is $|\varepsilon_{Li}^{PQ}| = \frac{(2-\gamma^2)w_i}{a(2-\gamma-\gamma^2) - (2-\gamma^2)w_i + \gamma w_j}$.

Similarly, since $\Pi_{id}^c(\gamma) < \Pi_i^c(\gamma)$, in the relevant γ -area, neither downstream firm 1 has an incentive to ex-post switch from quantity-setting to price-setting. Intuitively, as regards downstream firm 1, the negative price reduction effect dominates both positive effects: the cost saving effect and the output expansion effect. The following proposition summarizes.

Proposition 1

The symmetric Cournot mode of competition is always an equilibrium mode of competition. The reason is that, for all $\gamma \in (0, 1]$, neither the downstream firm nor the upstream firm, within each pair i , has an incentive for the downstream firm i to unilaterally deviate ex-post from quantity-setting to price-setting.

Proof: See Appendix 1B. \square

3.2 Symmetric Bertrand competition

We next propose as a candidate equilibrium the one where both upstream-downstream pairs independently reach a first stage implicit agreement on the price being (e.g., ex-post sustained as) each downstream firm's mode of competition.

Under this scenario, each downstream firm i , facing the direct demand function, $q_i(p_i, p_j) = \frac{a(1-\gamma) - p_i + \gamma p_j}{1-\gamma^2}$, will at the second stage choose its price p_i to maximize its profits, $\Pi_i(\gamma, w_i, p_i, p_j) = (p_i - w_i)q_i(p_i, p_j)$. Taking the first order conditions and solving the system of equations, the downstream firm i 's price and profits are then, $p_i^B(\gamma, w_i, w_j)$ and $\Pi_i^B(\gamma, w_i, w_j)$, respectively. Substituting $p_i^B(\gamma, w_i, w_j)$ into $q_i(p_i, p_j)$ we get the downstream firm i 's demand for input,

$L_i^B(\gamma, w_i, w_j)$. At the first stage, each upstream firm i sets the input price w_i so as to maximize its profits, $\pi_i^B(\gamma, w_i, q_i, q_j) = w_i^B L_i^B(\gamma, q_i, q_j)$. The upstream firm i 's input price reaction function is then given by, $w_i^B = w_i^B(\gamma, w_j)$, and solving the system of the input price reaction functions, we get a unique stable solution for the input price $w_i^B(\gamma)$. Using $w_i^B(\gamma)$, we subsequently get the downstream firm i 's price $w_i^B(\gamma)$, quantity $q_i^B(\gamma)$, and profits $\Pi_i^B(\gamma)$, as well as the upstream firm i 's profits $\pi_i^B(\gamma)$, corresponding to the symmetric Bertrand candidate equilibrium mode of competition (see Appendix 2A).

The above results constitute a Nash equilibrium only if no upstream-downstream pair i has an incentive to reach an alternative implicit agreement at the first stage, e.g., to agree on downstream firm i to adjust its own quantity, instead of its price, at the second stage, given that, at the same time, the downstream firm j will adjust its own price and the upstream firm i will consistently (and immediately) readjust its input price.

Suppose w.l.o.g. that at the first stage of the game, the upstream-downstream pair $i \equiv 1$ considers (an alternative agreement to) a second stage unilateral deviation from price-setting to quantity-setting. Such an agreement implies that, while the upstream firm 2 will sustain for the input price $w_2^B(\gamma)$ that corresponds to the symmetric Bertrand competition, the upstream firm 1's optimal response will be given by the input price reaction function which corresponds to the configuration where, at the second stage of the game, pair 1 chooses the quantity and pair 2 chooses the price i.e., $w_1^{OP} = w_1^{OP}(\gamma, w_2^B)$. Hence, the upstream firm 1 will readjust the downstream firm 1's specific input price to $w_{1d}^B(\gamma)$, with $w_{1d}^B(\gamma) > w_1^B(\gamma)$.

This is so because the elasticity of input demand of downstream firm i , when firm $i(j)$ sets the quantity (price), is lower than the respective one in case where both downstream firms set the price in the second stage.⁶ The upstream firm 1 now exploits its relatively higher input capacity per unit of input price increase, and sets a higher input price. Since $\frac{\mathcal{G}q_i^{PO}(\gamma, w_i, w_j)}{\mathcal{G}w_i} = \frac{2}{3\gamma^2 - 4} < 0$, this in turn decreases the downstream firm 1's demand for input and output, thus pushing up its market-clearing price.

Given $w_{1d}^B(\gamma)$ and $w_2^D(\gamma)$, the ensuing profits for upstream firm 1 under the considered deviation is $\pi_{1d}^B(\gamma, w_{1d}^B, w_2^B) = \pi_1^{OP}(\gamma, w_{1d}^B, w_2^B)$, and since it is found that $\pi_{1d}^B(\gamma) > \pi_1^B(\gamma)$, $\forall \gamma \in (0, 1]$, it proves that the upstream firm 1 has an incentive for downstream firm 1 to ex-post switch from price-setting to quantity-setting. Intuitively, the positive input price increase effect dominates the negative output decrease effect. Regarding the downstream firm 1, it proves that, $\Pi_{1d}^B(\gamma) > \Pi_1^B(\gamma)$, $\forall \gamma \in (0, 1]$, in the relevant γ -area. Hence, apart from its input supplier, the downstream firm 1 has also an incentive to (unilaterally) switch from price-setting to quantity-setting, ex-post. The reasoning here is that the positive price-increase effect dominates both negative effects: the cost increase effect and the output decrease effect.

The following proposition summarizes.

Proposition 2

The symmetric Bertrand mode of competition can never be an equilibrium mode of competition. The reason is that, for all $\gamma \in (0, 1]$, both the downstream firm and its

⁶ The elasticity of input demand for downstream firm i , when both downstream firms set the price is $|\varepsilon_{Li}^B| = \frac{(2 - \gamma^2)w_i}{a(2 - \gamma - \gamma^2) - (2 - \gamma^2)w_i + \gamma w_j}$. The respective elasticity, when downstream firm i sets the quantity and firm j sets the price is $|\varepsilon_{Li}^{OP}| = \frac{2w_i}{a(2 - \gamma) - 2w_i + \gamma w_j}$.

input supplier, in each upstream-downstream pair i , have an incentive for downstream firm i to unilaterally deviate ex-post from price-setting to quantity-setting.

Proof: See Appendix 2B. \square

3.3 Asymmetric Cournot (Bertrand) - Bertrand (Cournot) competition

Finally, we propose as a candidate equilibrium the one where at the first stage of the game the upstream-downstream pair $i(j)$ reaches an implicit agreement on the quantity (price) being (e.g., ex-post sustained as the) the downstream firm i 's $i(j)$ mode of competition. Of course, due to the symmetric industry structure, the reverse configuration is by-default proposed as similar candidate equilibrium.

Suppose w.l.o.g. that at the second stage, the downstream firm 1 adjusts its own quantity whereas firm 2 adjusts its own price. That is, firm 1 chooses q_1 so as to maximize its profits, subject to $p_1 = a(1-\gamma) + \gamma p_2 - (1-\gamma^2)q_1$, taking p_2 as given. Hence, firm 1's profit function is $\Pi_1^{QP} = q_1[a(1-\gamma) + \gamma p_2 + (\gamma^2 - 1)q_1 - w_1]$. On the other hand, the downstream firm 2 adjusts p_2 in order to maximize its profits, subject to $q_2 = a - \gamma q_1 - p_2$, taking p_1 as given. Thus, firm 2's profit function is $\Pi_2^{QP} = (p_2 - w_2)(a - \gamma q_1 - p_2)$. Taking the first order conditions and solving the system of equations, the firm 1's input demand and firm 2's price are, $L_1^{QP}(\gamma, w_1, w_2)$ and $p_2^{QP}(\gamma, w_1, w_2)$, respectively. It follows that firm 2's input demand is $L_2^{QP}(\gamma, w_1, w_2)$. Hence, the profits of downstream firm 1 and firm 2 in the candidate equilibrium respectively are, $\Pi_1^{QP}(\gamma, w_1, w_2)$ and $\Pi_2^{QP}(\gamma, w_1, w_2)$.

At the first stage, the upstream firms simultaneously and independently set the input prices so as to maximize their own profits, given by $\pi_1^{OP}(\gamma, w_1, q_1, q_2) = w_1 L_1^{OP}(\gamma, w_1, w_2)$ and $\pi_2^{OP}(\gamma, w_1, q_1, q_2) = w_2 L_2^{OP}(\gamma, w_1, w_2)$ with the input price reaction functions respectively being, $w_1^{OP} = w_1^{OP}(\gamma, w_2)$ and $w_2^{OP} = w_2^{OP}(\gamma, w_1)$. Solving the system of these reaction functions, we then get a unique stable solution for the input prices $w_1^{OP}(\gamma)$ and $w_2^{OP}(\gamma)$. Using $w_1^{OP}(\gamma)$ and $w_2^{OP}(\gamma)$, we subsequently get the downstream firm i 's quantity $q_i^{OP}(\gamma)$, price $p_i^{OP}(\gamma)$, and profits $\Pi_i^{OP}(\gamma)$ as well as the upstream firm i 's profits $\pi_i^{OP}(\gamma)$, $i=1,2$, in the candidate equilibrium (see Appendix 3A).

Apparently, to check for the Nash equilibrium, we must here look up for two possible alternative —first stage— agreements, one for each upstream-downstream pair:

The upstream-downstream pair 1 may agree on downstream firm 1 to adjust its own price, instead of its quantity, at the second stage. Given that at the same time, the downstream firm 2 will adjust its own price while the upstream firm 1 will consistently readjust its input price. In the continuation of the game such an alternative agreement implies that, given $w_2^{OP}(\gamma)$, the upstream firm 1's optimal response will be given by the input price reaction function that corresponds to the symmetric Cournot competition, i.e., $w_1^C = w_1^C(\gamma, w_2^{OP})$. Hence, the upstream firm 1 will (without delay) readjust its input price to $w_{1d}^{OP}(\gamma)$, with $w_{1d}^{OP}(\gamma) < w_1^{OP}(\gamma)$.

Regarding the upstream firm 1's profits, this —negative— input price decrease effect, is found to be dominated by the —positive— output expansion effect, yet, only if final products are too close substitutes, e.g., for high γ -values. The latter implies too fierce competition between downstream firms, hence, a considerably large

expansion in the downstream firm 1's output due to a unit input price decrease. Therefore, the upstream firm 1, in such an instance, has an incentive for the downstream firm 1 to ex-post deviate from quantity-setting to price-setting. On the other hand, nonetheless, the downstream firm 1 has a similar incentive only if products are not so close substitutes. The reason is that the —positive— input price decrease and output expansion effects would only then dominate the —negative— final product's price reduction effect. Hence, if products are sufficiently differentiated, the upstream firm 1 will effectively block the alternative —first stage— agreement for pair 1, while, for even lower γ -values, the firm-specific mode of competition leading to such an agreement will be never proposed by the downstream firm 1.

Consider, nonetheless, the alternative —first stage— agreement for the upstream-downstream pair 2. At the second stage, such an agreement implies that, given $w_1^{OP}(\gamma)$, the upstream firm 2 uses the input price reaction function that corresponds to the symmetric Bertrand competition, i.e., $w_2^B = w_2^B(\gamma, w_1^{OP})$ and (without delay) readjusts the downstream firm 2's specific input price to $w_{2d}^{OP}(\gamma)$, with $w_{2d}^{OP}(\gamma) > w_2^{OP}(\gamma)$. Given $w_1^{OP}(\gamma)$ and $w_{2d}^{OP}(\gamma)$, it subsequently proves that, in the upstream-downstream pair 2, both the firm and its input supplier have an incentive for the downstream firm 2 to ex-post deviate from price-setting to quantity-setting. The intuitive arguments reasoning this result are analogous to the case of the symmetric Bertrand competition (in sub-section 3.2).

The following proposition summarizes.

Proposition 3

The asymmetric mode of competition-configuration where the upstream-downstream pair i agrees over the quantity and the upstream-downstream pair j agrees over the

price, as the mode of competition of the downstream firm i and j respectively can never be an equilibrium mode of competition. The reasoning is the following:

- (i) In the upstream-downstream pair i : (a). The input supplier has an incentive for its downstream firm to unilaterally deviate ex-post from quantity-setting to price-setting, if $\gamma > 0.992$ (b). The downstream firm has a similar incentive to deviate from quantity-setting to price-setting, if $\gamma > 0.897$.
- (ii) In the upstream-downstream pair j , for all $\gamma \in (0,1]$, both the downstream firm and its input supplier have an incentive for the downstream firm j to unilaterally deviate ex-post from price-setting to quantity-setting.

Proof: See Appendix 3B. \square

4. Welfare analysis

In this Section we perform an analysis regarding the welfare effects of the different modes of competition. Social welfare is defined as the sum of consumers' surplus, downstream firms' profits and upstream firms' profits:

$$SW^m = \frac{1+\gamma}{4} (Q^m)^2 + 2\Pi_i^m + 2\pi_i^m, m = C, B, QP \quad (3)$$

Where, Q^m is total industry output. Substituting the relevant expressions into eq. (3), we obtain social welfare in the three cases under consideration (see Appendix 1A, 2A, 3A respectively).

The following proposition summarizes.

Proposition 4

The symmetric Bertrand competition always leads to the highest social welfare, the symmetric Cournot competition leads to the lowest, and the asymmetric one lies in-between, i.e., $SW^C > SW^{OP} > SW^B$.

The intuition is straightforward. Downstream firms' profits are the highest (lowest) in the symmetric Cournot (Bertrand) competition, while, the symmetric Cournot (Bertrand) competition results in the lowest (highest) consumers' surplus. This is a direct consequence of the fact that in Cournot competition downstream firms quote higher prices than the Bertrand ones. Regarding the upstream firms' profits, they are higher in the asymmetric configuration as compared with the respective ones in the symmetric Cournot. Yet, in the symmetric Bertrand, they are higher than the respective ones in the asymmetric configuration (symmetric Cournot), but only if products are sufficiently differentiated, i.e. $\gamma < 0.806$ ($\gamma < 0.886$). Nevertheless, the consumer surplus-effect always dominates the (sum of) the downstream firm's and the upstream firm's profits- effect(s). As a consequence, the symmetric Bertrand mode of competition is always preferable from the social welfare point of view. We also find that social welfare has a U-shaped relation with γ , in the three configurations under consideration. This happens because product differentiation has a negative effect on both the downstream firm's and the upstream firm's profits, in each vertical chain, while it has a positive effect on consumer surplus. Hence, if products are sufficiently differentiated, it is the profits-effect that dominates, while, as products become more homogenous, the consumer surplus-effect dominates.

5. Discussion – extensions

In our (basic) model we have assumed that there is an exclusive relation between upstream firm i and downstream firm i , with $i = 1, 2$. We may now in short

discuss the effects of non-exclusive relations, where each downstream firm can obtain its input from either upstream input supplier. In this case, if upstream suppliers sell perfectly homogenous inputs, they will be driven to zero profits, implying that they will be unable to affect the mode of competition that downstream firms will materialize. If, on the other hand, exists a positive degree of input-specificity, then upstream profits will be positive but lower than the respective ones under exclusive relations. In the background, the higher is the degree of input-specificity, the higher will be the input suppliers' bargaining power over the chain-specific input price/mode of competition scheme.

In our model we have also assumed that final products are substitutes. It nonetheless proves that the symmetric Bertrand mode of competition is always endogenously sustained as the industry's mode of competition, irrespective to the degree of product complementarity.⁷ Intuitively, this happens because Bertrand competition with complements is the dual of Cournot competition with substitutes (Singh and Vives, 1984).

6. Conclusions

Considering that input prices are endogenous, rather than exogenous, this paper takes a step further in the literature studying the mode of competition in a market for a final good. Since in a two-tier industry both the upstream firm's and the downstream firm's profits depend on the mode of competition in the downstream market, our main argument is that these two parties always need to adjust it collectively. Under competing vertical chains, we then propose that the mode of competition which in equilibrium emerges is the outcome of independent implicit agreements, among the downstream firm and its exclusive input supplier, in each

⁷ The detailed proof is available from the authors upon request.

vertical chain. The reason is that the input supplier always opts for its downstream firm's mode of competition which would secure the highest possible profits for its own. Therefore, in contrast to what has been ignored in the recent literature, the input supplier can —by virtue of its power over the firm-specific input price— effectively deny (or at least delay) production, whenever the downstream firm switches to a mode of competition which is inconsistent to that objective. Any ex-post deviation, to a mode of competition different than the one presumed by the downstream firm-specific input price, would be then materialized only if it has been so “pre-agreed” between the firm and its input supplier. Otherwise, and only then, the ex-ante presumed mode of competition proves to be credible.

Our main finding is that in a two-tier oligopoly, endowed with exclusive upstream-downstream relationships (like in the case of firm-specific monopoly unions with risk-neutral members) the quantity (Cournot) mode of competition is endogenously sustained by all downstream firms, irrespective to the degree of product differentiation. The reason being that each input supplier (labor union) would, by vetoing the firm's proposal, block any ex-post deviation to an input price (wage)/mode of competition scheme which does not sufficiently compensate the losses in input sales (union employment) induced by gains in the price of input (wage), and vice-versa.

In our analysis we have assumed two upstream firms. An interesting direction for further research is by giving the upstream firms the opportunity to merge. By doing so, we can investigate the input market structure which will endogenously emerge. Another direction for further research is to let upstream firms trade with their downstream firms through two-part tariff contracts, instead of wholesale price contracts. The above would link our research to the literature of mergers and

contracting in vertically related industries (see, e.g., Milliou and Petrakis, 2007; Symeonidis, forthcoming).

Appendix 1A.

$$L_i^C(\gamma, w_i, w_j) = \frac{a(2-\gamma) - 2w_i + \gamma w_j}{\gamma^2 - 4}$$

$$\Pi_i^C(\gamma, w_i, w_j) = \left[\frac{a(2-\gamma) - 2w_i + \gamma w_j}{\gamma^2 - 4} \right]^2$$

$$\pi_i^C(\gamma, w_i, w_j) = w_i \frac{a(2-\gamma) - 2w_i + \gamma w_j}{\gamma^2 - 4}$$

$$w_i^{QP}(\gamma, w_j) = \frac{a(2-\gamma) + \gamma w_j}{4}$$

$$w_i^C(\gamma) = \frac{a(\gamma - 2)}{\gamma - 4}$$

$$q_i^C(\gamma) = \frac{2a}{8 + 2\gamma - \gamma^2}$$

$$p_i^C(\gamma) = \frac{a(\gamma^2 - 6)}{(\gamma + 2)(\gamma - 4)}$$

$$\Pi_i^C(\gamma) = \left(\frac{2a}{8 + 2\gamma - \gamma^2} \right)^2$$

$$\pi_i^C(\gamma) = \frac{2a^2(\gamma - 2)}{(\gamma - 4)(8 + 2\gamma - \gamma^2)}$$

$$SW^C(\gamma) = \frac{4a^2(7 + \gamma - \gamma^2)}{(\gamma - 4)^2(\gamma + 2)^2}$$

Appendix 1B.

Given $w_2^C(\gamma)$, in the first stage of the game, the deviant upstream firm 1 uses its input price reaction function $w_1^{PQ}(\gamma, w_2^C) = \frac{a(2-\gamma-\gamma^2) + \gamma w_2^C}{2(\gamma^2 - 2)}$, that corresponds to the candidate equilibrium where the upstream-downstream pair 1 (pair 2) agrees over the price (quantity) (see Appendix 3A) as the downstream firm 1's (firm 2's) mode of competition. The upstream firm 1 optimally adjusts its downstream firm's-specific input price to $w_{1d}^C(\gamma) = \frac{a(8-4\gamma-4\gamma^2+\gamma^3)}{2(\gamma-4)(\gamma^2-2)}$, with $w_{1d}^C(\gamma) < w_1^C(\gamma)$, $\forall \gamma \in (0, 1]$.

Given $w_{1d}^C(\gamma)$ and $w_2^C(\gamma)$, the resulting deviant upstream firm 1's profits will be given

by $\pi_{1d}^C = \pi_1^{PQ}(\gamma, w_{1d}^C, w_2^C) = w_{1d}^C \left[\frac{a(2-\gamma-\gamma^2) + \gamma w_2^C - (2-\gamma^2)w_{1d}^C}{4-3\gamma^2} \right]$, with

$$\pi_{1d}^C = \pi_1^{PQ}(\gamma) = \frac{a^2(8-4\gamma-4\gamma^2+\gamma^3)^2}{4(\gamma-4)^2(8-10\gamma^2+3\gamma^4)}$$

The upstream firm 1 has no incentive for the downstream firm 1 to switch from quantity-setting to price-setting, since it can be checked that: $\pi_{1d}^C(\gamma) < \pi_1^C(\gamma)$, $\forall \gamma \in (0, 1]$.

Given $w_{1d}^C(\gamma)$ and $w_2^C(\gamma)$, the deviant downstream firm 1's profits will be given by

$$\Pi_{1d}^C = \Pi_1^{PQ}(\gamma, w_{1d}^C, w_2^C) = \left[\frac{a(2 - \gamma - \gamma^2) + \gamma w_2^C - (2 - \gamma^2)w_{1d}^C}{4 - 3\gamma^2} \right]^2, \text{ with}$$

$$\Pi_{1d}^C(b, \gamma) = \frac{a^2(8 - 4\gamma - 4\gamma^2 + \gamma^3)^2}{4(\gamma - 4)^2(4 - 3\gamma^2)^2}$$

The downstream firm 1 has no incentive to switch from quantity-setting to price-setting, since it can be checked that: $\Pi_{1d}^C(b, \gamma) < \Pi_1^C(b, \gamma)$, $\forall \gamma \in (0, 1]$.

Appendix 2A.

$$\Pi_i^B(\gamma, p_i, p_j) = (p_i - w_i) \frac{a(1 - \gamma) - p_i + \gamma p_j}{1 - \gamma^2}$$

$$p_i^B(\gamma, w_i, w_j) = \frac{a(2 - \gamma - \gamma^2) + 2w_i + \gamma w_j}{4 - \gamma^2}$$

$$L_i^B(\gamma, w_i, w_j) = \frac{a(2 - \gamma - \gamma^2) - (2 - \gamma^2)w_i + \gamma w_j}{4 - 5\gamma^2 + \gamma^4}$$

$$\Pi_i^B(\gamma, w_i, w_j) = \left[\frac{a(2 - \gamma - \gamma^2) - (2 - \gamma^2)w_i + \gamma w_j}{4 - 5\gamma^2 + \gamma^4} \right]^2$$

$$\pi_i^B(\gamma, w_i, w_j) = w_i \left[\frac{a(2 - \gamma - \gamma^2) - (2 - \gamma^2)w_i + \gamma w_j}{4 - 5\gamma^2 + \gamma^4} \right]$$

$$w_i^B(\gamma, w_j) = \frac{a(2 - \gamma - \gamma^2) + \gamma w_j}{2(2 - \gamma^2)}$$

$$w_i^B(\gamma) = \frac{a(\gamma^2 + \gamma - 2)}{2\gamma^2 + \gamma - 4}$$

$$q_i^B(\gamma) = \frac{a(2 - \gamma^2)}{(\gamma - 2)(\gamma + 1)(2\gamma^2 + \gamma - 4)}$$

$$p_i^B(\gamma) = \frac{2a(\gamma - 1)(\gamma^2 - 3)}{(\gamma - 2)(2\gamma^2 + \gamma - 4)}$$

$$\Pi_i^B(\gamma) = \frac{a^2(1 - \gamma)(\gamma^2 - 2)^2}{(\gamma - 2)^2(\gamma + 1)(2\gamma^2 + \gamma - 4)^2}$$

$$\pi_i^B(\gamma) = \frac{a^2(2 - \gamma^2)(\gamma^2 + \gamma - 2)}{(\gamma - 2)(\gamma + 1)(2\gamma^2 + \gamma - 4)}$$

$$SW^B(\gamma) = \frac{a^2(2 - \gamma^2)(14 - 12\gamma - 5\gamma^2 + 4\gamma^3)}{(\gamma - 2)^2(\gamma + 1)(2\gamma^2 + \gamma - 4)}$$

Appendix 2B.

Given $w_2^B(\gamma)$, in the first stage of the game, the deviant upstream firm 1 uses its input price reaction function $w_1^{OP}(\gamma, w_2^B) = \frac{a(2-\gamma) + \gamma w_2^B}{4}$, that corresponds to the candidate equilibrium where the upstream-downstream pair 1 (pair 2) agrees over the quantity (price) (see Appendix 3A) as the downstream firm 1's (firm 2's) mode of competition. The upstream firm 1 optimally adjusts its downstream firm's-specific input price to $w_{1d}^B(\gamma) = \frac{a(\gamma-2)}{\gamma-4}$, with $w_{1d}^B(\gamma) > w_1^B(\gamma)$, $\forall \gamma \in (0, 1]$.

Given $w_{1d}^B(\gamma)$ and $w_2^B(\gamma)$, the resulting deviant upstream firm 1's profits will be given by

$$\pi_{1d}^B = \pi_1^{OP}(\gamma, w_{1d}^B, w_2^B) = w_{1d}^B \left[\frac{a(\gamma-2) + 2w_1 - \gamma w_2^B}{3\gamma^2 - 4} \right], \text{ with}$$

$$\pi_{1d}^B = \pi_1^{OP}(\gamma) = \frac{2a^2(\gamma-2)(2\gamma^4 - 9\gamma^3 + 18\gamma^2 + 16\gamma - 32)}{(\gamma-4)^2(27\gamma^4 - 84\gamma^2 + 64)}$$

The upstream firm 1 has always an incentive for the downstream firm 1 to switch from price-setting to quantity-setting, since it can be checked that: $\pi_{1d}^B(\gamma) > \pi_1^B(\gamma)$, $\forall \gamma \in (0, 1]$.

Given $w_{1d}^B(\gamma)$ and $w_2^B(\gamma)$, the resulting deviant downstream firm 1's profits will be

$$\text{given by } \Pi_{1d}^B = \Pi_1^{OP}(\gamma, w_{1d}^B, w_2^B) = \frac{(1-\gamma^2)[a(\gamma-2) + 2w_{1d}^B - \gamma w_2^B]^2}{(3\gamma^2 - 4)^2}, \text{ with}$$

$$\Pi_{1d}^B(\gamma) = \frac{4a^2(1-\gamma^2)(2\gamma^4 - 9\gamma^3 + 18\gamma^2 + 16\gamma - 32)^2}{(\gamma-4)^2(16-9\gamma^2)^2(4-3\gamma^2)^2}$$

The downstream firm 1 also has always an incentive to switch from price-setting to quantity-setting, since it can be checked that: $\Pi_{1d}^B(\gamma) > \Pi_1^B(\gamma)$, $\forall \gamma \in (0, 1]$.

Appendix 3A.

$$L_1^{OP}(\gamma, w_1, w_2) = \frac{a(\gamma-2) + 2w_1 - \gamma w_2}{3\gamma^2 - 4}$$

$$p_2^{OP}(\gamma, w_1, w_2) = \frac{a(2-\gamma-\gamma^2) + \gamma w_1 - (2\gamma^2 - 2)w_2}{4 - 3\gamma^2}$$

$$L_2^{OP}(\gamma, w_1, w_2) = \frac{a(2-\gamma-\gamma^2) + \gamma w_1 - (2-\gamma^2)w_2}{4 - 3\gamma^2}$$

$$\begin{aligned} \Pi_1^{OP}(\gamma, w_1, w_2) &= \frac{(1-\gamma^2)[a(\gamma-2)+2w_1-\gamma w_2]^2}{(3\gamma^2-4)^2} & \Pi_2^{OP}(\gamma, w_1, w_2) &= \left[\frac{a(2-\gamma-\gamma^2)+\gamma w_1-(2-\gamma^2)w_2}{4-3\gamma^2} \right]^2 \\ \pi_1^{OP}(\gamma, w_1, w_2) &= w_1 \left[\frac{a(\gamma-2)+2w_1-\gamma w_2}{3\gamma^2-4} \right] & \pi_2^{OP}(\gamma, w_1, w_2) &= w_2 \left[\frac{a(2-\gamma-\gamma^2)+\gamma w_1-(2-\gamma^2)w_2}{4-3\gamma^2} \right] \\ w_1^{OP}(\gamma, w_2) &= \frac{a(2-\gamma)+\gamma w_2}{4} & w_2^{OP}(\gamma, w_1) &= \frac{a(2-\gamma-\gamma^2)+\gamma w_1}{2(\gamma^2-2)} \\ w_1^{OP}(\gamma) &= \frac{a(8-2\gamma-5\gamma^2+\gamma^3)}{16-9\gamma^2} & w_2^{OP}(\gamma) &= \frac{a(8-2\gamma-5\gamma^2)}{16-9\gamma^2} \\ q_1^{OP}(\gamma) &= \frac{2a(8-2\gamma-5\gamma^2+\gamma^3)}{64-84\gamma^2+27\gamma^4} & q_2^{OP}(\gamma) &= \frac{a(2-\gamma^2)(8-2\gamma-5\gamma^2)}{64-84\gamma^2+27\gamma^4} \\ p_1^{OP}(\gamma) &= \frac{a(6-5\gamma^2)(8-2\gamma-5\gamma^2+\gamma^3)}{64-84\gamma^2+27\gamma^4} & p_2^{OP}(\gamma) &= \frac{2a(3-2\gamma^2)(8-2\gamma-5\gamma^2)}{64-84\gamma^2+27\gamma^4} \\ \Pi_1^{OP}(\gamma) &= \frac{4a^2(1-\gamma^2)(8-2\gamma-5\gamma^2+\gamma^3)^2}{(64-84\gamma^2+27\gamma^4)^2} & \Pi_2^{OP}(\gamma) &= \frac{a^2(2-\gamma^2)^2(8-2\gamma-5\gamma^2)^2}{(64-84\gamma^2+27\gamma^4)^2} \\ \pi_1^{OP}(\gamma) &= \frac{2a^2(8-2\gamma-5\gamma^2+\gamma^3)^2}{(16-9\gamma^2)^2(4-3\gamma^2)} & \pi_2^{OP}(\gamma) &= \frac{a^2(\gamma^2-2)(8-2\gamma-5\gamma^2)^2}{(16-9\gamma^2)^2(3\gamma^2-4)} \\ SW^{OP}(\gamma) &= \frac{a^2(7168-2560\gamma-15680\gamma^2+4736\gamma^3+12272\gamma^4-2816\gamma^5-3976\gamma^6+496\gamma^7+425\gamma^8+25\gamma^9)}{4(64-84\gamma^2+27\gamma^4)^2} \end{aligned}$$

Appendix 3B.

Upstream-downstream pair 1 deviates

Given $w_2^{OP}(\gamma)$, in the first stage of the game, the deviant upstream firm 1 uses its input price reaction function $w_1^B(\gamma, w_2^{OP}) = \frac{a(2-\gamma-\gamma^2)+\gamma w_2^{OP}}{2(2-\gamma^2)}$, that corresponds to the symmetric Bertrand competition candidate equilibrium (see Appendix 2A). The

upstream firm 1 optimally adjusts its downstream firm's-specific input price to

$$w_{1d}^{OP}(\gamma) = \frac{a(32 - 8\gamma - 36\gamma^2 + 4\gamma^3 + 9\gamma^4)}{64 - 68\gamma^2 + 18\gamma^4}, \text{ with } w_{1d}^{OP}(\gamma) < w_1^{OP}(\gamma), \forall \gamma \in (0, 1].$$

Given $w_{1d}^{OP}(\gamma)$ and $w_2^{OP}(\gamma)$, the resulting deviant upstream firm 1's profits will be given

$$\text{by } \pi_{1d}^{OP} = \pi_1^B(\gamma, w_{1d}^{OP}, w_2^{OP}) = w_{1d}^{OP} \left[\frac{a(2 - \gamma - \gamma^2) - (2 - \gamma^2)w_{1d}^{OP} + \gamma w_2^{OP}}{4 - 5\gamma^2 + \gamma^4} \right] \text{ with}$$

$$\pi_{1d}^{OP}(\gamma) = \frac{a^2(32 - 8\gamma - 36\gamma^2 + 4\gamma^3 + 9\gamma^4)^2}{4(16 - 9\gamma^2)^2(8 - 14\gamma^2 + 7\gamma^4 - \gamma^6)}$$

It can be checked that the upstream firm 1 has an incentive for the downstream firm 1 to switch from quantity-setting to price-setting, i.e., $\pi_{1d}^{OP}(\gamma) > \pi_1^{OP}(\gamma)$, if $\gamma > 0.992$.

Given $w_{1d}^{OP}(\gamma)$ and $w_2^{OP}(\gamma)$, the resulting deviant downstream firm 1's profits will be

$$\text{given by } \Pi_{1d}^{OP} = \Pi_1^B(\gamma, w_{1d}^{OP}, w_2^{OP}) = \left[\frac{a(2 - \gamma - \gamma^2) - (2 - \gamma^2)w_{1d}^{OP} + \gamma w_2^{OP}}{4 - 5\gamma^2 + \gamma^4} \right]^2, \text{ with}$$

$$\Pi_{1d}^{OP}(\gamma) = \frac{a^2(32 - 8\gamma - 36\gamma^2 + 4\gamma^3 + 9\gamma^4)^2}{4(1 - \gamma^2)(64 - 52\gamma^2 + 9\gamma^4)^2}$$

It can be checked that the downstream firm 1 has an incentive to switch from quantity-setting to price-setting, i.e., $\Pi_{1d}^{OP}(\gamma) > \Pi_1^{OP}(\gamma)$, if $\gamma > 0.897$.

Upstream-downstream pair 2 deviates

Given $w_1^{OP}(\gamma)$, in the first stage of the game, the deviant upstream firm 2 uses its

input price reaction function $w_2^C(\gamma, w_1^{OP}) = \frac{a(2 - \gamma) + \gamma w_1^{OP}}{4}$, that corresponds to the

symmetric Cournot competition candidate equilibrium (see Appendix 1A). The upstream firm 2 optimally adjusts its downstream firm's-specific input price to

$$w_{2d}^{OP}(\gamma) = \frac{a(32 - 8\gamma - 20\gamma^2 + 4\gamma^3 + \gamma^4)}{4(9\gamma^2 - 16)}, \text{ with } w_{2d}^{OP}(\gamma) > w_2^{OP}(\gamma), \forall \gamma \in (0, 1].$$

Given $w_1^{OP}(\gamma)$ and $w_{2d}^{OP}(\gamma)$, the resulting deviant upstream firm 2's profits will be given

by $\pi_{2d}^{OP} = \pi_2^C(\gamma, w_1^{OP}, w_{2d}^{OP}) = w_{2d}^{OP} \left[\frac{a(2-\gamma) - 2w_{2d}^{OP} + \gamma w_1^{OP}}{\gamma^2 - 4} \right]$ with

$$\pi_{2d}^{OP}(\gamma) = \frac{a^2(32 - 8\gamma - 20\gamma^2 + 4\gamma^3 + \gamma^4)^2}{8(16 - 9\gamma^2)^2(4 - \gamma^2)}$$

The upstream firm 2 has always an incentive for the downstream firm 2 to switch from price-setting to quantity-setting, since it can be checked that: $\pi_{2d}^{OP}(\gamma) > \pi_2^{OP}(\gamma)$, $\forall \gamma \in (0, 1]$.

Given $w_1^{OP}(\gamma)$ and $w_{2d}^{OP}(\gamma)$, the resulting deviant downstream firm 2's profits will be

given by $\Pi_{2d}^{OP} = \Pi_2^C(\gamma, w_1^{OP}, w_{2d}^{OP}) = \left[\frac{a(2-\gamma) - 2w_{2d}^{OP} + \gamma w_1^{OP}}{\gamma^2 - 4} \right]^2$, with

$$\Pi_{2d}^{OP}(\gamma) = \frac{a^2(32 - 8\gamma - 20\gamma^2 + 4\gamma^3 + \gamma^4)^2}{4(64 - 52\gamma^2 + 9\gamma^4)^2}$$

The downstream firm 2 (also) has always an incentive to switch from price-setting to quantity-setting, since it can be checked that: $\Pi_{2d}^{OP}(\gamma) > \Pi_2^{OP}(\gamma)$, $\forall \gamma \in (0, 1]$.

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