Outsourcing without a Cost Advantage

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Preliminary Version

Abstract

We study outsourcing to an external supplier without a cost advantage in input production. We show that the external supplier can profitably induce outsourcing by a vertically integrated firm and its non-integrated downstream rival through the use of two-part tariffs. It manages to do so although outsourcing raises the cost of the vertically integrated firm more than its rivals' cost. We also show that outsourcing is welfare detrimental and that it is even more detrimental when input trading is through two-part tariffs than through wholesale price contracts.

Keywords: strategic outsourcing; make-or-buy; two-part tariffs; common supplier; raise rivals' cost

JEL classification: D43; L11; L21; L22; L23

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1 Introduction

Outsourcing constitutes a widespread business practice. In fact, in today's world, it is rare to find a firm that does not outsource a part of its production.[1] Often firms outsource to the same external suppliers as their rivals. For example, Hewlett–Packard and IBM both source electronic equipment from Flextronics, Airbus and Boeing source aircraft components from Spirit AeroSystems, Pratt & Whitney and GE Aviation source jet engine components from Ishikawajima Harima Heavy Industries, Apple and Samsung procure ceramic capacitors from Murata, Mercedes and BMW outsource car assembly to Magna Steyr.

The most obvious and extensively studied rationale for outsourcing is cost–reduction, typically due to the external supplier's lower input production cost.[2] This rationale is consistent with many instances of outsourcing to suppliers located in countries with lower labor or material costs and/or to suppliers that hold superior input production technologies.[3] In some instances, however, firms outsource to suppliers which are located domestically or in foreign countries of similar development level and do not necessarily have more efficient production technologies. Boeing, for example, since the 1990s outsources the production of a significant percentage of its aircraft fuselage to a consortium in Japan, which includes Mitsubishi Heavy Industries, Kawasaki Heavy Industries and Fuji Heavy Industries, although neither labor costs nor other costs in the Japanese aircraft industry are known to be lower than in the US.[4] In fact, wages in Japan as well as in several other countries where key Boeing suppliers hang their hats, such as Germany and France, are high.

In this paper, we depart from the cost–reduction rationale and explore the incentives for outsourcing to a common supplier who does not have a cost advantage in input production. Our focus is on input trading: How input trading can induce outsourcing and affect the efficiency of the emerging production pattern.

We consider a framework in which two firms produce substitute products using an input that both can source from a monopolist external supplier, while one of them can alternatively produce the input in–house at the same cost as the external supplier. The supplier offers two–part tariffs first to the firm with input production capability and then to the rival firm. When a firm accepts its offer, it sources the input from the external supplier – outsources.

In equilibrium, both firms outsource to the external supplier without cost advantage. This finding hinges on the supplier's ability to manipulate the input cost of its customers and create cost asymmetries. Two–part tariff contracts grant such flexibility; they allow the

[1] For information regarding the extent of outsourcing, see e.g., Outsourcing and Offshoring: Here, there and everywhere (special report), *The Economist* (January 19, 2013).

[2] Another well recognized motive for outsourcing is firms' intention to focus on their core activities, such as product design, innovation, and marketing.

[3] This is the main rationale of outsourcing according to a number of empirical studies and surveys on outsourcing, see e.g. National Academy on Engineering (2008), Deloitte (2016).

[4] For more details, see Chen (2011).

supplier to charge a wholesale price so as to favor or not a customer and, in turn, use the fixed fee to recuperate or compensate. For instance, when the firm with the in–house production capability rejects the supplier's offer, the supplier subsequently subsidizes, via the wholesale price, its only customer – the firm without in–house production capability – to increase its aggressiveness in the market. In equilibrium the supplier sets a positive mark–up to the firm with the in–house production capability and sells at cost at the rival firm. Firms accept the supplier's offers although they are characterized by price discrimination. The supplier favors the firm without input production capability, first, because sequential trading allows the supplier to enhance the latter's aggressiveness more effectively and without having to subsidize it, and second, because the supplier can fully extract its profits via the fixed fee. Therefore, the supplier both can and does induce outsourcing through its contract offers.

The ability and the incentives of the supplier to induce outsourcing are contract dependent. When linear contracts are used, the supplier and the rest of the firms are indifferent between outsourcing and insourcing. The supplier's wholesale pricing strategy is reversed then; it sells at cost to the firm with the input production capability and above cost to its rival because without a fixed fee, the supplier cannot compensate the first firm for the loss that it would incur from its subsequent better offer to the rival firm.

Outsourcing with two–part tariffs is detrimental for consumer surplus and welfare. This is a straightforward implication of the higher input sourcing terms under outsourcing that result in higher retail prices. Importantly, consumer surplus and welfare can be lower under outsourcing with two–part tariffs than under outsourcing (insourcing) with wholesale price contracts. This finding contrasts with the standard view in the literature that two–part tariffs, by not giving rise to the double marginalization externality, are more efficient than wholesale price contracts. We demonstrate that two–part tariffs can induce a more inefficient outcome than wholesale price contracts.

Extending our analysis, we show that if the external supplier had full control over the choice of contract form, it would opt for the welfare–detrimental two–part tariffs rather than for wholesale price contracts. Thus, we provide justification for the contract form used in our main model. We also provide justification for the sequential trading assumed in our model and show that the supplier would prefer to trade sequentially rather than simultaneously with its customers. Importantly, we show that the assumed asymmetry in firms' input production capabilities is not crucial for the emergence of outsourcing; outsourcing would arise in equilibrium even if both firms had the option of in–house input production. However, outsourcing would not be welfare–detrimental then.

Outsourcing has been studied extensively in various fields, including industrial organization, operational management, and marketing. Many papers have explored the cost–saving motives of outsourcing (e.g., Lewis and Sappington, 1989, Venkatesan, 1992, van Mieghem,

1999, Cachon and Harker, 2002).[5] Others have focused on the strategic motives of outsourcing and showed that outsourcing can be used, for instance, to facilitate collusion (e.g., Cachon and Harker, 2002, Buehler and Haucap, 2006, Gilbert et al., 2006), raise rivals' cost (Arya et al. 2008), or place the rival in a disadvantageous Stackelberg follower position (Chen et al., 2010). In contrast to our paper, in most papers that offer strategic explanations, a necessary assumption for the emergence of outsourcing is that the external supplier enjoys a cost advantage in input production.[6] In addition, most papers on outsourcing assume that wholesale price contracts are used in input trading. As we discuss below, the wholesale price contracts assumption does not have support in the vertical contracting literature. Moreover, it lacks wide support in empirical studies, many of which conclude that in various industry sectors, such as in the US yogurt market and in the bottled water market in France, input trading is through two–part tariffs (e.g., Villas–Boas, 2007, Bonnet and Dubois, 2010). Considering input trading through two–part tariffs, we show how an external supplier without a cost advantage can use the contract terms in such as way as to profitably induce outsourcing.[7]

Arya et al. (2008) and Buehler and Haucap (2008) are the closest papers to our work. Both consider outsourcing to a common supplier in a setting with sequential trading and asymmetry in firms' input production capabilities. Arya et al. (2008) conclude that the higher efficiency of the external supplier is necessary for the emergence of outsourcing. Importantly, Arya et al. (2008) argue that the firm with in–house production capability opts for outsourcing in order to alter the supplier's vested interests in its rival and, in turn, raise its rival's cost. We show instead that, when two–part tariffs are used, outsourcing arises even when the supplier does not have a cost advantage. We also show that under outsourcing the supplier continues to have higher vested interests in the rival firm of its outsourcee and that outsourcing raises the cost of the outsourcee even more than it raises its rival's cost. In fact, the firm with the in–house capability would make a loss under outsourcing, and thus, it would not opt for outsourcing if the supplier was not able to compensate it through the fixed fee. Hence, in contrast to Arya et al. (2008), in our paper outsourcing is driven by the ability of the supplier to use the input trading terms in its own favor. Our explanation also

[5] Starting with Coase (1937), another large branch of this literature, especially in economics, has focused on firm's boundaries and pointed out that asset specificity and contract incompleteness contribute to the expansion of boundaries, thereby restrict outsourcing (e.g., Grossman and Hart, 1986, Grossman and Helpman, 2002).

[6] Exceptions include Chen (2011), Liu and Tyagi (2011), Kabiraj and Sinha (2014), Cao et al. (2018) and Colombo and Scrimitore (2018), who do not assume that the external supplier is more efficient in input production. However, the motive for outsourcing in these papers or their focus differs from ours. In Chen (2011) the motive for outsourcing is entry-deterrence, in Kabiraj and Sinha (2014) technology transfer, and in Cao et al. (2018) the raise in rivals' cost. In Liu and Tyagi (2011) the focus is on the impact of outsourcing on product position and in Colombo and Scrimitore (2008).

[7] In this sense, our paper is also related to contributions by e.g., Bonanno and Vickers (1988) and Jansen (2003), which have explored how two-part tariff contracts can induce vertical separation (outsourcing) in place of vertical integration (in-house production). These contributions, however, have focused on settings with exclusive - specialized input suppliers rather than with a common supplier.

differs significantly from that of Buehler and Haucap (2006), who use a reduced–form model and argue that firms opt for outsourcing to benefit from the softening competition that results from the exogenously assumed higher and uniform wholesale prices under outsourcing. We argue instead that outsourcing arises even though it places the firm with the in–house production capability in a worse competitive position in the market.

Our paper is also related to the literature on supply chain coordination – vertical contracting. This literature has studied the efficiency of various contracts forms in many settings, including settings in which a monopolist input supplier transacts with multiple competing firms (e.g., McAfee and Schwartz, 1994, Cachon and Lariviere 2005, Gilbert et al., 2006, Marx and Shaffer, 2002 and 2007, Taylor 2002, Rey and Vergé, 2004, Milliou and Petrakis, 2007). A number of papers in this literature, in line with our paper, acknowledge the fact that due to the inability of the monopolist to commit that it will not behave opportunistically, two–part tariffs do not always suffice for the maximization of industry profits. Still, there is a wide consensus in this literature that wholesale price generate less efficient market outcomes relative to two–part tariffs. We contribute to this literature by demonstrating, first, that the contract form can be crucial for the production pattern, and second, that the wholesale price contracts can outperform two–part tariffs in terms of market efficiency.

The structure of the rest of the paper is as follows. In Section 2, we describe our main model and explore the incentives for outsourcing and its implications. In Section 3, we examine what happens when firms trade through wholesale price contracts. In Section 4, we extend our model to the case in which all firms can produce the input in–house. In Section 5, we discuss what would happen under simultaneous trading. Finally, in Section 6, we conclude.

2 Model and equilibrium analysis

Our model builds on the two–tier supply chain model of Arya et al. (2008). There are two firms in the market, firm 1 and firm 2, that produce imperfect substitutes. The inverse demand for the product of firm i, with $i, j = 1, 2$ and $i \neq j$, is given by $p_i(q_i, q_j) = a - q_i - \gamma q_j$, where p_i and q_i are its price and quantity, q_j is the quantity of the rival product, and γ, with $\gamma \in (0, 1]$, is a measure of product substitutability.[8]

To produce its product, each firm i uses an input in a one–to–one proportion. Firm 1 can produce the input in–house at marginal cost s or outsource it to an external firm, firm S, which produces the input also at marginal cost s, with $a > s > 0$. Firm 2 has no input production capability; it can only outsource the input to firm S. This can be so because, as Arya et al. (2008) argue, firm 2 is a new entrant in the market. Firm S and firm i trade

[8] See Singh and Vives (1984) for details regarding the derivation of the demand function from the representative consumer's utility maximization problem.

through a two–part tariff contract, consisting of a wholesale price per unit of input, w_i, and a fixed fee, F_i. In the next sections, we will also explore what happens when firm 2 also has the ability to produce the input in–house and when trade is through wholesale price contracts.

Firms play a three–stage game with observable actions. In stage one, S makes a take–it–or–leave–it offer to firm 1 over (w_1, F_1). Firm 1 decides whether to accept or reject it. In case of rejection, it produces the input in–house. In stage two, S makes a take–it–or–leave–it offer to firm 2 over (w_2, F_2) and, in turn, firm 2 accepts or rejects the offer. In the last stage, the firms that are active in the final product market choose their quantities simultaneously and separately. A justification for this timing is that firm 2 is an entrant in the market, while firm 1 is an incumbent. Another justification is that, as we will demonstrate in section 5, the supplier prefers to trade sequentially rather than simultaneously with its customers.

In the last stage, each firm i chooses q_i to maximize its (gross from F_i) profits: $\pi_i(q_i, q_j) = p_i(q_i, q_i)q_i - k_i q_i$, where k_i is firm i's per unit cost, with $k_1 = s$ and $k_1 = w_1$ under insourcing and outsourcing by firm 1 respectively, and $k_2 = w_2$. The first order conditions give rise to: $R_i(q_j, k_i) = (a - k_i - \gamma q_j)/2$. Obviously, a reduction in k_i increases firm i's aggressiveness in the final market. The resulting equilibrium quantities in terms of k_1 and k_2 are:

$$q_i(k_i, k_j) = \frac{a(2-\gamma) - 2k_i + \gamma k_j}{4 - \gamma^2}. \tag{1}$$

2.1 Input sourcing terms

In stage two, we have the *outsourcing* subgame when firm 1 has accepted the offer of firm S, and the *insourcing* subgame, otherwise.

In the *insourcing* subgame, firm S offers (w_2, F_2) to firm 2 to maximize its own profits subject to the constraint that firm 2 accepts its offer; it solves the following:

$$\max_{w_2, F_2} \ \pi_S(w_2, F_2) = (w_2 - s)q_2(w_2, s) + F_2, \tag{2}$$

$$\text{s.t.} \quad \pi_2(q_2(w_2, s), q_1(s, w_2)) - F_2 \geq 0$$

The constraint is binding. Thus, we rewrite (2) as:

$$\begin{aligned} \max_{w_2} \ \pi_S(w_2) &= (w_2 - s)q_2(w_2, s) + \pi_2(q_2(w_2, s), q_1(s, w_2)) \\ &= [p_2(q_2(w_2, s), q_1(s, w_2)) - s]q_2(w_2, s). \end{aligned}$$

This yields firm 2's equilibrium wholesale price under *insourcing*:

$$w_2^I = \frac{8s - \gamma^2(a(2-\gamma) + s(2+\gamma))}{4(2-\gamma^2)}. \tag{3}$$

It is easy to check that $w_2^I < s$; firm S sells the input below its production cost – it subsidizes

the production of its only customer – firm 2. Doing so, it generates more profits for firm 2 and extracts them through F_2. A straightforward implication is that firm 1 has a cost disadvantage in the final market.

Substituting (3) into the constraint, we find the equilibrium fixed fee under *insourcing*: $F_2^I = \frac{(2-\gamma)^2(a-s)^2}{4(2-\gamma^2)^2}$. Similarly, we find firms' net equilibrium profits under *insourcing*:

$$\pi_1^I = \frac{[\gamma(2+\gamma)-4]^2(a-s)^2}{16(\gamma^2-2)^2}; \quad \pi_2^I = 0; \quad \pi_S^I = \frac{(\gamma-2)^2(a-s)^2}{8(2-\gamma^2)}.$$

In the *outsourcing* subgame, firm S offers (w_2, F_2) to firm 2 given (w_1, F_1) from the previous stage. That is, firm S solves:

$$\max_{w_2, F_2} \ \pi_S(w_2, F_2) = (w_1 - s)q_1(w_1, w_2) + (w_2 - s)q_2(w_2, w_1) + F_1 + F_2, \tag{4}$$

$$\text{s.t.} \quad \pi_2(q_2(w_2, w_1), q_1(w_1, w_2)) - F_2 \geq 0$$

The constraint is binding and (4) results in:

$$w_2(w_1) = \frac{(2-\gamma)(4s - \gamma^2(a+s))}{4(2-\gamma^2)} + \frac{\gamma w_1}{2}. \tag{5}$$

Observe that $\partial w_2/\partial w_1 > 0$. This is because when w_1 increases, firm 2 enjoys a competitive advantage that allows firm S to increase w_2 without restricting too severely its input purchases (Arya et al., 2008).

In the previous stage, firm S offers (w_1, F_1) to firm 1. In case firm 1 rejects the offer, the profits of firm 1 and firm S are given by π_1^I and π_S^I from above. Hence, firm 1 will accept the offer if and only if its profits are higher with *outsourcing* than with *insourcing.* In light of this, firm S solves the following:

$$\max_{w_1, F_1} \pi_S(w_1, F_1) = (w_1 - s)q_1(w_1, w_2^O(w_1)) + [w_2^O(w_1) - s]q_2(w_2^O(w_1), w1) + F_2^O + F_1, \tag{6}$$

$$\text{s.t.} \quad \pi_1(q_1(w_1, w_2^O(w_1)), q_2(w_2^O(w_1), w_1)) - F_1 \geq \pi_1^I$$

The constraint is binding and we rewrite (6) as:

$$\begin{aligned} \max_{w_1} \pi_S(w_1, F_1) \quad = \quad & (w_1 - s)q_1(w_1, w_2^O(w_1)) + [w_2^O(w_1) - s]q_2(w_2^O(w_1), w1) + F_2^O \\ & + \pi_1(q_1(w_1, w_2^O(w_1)), q_2(w_2^O(w_1), w_1)) - \pi_1^I. \end{aligned}$$

The resulting equilibrium contract terms offered to firm 1 under *outsourcing* are:

$$w_1^O = \frac{a(2-\gamma)\gamma + (4-\gamma(2+\gamma))s}{2(2-\gamma^2)}; \tag{7}$$

$$F_1^O = \frac{\gamma(2-\gamma)(\gamma(6+\gamma)-8)(a-s)^2}{16(\gamma^2-2)^2}. \tag{8}$$

Firm 2's equilibrium wholesale price under *outsourcing* follows after the substitution of (7) into (5): $w_2^O = s$. Two observations are in order. First, $w_1^O > w_2^O$; firm S favors firm 2, and thus, firm 1 faces a cost disadvantage relative to its rival under *outsourcing* too. Second, firm S does not manage to maximize the total industry profits; the equilibrium contract terms differ from the ones that would maximize the sum of firms' profits. This is so because firm S suffers from opportunism: the firm with which it trades first knows that firm S will have incentives to offer better trading terms to the firm with which it trades second.[9]

Proposition 1 *Outsourcing raises the per unit cost of both firm* 1 *and firm* 2, $k_1^O > k_1^I$ *and* $k_2^O > k_2^I$.

Proof: The per unit cost of firm 1 is $k_1^I = s$ under insourcing and $k_1^O = w_1^O$ (see (7)) under outsourcing. Since $w_1^O > s$, it follows immediately that $k_1^O > k_1^I$.

The per unit cost of firm 2 is $k_2^I = w_2^I$ (see (3)) under insourcing and $k_2^O = w_2^O = s$ under outsourcing. Since $w_1^O > s$, we have $k_2^O > k_2^I$. ■

Proposition 1 informs us that outsourcing deteriorates the input sourcing terms that both firm 1 and firm 2 face. Therefore, when firm 1 outsources, it raises its rival's cost at the expense of increasing its own cost. In fact, its own cost increases by more than its rival's cost: $k_1^O - k_2^O > k_1^I - k_2^I$. This means that opting for outsourcing, firm 1 inflicts itself a higher damage, in terms of per unit cost, than the one it inflicts to its rival. An implication of this is that outsourcing decreases firm 1's output, $q_1(s, w_2^I) > q_1(w_1^O, w_2^O)$, while it leaves firm 2's output intact, $q_2(w_2^I, s) = q_2(w_2^O, w_1^O)$.[10] A further implication is that firm S offers $F_1^O < 0$ to firm 1 to compensate it for the damage, while it continues to offer $F_2^O = F_2^I > 0$ to firm 2.

Firms' net equilibrium profits under *outsourcing* follow from the appropriate substitutions:

$$\pi_1^O = \frac{[\gamma(2+\gamma)-4]^2(a-s)^2}{16(\gamma^2-2)^2}; \quad \pi_2^O = 0; \quad \pi_S^O = \frac{(2-\gamma)^3(\gamma+2)(a-s)^2}{16(\gamma^2-2)^2}. \tag{9}$$

2.2 Choice of input sourcing mode

Next, we endogenize the input sourcing mode: *outsourcing* or *insourcing*. We find that there exist two–part tariff contracts that guarantee higher profits for firm S and firm 1 under

[9] For a more detailed presentation of the supplier's opportunism problem in settings with sequential trading, see e.g., McAfee and Schwartz (1994) and Marx and Shaffer (2002, 2007).

[10] This is because from (1), we have: $dq_1/dw_1^O = \frac{\partial q_1}{\partial w_2^O}\frac{\partial w_2^O}{\partial w_1^O} + \frac{\partial q_1}{\partial w_1^O} < 0$ and $dq_2/dw_1^O = \frac{\partial q_2}{\partial w_2^O}\frac{\partial w_2^O}{\partial w_1^O} + \frac{\partial q_2}{\partial w_1^O} = 0$.

outsourcing than under insourcing; hence, offering such contracts, firm S induces outsourcing in equilibrium.

Proposition 2 *Outsourcing always arises in equilibrium.*

Proof: We start by noting that both under outsourcing and insourcing, firm S serves firm 2. This is because when firm S serves firm 2, its profits are positive, $\pi_S^O > 0$ and $\pi_S^I > 0$, while when it does not serve firm 2, its profits are zero. The latter occurs because when firm 1 opts for insourcing, firm S makes no sales and when firm 1 opts for outsourcing, outsourcing does not generate more gross profits than in–house production. It follows that firm S's profits are given by π_S^O () and π_S^I under outsourcing and insourcing respectively. Comparing them, we find that the profits of firm S are strictly higher under outsourcing: $\pi_S^O - \pi_S^I = \gamma^2(\gamma-2)^2(a-s)^2/16(\gamma^2-2)^2 > 0$. In contrast, the profits of firm 1 and firm 2 are equal under outsourcing and insourcing: $\pi_1^O - \pi_1^I = \pi_2^O - \pi_2^I = 0$. It follows that firm S wants to induce outsourcing. Firm S can do so by offering $(w_1^O, F_1^O - \varepsilon)$ and $(w_2^O, F_2^O - \varepsilon)$ to firm 1 and firm 2 respectively, with $\varepsilon > 0$ and $\varepsilon \to 0$. ■

Under insourcing, firm S has vested interests only in firm 2 – its revenues come exclusively from it. Under outsourcing, firm S can also have revenues from firm 1. But, its vested interests in firm 2 continue to be higher than those in firm 1. This is because while it can fully extract firm 2's profits, it has to compensate firm 1 for its in–house production option. An additional reason is that sequential trading allows firm S to extract more profits from the firm with which it trades second (see e.g., McAfee and Schwartz, 1994, Marx and Shaffer 2002 and 2007, Bedre–Defolie, 2012). Through outsourcing firm S improves the position of the firm in which it has higher vested interests; it increases the downstream cost asymmetry in favor of firm 2. This leads, as mentioned above, to a lower output for firm 1 and to the same output for firm 2. Firm S manages to do this without any longer having to subsidize firm 2 since $w_2^O = s > w_2^I$. Stated differently, outsourcing allows firm S "to kill two birds with one stone": it expands the market share of its preferred customer and increases its own revenues.

Interestingly, under outsourcing, firm S purposely makes a net loss from its transactions with firm 1. Firm S serves firm 1 not in order to enjoy higher input demand. It serves firm 1 to increase the profits that it makes from its sales to firm 2. This becomes particularly clear in the special case in which $\gamma = 1$, where firm S fully forecloses firm 1 from the market $(q_1^O = 0)$.[11]

It is important to stress that although the supplier does not have a cost–advantage, it manages to induce outsourcing. The reverse – the existence of a cost advantage – is a

[11] In fact, when $\gamma = 1$, firm S manages to maximize the total industry profits through outsourcing; the opportunism problem is absent.

necessary condition for the emergence of outsourcing in the literature (e.g., Arya et al., 2008, Feng and Lu, 2013). As we explain in detail in the next section, this difference hinges on the contract form.

The above explanation for outsourcing departs from collusion explanations in the literature (e.g., Buehler and Haucap, 2006, Gilbert et al., 2006), although it shares some features with them. The raise in input sourcing costs induced by outsourcing clearly restricts market competition. However, accompanied in our setting by a raise in cost asymmetry, it is not mutually profitable for all firms: while it does not affect firm 2's gross from the fixed fee profits, it decreases firm 1's gross profits.[12] The weaker competition faced by firm 2 works only in favor of the supplier – it allows it to enlarge its own profits. Firm 1 would not opt for outsourcing if it was not compensated for its loss. F_1 serves, thus, as a bribe: firm S pays firm 1 to abstain from producing the input itself.

The positive impact of outsourcing on the supplier's profits dominates its negative impact on the (variable) profits of its customers and results in higher total industry profits. This comes at a cost for consumers and welfare.

Proposition 3 *Total industry profits are higher, while consumer surplus and welfare are lower under outsourcing than under insourcing.*

Proof: Calculating and comparing total industry profits, PS, under outsourcing and insourcing, we find: $PS^O - PS^I = (\pi_1^O + \pi_2^O + \pi_S^O) - (\pi_1^I + \pi_2^I + \pi_S^I) = \gamma^2(\gamma-2)^2(a-s)^2/16(\gamma^2-2)^2 > 0$. Consumer surplus, CS, is given by: $aq_1^v + aq_2^v - (1/2)(q_1^{v2} + q_2^{v2} + \gamma q_1^v q_2^v) - (a - q_1^v - \gamma q_2^v)q_1 - (a - q_2^v - \gamma q_1^v)q_2^v$, with $v = O, I$. Comparing CS under outsourcing and insourcing, we find: $CS^O - CS^I = \gamma(2-\gamma)(a-s)^2[\gamma(7\gamma-6) - 8]/16(\gamma^2-2)^2 < 0$. Finally, comparing welfare – total surplus, TS, under outsourcing and insourcing, we find: $TS^O - TS^I = PS^O + CS^O - PS^I - CS = \gamma(2-\gamma)(a-s)^2[\gamma(5\gamma-2) - 8]/32(\gamma^2-2)^2 < 0$. ■

The higher input sourcing costs under outsourcing lead to higher retail prices and, thereby, render outsourcing detrimental for consumer surplus. Outsourcing to a supplier which neither faces a lower input cost nor subsidizes final production, is also welfare detrimental. Thus, the production pattern that emerges in equilibrium – outsourcing – is inefficient.

3 Wholesale price contracts

We now examine what happens when firms trade through wholesale price contracts. In the last stage, the equilibrium quantities are given by (1). In stage two, in the *insourcing*

[12] This finding is consistent with the empirical findings of Görzig and Stephen (2002) and Marjit and Mukherjee (2008), according to which outsourcing can reduce firm's profitability.

subgame, firm S offers w_2 to firm 2 solving $\max_{w_2} \pi_S(w_2) = (w_2 - s)q_2(w_2, s)$. This yields:

$$w_2^{IW} = [a(2-\gamma) + s(2+\gamma)]/4. \tag{10}$$

As expected, in the absence of a fixed fee, firm S sets a positive mark–up on the wholesale price, $w_2^I > s$, generating a cost disadvantage for firm 2. The resulting equilibrium profits are:

$$\pi_1^{IW} = \frac{(a-s)^2(4+\gamma)^2}{16(2+\gamma)^2}; \quad \pi_2^{IW} = \frac{(a-s)^2}{4(2+\gamma)^2}; \quad \pi_S^{IW} = \frac{(a-s)^2(2-\gamma)}{8(2+\gamma)}.$$

In the *outsourcing* subgame, firm S offers w_2, given w_1 from the previous stage; it solves:

$$\max_{w_2} \ \pi_S(w_1, w_2) = (w_1 - s)q_1(w_1, w_2) + (w_2 - s)q_2(w_2, w_1), \tag{11}$$

This leads to:

$$w_2(w_1) = (a+s)/2 - (a + s - 2w_1)\gamma/4. \tag{12}$$

In stage one, firm S makes its offer to firm 1. In case firm 1 rejects the offer, the profits of firm 1 and firm S are given by π_1^{IW} and π_S^{IW}. The supplier will have an incentive to induce outsourcing if and only if:

$$\pi_S(w_1, w_2(w_1)) - \pi_S^{IW} = (a - w_1)(w_1 - s)/2 > 0. \tag{13}$$

Thus, if and only if it offers $w_1 > s$. At the same time, firm 1 will accept firm S's offer if and only if its profits under *outsourcing* exceed its profits under *insourcing*:

$$\pi_1(w_1, w_2(w_1)) - \pi_1^{IW} = \frac{(s - w_1)(a(4+\gamma) - 2s - w_1(2+\gamma))}{4(2+\gamma)} > 0. \tag{14}$$

Condition (14) is not satisfied whenever $w_1 > s$. Consequently, outsourcing can arise in equilibrium only if it coincides with insourcing, i.e., if firm S offers $w_1^{OW} = s$ and $w_2^{OW} = w_2^{IW}$. A lower w_1, i.e., $w_1 < s$, would trigger a lower w_2 in the next stage, since $dw_2/dw_1 > 0$, and result in a higher quantity for firm 1, since $dq_1/dw_1 < 0$, and no change in the quantity of firm 2, since $dq_2/dw_1 = 0$. Hence, firm S would end up selling more units to firm 1 at a loss and the same amount of units to firm 2 at a lower wholesale price than before. In other words, the supplier would experience a loss from one customer and a decrease in its revenues from the other. Clearly, this would not be profitable. We state this formally in the next proposition.

Proposition 4 *With wholesale price contracts, (i) the external supplier cannot profitably induce outsourcing, and (ii) outsourcing coincides with insourcing.*

When linear contracts are used, firm S does not strictly prefer outsourcing to insourcing. In fact, if outsourcing entails any fixed costs, such as administrative costs or expansion costs,

firm S does not wish to induce outsourcing. As we know from Proposition 2, the opposite holds when two–part tariffs are used; firm S profitably induces outsourcing even when it does not have a cost advantage. This makes us conclude that the contract form is not innocuous: it can have significant implications for the production pattern that emerges in equilibrium. Intuitively, the presence of the fixed fee in the case of two–part tariffs allows firm S to compensate firm 1 for its potential loss under outsourcing relatively to insourcing. In addition, it allows firm S to fully extract firm 2's profits and, thereby, to have higher vested interests in firm 2 than in firm 1.

As the next Proposition informs us, the contract form can also have important welfare implications.

Proposition 5 *When products are sufficiently close substitutes, $\gamma > \sqrt{3} - 1$, consumer surplus and welfare are lower under two–part tariffs and outsourcing than under wholesale price contracts.*

Proof: We calculate consumer surplus and total surplus under outsourcing/insourcing with wholesale prices:

$$CS^{OW} = \frac{(a-s)^2[20+\gamma(32+7\gamma)]}{32(2+\gamma)^2};\ TS^{OW} = \frac{(a-s)^2(38+5\gamma)}{32(2+\gamma)}.$$

Taking the difference of consumer surplus and of total surplus under outsourcing with two–part tariffs and under outsourcing/insourcing with wholesale price contracts, we have:

$$\begin{aligned} CS^O - CS^{OW} &= \frac{(a-s)^2}{32}\left(\frac{4[8+\gamma^2(-13+6\gamma)]}{(\gamma^2-2)^2} - \frac{20+\gamma(32+7\gamma)}{(2+\gamma)^2}\right), \\ TS^O - TS^{OW} &= \frac{(a-s)^2}{32}\frac{[\gamma(2+\gamma)-2][\gamma(2-5\gamma)+10](2-\gamma)}{(2+\gamma)(\gamma^2-2)^2}. \end{aligned}$$

It is easy to check that the above inequalities are negative if and only if $\gamma > \sqrt{3} - 1$.■

Recall that under two–part tariffs and outsourcing, the wholesale price charged to one firm exceeds the marginal cost. The latter also holds when wholesale price contracts are used independently of whether there is insourcing or outsourcing. Thus, welfare is not maximized with either contract form. However, the mark–up on the wholesale price that firm S sets is higher with two–part tariffs than with wholesale prices, $w_1^O > w_2^{IW}$. As a result, welfare can be lower with two–parts tariffs than with wholesale prices. This finding contrasts with the standard view in the literature that two–part tariffs are more efficient than linear contracts (e.g., Tirole, 1988) because they offer to firms the flexibility to alleviate the double marginalization externality. We show that when the input production pattern is endogenous, a welfare inferior outsourcing equilibrium can arise with two–part tariffs.

Given the crucial role of the contract form for market outcomes, next, we endogenize it.

Assuming that the supplier has full control over the choice of contract form, we find that it will always opt for two–part tariffs.

Proposition 6 *The external supplier strictly prefers trading through two part tariff contracts than through wholesale price contracts.*

Proof: We calculate the difference between firm S's profits under outsourcing with two–part tariffs and with wholesale prices (which coincide with its profits under insourcing):

$$\pi_S^O - \pi_S^{IW} = \frac{(a-s)^2(2-\gamma)(8-\gamma^4)}{16(2+\gamma)(2-\gamma^2)^2}.$$

The above difference is always positive.

Similarly, we calculate the difference between firm S's profits under insourcing with two–part tariffs and with wholesale prices:

$$\pi_S^I - \pi_S^{IW} = \frac{(a-s)^2(2-\gamma)}{4(2+\gamma)(2-\gamma^2)}.$$

This difference is also always positive. ■

One might wonder what would happen if firm 2 too had the possibility to produce the input in–house at marginal cost s and trading was through wholesale price contracts. Then, in stage two, independently of whether firm 1 has opted for outsourcing or not, the highest wholesale price that firm 2 will accept in order to source the input from S is equal to s. Knowing this, firm S will offer $w_2^O = w_2^I = s$. In the previous stage, firm 1 too will not accept to source the input from S unless the wholesale price that firm S offers is lower or equal to s. Given that my offering $w_1 < s$ firm S will make a loss, firm S will offer $w_1^O = s$. Therefore, outsourcing will coincide with insourcing – Proposition 4 will continue to hold. Proposition 6 will also continue to hold: firm S will (weakly) prefer trading with two–part tariffs than with wholesale price contracts in the symmetric options case too. In fact, firm S will always makes no profits with wholesale price contracts, while with two–part tariffs it will make positive profits when both firms opt for outsourcing (as they will do in equilibrium), as well as when one of the firms outsources – it will makes zero profits only when none of the firms outsources. However, Proposition 5 will not longer hold; both consumer surplus and total surplus will be higher with two–part tariffs and outsourcing than with wholesale prices/in–house production by both, while the opposite will hold for the total industry profits.

4 Symmetric input sourcing options

In this section, we examine what happens when firm 2 can also produce the input in–house at marginal cost s. The last stage of the game is the same as in our main model, leading to

(1) with (i) $k_1 = w_1$ and $k_2 = w_2$ under outsourcing by both firms (OO); (ii) $k_1 = k_2 = s$ under insourcing by both firms (II), (iii) $k_1 = w_1$ and $k_2 = s$ under outsourcing only by firm 1 (OI); and (iv) $k_1 = s$ and $k_2 = w_2$ under outsourcing only by firm 2 (IO).

In the previous stage, in the *insourcing* subgame, firm S optimally offers (w_2, F_2). In particular, it solves:

$$\max_{w_2,F_2} \ \pi_S(w_2, F_2) = (w_2 - s)q_2(w_2, s) + F_2,$$

$$\text{s.t.} \quad \pi_2(q_2(w_2, s), q_1(s, w_2)) - F_2 \geq \pi_2(q_2(s, s), q_1(s, s))$$

Taking into account that the constraint is binding and solving for w_2, we find that it coincides with (3): $w_2^{IO} = w_2^I$. The resulting profits firms' profits in this case are included in Table 1 of the Appendix. We note that $\pi_S^{IO} > \pi_S^{II} = 0$; hence, firm S will choose to serve firm 2 in this subgame.

In the *outsourcing* subgame, in stage two, firm S solves the following:

$$\max_{w_2,F_2} \ \pi_S(w_2, F_2) = (w_1 - s)q_1(w_1, w_2) + (w_2 - s)q_2(w_2, w_1) + F_1 + F_2,$$

$$\text{s.t.} \quad \pi_2(q_2(w_2, w_1), q_1(w_1, w_2)) - F_2 \geq \pi_2(q_2(s, w_1), q_1(w_1, s))$$

The constraint is binding, and solving for w_2, we find again (5). In stage one, firm S makes its offer to firm 1. If firm 1 rejects the offer, the profits of firm 1 and firm S will be given by π_1^{IO} and π_S^{IO}. Therefore, in order firm 1 to accept the offer, its profits with outsourcing should exceed its profits with insourcing. It follows that firm S solves the following:

$$\max_{w_1,F_1} \pi_S(w_1, F_1) = (w_1 - s)q_1(w_1, w_2(w_1)) + (w_2 - s)q_2(w_2(w_1), w1) + F_2(w_2(w_1)) + F_1, \quad (15)$$

$$\text{s.t.} \quad \pi_1(q_1(w_1, w_2(w_1)), q_2(w_2(w_1), w_1)) - F_1 \geq \pi_1^{IO}$$

The constraint is binding. Solving, we find:

$$w_1^{OO} = \frac{a(-2+\gamma)\gamma^5 + (-64 + \gamma^2(2+\gamma)(24 - 12\gamma + \gamma 3))s}{2(-2+\gamma^2)(16 - 4\gamma^2 + \gamma^4)}.$$

Substituting w_1^{OO} into (5), we also find:

$$w_2^{OO} = \frac{-32s + \gamma^2(16s + (-2+\gamma)(2+\gamma)(a(-2+\gamma) + (-1+\gamma)\gamma s))}{(-2+\gamma^2)(16 - 4\gamma^2 + \gamma^4)}.$$

We note that now $w_1^{OO} > s$, while $w_2^{OO} < s$. Thus, in contrast to our main model, the wholesale price offered to firm 2 is now lower with outsourcing than with insourcing by firm 1. This is so because the starting point – the variable cost of firm 2 in case of insourcing by firm 1 – is different now: it is s, while in our main model, it was $w_2^I < s$. From the appropriate substitutions, we obtain the equilibrium profits, π_S^{OO},π_1^{OO}, and π_2^{OO} which can be found it

Table 1 of the Appendix.

We already know that firm S prefers to serve firm 2 when firm 1 opts for insourcing; it prefers IO to II. Does it also prefer to serve firm 2 when firm 1 opts for outsourcing? To answer this, we need to specify what happens when firm S serves firm 1 but not firm 2 – OI. In stage one, firm S solves the following:

$$\max_{w_1,F_1} \pi_S(w_1,F_1) = (w_1 - s)q_1(w_1,s) + F_1, \tag{16}$$

$$\text{s.t.} \quad \pi_1(q_1(w_1,s),q_2(s,w_1)) - F_1 \geq \pi_1^{II}$$

Again the constraint is binding and the resulting equilibrium wholesale price is: $w_1^{OI} = w_2^I < s$. The equilibrium profits, included in Table 1, follow.

Proposition 7 *When all firms have in–house input production capability, outsourcing to both firm* 1 *and firm* 2 *always arises in equilibrium.*

Proof: We find: $\pi_S^{OI} - \pi_S^{IO} = 0$. We also find that firm S has incentives to induce firm 2 to outsource through the (w_2^{OO}, F_2^{OO}) contract:

$$\pi_S^{OO} - \pi_S^{OI} = \frac{\gamma^4(\gamma-2)^2[32-(\gamma^3-4\gamma)^2](a-s)^2}{8(24\gamma^2-6\gamma^4+\gamma^6-32)^2} > 0.$$

At the same time, firm 2 has incentives to accept: $\pi_2^{OO} \geq \pi_2^{OI}$. Moreover, firm S has incentives to induce firm 1 to outsource with the (w_1^{OO}, F_1^{OO}) contract:

$$\pi_S^{OO} - \pi_S^{IO} = \frac{\gamma^{10}(a-s)^2}{16(2+\gamma)^2(\gamma^2-2)^2(16-4\gamma^2+\gamma^4)} > 0.$$

And firm 1 has incentive to accept: $\pi_1^{OO} \geq \pi_1^{IO}$. ■

Interestingly, while in equilibrium both firms outsource, firm 1, in contrast to its rival, would be better off if neither firm outsourced: $\pi_1^{OO} < \pi_1^{II}$ and $\pi_2^{OO} > \pi_2^{II}$. Thus, in equilibrium, firm 1 is trapped into a prisoners' dilemma situation. This occurs because when firm 1 receives its offer, it can anticipate that it cannot induce II by opting for insourcing. In particular, if firm 1 opts for insourcing, firm 2 will become the supplier's sole customer and consequently will receive a more favorable contract, indeed $w_2^{IO} < s$, creating a cost disadvantage for firm 1 and leading to $\pi_2^{IO} \geq \pi_2^{II}$, i.e., leading to outsourcing by firm 2. Given that $\pi_1^{IO} \leq \pi_1^{OO} < \pi_1^{II}$ and that II is strategically unattainable, firm 1 will compromise with OO; it will opt for outsourcing, and in turn, firm 2 will also opt for outsourcing since it enjoys then an advantageous position, $\pi_2^{II} < \pi_2^{OI} \leq \pi_2^{OO}$, that stems from the sequence of contract offers.

We have established that a supplier, without any input cost advantage towards the incumbent firms, can change a duopoly market equilibrium non–trivially: it can generate positive

profits by harming one duopolist while benefiting the other. Thus, the use of two part tariff contracts can facilitate the entry of a technologically redundant input supplier in an industry. It remains to check to which direction consumer and total welfare will be affected.

Proposition 8 *When all firms have in–house input production capability, total industry profits are lower, while consumer surplus and welfare are higher under outsourcing than under insourcing.*

Proof: We compare consumer surplus, producer surplus and total surplus in the II case and the OO case, and we find:

$$\begin{aligned} CS^{II} - CS^{OO} &= \frac{(a-s)^2\gamma^2 K}{8(2+\gamma)^2(24\gamma^2 - 6\gamma^4 + \gamma^6 - 32)^2} < 0, \\ PS^{II} - PS^{OO} &= \frac{-(a-s)^2\gamma^3 L}{4(2+\gamma)^2(24\gamma^2 - 6\gamma^4 + \gamma^6 - 32)^2} > 0, \\ TS^{II} - TS^{OO} &= \frac{(a-s)^2\gamma^2(\gamma-2)M}{8(2+\gamma)^2(24\gamma^2 - 6\gamma^4 + \gamma^6 - 32)^2} < 0, \end{aligned}$$

where $K \equiv \gamma[-2048+\gamma(3328+\gamma(2304-\gamma(1600+\gamma(1152\gamma(400+\gamma(352+\gamma(3\gamma(\gamma+2\gamma^2-20)+56)))))))] - 2048$, $L \equiv \gamma[256+\gamma(1024-\gamma(64+\gamma(448+\gamma(16-\gamma(128+\gamma(8+\gamma(\gamma(2\gamma-1)-20)))))))] - 1024$, and $M \equiv 512 - \gamma^2[576+\gamma(64-\gamma(224+\gamma(48+\gamma(\gamma(4+\gamma)(2\gamma-3)-52))))]$. ■

Interestingly, outsourcing is now reduces consumer and total welfare. On this basis, we can conclude that the use of two–part tariff contracts can result in the presence of an otherwise redundant input supplier in the market – a presence which is socially desirable.

5 Simultaneous trading

Up to now, we have assumed that trading occurs sequentially. Next, we consider what happens if trading takes place simultaneously. To do so, we modify our model and assume that in stage one, firm S decides whether or not it will opt for outsourcing.[13] In stage two, if firm S has not opted for outsourcing, it makes a take–it–or–leave–it offer to firm 2 over (w_2, F_2). If it has opted for outsourcing, it makes simultaneous and separate offers to firm 1 and firm 2 over (w_1, F_1) and (w_2, F_2) respectively and, in turn, each firm decides whether it will accept or reject its offer. In the last stage, each firm chooses its quantity after observing the contract terms and the acceptance/rejection decision of its rival.[14]

The solution of the last stage of the game is given again by (1). Moreover, the solution to stage two when firm S has opted for insourcing coincides with the respective one in our main

[13] For instance, it decides whether it will expand or adjust its production facility so that to serve firm 1 too.

[14] In other words, we assume that contract terms are *interim observable* as e.g., in McAfee and Schwartz (1994), Rey and Vergé (2004) and Milliou and Petrakis (2007).

model; hence, under insourcing, we have w_2^I, π_S^I, π_1^I and π_2^I from before. When instead firm S has opted for outsourcing, firm S offers (w_i, F_i) to firm i, taking as given its equilibrium offer to firm j, (w_j^{OS}, F_j^{OS}). In particular, it solves the following:

$$\max_{w_i, F_i} \pi_S(w_i, F_i) = (w_i - s)q_i(w_i, w_j^{OS}) + (w_j^{OS} - s)q_j(w_j^{OS}, w_i) + F_i + F_j^{OS}, \qquad (17)$$

$$\text{s.t.} \quad \pi_i(q_i(w_i, w_j^{OS}), q_j(w_j^{OS}, w_i)) - F_i \geq \pi_i^I$$

The constraint is binding. This means that the maximization problem can be written as:

$$\max_{w_i} \pi_S(w_i) = [p_i(q_i(w_i, w_j^{OS}), q_j(w_j^{OS}, w_i)) - s]q_i(w_i, w_j^{OS}) - \pi_i^I + (w_j^{OS} - s)q_j(w_j^{OS}, w_i) + F_j^{OS}.$$

This yields:

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

A number of important observations are in order. First, $w_i^{OS} < s$. This is due to the opportunism problem (also called "commitment problem") that the upstream monopolist faces when it trades with two competing firms and cannot publicly commit to the contract terms that it will offer; it cannot commit to firm i that it will not behave opportunistically and offer better terms to firm j (see e.g., McAfee and Schwartz, 1994 and 1995, Rey and Vergé, 2004, Milliou and Petrakis, 2007). Second, $w_i^{OS} < w_2^I$. Thus, in contrast to our main model, outsourcing now *decreases* firm 1's cost as well as its rival's cost. A straightforward implication of these observations is that outsourcing leads to the disappearance of the cost asymmetry between firm 1 and firm 2 that input trading generates under insourcing. Hence, under simultaneous trading, outsourcing works in favor of the firm with the in–house production capability – firm 1.

Since firm 1 and firm 2 have different outside options, their equilibrium fixed fees differ. In particular, $F_2^{OS} > F_1^{OS} > 0$. Making the appropriate substitutions, we obtain the equilibrium profits of firm S under outsourcing, π_S^{OS}, and comparing them with its profits under insourcing π_S^I, we find: $\pi_S^{OS} < \pi_S^I$. Therefore, firm S does not opt for outsourcing when it trades simultaneously with firm 1 and firm 2. This is so mainly because the opportunism problem that it faces under outsourcing is severe. This contrasts with what happens under sequential trading: firm S makes higher profits then with outsourcing than with insourcing. On this basis, we can conclude that firm S would optimally choose to trade sequentially with the two firms rather than simultaneously. This finding is driven by the fact that its opportunism problem is more severe under simultaneous than under sequential trading – it generates even lower total industry profits in the former case. Importantly, this finding implies that the order of moves that we adopt in our main model can arise endogenously.

Note that it can also be shown that when firm 2 also has the option to produce the input

in–house, then in equilibrium firm S will not induce OO; it will induce IO. However, its profits with sequential trading and OO will be higher than its profits with simultaneous trading and IO. Therefore, just like in our main model, the supplier would opt for sequential rather than with simultaneous trading with its customers. Furthermore, when firm 2 has the option to produce the input in–house and contracts are fully unobservable (i.e., they are not observed even before the last stage of the game), then the supplier will always offer $w_1^{OO} = w_2^{OO} = s$ and $F_1^{OO} = F_2^{OO} = 0$ in the OO case and in turn will obtain zero profits. The supplier will also offer $w_1^{O1} = s$ and $F_1^{OI} = 0$ in the OI case and $w_2^{IO} = s$ and $F_2^{IO} = 0$ in the IO case (see e.g., Katz, 1991, Pagnozzi and Picolo, 2012, Bakaouka and Milliou, 2018). Thus, the supplier will always make zero profits, and in turn, it will be indifferent between outsourcing and insourcing. Still, the supplier, again will prefer sequential to simultaneous trading with its customers.

6 Conclusion

We have shown that outsourcing to an external input supplier without a cost advantage can emerge in equilibrium when input trading is through two–part tariff contracts. Such contracts allow the supplier to alter the cost of its customers and artificially create cost asymmetries that dampen competition and increase its own revenues.

We have also shown that outsourcing decreases consumer surplus and welfare. Therefore, two–part tariff contracts can be used to generate a more inefficient production pattern – inefficient outsourcing. Importantly, we have shown that consumer surplus and welfare can be lower with two–part tariffs than with linear contracts.

Our analysis suggests that the emergence of dominant input suppliers is not necessarily due to their cost advantages. It can be due to input trading – the contract form and terms that input suppliers offer to final product manufacturers.

In future work, we plan to examine the robustness of our findings under price competition. We also plan to explore the incentives for outsourcing in markets with vertically integrated suppliers or exclusive suppliers.

7 Appendix

Table 1: Profits with Symmetric Input Sourcing Options

$\pi_S^{OO} = -\frac{\gamma^4(\gamma-2)^3(2+\gamma)(a-s)^2}{16(\gamma^2-2)^2(16-4\gamma^2+\gamma^4)}$	$\pi_1^{OO} = \frac{[\gamma(2+\gamma)-4]^2(a-s)^2}{16(\gamma^2-2)^2}$	$\pi_2^{OO} = \frac{(\gamma-2)^6(2+\gamma)^4(a-s)^2}{4(24\gamma^2-6\gamma^4+\gamma^6-32)^2}$
$\pi_S^{II} = 0$	$\pi_1^{II} = \frac{(a-s)^2}{(2+\gamma)^2}$	$\pi_2^{II} = \frac{(a-s)^2}{(2+\gamma)^2}$
$\pi_S^{OI} = \frac{\gamma^8(2+\gamma)^4(\gamma-2)^2(8-\gamma^2)(a-s)^2}{16(24\gamma^2-6\gamma^4+\gamma^6-32)^2}$	$\pi_1^{OI} = \frac{H(a-s)^2}{16(24\gamma^2-6\gamma^4+\gamma^6-32)^2}$	$\pi_2^{OI} = \frac{(\gamma-2)^6(2+\gamma)^4(a-s)^2}{4(24\gamma^2-6\gamma^4+\gamma^6-32)^2}$
$\pi_S^{IO} = \frac{\gamma^4(a-s)^2}{8(2+\gamma)^2(2-\gamma^2)}$	$\pi_1^{IO} = \frac{[\gamma(2+\gamma)-4]^2(a-s)^2}{16(\gamma^2-2)^2}$	$\pi_2^{IO} = \frac{(a-s)^2}{(2+\gamma)^2}$.

where $H \equiv 4096 + (\gamma - 2)\gamma(2048 + \gamma(2560 + \gamma(-768 + \gamma(-640 + \gamma(448 + \gamma(224 + \gamma(-48 - 16\gamma + 6\gamma^3 + \gamma^4)))))))$. Notice that the payoffs in the OI case are out of equilibrium; they represent the case where the supplier offers (w_2^{OO}, F_2^{OO}) to firm 2 but firm 2 rejects. Notice that by construction $\pi_2^{OO} = \pi_2^{OI}$, i.e. the supplier offers a contract that leaves firm 2 with the profit it obtains if it produces in–house.

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