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Journal of Regulatory Economics

ISSN 0922-680X
Volume 41
Number 2

J Regul Econ (2012) 41:238-268
DOI 10.1007/s11149-011-9164-1

Springer

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ORIGINAL ARTICLE

On the social optimality of make-or-buy decisions

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Published online: 30 September 2011

Abstract This article examines the impact of input prices on an entrant's make-or-buy decision and on the subsequent social welfare level for three alternative models of downstream competition. For each particular model, it derives the range of input prices that induce the entrant to undertake: (a) the productively efficient make-or-buy decision; and (b) the socially optimal make-or-buy decision. The main conclusion of this article is that the entrant's efficient make-or-buy decision is always socially optimal in the case of the Hotelling model, is socially optimal for the set of input prices that induce the entrant to undertake the efficient decision in the case of Cournot competition and is not necessarily socially optimal in the Bertrand vertical differentiation model. Last, this article examines the conditions under which the efficient and/or socially optimal make-or-buy decision undertaken by an entrant fulfills the regulatory two-fold goal of promoting service-based competition and encouraging facilities-based competition. Therefore, this article also provides the optimal access pricing policy that results in the best feasible outcome in terms of social welfare, productive efficiency, competition level and investment level for a given downstream competition model.

Keywords Access regulation · Downstream competition · Investment incentives · Productive efficiency · Social welfare · Telecommunications

JEL Classification L43 · L51 · L96

M. Tselekounis · D. Varoutas (✉) · D. Martakos
Department of Informatics and Telecommunications, National and Kapodistrian University of Athens, Panepistimiopolis, Ilissia, 15784 Athens, Greece
e-mail: D.Varoutas@di.uoa.gr

1 Introduction

The Telecommunications Act of 1996 authorized new suppliers (entrants) of telecommunications services to have access to incumbent suppliers' key network elements at cost-based prices. The purpose of this policy is "to promote competition and reduce regulation in order to secure lower prices and higher quality services for (American) telecommunications consumers and encourage the rapid deployment of new telecommunications technologies". Hence, the ultimate goal of this unbundling policy is twofold. First, it aims at inducing service-based competition in the downstream (retail) market which leads to lower prices, higher quality and higher social welfare. Second, once service-based competition has been established, it aims at promoting facilities-based competition which leads to innovation and market growth. Service-based competition requires mandated access to the incumbent network, whereas facilities-based competition requires investment in network infrastructure by incumbents, and especially entrants.

The promotion of service-based competition is mainly based on cost-oriented input (or access) prices, and especially on Long-Run Incremental Cost (LRIC) methodology.[1] The main advantage of this methodology is that it provides the new entrants with significant incentives to enter the market and, as a result, the consumers enjoy the short-run benefits from service-based competition. On the contrary, the main drawback of this methodology is that it discourages both incumbents and new entrants to invest in new access infrastructures (the so-called Next Generation Access networks, or NGA).

Indeed, Jorde et al. (2000) study the impact of cost-based input prices on the incumbents' incentives to upgrade their access network and find that the input prices based on LRIC methodology discourage incumbents to invest. Ingraham and Sidak (2003) confirm empirically the result of Jorde et al. (2000). According to Cave and Prosperetti (2001), the reason for this negative relationship between access regulation and incumbents' investment incentives is that input prices based on LRIC discourage incumbents to invest in networks because they anticipate that they will be required to offer access to their rivals at cost-based prices.

In addition, Jorde et al. (2000) show that regulating input prices based on LRIC methodology encourages entrants to deviate from the socially optimal investment level and to delay entry. Furthermore, Bourreau and Dogan (2006) show that unbundling of the local loop may delay facilities-based competition, even in an unregulated environment.

Therefore, cost-based input prices cannot induce both effective competition and investments in new access networks. One of the most known theories for tackling this trade-off is the so called "ladder of investment theory" proposed by Cave and Vogelsang (2003). This theory is based on the fact that entrants will typically invest in replicable assets first and then progress to less replicable ones. Thus, it suggests that at the initial stage of competition the input price for the less replicable network elements should be low but increasing over time as assets are replicated. Although this theory

[1] See Armstrong (2002) and Valletti and Estache (1998) for an excellent and extensive review of the literature on access pricing.

has been fiercely criticized by Crandall et al. (2004) and Hazlett and Bazelon (2005), the EC Recommendation on regulated access to NGA (European Commission 2010)[2] stresses that the appropriate array of remedies imposed by an NRA should reflect a proportionate application of the ladder of investment theory.

The papers closest to ours are Sappington (2005) and Gayle and Weisman (2007a) which study the impact of different downstream interactions on a new entrant's profits when it purchases an essential upstream input from the incumbent and when it makes the upstream input itself. In particular, Sappington (2005) uses the standard Hotelling (1929) model of downstream competition to show that input prices are irrelevant for an entrant's decision to make or buy an input required for downstream production. This result is striking since it negates most of the aforementioned studies concluding that cost-based input prices promote effective competition but discourage both incumbents and new entrants to invest in new access infrastructures.

According to Sappington, the reason for this result is that previous studies fail to take into account the impact of a new entrant's make-or-buy decision on subsequent retail price competition. When the incumbent sells an upstream input to the new entrant, the incumbent faces an opportunity cost of expanding its retail output. The incorporation of this opportunity cost into the incumbent's total cost makes the incumbent act as if its upstream cost of production were equal to the specified input price. Therefore, regardless of the input price, the entrant will choose to buy (respectively, make) the upstream input whenever the incumbent (respectively, entrant) has an innate upstream cost advantage. Therefore, the entrant's decision always minimizes industry costs and ensures efficient entry and utilization of the telecommunications infrastructure. Thus, the entrant always undertakes the efficient make-or-buy decision.

After Sappington's suggestion, Gayle and Weisman (2007a) consider alternative downstream interactions and show that input prices are not necessarily irrelevant in the Bertrand vertical differentiation model and are not irrelevant in the Cournot model. This implies that departure from cost-based input prices may distort the efficiency of the entrant's make-or-buy decision.

As a result, Sappington (2005) and Gayle and Weisman (2007a) study the impact of input prices on the efficiency of the entrant's make-or-buy decisions. This article studies the impact of input prices on the social optimality of the entrant's make-or-buy decisions under the alternative theoretical settings of Sappington (2005) and Gayle and Weisman (2007a). First, we make explicit the Sappington's conjecture that regardless of the established price of the upstream input, the entrant always undertakes the make-or-buy decision that is not only efficient, but also socially optimal. Second, we explore the robustness of this result in the Bertrand vertical differentiation model and in the Cournot model. We find that the social optimality of the entrant's make-or-buy decision is affected by two crucial factors: (a) the particular level of the price of the upstream input; and (b) the cost differential between the incumbent's and the entrant's unit costs of producing the upstream input. For this reason, we obtain the range of both input prices and upstream cost differential that induce the entrant to undertake the socially desirable decision.

[2] See http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32010H0572:EN:NOT.

By combining our results with those of Sappington (2005) and Gayle and Weisman (2007a), we show that the entrant's efficient make-or-buy decision is always socially optimal in the case of Hotelling, is socially optimal for the set of input prices that induce the entrant to undertake the efficient decision in the case of Cournot competition and is not necessarily socially optimal in the Bertrand vertical differentiation model. Therefore, we make regulatory implications concerning the range of input prices that tackle the regulatory trade-off, while (cannot) result in the most efficient outcome.

The rest of this article is organized as follows. Section 2 gives an outline of the basic assumptions and definitions. Section 3 presents the main findings concerning the impact of input prices on the social optimality of make-or-buy decisions in the Hotelling model, in the Cournot model and in the Bertrand vertical differentiation model. The last section compares the results of the three models, summarizes the key findings and makes regulatory implications. The proofs of all assumptions, lemmas and propositions are in the Appendix A.

2 Assumptions and definitions

We consider a duopoly case where two suppliers compete according to a particular model of downstream competition. Each unit of the downstream service requires one unit of the upstream input and one unit of the downstream input. Each firm supplies its own downstream input. The unit costs of producing the downstream input are c_d^I and c_d^E for the incumbent and the entrant, respectively. Without loss of generality, we further assume that the unit cost of producing the downstream input is the same for the two retailers and is set to zero. The incumbent and entrant's unit costs of producing the upstream input are denoted by c_u^I and c_u^E, respectively.

The entrant has to decide between buying the upstream input from the incumbent at a regulated price w and making the upstream input itself. The entrant is understood to make the efficient make-or-buy decision if it purchases the input from the incumbent when the incumbent is the least-cost supplier ($c_u^I < c_u^E$) and produces the input itself whenever it is the least-cost supplier ($c_u^E < c_u^I$). In addition, the entrant is understood to make the socially optimal make-or-buy decision if it chooses to buy (respectively, make) the upstream input when this decision leads to higher social welfare level than its decision to make (respectively, buy) the upstream input. The timing of the game is as follows. First, the regulator sets the input price w. After observing the input price, the entrant decides whether it will buy the upstream input from the incumbent or produce it itself. Last, the two providers choose their retail prices that maximize their profits.

We use the backward induction method to find the equilibrium of the whole game. Therefore, the analysis begins with the computation of the retail prices and the outputs of the firms. Then, using these results, the entrant undertakes its make-or-buy decision, which depends on the regulated input price. Finally, based on the previous information, the regulator sets the input price that induces the entrant to undertake the best feasible outcome in terms of social welfare, productive efficiency, competition level and investment level. In this article, we examine the impact of input prices on each regulatory goal for three alternative models of downstream competition: Hotelling model, Cournot model and Bertrand vertical differentiation model.

3 Findings

3.1 Hotelling model

The two rivals, whose final services are differentiated á la Hotelling (1929), are located at the two extremities of the market. In particular, the incumbent is located at point $L^I = 0$ and the entrant is located at point $L^E = 1$. N consumers are uniformly distributed on the unit interval [0,1]. Consumers are endowed with utility $U_L(L^i, P^i) = v - P^i - t\left|L^i - L\right|$ where locations (L^i) and prices (P^i) for the incumbent and the entrant are denoted by the superscript I and E, respectively, i.e. $i = I, E$. The term $t\left|L^i - L\right|$ can be interpreted as the disutility which the consumer located at point $L \in [0, 1]$ incurs through the distance of transport. The first term, $v > 0$, can be interpreted as the reservation price and it is assumed that it exceeds the sum of price and transport cost in order to ensure that each consumer buys one unit of the final service. Note that consumer utility U_L has a maximum where the consumer's location L and the firm's location coincide.

Sappington (2005) discusses the entrant's make-or-buy decision by comparing the entrant's profits when it decides to buy the upstream input from the incumbent (Π_B^E) with its profits when it chooses to make the upstream input itself (Π_M^E). His main finding is stated in Proposition 1:

Proposition 1 (Sappington 2005) *Regardless of the established price* (w) *of the upstream input:* (a) *the entrant prefers to buy the upstream input from the incumbent when the incumbent is the least-cost supplier of the input* (*i.e.* $\Pi_B^E > \Pi_M^E$ *if* $c_u^{\mathrm{I}} < c_u^E$)*; and* (b) *the entrant prefers to make the upstream input itself when it is the least-cost supplier of the input* (*i.e.* $\Pi_{\mathrm{M}}^E > \Pi_B^E$ *if* $c_u^E < c_u^I$).

From Proposition 1 we infer that input prices are irrelevant for the entrant's make-or-buy decision. In addition, it is obvious that the entrant's decision always results in the most efficient outcome. Hence, regardless of the established price of the upstream input, the entrant always undertakes the efficient make-or-buy decision. Furthermore, we show in the Appendix A1[3] that input prices do not have an impact on social welfare.[4] Therefore, input prices are irrelevant not only for the entrant's efficient make-or-buy decision, but also for the regulator's goal to maximize social welfare. The reason is that a marginal increase (decrease) in the input price causes a unit increase (decrease) in the incumbent's profits and a unit decrease (increase) in consumer surplus. As social welfare is the unweighted sum of industry profits and consumer surplus, it is thus not affected by a marginal change in input prices.

[3] See Eq. A13.

[4] Shim and Oh (2006) also state that the level of the input price does not affect the entrant's profits and the total social surplus. However, they do not combine this result with the entrant's efficient make-or-buy decision.

However, our primary goal is to examine the social optimality of the entrant's efficient make-or-buy decision. Thus, we compare the social welfare level obtained when the entrant chooses to buy the upstream input (SW_B) to the respective level of social welfare obtained when the entrant chooses to make the upstream input itself (SW_M). We can then state the following proposition:

Proposition 2 *Regardless of the established price* (w) *of the upstream input:* (a) *the entrant's decision to buy the upstream input from the incumbent is socially optimal when the incumbent is the least-cost supplier of the input (i.e. $SW_B > SW_M$ if $c_u^I < c_u^E$); and* (b) *the entrant's decision to make the upstream input itself is socially optimal when it is the least-cost supplier of the input (i.e. $SW_M > SW_B$ if $c_u^E < c_u^I$).*

Combining Propositions 1 and 2 concludes that the entrant's decision to buy the upstream input from the incumbent if $c_u^{\mathrm{I}} < c_u^E$ and to make the upstream input itself if $c_u^E < c_u^{\mathrm{I}}$, is not only efficient, but also socially optimal. Hence, the maximization of social welfare is in line with the entrant's efficient make-or-buy decision.

Proposition 3 *In the equilibrium of the Hotelling model, the efficient make-or-buy decision undertaken by the entrant is always socially optimal.*

Proposition 3 presents a significant finding: although access price regulation affects neither the efficient make-or-buy decision undertaken by the entrant nor the level of social welfare, the regulator always succeeds in fulfilling the maximization of social welfare by not intervening in the upstream market. When $c_u^E < c_u^I$ the entrant chooses to make the upstream input and, as a result, it invests in alternative infrastructures, which is socially optimal. In this case, the absence of access price regulation tackles the trade-off between service-based and facilities-based competition. Thus the regulator's twofold aim is fulfilled. On the contrary, when $c_u^I < c_u^E$ the entrant chooses to buy the upstream input from the incumbent, which is also socially optimal. In this case, the society only enjoys the short-run benefits from service-based competition.

3.2 Cournot model

The two rivals, whose final services are homogeneous, choose their optimal amount of output they will produce independently and simultaneously. The inverse demand function is given by $P(Q) = A - BQ$, where $P(Q)$ is the retail market price, $A > 0$ is the reservation price, $B > 0$ is the slope of the inverse demand function and $Q = Q^I + Q^E$ is market output, where Q^I and Q^E denote the incumbent and the entrant's output, respectively.

Gayle and Weisman (2007a) discuss the impact of input prices on the entrant's make-or-buy decision by comparing the entrant's profits when it decides to buy the upstream input from the incumbent with its profits when it chooses to make the upstream input itself. Their main finding is stated in Proposition 4:

Proposition 4 (Gayle and Weisman 2007a) *In the equilibrium of the Cournot model:* (a) *The entrant makes the input rather than buys the input from the incumbent when $c_u^E < w$; and* (b) *The entrant buys the input from the incumbent when $c_u^E > w$.*

From Proposition 4, it can be deduced that input prices are not irrelevant for the entrant's make-or-buy decision. In addition, the entrant's decision results in the most efficient outcome when $c_u^E < \min\{w, c_u^I\}$ or $c_u^E > \max\{w, c_u^I\}$. Therefore, there is a potential efficiency distortion in the make-or-buy decision and hence input prices are not irrelevant. Concerning the impact of input prices on social welfare, we find that that the society is indifferent about the entrant's decision to make or buy the upstream input when:

$$6(c_u^I)^2 - 14(c_u^I)(c_u^E) - 4(c_u^I)w + 6A(c_u^I) + 11(c_u^E)^2 - 8A(c_u^E) + w^2 + 2Aw = 0 \tag{1}$$

By solving Eq. 1 with respect to w, the optimal input price (w^*) that makes the society be indifferent about the entrant's make-or-buy decision is derived:[5]

$$w^* = -A + 2(c_u^I) + \sqrt{A^2 + 14(c_u^I)(c_u^E) - 11(c_u^E)^2 + 8A(c_u^E) - 10A(c_u^I) - 2(c_u^I)^2} \tag{2}$$

Proposition 5 (a) *The entrant's decision to buy the upstream input from the incumbent is socially optimal when $w < w^*$; and* (b) *the entrant's decision to make the upstream input itself is socially optimal when $w > w^*$.*

By combining Propositions 4 and 5, it is deduced that the entrant's decision is always socially optimal when $c_u^E = w^*$. Therefore, for any $w^* \neq c_u^E$ there is a potential social welfare distortion in the make-or-buy decision and hence input prices may not be irrelevant. For this reason, we derive the set of input prices that induce the entrant to undertake the socially optimal make-or-buy decision. Then, we examine whether the entrant's efficient make-or-buy decision is also socially optimal. It is instructive to limit our study to the range of input prices for which a Nash equilibrium exists:

Assumption 1 Let (α) $A^2 + 14(c_u^I)(c_u^E) - 11(c_u^E)^2 + 8A(c_u^E) - 10A(c_u^I) - 2(c_u^I)^2 \geq 0$; (b) $w \leq \overline{w} = (A + c_u^I)/2$; and (c) $w \geq \underline{w} = [-5(A + c_u^I) + 3\sqrt{5}(A - c_u^I)]/(-10)$.

The first constraint ensures that $w \in \mathrm{R}^+$, the second one that the entrant is active when it buys the upstream input from the incumbent (i.e. $Q_B^E \geq 0$) and the third one that the incumbent's profits are non-negative when it sells the upstream input to the entrant (i.e. $\Pi_B^I \geq 0$).[6] Therefore the second inequality provides the highest input price ($\overline{w}$) at which a Nash equilibrium exists, whereas the third inequality provides the lowest input price ($\underline{w}$) at which a Nash equilibrium exists.

Since w^* is affected by both c_u^I and c_u^E, we should discriminate between three cases regarding the upstream cost differential in order to derive the set of input prices that induce the entrant to undertake the socially optimal make-or-buy decision.

[5] The second solution of Eq. 1 is rejected because it leads to negative input prices (see Appendix A2).

[6] Another necessary constraint to ensure that $\Pi_B^I \geq 0$ is $w \leq \overline{\overline{w}} = [-5(A + c_u^I) - 3\sqrt{5}(A - c_u^I)]/(-10)$. However, the second constraint of the first assumption is sufficient to ensure that $w \leq \overline{\overline{w}}$ (See Appendix A2).

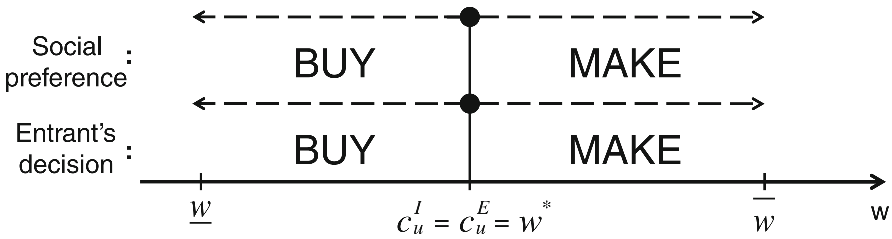

Fig. 1 The effect of input prices on the social optimality of make-or-buy decisions when neither provider has an upstream cost advantage

3.2.1 Neither provider has an innate upstream cost advantage

In this case, the unit cost of producing the upstream input is the same for the two retailers, that is $c_u^I = c_u^E$. Substituting $c_u^I = c_u^E$ into Eq. 2 gives the optimal input price (w^*) that makes the society be indifferent about the entrant's make-or-buy decision.

Lemma 1 *If* $c_u^I = c_u^E$ *then* $\underline{w} < c_u^I = c_u^E = w^* < \overline{w}$.

Figure 1 presents a graphical analysis of Propositions 4 and 5 for the case described in Lemma 1.

It is deduced that when neither provider has an innate upstream cost advantage: (a) the entrant's decision to buy the upstream input from the incumbent is socially optimal when $w < c_u^E$; and (b) the entrant's decision to make the upstream input itself is socially optimal when $w > c_u^E$. We conclude that the entrant's decision to make or buy the upstream input is always socially optimal when neither provider has an innate upstream cost advantage. However, the fulfillment of the regulator's two-fold goal requires the regulator to set the input price at a higher level than the providers' unit cost of producing the upstream input. Therefore, it is obvious that the optimal regulatory policy is to induce the entrant to produce the upstream input itself.

3.2.2 The entrant has an innate upstream cost advantage

In this case, the entrant is more efficient than the incumbent in producing the upstream input, that is $c_u^E < c_u^I$. We should calculate the optimal input price (w^*) in order to derive the set of input prices that induce the entrant to undertake the socially optimal make-or-buy decision. The impact of the entrant's upstream cost advantage on the optimal input price (w^*) is described by the following Lemma:

Lemma 2 (a) *If* $(c_u^E)' < c_u^E < c_u^I$ *then* $\underline{w} < w^* < c_u^E < c_u^I < \overline{w}$; *and* (b) *if* $c_u^E < (c_u^E)' < c_u^I$ *then* $w^* < \underline{w} < c_u^E < c_u^I < \overline{w}$, *where* $(c_u^E)' = \frac{4A+7c_u^I}{11} - (A + c_u^I)\sqrt{\frac{198\sqrt{5}-54}{5}}$.

Figure 2 presents a graphical analysis of Propositions 4 and 5 for each of the two cases described in Lemma 2.

A number of observations derived by the analysis of Fig. 2 are instructive. First when the upstream cost differential is low enough, the socially optimal decision for

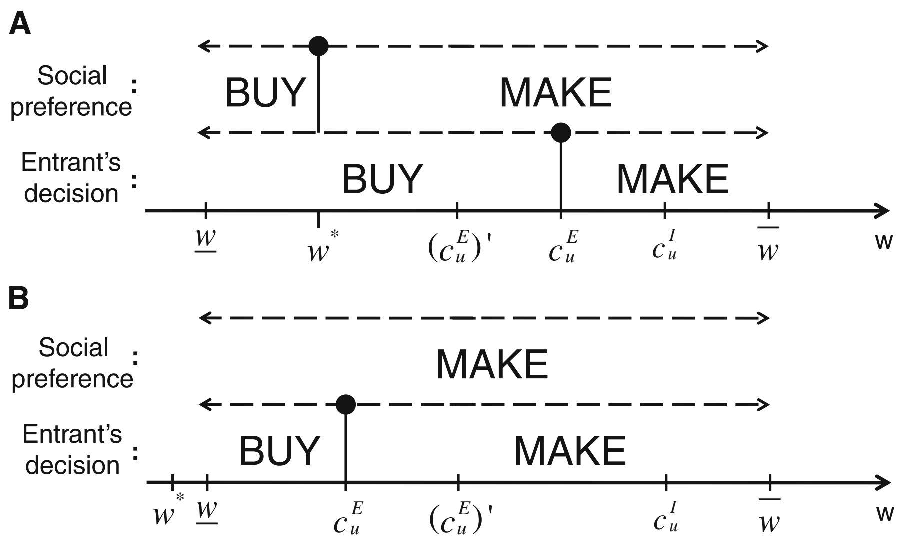

Fig. 2 **a** The effect of input prices on the social optimality of make-or-buy decisions when the entrant is not much more efficient than the incumbent. **b** The effect of input prices on the social optimality of make-or-buy decisions when the entrant is much more efficient than the incumbent

the entrant is to make the upstream input even for relative low input prices, whereas when the upstream cost differential is high enough, the socially optimal decision for the entrant is to make the upstream input regardless of the input price. The rationale of this result is that the more efficient the entrant is in producing the upstream input, the larger the range of input prices that lead the society to prefer the entrant to make the upstream input. As a result, a low (respectively, high) enough upstream cost differential causes input prices to be relevant (respective, irrelevant) for the social optimality of an entrant's make-or-buy decision. Second, an entrant's make-or-buy decision is socially optimal when: (a) $w < w^*$ or $w > c_u^E$ for $(c_u^E)' < c_u^E < c_u^I$; and (b) $w > c_u^E$ for $c_u^E < (c_u^E)' < c_u^I$. This implies that there is a potential distortion of the social optimality of make-or-buy decisions. Third, regardless of the upstream cost differential, an entrant's efficient make-or-buy decision is always socially optimal. Indeed, the entrant is understood to make the efficient make-or-buy decision if it produces the input itself since it is the least-cost supplier ($c_u^E < c_u^I$). Therefore, the entrant undertakes the efficient make-or-buy decision if $w > c_u^E$, which also leads to the socially optimal outcome.

In conclusion, the entrant's efficient decision not only leads to the socially optimal outcome, but also tackles the trade-off between fostering effective competition and encouraging investments in new access infrastructures. Thus, the regulator should set $w > c_u^E$.

3.2.3 The incumbent has an innate upstream cost advantage

In this case, the incumbent is more efficient than the entrant in producing the upstream input, that is $c_u^E > c_u^I$. Like the case in which the entrant had an innate upstream cost

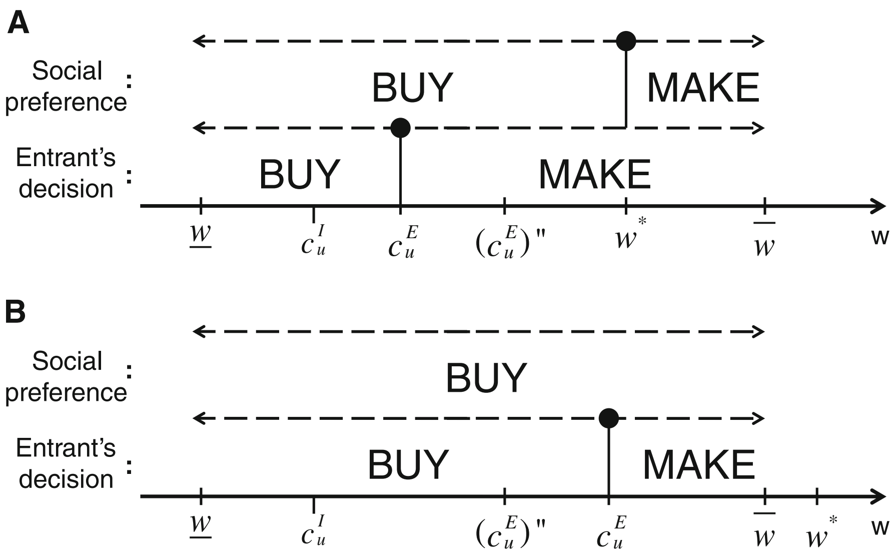

Fig. 3 **a** The effect of input prices on the social optimality of make-or-buy decisions when the incumbent is not much more efficient than the entrant. **b** The effect of input prices on the social optimality of make-or-buy decisions when the incumbent is much more efficient than the entrant

advantage, we should calculate the optimal input price (w^*) in order to derive the set of input prices that induce the entrant to undertake the socially optimal make-or-buy decision. The impact of the incumbent's upstream cost advantage on the optimal input price (w^*) is described by the following Lemma:

Lemma 3 (a) *If* $c_u^I < c_u^E < (c_u^E)''$ *then* $\underline{w} < c_u^I < c_u^E < w^* < \overline{w}$*; and* (b) *if* $(c_u^E)'' < c_u^E \leq \overline{w}$ *then* $\underline{w} < c_u^I < c_u^E < \overline{w} \leq w^*$*, where* $(c_u^E)'' = \frac{5A+17c_u^I}{22}$.

Figure 3 presents a graphical analysis of Propositions 4 and 5 for each of the two cases described in Lemma 3.

From Fig. 3, it is deduced that when the upstream cost differential is low enough, the socially optimal decision for the entrant is to buy the upstream input even for relative high input prices, whereas when the upstream cost differential is high enough, the socially optimal decision for the entrant is to buy the upstream input regardless of the input price. The rationale of this result is that the more efficient the incumbent is in producing the upstream input, the larger the range of input prices that lead the society to prefer the entrant to buy the upstream input. As a result, a low (respectively, high) enough upstream cost differential causes input prices to be relevant (respective, irrelevant) for the social optimality of an entrant's make-or-buy decision. Another significant deduction is that an entrant's make-or-buy decision is socially optimal when: (a) $w > w^*$ or $w < c_u^E$ for $c_u^I < c_u^E < (c_u^E)''$; and (b) $w < c_u^E$ for $(c_u^E)'' < c_u^E \leq \overline{w}$. This implies that there is a potential distortion of the social optimality of make-or-buy decisions. Last, regardless of the upstream cost differential, an entrant's efficient make-or-buy decision is always socially optimal. Indeed, the entrant is understood to make the efficient make-or-buy decision if it purchases the input since the incumbent is the least-cost supplier ($c_u^E > c_u^I$). Therefore, the entrant undertakes the efficient make-or-buy decision if $w < c_u^E$, which also leads to the socially optimal outcome.

However, the social optimality of facilities-based competition is fulfilled only when the upstream cost differential is low enough, the regulated access price is relative high ($w > w^*$) and, of course, at the cost of the productive efficiency. In this case there is another trade-off between the productive efficiency and the social optimality of make-or-buy decisions.

3.2.4 Discussion

Given that the downstream competition is characterized by the Cournot model, the analysis of the impact of input prices on social welfare shows that regardless of which provider has an innate upstream cost advantage, input prices are (not) irrelevant for the social optimality of the entrant's make-or-buy decision when the upstream cost differential is high (low) enough.

In addition, although the absence of access price regulation always leads to the socially optimal make-or-buy decision in the case of Hotelling, regulatory intervention is necessary in order to induce the entrant to undertake the socially optimal make-or-buy decision in the case of the Cournot competition. This implies that there is a potential distortion in the social optimality of make-or-buy decisions, and especially in the fulfillment of the regulator's twofold goal.

However, the main conclusion of the analysis of the entrant's make-or-buy decision from a social perspective is that the entrant's efficient decision is always socially optimal. Therefore, we can state the following proposition:

Proposition 6 *In the equilibrium of the Cournot model, the efficient make-or-buy decision undertaken by the entrant is always socially optimal.*

Proposition 6 states that when $c_u^E < c_u^I$ (respectively, $c_u^E > c_u^I$), the entrant's decision to make (respectively, buy) the upstream input not only leads to the most efficient outcome, but also to the socially optimal one. It is worth noting, that in the Hotelling model, as well as, in the Cournot model, the entrant's efficient make-or-buy decision is always socially optimal. However, in the former case the social optimality of the efficient make-or-buy decisions is fulfilled without any regulatory intervention in the upstream market, whereas in the latter case the regulatory intervention is necessary for ensuring such optimality. In particular, the regulator should set $w > c_u^E$ if $c_u^E < c_u^I$ and $w < c_u^E$ if $c_u^E > c_u^I$ in order to ensure the social optimality of the efficient make-or-buy decision undertaken by the entrant. Any deviation from this regulatory policy may result in a socially optimal outcome which is not efficient, or to an entrant's decision that is not socially optimal.

Therefore, we demonstrate a continuum of findings in which, depending of the input prices, the entrant's make-or-buy decision is both efficient and socially optimal, is only socially optimal and is neither efficient nor socially optimal.

3.3 Bertrand vertical differentiation model

In the Bertrand vertical differentiation model, the final products of the two rivals can be ordered in an objective way according to their perceived difference in quality. In this article, it is assumed that the incumbent produces the high quality good and the entrant produces the lower quality good. Like Gayle and Weisman (2007a), we assume that a consumer requires only one unit of the product and her indirect utility for the high quality good is given by, $V_h = \theta\,\lambda_h - p_h$, while her indirect utility for the low quality good is given by, $V_l = \theta\,\lambda_l - p_l$, where $\lambda_h > \lambda_l$. Each consumer has a unique θ, which captures taste heterogeneity in the population and is assumed to be uniformly distributed on the interval [0, 1]. Without loss of generality, we also normalize the population of consumers to 1.

Gayle and Weisman (2007a) discuss the impact of input prices on the entrant's make-or-buy decision by comparing the entrant's profits when it decides to buy the upstream input from the incumbent with its profits when it chooses to make the upstream input itself. Their main finding is stated in Proposition 7:

Proposition 7 (Gayle and Weisman 2007a) *In the equilibrium of the Bertrand vertical differentiation model:* (a) *The entrant makes the input rather than buys from the incumbent when $c_u^E < c_u^I$ for $w \geq c_u^E$; and* (b) *The entrant buys the input from the incumbent if and only if $c_u^E > c_u^I$ and $(2\lambda_h - \lambda_l)(w - c_u^E) < \lambda_l(w - c_u^I)$.*

The main conclusion of the above proposition is that when the entrant is (not) the least-cost supplier, its make-or-buy decision is (not) independent of input prices in a Bertrand framework. Therefore, input prices are not necessarily irrelevant in the Bertrand vertical differentiation model. This implies that there is a potential efficiency distortion in the make-or-buy decision. In this article, we examine the impact of input prices on social welfare when the entrant chooses to buy the upstream input from the incumbent and when it chooses to make the upstream input itself. Therefore, we should compare the level of social welfare when an entrant purchases an essential upstream input from the incumbent to the respective level of social welfare when an entrant makes the upstream input itself. The results of this comparison can be summarized in the following proposition:

Proposition 8 (a) *The entrant's decision to buy the upstream input from the incumbent is socially optimal when $w < w^{**}$; and* (b) *the entrant's decision to make the upstream input itself is socially optimal when $w > w^{**}$, where w^{**} represents the input price that makes the society be indifferent about the entrant's decision to make or buy the upstream input.*[7]

From Proposition 8, we deduce that input prices are not irrelevant for the maximization of social welfare and, as a result, for the social optimality of the entrant's make-or-buy decision. However, the main goal of this article is not to show that input

[7] It is worth noting that the value of w^{**} depends on the model's parameters, as described in the Appendix A3. In some special cases, which are also described in the Appendix A3, there are two positive input prices that cause $SW_M = SW_B$.

prices are not irrelevant for the maximization of social welfare, but (a) to find the conditions under which the entrant's make-or-buy decision is socially optimal; and (b) to provide the set of input prices that induce the entrant to undertake not only the socially optimal decision but also the most efficient one. Thus, we should combine the results of Propositions 7 and 8.

The main part of the analysis that follows is conducted via numerical simulations due to the complexity of closed-form solutions for the endogenous variable w^{**}. Therefore, we use numerical examples in order to derive the equilibrium results. Like in the case of the Cournot model, we discriminate between three main cases: (a) neither provider has an innate upstream cost advantage; (b) the entrant has an innate upstream cost advantage; and (c) the incumbent has an innate upstream cost advantage.

The analysis conducted is similar to Gayle and Weisman (2007a) and Gayle and Weisman (2007b) with the exception that this article takes into account the impact of the upstream cost differential on the entrant's make-or-buy decision and, as a result, on the subsequent social welfare level. In other words, we examine the social optimality of make-or-buy decisions for many combinations of the incumbent's and the entrant's unit costs of producing the upstream input rather than fixing arbitrarily their upstream unit costs. For each combination, we estimate the input prices that cause (a) the society; and (b) the entrant, to be indifferent between the latter's decision to make or buy the upstream input (w^{**} and $w_e = [(2\lambda_h - \lambda_l)c_u^E - \lambda_l c_u^I]/2(\lambda_h - \lambda_l)$, respectively). The results are presented in Table 1 (Appendix B).

Note that when the entrant chooses to buy the upstream input, the curve that represents its profits (Π_B^l) is a convex and decreasing function of w, whereas the curve that represents the social welfare (SW_B) is a concave and decreasing function of w. Since the entrant's profits and the social welfare are not affected by input prices when the entrant chooses to make the upstream input itself, the respective curves Π_M^l and SW_M are horizontal lines. In this numerical example the incumbent's upstream cost of providing the upstream input is fixed at 0.55. Therefore, we assume different values of the entrant's upstream cost of providing the upstream input in order to study the effect of both upstream cost differential and input prices on the social optimality of make-or-buy decisions.

3.3.1 The entrant has an innate upstream cost advantage

We begin the analysis by assuming a very high upstream cost differential ($c_u^E = 0.1$). Increasing the assumed value for c_u^E ($0.1 \leq c_u^E \leq 1$) does not affect the entrant's profits curve Π_B^l and the social welfare curve SW_B, but it does serve to shift the entrant's profits curve Π_M^l downwards and the social welfare curve SW_M initially downwards and then upwards.

From Table 1 we deduce that when the entrant is much more efficient than the incumbent in making the upstream input ($c_u^E = 0.1$ and $c_u^E = 0.2$), the Π_M^l curve is above the Π_B^l curve and the SW_M curve is above the SW_B curve for $0 < w < 1.5$.[8,9]

[8] See Appendix B for the proof of this inequality.

[9] See, indicatively, Figs. 4 and 5 in the Appendix B.

Therefore, regardless of the input prices, the entrant's decision to make the upstream input is socially optimal when the entrant is much more efficient than the incumbent in making the upstream input. The implication is that the entrant's efficient make-or-buy decision is socially optimal.

It should be noted that as the entrant becomes less efficient in making the upstream input (but it is still more efficient than the incumbent), the incumbent's profits increase, the entrant's profits decrease and consumer surplus decrease. Hence, it is obvious that increasing c_u^E makes the Π_M^l curve shift downwards and hence intersects the Π_B^l curve at a higher input price level. This implies that as the entrant becomes less efficient, it chooses to buy the upstream input from the incumbent for a larger range of input prices. Concerning the impact of an increase in c_u^E on social welfare, we find that SW_M decreases with an increase in c_u^E as far as $c_u^E < c_u^I$. However, the SW_M curve intersects the SW_B curve at a $w \in (0, 1.5)$ only for low enough upstream cost differential ($c_u^E > 0.3$). In these cases, $w^{**} > w_e$.[10] This implies that the society prefers the entrant to buy the upstream input from the incumbent for a larger range of input prices than the range that induces the entrant to buy the upstream input. Or, in other words, the society prefers the entrant to make the upstream input from the incumbent for a lower range of input prices than the range that induces the entrant to make the upstream input itself. Therefore, the entrant's efficient make-or-buy decision is not socially optimal for $w \in [w_e, w^{**})$ and is socially optimal for $w > w^{**}$.

3.3.2 Neither provider has an innate upstream cost advantage

Not surprisingly, when neither provider has an innate upstream cost advantage ($c_u^I = c_u^E = 0.55$), both the society and the entrant are indifferent between the latter's decision to make-or-buy the upstream input for the same input price ($w^{**} = w_e$).[11] This implies that when $w < w_e$ (respectively, $w > w_e$), the entrant chooses to buy (respectively, make) the upstream input. By combining this result with Proposition 8, we deduce that when $c_u^I = c_u^E$, the make-or-buy decision undertaken by the entrant is socially optimal.

3.3.3 The incumbent has an innate upstream cost advantage

A further increase in c_u^E makes the incumbent has an upstream cost advantage. As the incumbent becomes more efficient than the entrant in producing the upstream input (or as c_u^E further increases), the incumbent's profits increase, the entrant's profits decrease and consumer surplus decrease. This implies that the Π_M^l curve intersects the Π_B^l curve at a higher input price level. Therefore, the higher the c_u^E, the higher the range of input prices that induce the entrant to buy the upstream input from the incumbent.

Concerning the impact of an increase in c_u^E on social welfare, we find that SW_M decreases with an increase in c_u^E as far as $c_u^E < (c_u^E)^*$. Therefore, the SW_M curve

10 See Table 1 and, indicatively, Figs. 6 and 7 in the Appendix B.

11 See Table 1 and Figs. 8 and 9 in the Appendix B.

intersects the SW_B curve at a higher input price. However, if $c_u^E > (c_u^E)^*$, a further increase in c_u^E causes SW_M to increase. Therefore, the SW_M curve intersects the SW_B curve at a lower input price. This implies that if the incumbent is much more efficient than the entrant in producing the upstream input, the society prefers the entrant to make the input for a very large range of input prices even though this is not an efficient outcome.

It is worth noting that regardless of the impact of an increase in c_u^E on social welfare, the input price that makes the society be indifferent about the entrant's make-or-buy decision is always lower than the respective level of input price that makes the entrant be indifferent between making or buying the upstream input, that is $w^{**} < w_e$.[12] This implies that the society prefers the entrant to buy the upstream input from the incumbent for a lower range of input prices than the range that induces the entrant to buy the upstream input. Therefore, the entrant's efficient make-or-buy decision is not socially optimal for $w \in (w^{**}, w_e]$ and is socially optimal for $w < w^{**}$.

3.3.4 Discussion

The main conclusion concerning the analysis of the social optimality of make-or-buy decisions in the case of the Bertrand model can be stated in the following proposition:

Proposition 9 *In the equilibrium of the Bertrand vertical differentiation model, the efficient make-or-buy decision undertaken by the entrant is not necessarily socially optimal.*

Proposition 9 shows that unlike the cases of Hotelling and Cournot models, in which the efficient make-or-buy decision undertaken by the entrant is always socially optimal, in the Bertrand vertical differentiation model the entrant's efficient make-or-buy decision is not necessarily socially optimal. In particular, there is a set of input prices that induce the entrant to undertake its efficient make-or-buy decision which leads to lower social welfare level than the respective level resulted by not undertaking the efficient make-or-buy decision.

4 Conclusions

The aim of this article was to study the impact of input prices on an entrant's efficient make-or-buy decision from a social perspective. Thus, it improved the results of Sappington (2005) and Gayle and Weisman (2007a), which study the impact of input prices on an entrant's efficient make-or-buy decision, by examining their impact on the subsequent level of social welfare. Some very instructive results for regulatory purposes were drawn.

First, this article showed that when the downstream competition is described by the Hotelling model, input prices do not affect the maximization of social welfare. In addition, combining this result with those of Sappington leads us to conclude that the entrant's make-or-buy decision is not only socially optimal, but also leads to the most

[12] See Table 1 and, indicatively, Figs. 10 and 11 in the Appendix B.

efficient outcome. Therefore, the absence of access regulation always leads to both efficient and socially optimal outcome. However, the inability of regulator to affect the exogenous factors, such as the providers' unit costs of producing the upstream input, may distort the fulfillment of the regulator's two-fold goal of promoting competition and encouraging investments in access infrastructures.

Second, it found that when the two providers compete á la Cournot, input prices are not necessarily irrelevant for the society's preference for the entrant's decision to make or buy the upstream input. The combination of this result with those of Gayle and Weisman showed that the entrant's make-or-buy decision is not necessarily socially optimal. However, the entrant's efficient make-or-buy decision always results in the socially optimal outcome. In particular, when the entrant has an innate upstream cost advantage, the regulator can set such an input price that leads the entrant to make the upstream input. This policy leads to: (a) the most efficient outcome; (b) the socially optimal outcome; and (c) the fulfillment of regulator's two-fold goal. However, when the incumbent has an innate upstream cost advantage, the entrant's efficient make-or-buy decision only promotes service-based competition. In this case, the regulator's two-fold goal can only be fulfilled when the upstream cost differential is low enough and, of course, at the cost of efficiency distortion.

Last, in the case of the Bertrand vertical differentiation model, the impact of input prices on the society's preference for the entrant's make-or-buy decision and on the social optimality of make-or-buy decisions is as described in the case of the Cournot model. However, in the case of Bertrand model, the entrant's efficient make-or-buy decision does not always result in the socially optimal outcome. The rationale of these results is that if the entrant is much more efficient than the incumbent in producing the upstream input, the absence of access regulation leads the entrant to make the upstream input which not only results in the most efficient and socially optimal outcome, but also fulfills the regulator's two-fold goal. However, if the entrant is not much more efficient than the incumbent or the incumbent has an innate upstream cost advantage, the regulator's intervention is necessary in order to set such an input price which induces the entrant to undertake the efficient make-or-buy decision that is also socially optimal.

The above analysis showed that the particular model that describes the competition in the downstream market, as well as, each provider's efficiency in producing the upstream input have a significant impact on the social optimality of the entrant's (efficient) make-or-buy decisions. This implies that regulators should have perfect information about each provider's unit cost of producing the upstream input and the way that the two providers compete in the downstream market in order to draw their optimal access pricing policy. This article assessed the impact of input prices on the entrant's make-or-buy decisions and on the subsequent social welfare level for every upstream cost differential for three alterative models of downstream competition. Thus, this article provided the optimal access pricing policy that results in the best feasible outcome in terms of social welfare, productive efficiency, competition level and investment level given the upstream cost differential and the particular model of downstream competition employed.

Acknowledgements The authors are grateful to the editor and the anonymous referees for constructive suggestions which considerably improve this manuscript. This research has been co-financed by the European Union (European Social Fund—ESF) and Greek national funds through the Operational Program "Education and Lifelong Learning" of the National Strategic Reference Framework (NSRF)—Research Funding Program: Heracleitus II. Investing in knowledge society through the European Social Fund.

Appendix A

A1. Hotelling model

Case 1: *The entrant chooses to make* (M) *the upstream input itself*

Let $\hat{L} \in [0,1]$ denote the location of the consumer that is indifferent between purchasing from the incumbent and the entrant. Therefore, $\hat{L} = Q^I_M$. The analysis is similar to Sappington (2005) with one exception that $c^I_d = c^E_d = 0$. As a result, see Sappington (2005) for equations that give the equilibrium prices (P), output levels (Q) and profits (Π), for $i, j = I, E, i \neq j$, where prices, outputs and profits for the incumbent and the entrant are denoted by the superscript I and E, respectively.

$$P^i_M = t + \frac{2\,c^i_u + c^j_u}{3} \tag{A1}$$

$$Q^i_M = N\left[\frac{1}{2}\left(1 + \frac{c^j_u - c^i_u}{3t}\right)\right] \tag{A2}$$

$$\Pi^i_M = N\left[\frac{(3t - c^i_u + c^j_u)^2}{18t}\right] \tag{A3}$$

Consumer surplus is given by:

$$CS_M = N\left\{\int_o^{\hat{L}} [v - P^I_M - t(L-0)]dL + \int_{\hat{L}}^1 [v - P^E_M - t(1-L)]dL\right\} \Rightarrow \tag{A4}$$

$$CS_M = N\left[v + (P^E_M - P^I_M)\,Q^I_M - P^E_M - \frac{t}{2} + t\,Q^I_M - t\,(Q^I_M)^2\right] \tag{A5}$$

Substituting (A1) and (A2) into (A5) provides the resulting level of consumer surplus:

$$CS_{\mathrm{M}} = N[36vt + (c^I_u)^2 - 2(c^I_u)(c^E_u) - 18(c^I_u)t + (c^E_u)^2 - 18(c^E_u)t - 45\,t^2]/(36t) \tag{A6}$$

Social welfare is the sum of both providers' profits and consumer surplus:

$$SW_M = N[36vt + 5(c_u^I)^2 - 10(c_u^I)(c_u^E) - 18(c_u^I)t + 5(c_u^E)^2 - 18(c_u^E)t - 9t^2]/(36t) \tag{A7}$$

Case 2: *The entrant chooses to buy* (B) *the upstream input from the incumbent*
Equilibrium prices, output levels and profits for the incumbent (I) and the entrant (E) are as described in Eqs. (A8)–(A11), for $i, j = I, E, i \neq j$:

$$P_B^i = w + t \tag{A8}$$

$$Q_B^i = N\frac{1}{2} \tag{A9}$$

$$\Pi_B^I = N\left(\frac{t}{2} + w - c_u^I\right) \tag{A10}$$

$$\Pi_B^E = N\frac{t}{2} \tag{A11}$$

For the proof of Eqs. (A8)–(A11) see Sappington (2005). In addition, the consumer surplus level obtained when the entrant chooses to buy the upstream input from the incumbent is given by substituting (A8) and (A9) into (A5). Therefore:

$$CS_B = N(v - w - 5t/4) \tag{A12}$$

Social welfare is the sum of both providers' profits and consumer surplus:

$$SW_B = N(v - c_u^I - t/4) \tag{A13}$$

Proof of Proposition 1 The result of Proposition 1 is derived by comparing Eqs. (A3) and (A11). See Sappington (2005) for the whole proof.

Proof of Proposition 2 From Eqs. (A7) and (A13):

$$SW_M >=< SW_B \Leftrightarrow \tag{A14}$$

$$N[36vt + 5(c_u^I)^2 - 10(c_u^I)(c_u^E) - 18(c_u^I)t + 5(c_u^E)^2 - 18(c_u^E)t - 9t^2]/(36t) >=<$$
$$N(v - c_u^I - t/4) \Leftrightarrow \tag{A15}$$

$$\frac{(c_u^E - c_u^I)}{2}\left[\frac{5(c_u^E - c_u^I)}{18t} - 1\right] >=< 0 \tag{A16}$$

Like Sappington (2005), we assume that both the incumbent and the entrant serve retail consumers in equilibrium. Hence, $\left|c_u^j - c_u^i\right| < 3t(for\, i, j = I, E, i \neq j)$. This implies that $\frac{5(c_u^E - c_u^I)}{18t} - 1 < 0$. Therefore, from (A16) it is deduced that: (a) if $c_u^E = c_u^I$, then $SW_M = SW_B$; (b) if $c_u^E > c_u^I$, then $SW_M < SW_B$; and (c) if $c_u^E < c_u^I$, then $SW_M > SW_B$.

Proof of Proposition 3 Given that the entrant is understood to make the efficient make-or-buy decision if it purchases the input from the incumbent when the incumbent is the least-cost supplier ($c_u^I < c_u^E$) and produces the input itself whenever it is the least-cost supplier ($c_u^E < c_u^I$), Proposition 3 is derived straightforward by combining Propositions 1 and 2.

A2. Cournot model

Case 1: *The entrant chooses to make* (M) *the upstream input itself*

The analysis is similar to Gayle and Weisman (2007a) with one exception that $c_d^I = c_d^E = 0$. In particular, when the entrant chooses to make the upstream input itself, the profit functions for the incumbent and the entrant are given, respectively, by:

$$\Pi_M^I = (P_M - c_u^I)\, Q_M^I \tag{A17}$$
$$\Pi_M^E = (P_M - c_u^E)\, Q_M^E \tag{A18}$$

where $P = A - B(Q_M^I + Q_M^E)$. Taking the first order conditions of (A17) and (A18) with respect to Q_M^I and Q_M^E, respectively, and solving simultaneously yields the Nash outputs:

$$Q_M^i = \frac{A + c_u^j - 2\, c_u^i}{3B} \tag{A19}$$

for $i, j = I, E, i \neq j$. Substituting Eq. (A19) into the inverse demand function $P(Q) = A - BQ$ yields the equilibrium retail price:

$$P_M^i = \frac{A + c_u^i + c_u^j}{3} \tag{A20}$$

Substituting Eqs. (A19) and (A20) into Eqs. (A17) and (A18) yields each provider's profits:

$$\Pi_M^i = \frac{\left(A + c_u^j - 2\, c_u^i\right)^2}{9B} \tag{A21}$$

Consumer surplus is given by:

$$CS_{\mathrm{M}} = \frac{Q_M^2}{2} = \frac{\left(Q_M^I + Q_M^E\right)^2}{2} \Rightarrow \tag{A22}$$
$$CS_{\mathrm{M}} = \frac{\left(2A - c_u^I - c_u^E\right)^2}{18B} \tag{A23}$$

Social welfare is given by adding both providers' profits and consumer surplus:

$$SW_M = \frac{(A + c_u^E - 2\,c_u^I)^2}{9B} + \frac{(A + c_u^I - 2\,c_u^E)^2}{9B} + \frac{(2A - c_u^I - c_u^E)^2}{18B} \tag{A24}$$

Case 2: *The entrant chooses to buy* (B) *the upstream input from the incumbent*

The analysis is similar to Gayle and Weisman (2007a) with the exception that $c_d^I = c_d^E = 0$. Therefore, see Gayle and Weisman (2007a) for Eqs. A25 to A29 that provide the equilibrium retail prices (for $i, j = I, E, i \neq j$), each provider's output and each provider's profits when the entrant chooses to buy the upstream input itself.

$$P_B^i = \frac{A + w + c_u^I}{3} \tag{A25}$$

$$Q_B^I = \frac{A + w - 2\,c_u^I}{3B} \tag{A26}$$

$$Q_B^E = \frac{A - 2w + c_u^I}{3B} \tag{A27}$$

$$\Pi_B^I = \frac{(A + w - 2\,c_u^I)^2}{9B} + \frac{(w - c_u^I)(A - 2w + c_u^I)}{3B} \tag{A28}$$

$$\Pi_B^E = \frac{(A - 2w + c_u^I)^2}{9B} \tag{A29}$$

Consumer surplus is given by:

$$CS_B = \frac{Q_B^2}{2} = \frac{(Q_B^I + Q_B^E)^2}{2} \Rightarrow \tag{A30}$$

$$CS_B = \frac{(2A - c_u^I - w)^2}{18B} \tag{A31}$$

Social welfare is given by adding both providers' profits and consumer surplus:

$$SW_B = \frac{(A + w - 2\,c_u^I)^2}{9B} + \frac{(A + c_u^I - 2w)^2}{9B} + \frac{(2A - c_u^I - w)^2}{18B} + \frac{(w - c_u^I)(A - 2w + c_u^I)}{3B} \tag{A32}$$

Proof of Proposition 4 The result of Proposition 4 is derived by comparing Eqs. (A21) and (A29). See Gayle and Weisman (2007a) for the whole proof.

Proof of Proposition 5 From Eqs. (A24) and (A32):

$$SW_M >=< SW_B \Leftrightarrow \tag{A33}$$

$$\frac{(A+c_u^E-2c_u^I)^2}{9B}+\frac{(A+c_u^I-2c_u^E)^2}{9B}+\frac{(2A-c_u^I-c_u^E)^2}{18B} >=<$$

$$\frac{(A+w-2c_u^I)^2}{9B}+\frac{(A+c_u^I-2w)^2}{9B}+\frac{(2A-c_u^I-w)^2}{18B}+\frac{(w-c_u^I)(A-2w+c_u^I)}{3B} \Rightarrow \tag{A34}$$

$$6(c_u^I)^2-14(c_u^I)(c_u^E)-4(c_u^I)w+6A(c_u^I)+11(c_u^E)^2-8A(c_u^E)+w^2+2Aw >=< 0 \Rightarrow \tag{A35}$$

$$w >=< -A+2(c_u^I)\pm\sqrt{A^2+14(c_u^I)(c_u^E)-11(c_u^E)^2+8A(c_u^E)-10A(c_u^I)-2(c_u^I)^2} \tag{A36}$$

From (A36) we conclude that the society is indifferent about the entrant's make-or-buy decisions when $w^*=-A+2(c_u^I)\pm\sqrt{A^2+14(c_u^I)(c_u^E)-11(c_u^E)^2+8A(c_u^E)-10A(c_u^I)-2(c_u^I)^2}$. It is worth noting that we reject the second solution since it results in negative access prices. Therefore, (a) if $w=w^*$, then $SW_M=SW_B$; (b) if $w>w^*$, then $SW_M>SW_B$; and (c) if $w<w^*$, then $SW_M<SW_B$.

Proof of Assumption 1

(a) The first constraint is derived straightforward by (A36).
(b) When the entrant buys the upstream input from the incumbent, an increase in the access price causes the new entrant's output to decrease. Therefore, in order to ensure that the new entrant is active in the market, we assume that $Q_B^E \geq 0$ or $w \leq \overline{w}=(A+c_u^I)/2$.
(c) When the entrant buys the upstream input from the incumbent, a decrease in the access price causes the incumbent's profits to decrease. Therefore, in order to ensure that the incumbent's profits are non-negative, we assume that $\Pi_B^{\mathrm{I}} \geq 0$ or

$$\frac{(A+w-2c_u^I)^2}{9B}+\frac{(w-c_u^I)(A-2w+c_u^I)}{3B} \geq 0 \Rightarrow \tag{A37}$$

$$-5w^2+5w(A+c_u^I)+[A^2-7Ac_u^I+(c_u^I)^2] \geq 0 \Rightarrow \tag{A38}$$

$$[-5(A+c_u^I)+3\sqrt{5}(A-c_u^I)]/(-10) \leq w \leq [-5(A+c_u^I)-3\sqrt{5}(A-c_u^I)]/(-10) \tag{A39}$$

Therefore, the lower limit of the input prices is $\underline{w}=[-5(A+c_u^I)+3\sqrt{5}(A-c_u^I)]/(-10)$. Concerning the upper limit of the input prices, we state that the upper limit is $\overline{w}=(A+c_u^I)/2$ if and only if

$$(A + c_u^I)/2 < [-5(A + c_u^I) - 3\sqrt{5}(A - c_u^I)]/(-10) \Leftrightarrow \tag{A40}$$

$$0 > -6\sqrt{5}(A - c_u^I) \tag{A41}$$

Therefore, is it obvious that (A41) holds and therefore the upper limit is $\overline{w} = (A + c_u^I)/2$.

Proof of Lemma 1
First, note that $\underline{w} < c_u^I < \overline{w}$. The reason is that

$$[-5(A + c_u^I) + 3\sqrt{5}(A - c_u^I)]/(-10) < c_u^I \Rightarrow \tag{A42}$$

$$-5(A + c_u^I) + 6,7(A - c_u^I)] > -10\, c_u^I \Rightarrow \tag{A43}$$

$$1,7(A - c_u^I) > 0 \tag{A44}$$

and $c_u^I < (A + c_u^I)/2 \Rightarrow 0 < A - c_u^I$ which both holds.

Furthermore, in this case, we assume that $c_u^I = c_u^E$. Therefore, substituting $c_u^I = c_u^E$ into (A36) yields:

$$SW_M >=< SW_B \Leftrightarrow \tag{A45}$$

$$w >=< -A + 2(c_u^I) + \sqrt{(A - c_u^I)^2} = c_u^I \tag{A46}$$

Therefore, $w^* = -A + 2(c_u^I) + \sqrt{(A - c_u^I)^2} = c_u^I$. Then Lemma 1 is straightforward.

Proof of Lemma 2 In this case, we assume that $c_u^E < c_u^I$. In addition c_u^E cannot be lower than $\underline{w}$ because if $c_u^E < \underline{w}$ then the first constraint of Assumption 1 is violated. Therefore, $\underline{w} < c_u^E < c_u^I$. However, the value of c_u^E affects the relative value of w^* with respect to $\underline{w}$. For this reason, we calculate the values of c_u^E that causes $w^* = \underline{w}$. Hence,

$$-A + 2(c_u^I) + \sqrt{A^2 + 14(c_u^I)(c_u^E) - 11\,(c_u^E)^2 + 8A(c_u^E) - 10A(c_u^I) - 2\,(c_u^I)^2}$$
$$= -5(A + c_u^I) + 3\sqrt{5}(A - c_u^I)]/(-10) \tag{A47}$$

The solution of (A47) shows that $w^* = \underline{w}$ if

$$c_u^E = \frac{4A + 7\,c_u^I}{11} \pm (A \mp c_u^I)\sqrt{\frac{198\sqrt{5} - 54}{5}} \tag{A48}$$

The first solution of (A48) is rejected because it causes $c_u^E > c_u^I$. Therefore, the critical value of c_u^E that causes $w^* = \underline{w}$ is $(c_u^E)' = \frac{4A+7c_u^I}{11} - (A + c_u^I)\sqrt{\frac{198\sqrt{5}-54}{5}}$. It follows that $(c_u^E)' < c_u^I$.

As a result if $c_u^E < (c_u^E)' < c_u^I$ then $w^* < \underline{w}$ and if $(c_u^E)' < c_u^E < c_u^I$ then $w^* > \underline{w}$. However, we should also prove that $w^* < c_u^E$ when $c_u^E < c_u^I$. Indeed,

$$w^* < c_u^E \Rightarrow \tag{A49}$$

$$-A+2(c_u^I)+\sqrt{A^2+14(c_u^I)(c_u^E)-11(c_u^E)^2+8A(c_u^E)-10A(c_u^I)-2(c_u^I)^2} < c_u^E \Rightarrow \tag{A50}$$

$$A^2+14(c_u^I)(c_u^E)-11(c_u^E)^2+8A(c_u^E)-10A(c_u^I)-2(c_u^I)^2 < (A+c_u^E-2c_u^I)^2 \Rightarrow \tag{A51}$$

$$A(c_u^E-c_u^I)-2c_u^E(c_u^E-c_u^I)+c_u^I(c_u^E-c_u^I)<0 \Rightarrow \tag{A52}$$

$$(c_u^E-c_u^I)(A-2\,c_u^E+c_u^I)<0 \tag{A53}$$

which holds since $c_u^E < c_u^I$ and $A - 2c_u^E + c_u^I > 0$ because $Q_B^E > 0$. Note that if $c_u^E = c_u^I$ then $w^* = c_u^E = c_u^I$ (as we have already proven) and if $A - 2c_u^E + c_u^I = 0 \Rightarrow c_u^E = (A + c_u^I)/2$, then $w^* = c_u^E$, as well. However, since we assume that $c_u^E < c_u^I$, the only feasible solution is $w^* < c_u^E$. This completes the proof of Lemma 2.

Proof of Lemma 3 In this case, we assume that $c_u^E > c_u^I$. Therefore, from (A53) we deduce that $w^* > c_u^E$ if $c_u^I < c_u^E < (A+c_u^I)/2$ and $w^* = c_u^E$ if $c_u^E = \overline{w} = (A+c_u^I)/2$. As a result, we have examined the relative value of w^* with respect to c_u^E. In addition, we should examine the relative value of w^* with respect to $\overline{w}$. For this reason, we calculate the values of c_u^E that causes $w^* = \overline{w}$. Hence,

$$-A+2(c_u^I)+\sqrt{A^2+14(c_u^I)(c_u^E)-11\,(c_u^E)^2+8A(c_u^E)-10A(c_u^I)-2\,(c_u^I)^2} = (A+c_u^I)/2 \tag{A54}$$

The solution of (A54) shows that $w^* = \overline{w}$ if

$$c_u^E = (c_u^E)'' = \frac{5A+17\,c_u^I}{22} \tag{A55}$$

or

$$c_u^E = (A+c_u^I)/2 \tag{A56}$$

Therefore, we conclude that: (a) if $c_u^E = (A + c_u^I)/2$ then $c_u^E = w^* = \overline{w}$; (b) if $c_u^E < (c_u^E)''$ then $w^* < \overline{w}$; and (c) if $c_u^E > (c_u^E)''$ then $w^* > \overline{w}$. Moreover, if $c_u^E = (c_u^E)''$ then $w^* = \overline{w}$. Last, from Eq. A55 it is obvious that $c_u^I < (c_u^E)''$ since $A > c_u^I$. This completes the proof of Lemma 3.

Proof of Proposition 6 Firstly, let $c_u^I < c_u^E$. Given that (a) the entrant is understood to make the efficient make-or-buy decision if it purchases the input from the incumbent when the incumbent is the least-cost supplier ($c_u^I < c_u^E$); and (b) the implication of Proposition 4 that the entrant buys the input from the incumbent when $w < c_u^E$, we conclude that the entrant undertakes the efficient make-or-buy decision when $w < c_u^E$. In addition, given the result of Lemma 3 that $c_u^E < w^*$ and the implication of Proposition 5 that the entrant's decision to buy the upstream input from the incumbent is socially optimal when $w < w^*$, it follows that $w < c_u^E$ is a necessary and sufficient condition to ensure that the entrant's efficient decision to buy the upstream input is also socially optimal.

Secondly, let $c_u^E < c_u^I$. Given that (a) the entrant is understood to make the efficient make-or-buy decision if it makes the input when it is the least-cost supplier ($c_u^E < c_u^I$); and (b) the implication of Proposition 4 that the entrant makes the input when $w > c_u^E$, we conclude that the entrant undertakes the efficient make-or-buy decision when $w > c_u^E$. In addition, given the result of Lemma 2 that $c_u^E > w^*$ and the implication of Proposition 5 that the entrant's decision to make the upstream input is socially optimal when $w > w^*$, it follows that $w > c_u^E$ is a necessary and sufficient condition to ensure that the entrant's efficient decision to make the upstream input is also socially optimal.

By combining the above results, it can be concluded that the entrant's efficient make-or-buy decision is always socially optimal in the equilibrium of the Cournot model.

A3. Bertrand vertical differentiation model

The analysis is similar to Gayle and Weisman (2007a) with one exception that $c_d^I = c_d^E = 0$. Therefore, the consumer whose taste parameter is $\tilde{\theta} = P^l/\lambda_l$ is indifferent between buying and not buying, whereas the consumer whose taste parameter is $\hat{\theta} = (P^h - P^l)/(\lambda_h - \lambda_l)$ is indifferent between the high and the low quality product. As a result, the demand functions for the incumbent and the entrant are given, respectively, by:

$$Q^l = \frac{P^h}{\lambda_h - \lambda_l} - \frac{\lambda_h P^l}{\lambda_l(\lambda_h - \lambda_l)} \tag{A57}$$

$$Q^h = 1 - \frac{P^h - P^l}{\lambda_h - \lambda_l} \tag{A58}$$

Case 1: *The entrant chooses to make* (M) *the upstream input itself*

The profit functions for the incumbent and the entrant are given, respectively, by:

$$\Pi_M^h = (P^h - c_u^I)Q^h \tag{A59}$$

$$\Pi_M^l = (P^l - c_u^E)Q^l \tag{A60}$$

See Gayle and Weisman (2007a) for Eqs. (A61), (A62), (A63) and (A64) that provide the equilibrium retail prices, the entrant's output and the entrant's profits when the entrant chooses to make the upstream input itself.

$$P_M^h = \frac{\lambda_h[2(\lambda_h - \lambda_l) + 2\,c_u^I + c_u^E]}{4\,\lambda_h - \lambda_l} \tag{A61}$$

$$P_M^l = \frac{\lambda_l(\lambda_h - \lambda_l) + \lambda_l\, c_u^I + 2\,\lambda_h\, c_u^E}{4\,\lambda_h - \lambda_l} \tag{A62}$$

$$Q_M^l = \frac{\lambda_h[\lambda_l(\lambda_h - \lambda_l) + \lambda_l\, c_u^I + \lambda_l\, c_u^E - 2\,\lambda_h\, c_u^E]}{\lambda_l(4\,\lambda_h - \lambda_l)(\lambda_h - \lambda_l)} \tag{A63}$$

$$\Pi_M^l = \frac{\lambda_h[\lambda_l(\lambda_h - \lambda_l) + \lambda_l\, c_u^I + \lambda_l\, c_u^E - 2\,\lambda_h\, c_u^E]^2}{\lambda_l(\lambda_h - \lambda_l)\,(4\,\lambda_h - \lambda_l)^2} \tag{A64}$$

Substituting Eqs. (A61) and (A62) into Eq. (A58) and rearranging yields the incumbent's output.

$$Q_M^h = \frac{2\lambda_h(\lambda_h - \lambda_l) + c_u^I(2\,\lambda_h - \lambda_l) + \lambda_l\, c_u^E}{(4\,\lambda_h - \lambda_l)(\lambda_h - \lambda_l)} \tag{A65}$$

In addition, substituting the resulting incumbent's output Q_M^h and (A61) into (A59) gives the incumbent's profits:

$$\Pi_M^h = \frac{[2\lambda_h(\lambda_h - \lambda_l) + c_u^I(2\,\lambda_h - \lambda_l) + \lambda_l\, c_u^E]^2}{(\lambda_h - \lambda_l)\,(4\,\lambda_h - \lambda_l)^2} \tag{A66}$$

Consumer surplus is given by:

$$CS = \int_{\tilde{\theta}}^{\hat{\theta}} (\theta\lambda_l - P^l)d\theta + \int_{\hat{\theta}}^{1} (\theta\lambda_h - P^h)d\theta \Rightarrow \tag{A67}$$

$$CS = \frac{\lambda_l}{2}(\hat{\theta}^2 - \tilde{\theta}^2) - P^l\, Q^l + \frac{\lambda_h}{2}(1 - \hat{\theta}^2) - P^h\, Q^h \tag{A68}$$

Substituting the equilibrium prices and quantities and the resulting values of $\hat{\theta}$ and $\tilde{\theta}$ into (A68) provides the consumer surplus level when the entrant chooses to make the upstream input itself.

$$CS_M = \frac{\begin{array}{c}\lambda_h[4\,\lambda_h{}^3\,\lambda_l{}^2 + \lambda_h{}^2\,\lambda_l{}^2 - 8\,\lambda_h{}^2\,\lambda_l\, c_u^E + 4\,\lambda_h{}^2\,(c_u^E)^2 - 5\,\lambda_h\,\lambda_l{}^3 + \\ 6\,\lambda_h\,\lambda_l{}^2\, c_u^I + 8\,\lambda_h\,\lambda_l{}^2\, c_u^E + 4\,\lambda_h\,\lambda_l\,(c_u^I)^2 - 3\,\lambda_h\,\lambda_l\,(c_u^E)^2]\end{array}}{2\lambda_l(\lambda_h - \lambda_l)\,(4\,\lambda_h - \lambda_l)^2} \tag{A69}$$

Social welfare is the sum of both providers' profits and consumer surplus, that is:

$$SW_M = \Pi_M^h + \Pi_M^l + CS_M \tag{A70}$$

Case 2: *The entrant chooses to buy* (B) *the upstream input from the incumbent*

The profit functions for the incumbent and the entrant are given, respectively, by:

$$\Pi_B^h = (P^h - c_u^I)Q^h + (w - c_u^I)Q^l \tag{A71}$$
$$\Pi_B^l = (P^l - w)Q^l \tag{A72}$$

See Gayle and Weisman (2007a) for Eqs. (A73), (A74), (A75) and (A76) that provide the equilibrium retail prices, the entrant's output and the entrant's profits when the entrant chooses to buy the upstream input from the incumbent.

$$P_B^h = \frac{\lambda_h[2(\lambda_h - \lambda_l) + 3w]}{4\,\lambda_h - \lambda_l} \tag{A73}$$
$$P_B^l = \frac{\lambda_l(\lambda_h - \lambda_l) + w\,(2\,\lambda_h + \lambda_l)}{4\,\lambda_h - \lambda_l} \tag{A74}$$
$$Q_B^l = \frac{\lambda_h(\lambda_l - 2w)}{\lambda_l(4\,\lambda_h - \lambda_l)} \tag{A75}$$
$$\Pi_B^l = \frac{\lambda_h(\lambda_h - \lambda_l)\,(\lambda_l - 2w)^2}{\lambda_l\,(4\,\lambda_h - \lambda_l)^2} \tag{A76}$$

Substituting Eqs. (A73) and (A74) into Eq. (A58) and rearranging yields the incumbent's output:

$$Q_B^h = \frac{2\lambda_h - w}{4\,\lambda_h - \lambda_l} \tag{A77}$$

In addition, substituting the resulting incumbent's output Q_B^h and Eqs. (A73) and (A75) into Eq. (A71) gives the incumbent's profits:

$$\Pi_B^h = \frac{\begin{array}{l} 4\,\lambda_h{}^3\,\lambda_l - 4\,\lambda_h{}^2\,\lambda_l{}^2 + 8\,\lambda_h{}^2\,\lambda_l\,w - 12\,\lambda_h{}^2\,\lambda_l\,c_u^I - 8\,\lambda_h{}^2\,w^2 + 8\,\lambda_h{}^2\,c_u^I\,w + \\ \lambda_h\,\lambda_l{}^2\,w + 3\,\lambda_h\,\lambda_l{}^2\,c_u^I - \lambda_h\,\lambda_l\,w^2 + 2\,\lambda_h\,\lambda_l\,c_u^I\,w - \lambda_l{}^2\,c_u^I\,w \end{array}}{\lambda_l\,(4\,\lambda_h - \lambda_l)^2} \tag{A78}$$

Consumer surplus is given by (A68). Substituting the equilibrium prices and quantities and the resulting values of $\hat{\theta}$ and $\tilde{\theta}$ into (A68) provides the consumer surplus level when the entrant chooses to buy the upstream input from the incumbent.

$$CS_B = \frac{\lambda_h(4\,\lambda_h{}^2\,\lambda_l + 5\,\lambda_h\,\lambda_l{}^2 - 16\,\lambda_h\,\lambda_l\,w + 4\,\lambda_h\,w^2 - 2\,\lambda_l{}^2\,w + 5\,\lambda_l\,w^2)}{2\lambda_l\,(4\,\lambda_h - \lambda_l)^2} \tag{A79}$$

Social welfare is the sum of both providers' profits and consumer surplus, that is:

$$SW_B = \Pi_B^h + \Pi_B^l + CS_B \tag{A80}$$

Proof of Proposition 7 The result of Proposition 7 is derived by comparing Eqs. (A64) and (A76). See Gayle and Weisman (2007a) for the whole proof.

Proof of Proposition 8 From Eqs. (A70) and (A80):

$$SW_M >=< SW_B \Leftrightarrow \tag{A81}$$

$$\frac{\begin{array}{l}(8\,\lambda_h{}^3\,\lambda_l\,c_u^E - 8\,\lambda_h{}^3\,\lambda_l\,w + 16\,\lambda_h{}^3\,c_u^I\,w - 12\,\lambda_h{}^3\,(c_u^E)^2 - 4\,\lambda_h{}^3\,w^2 - 4\,\lambda_h{}^2\,\lambda_l{}^2\,c_u^I \\ -12\,\lambda_h{}^2\,\lambda_l{}^2\,c_u^E + 16\,\lambda_h{}^2\,\lambda_l{}^2\,w + 12\,\lambda_h{}^2\,\lambda_l\,(c_u^I)^2 + 16\,\lambda_h{}^2\,\lambda_l\,c_u^I\,c_u^E + 12\,\lambda_h{}^2\,\lambda_l\,c_u^I\,w \\ +9\,\lambda_h{}^2\,\lambda_l\,(c_u^E)^2 - \lambda_h{}^2\,\lambda_l\,w^2 + 4\,\lambda_h\,\lambda_l{}^3\,c_u^I + 4\,\lambda_h\,\lambda_l{}^3\,c_u^E - 8\,\lambda_h\,\lambda_l{}^3\,w + 9\,\lambda_h\,\lambda_l{}^2\,(c_u^I)^2 \\ -6\,\lambda_h\,\lambda_l{}^2\,c_u^I\,c_u^E - 6\,\lambda_h\,\lambda_l{}^2\,c_u^I\,w - 2\,\lambda_h\,\lambda_l{}^2\,(c_u^E)^2 + 5\,\lambda_h\,\lambda_l{}^2\,w^2 - 2\,\lambda_l{}^3\,(c_u^I)^2 + 2\,\lambda_l{}^3\,c_u^I\,w)\end{array}}{2\lambda_l(\lambda_h - \lambda_l)\,(4\,\lambda_h - \lambda_l)^2}$$

$$>=< 0 \tag{A82}$$

Solving (A82) with respect to w provides two values of w that make the society be indifferent about the entrant's decision to make or buy the upstream input. Depending on the particular values of c_u^I and c_u^E, (a) the one optimal value of w is positive and the other negative; (b) both are positive; or (c) do not exist. In the numerical example provided here, it is assumed that c_u^I is low enough in order to exclude the second case. Thus, let us denote the potential positive root of Eq. A82 by w^{**}. Therefore, Proposition 8 has been just proved. However, if c_u^I is high enough ($c_u^I \geq 0.65$ in our example), the SW_B curve initially increases with an increase in the input price, reaches its maximum level and then decreases. Therefore, for high enough c_u^E ($c_u^E \geq 0.45$ in our example), there are two positive values of w that make the society be indifferent about the entrant's decision to make or buy the upstream input. In addition, if c_u^E is low enough, SW_M is greater than SW_B for all admissible values of w.

Proof of Proposition 9 From Table 1 we deduce that if $c_u^E < c_u^I$ then $w_e < w^{**}$. Therefore, the entrant undertakes the efficient decision to make the upstream input itself for $w > w_e$, whereas such a decision is socially optimal only for $w > w^{**}$. Since, $w^{**} > w_e$, it can be concluded that the entrant's efficient decision to make the upstream input is not socially optimal for $w \in [w_e, w^{**})$ and is socially optimal for $w > w^{**}$. In addition, regardless of the input price, the entrant's efficient decision to make the upstream input is also socially optimal when the upstream cost differential is very high (see Figs. 4, 5). On the contrary, from Table 1 we deduce that if $c_u^E > c_u^I$ then $w_e > w^{**}$. Therefore, the entrant undertakes the efficient decision to buy the upstream input from the incumbent for $w < w_e$, whereas such a decision is socially optimal only for $w < w^{**}$. It can be concluded that the entrant's efficient decision to buy the upstream input is not socially optimal for $w \in (w^{**}, w_e]$ and is socially optimal for $w < w^{**}$. Hence, the efficient make-or-buy decision undertaken by the entrant is not necessarily socially optimal.

Appendix B

The following is a numerical example used to analyze the impact of input prices on the social optimality of an entrant's efficient make-or-buy decision when the downstream competition is described by the Bertrand vertical differentiation model. It is instructive to limit our study to the range of input prices for which both providers are

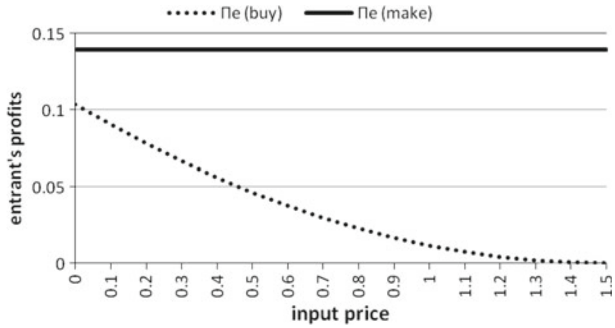

Fig. 4 Entrant's profits as a function of w for $c_u^E = 0.1$

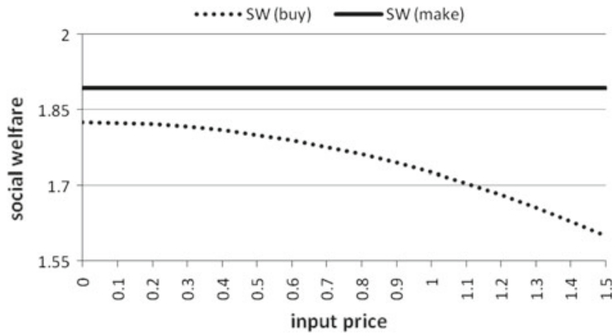

Fig. 5 Social welfare level as a function of w for $c_u^E = 0.1$

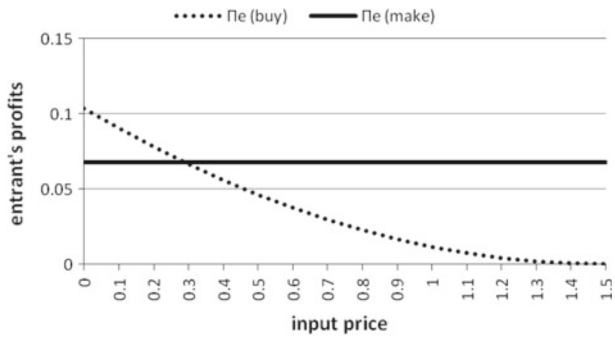

Fig. 6 Entrant's profits as a function of w for $c_u^E = 0.4$

active in the market. Thus, we assume that $w < \lambda_l/2$ which ensures that $Q_{B^l} > 0$ and $c_u^E < \frac{\lambda_l(\lambda_h-\lambda_l)+\lambda_l c_u^I}{2\lambda_h-\lambda_l}$ which ensures that $Q_M^l > 0$. The assumed parameter values are $c_u^I = 0.55$, $\lambda_h = 5$ and $\lambda_l = 3$. Therefore, we find the entrant's profits and the social welfare level when the former chooses to make the upstream input itself and when it chooses to buy the upstream input from the incumbent for $0 < w < 1.5$ and $0 < c_u^E < 1.092$. This implies that we discriminate between three cases regarding the incumbent's and the entrant's unit costs of producing the upstream input:

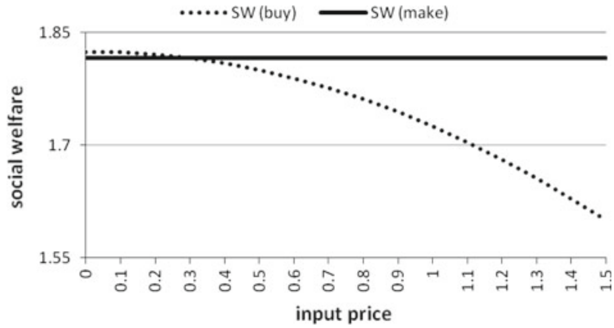

Fig. 7 Social welfare level as a function of w for $c_u^E = 0.4$

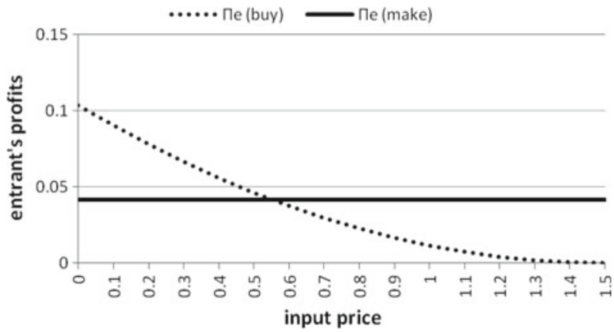

Fig. 8 Entrant's profits as a function of w for $c_u^E = 0.55$

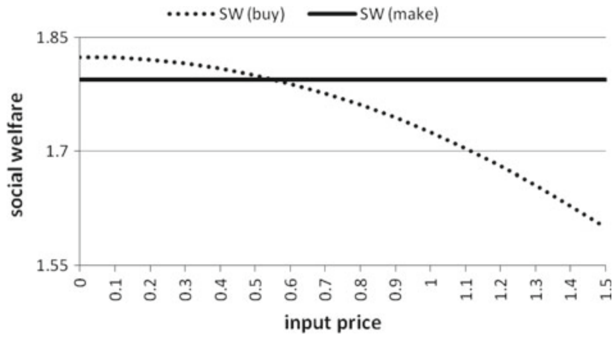

Fig. 9 Social welfare level as a function of w for $c_u^E = 0.55$

(a) when $0 < c_u^E < 0.55$, the entrant has an innate upstream cost advantage. See, indicatively, Figs. 4 and 5 for the case that the upstream cost differential is high enough and Figs. 6 and 7 for the case that the upstream cost differential is low enough;
(b) when $c_u^E = 0.55$, neither provider has an innate upstream cost advantage. The derived results are presented in Figs. 8 and 9; and

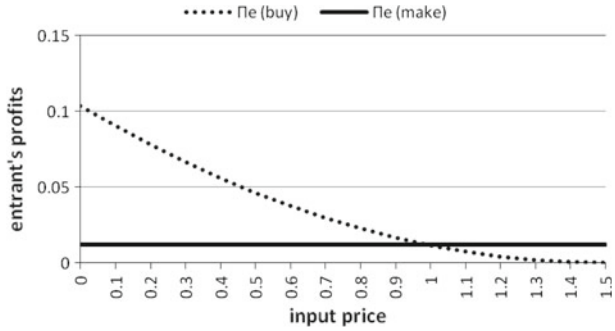

Fig. 10 Entrant's profits as a function of w for $c_u^E = 0.8$

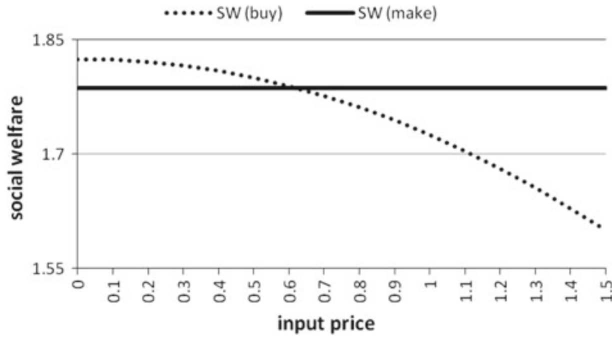

Fig. 11 Social welfare level as a function of w for $c_u^E = 0.8$

Table 1 The values of w^{**} and w_e for different upstream cost differentials

c_u^E	w_e	w^{**}
0.1	–	–
0.2	–	–
0.3	0.1125	–
0.4	0.2875	0.3023
0.5	0.4624	0.4957
0.55	0.55	0.55
0.6	0.6375	0.5881
0.7	0.8125	0.6268
0.8	0.9875	0.6219
0.9	1.1625	0.5724
1	1.3975	0.4638

(c) when $0.55 < c_u^E < 1.092$, the incumbent has an innate upstream cost advantage. See, indicatively, Figs. 10 and 11 for a graphical presentation of the derived results.

Table 1 shows the values of input prices w^{**} and w_e for different values of c_u^E that affect the upstream cost differential.

Applying the values of Table 1 to Propositions 7 and 8 and combining the derived results proves Proposition 9 (as proved in Appendix A3). It is worth noting that the particular values of parameters λ_h and λ_l do not have an impact on the social optimality of an entrant's make-or-buy decisions. Figures 4–11 present graphically the derived results of Table 1 when $c_u^E = 0.1$, $c_u^E = 0.4$, $c_u^E = 0.55$ and $c_u^E = 0.8$. Each of these four upstream cost differentials reflects an indicative example of the special cases described above and in the text.

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