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Strategic investment and international outsourcing in unionised oligopoly

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ABSTRACT

We develop an oligopoly model in which firms facing unionised domestic labour markets choose between producing an intermediate good in-house and outsourcing it to a non-unionised foreign supplier that makes a relationship-specific investment in developing the intermediate. The paper sheds light on the issue of whether international outsourcing offers a means to 'escape' the power of domestic unions and on the existence of intra-industry wage dispersion. We show that outsourcing typically increases marginal costs even when it lowers union wages. Despite this, more powerful unions increase the incentive to outsource.

1. Introduction

This paper develops an oligopoly model in which firms facing unionised domestic labour markets choose between producing an intermediate good in-house and outsourcing[1] it to a non-unionised foreign supplier that makes a relationship-specific investment in developing the intermediate.

The process of globalisation of goods and services markets and improvements in the technology of communication has been accompanied by a deepening in international specialisation and a tendency towards a vertical fragmentation of production across national borders. As a result, the 'make-or-buy' internalisation choice of firms (i.e. whether to produce an intermediate in-house or outsource it to an upstream supplier) is increasingly international in nature — as outsourcing is directed towards suppliers located abroad. In this context, the role of labour markets in influencing the mode-of-operation decision of firms has attracted increasing attention in public and policy debates. The conventional wisdom that emerges from these debates suggests that international outsourcing may be used by firms as a way to 'escape' distorted domestic labour markets. Specifically, given the still significant role played by unionisation in many industrialised economies, it has been suggested that outsourcing may represent a means to weaken trade unions[2] and that strong unions may make outsourcing more attractive. More generally, these views are consistent with the widespread perception that international market integration erodes the power of domestic unions — e.g. Rodrik (1997) and Brown et al. (2009). The key argument underlying this conventional wisdom is that the internationalisation of economies allows for an easier replacement of domestic workers by foreign workers — be it via final good import competition or via the international fragmentation of the vertical production chain. However, a key feature of outsourcing is that it does not necessarily only involve substitute activities but also ones that complement those that a firm continues

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[1] By outsourcing we mean the acquisition of an input or service from a non-affiliated firm. Others have used it in a less restrictive sense to refer to the sourcing of inputs from a foreign operation which could include production in a foreign affiliate of the same firm (an early example of this is Zhao, 2001).

[2] For instance, machinist union leaders at Boeing see the company's refusal to allow them to bid for work against outside contractors as evidence that Boeing's outsourcing policy is not aimed at improving efficiency, but rather at weakening the union (*Seattle Times*, 10th Sept 2008).

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to perform in the domestic economy — and this can have significant effects on the behaviour of unions.

Theoretical work on the effects of labour market institutions on the outsourcing decision is still fairly limited.[3] Lommerud et al. (2009) build on the well-known results by Horn and Wolinsky (1998) and show, within a partial equilibrium monopolistically competitive framework, that outsourcing increases the aggressiveness of unions — provided that the activities performed in the home country are sufficiently complementary to those performed abroad, since in this instance there is a lower incentive for unions to restrain wage demands on behalf of the workers that remain employed in the domestic economy.[4] This result suggests the possibility that, in order to limit these *adverse* wage effects, firms may be less inclined to outsource in the presence of unionisation — and particularly so if the bargaining power of unions is high. Indeed, in Lommerud et al. (2009) a higher bargaining power of unions leads to a ceteris paribus reduction in the incentive to outsource. In discussing this result, they perceptively point to the evidence that outsourcing (measured by a country's share of parts and component in total imports) does not appear to be more prevalent in countries with higher union coverage rates — which suggests that high union coverage does not increase the incentive to outsource, or that unions' strength is not reduced by outsourcing. However, a significant body of empirical work supports the view that the presence of more powerful unions may encourage outsourcing and that outsourcing in turn may lead to a weakening of the bargaining power of unions.[5]

In this paper, we examine the relationship between union power and the outsourcing decision of firms within an oligopoly framework in which there is a high degree of specificity of the outsourced input.[6] We argue that to the extent that firms possess market power, a fuller understanding of the trade-offs involved in their mode-of-operation decision requires acknowledging the role of strategic considerations; furthermore, it is important to recognise that outsourcing activities often involve inputs that are non-generic and that cannot be procured in spot-markets. In these instances, outsourcing requires a firm to enter a bilateral relationship with a supplier that needs to make a relationship-specific investment in the design and production of the input. In the presence of contract incompleteness – that typically characterises these relationships – the relationship-specificity of investment then affects the incentives of firms (e.g. via the emergence of hold-up problems) and interacts with their strategic behaviour with respect to both competitors and unions. To incorporate these features into our analysis, we extend the oligopoly outsourcing framework developed by Leahy and Montagna (2011) to allow for unionisation and the partial outsourcing of labour.[7] Specifically, we consider the choice that oligopolistic firms facing unionised domestic labour markets make between producing a highly specialised intermediate input in-house and outsourcing it to a non-unionised foreign supplier. The intermediate input requires an investment in quality and customisation that determines the productivity of the labour used in the production of a unit of the final good. Under vertical integration, the investment in quality is done in-house, whilst under outsourcing it is made by the foreign supplier that will have to make a relationship-specific investment. With incomplete investment contracts, a hold-up problem will thus arise — which translates in this model into an under-investment in the quality of the intermediate that will work towards an increase in the marginal production cost of the downstream firm.[8] An important difference between this paper and others in the literature is that here the productivity of the intermediate is endogenous. A key implication of this is that our model introduces a distinction between the cost of acquiring the intermediate and the marginal cost of producing the final good incurred by the downstream firm. The latter is affected by more than just the wage negotiated with the union (as instead happens in other models) and depends on the quality (determined by the level of investment) as well as the price of the intermediate (negotiated with the supplier). Our model thus differs substantially from that developed by Lommerud et al. (2009) who rely on a monopolistically competitive framework (and thus rule out by assumption the existence of strategic interaction between firms) and who consider the case of generic inputs that do not require any relationship specific investment by suppliers.[9]

The key results of the paper are that: (i) outsourcing may lead to higher wages and higher marginal costs in the production of the final good — *nevertheless*, even when this is the case, some firms will still have an incentive to outsource; (ii) an increase in the bargaining power of unions increases the incentive to outsource — *and yet* the outsourcing does not succeed in reducing marginal costs (unless the upstream supplier has a substantial underlying cost advantage over the downstream firm); (iii) asymmetric equilibria can emerge in which firms adopt different mode-of-operation strategies and pay different wages — *even* when the downstream firms are ex-ante identical.

A number of key mechanisms underpin these results. First, since the impact of domestic wages on a firm's marginal cost is relatively less important when the firm outsources part of its production abroad, because reliance on domestic labour is lower, outsourcing can result in a higher wage. This is consistent with the Horn and Wolinsky's (1998) complementarity argument discussed above.

[3] Skaksen (2004) studies the implications of the potential of international outsourcing on union wages within a general equilibrium framework in which the decision to outsource occurs *after* union-firm wage negotiations. Koskela and Schöb (2008) analyse the effects of labour market reforms on the decision to outsource of unionised firms when outsourcing and domestic labour are substitute. A related literature studies how unionisation affects the decision to do FDI: e.g. Zhao (1995, 2001), Bughin and Vannini (1995), Leahy and Montagna (2000), Naylor and Santoni (2003), Zhao and Okamura (2010).

[4] Horn and Wolinsky (1998) were the first to analyse the role of complementarities between workers' tasks in determining the incentives underpinning the organisation of unions: they found that unions could benefit from fragmentation of production when tasks are complements. Consistent with this, in Skaksen and Sörensen (2001) outward foreign direct investment can trigger more aggressive wage demands by unions bargaining with a monopoly firm when the degree of complementarities between the domestic and foreign operations is sufficiently high.

[5] Evidence that a higher bargaining power of unions are associated with more outsourcing is provided, e.g., by Kramarz (2008) who estimates matched employer–employee data for France, and by Bas and Carluccio (2010) who use firm-level trade data for multinational firms with operation in France. More generally, a substantial body of literature supports the supposition that union wages and/or the bargaining power of unions are weakened by the internationalisation of the economy; see for instance MacPherson and Stewart (1990), Freeman and Katz (1991), Gaston and Trefler (1995); more recent examples include Dumont et al (2006), Abraham et al. (2009), Boulhol et al. (2006), and Moreno and Rodriguez (2010).

[6] In Zhao (2001) and Zhao and Okamura (2010) the offshored input is generic in nature and does not entail a non-affiliated supplier making a relationship-specific investment (RSI) as happens instead in our case.

[7] Partial outsourcing is a realistic scenario that has received increasing attention in recent years. Partial outsourcing of components, rather than labour, has been examined by Shy and Stenbacka (2005) who show that an intensification of competition increases the set of components that are outsourced relative to those that are produced in-house. Lommerud et al. (2009) study the partial outsourcing of inputs in the context of unionised labour markets. Neither paper looks at outsourcing in the context of asset specificity and contract incompleteness.

[8] As is standard in the literature, contract incompleteness originates from the inability of third parties to verify the suitability of the inputs provided by the suppliers. See Spencer (2005) and Helpman (2006) for overviews. Grossman and Hart (1986) and Hart and Moore (1990) formalise the emergence of a hold-up problem from ex-ante investment distortions in a context in which negotiating advantages arise from asset ownership.

[9] The early transaction cost literature pioneered by Coase (1937) and Williamson (1975, 1985) did not formalise market interactions between competitors and focussed on a single buyer–supplier pair. More recently, this relationship has been contextualised within general equilibrium monopolistically competitive market structures (e.g. Grossman and Helpman, 2002, 2003, 2005) that highlight the role of market 'thickness' in determining outsourcing (see also McLaren, 2000). To our knowledge, in the oligopoly literature Leahy and Montagna (2011) were the first to incorporate issues related to incomplete contracts and relationship-specific investment and their role in determining the nature of the trade-offs facing firms when making their make-or-buy decision. The oligopoly literature on outsourcing typically abstract from these issues (e.g. Nickerson and Vanden Bergh, 1999; Shy and Stenbacka, 2003; Chen et al, 2004).

Additionally, outsourcing in the presence of unionisation exposes the firm to two hold-up problems, one resulting from its bargaining with the union and the other stemming from its dependence on an upstream supplier. As a result, outsourcing does not *trivially* result in a lower marginal cost of production of the downstream firm which is instead likely to increase — even if there are substantial underlying cost advantages of the foreign supplier in producing the intermediate.[10] This result offers a theoretical rationale for the evidence that outsourcing does not unambiguously lead to higher productivity and/lower production costs.[11] Second, the governance costs of running an integrated organisation as well as the strategic interaction between downstream firms imply that, despite these effects of outsourcing on marginal production costs, some firms may still have an incentive to subcontract upstream activities to foreign suppliers. Third, because outsourcing may result in a higher marginal cost and lower operating profits, it reduces the extent of rents that a stronger union can extract from domestic production. Furthermore, as a result of this, outsourcing leads to a lower sensitivity of profits to the bargaining power of unions. We show that this implies that an increase in the latter raises the relative incentive to outsource. This contrasts with the negative relationship between union bargaining power and outsourcing found by Lommerud et al. (2009) — which is due to the fact that in their framework outsourcing unambiguously increases operating profits (and hence the extent of rents that a more powerful union can extract from the remaining in-house production). In our model, union bargaining power has a stronger negative effect on profits under vertical integration than it does under outsourcing — because, as explained above, under outsourcing reliance on domestic labour is lower. Finally, the existence of strategic interaction between downstream firms allows for the emergence of asymmetric mode-of-operation equilibria, in which the firms choose different organisational forms even when they are ex-ante identical; this is in sharp contrast to the results obtained in the monopolistically competitive framework in which asymmetric equilibria only arise in the presence of ex-ante efficiency differences. Despite the additional complexity arising from unionisation, this result is consistent with Leahy and Montagna (2011) who show that outsourcing – by *softening* the investment behaviour of rivals – can be viewed as a *defensive business strategy* that can be the best response to rivals' choice of vertical integration. However, the presence of unionisation, by endogenising the wage paid by firms, results in this model in the emergence of asymmetric wages, even when the firms' underlying cost parameters are the same. Thus, an important contribution of the paper – which directly stems from the strategic interaction between firms – is that it provides a new explanation for the observed increase in within-group wage dispersion that has accompanied increasing international openness in most OECD countries.[12]

The plan of the remainder of the paper is as follows. Section 2 sets out the model. The game is solved in Section 3 and the equilibrium regimes are discussed in Section 4. Section 5 concludes the paper.

2. The model

We consider an industry in which there are two final good firms that sell a homogenous good to an integrated market. This may be the home market of one or both of the firms or a third market. To economise on notation, we further assume that sales to the final good market do not involve a transport cost.[13] The inverse demand is given by:

$$p = a - \bar{y}, \tag{1}$$

where p is the price of the good, a is a constant parameter, and $\bar{y} = y_1 + y_2$, with y_1 and y_2 being the quantities produced by firms 1 and 2 respectively.

The production of the final good requires a specialised component, which is combined in fixed proportions with labour. One unit of this intermediate is required per unit of output. For firm i ($i = 1,2$), let $l_i = \bar{l} - z_i > 0$ be the per-unit labour input requirement for the production of the final good, where $\bar{l}$ is constant and z_i captures the 'usefulness' of the intermediate: a high z_i reflects a better intermediate, one that requires to be combined with fewer units of labour in order to produce a unit of output; thus, a good quality intermediate leads to a lower labour requirement per unit of output and hence to a higher labour productivity. The 'usefulness' of the intermediate to the final producer depends on the level of investment (K) in its quality and customisation for the final good production. We assume that $z = \sqrt{K}$, i.e. there are diminishing returns to investment. This is a plausible assumption and one that is needed to ensure an interior solution.[14] We further assume that this investment does not require the use of labour.[15] The chosen functional forms enable us to obtain, in a manner which is both tractable and parsimonious, a positive relationship between the productivity of labour and the investment in the quality of the complementary input: the linear effect of quality on input requirement (or productivity of labour) and the fact that quality is related to the square root of investment are to be taken together and imply that investment reduces the labour requirement but with diminishing returns.

The firm can either produce the intermediate in-house (vertical integration) or outsource it to a foreign supplier. If produced in-house, the specialized component can be obtained at a marginal cost of $r_i = w_i \hat{r}_i$, where w_i is the wage paid by the firm and $\hat{r}_i$ is the per-unit labour requirement in its production. If it is outsourced to a foreign intermediate producer, the price of the intermediate input is q_i. To deliver this input to the home country where it is combined with labour, the outsourcing firm must pay a transport cost of t per unit of output.[16]

Labour markets in the domestic economy are unionised with firm-specific unions bargaining with firms over the wage, whilst they are perfectly competitive in the foreign country. The foreign country's wage is therefore exogenous and can be normalised at unity.

Using the superscripts V and O to denote vertical integration and outsourcing respectively, marginal production cost for firm i will thus be:

$$c_i^V = w_i(\hat{r}_i + \bar{l} - z_i) \tag{2a}$$

if the firm produces the intermediate in-house, and

$$c_i^O = q_i + w_i(\bar{l} - z_i) + t_i \tag{2b}$$

if the firm outsources its production to a foreign supplier.

[10] Thus, outsourcing in our model does not unambiguously increase operating profits, as in many other papers in which it is *assumed* to reduce marginal costs of production.

[11] See, for instance, the empirical results in Görg and Hanley (2004) and Görzig and Stephan (2002) and references therein.

[12] To a considerable extent, the substantial increase in wage inequality experienced by OECD countries in the last few decades can be ascribed to 'within-group' wage dispersion, i.e. among workers with similar characteristics (for a recent review of the empirical literature supporting this, see Machin and Van Reenen, 2008). In turn, empirical evidence based on firm-level data suggests that the increasing within-group wage inequality is mainly driven by wage dispersion between heterogeneous firms within industries (see, e.g. Faggio et al, 2007).

[13] It is easy to show that adding a transport cost in selling would not change the results of the paper qualitatively.

[14] This functional relationship between investment and marginal production cost is standard in the R&D literature (e.g. D'Aspremont and Jacquemin, 1988).

[15] It is common in the literature to assume that fixed and investment costs use different factor inputs from production. In an early example, Lawrence and Spiller (1983) distinguish between capital and labour and assume that they are exclusively used in fixed and variable costs respectively.

[16] Note that the results would not be materially changed were we to assume instead that it is the upstream firm that pays the transport cost.

If firm i is vertically integrated, its profit function is given by:

$$\pi_i^V = \left(p - c_i^V\right) y_i - K_i - G, \tag{3a}$$

where G represents the fixed governance cost[17] associated with vertical integration. On the other hand, if the firm chooses to outsource, its profit function will instead be:

$$\pi_i^O = \left(p - c_i^O\right) y_i. \tag{3b}$$

When a firm chooses to outsource, it avoids both the investment costs and the governance cost of vertical integration. The investment costs are now borne by a foreign intermediate goods producer with whom the downstream firm has an outsourcing relationship and who has profits:

$$\mu_i = (q_i - r_i^m) m_i - K_i - E_i, \tag{4}$$

where r_i^m is the marginal production cost of the intermediate producer paired with downstream firm i. r_i^m can differ from r_i, the marginal production cost of producing the intermediate in-house. Output of the intermediate is given by m_i. Since one unit of the intermediate is needed in the production of each unit of final output, we can write $m_i = y_i$. The upstream firm must also incur a fixed entry cost E_i. Note that in Eq. (4) and thereafter we use the subscript i to refer to an upstream–downstream pair (i.e. i represents the upstream firm that has a bilateral outsourcing relationship with downstream firm i).

3. The game

The model is a four-stage game. In stage one, firms decide whether to produce their intermediate in-house at home or outsource it to a firm in a non-unionised foreign location. If both firms outsource, then they each engage different foreign upstream firms to develop and supply the intermediate for them. In stage two, the firms invest in the development of the intermediate.[18] If they opt for vertical integration, firms undertake the investment in-house. If they outsource, then the specialised supplier firm undertakes the investment. In stage three, the firms bargain with their firm-specific union over the wage and (if they outsource) they simultaneously bargain with the intermediate supplier over the price of the intermediate. We assume that the final good producer only has enough time to negotiate with a single supplier. As in Grossman and Helpman (2003), should bargaining breakdown, the producer will not have sufficient time to produce the intermediate itself, and so will exit the market — whilst the supplier will have wasted its investment. In stage four, firms produce and sell the final output.

We derive the subgame-perfect Nash equilibrium. As the game is solved by backward induction, we discuss the stages in reverse order starting with the final stage.

3.1. Stage 4

In the final stage of the game, the two firms engage in Cournot competition. Outputs are determined by maximising *operating* profits, defined as $\tilde{\pi}_i^h = (p - c_i^h) y_i$ (where $h = V,O$), since at this stage all fixed and investment costs have been sunk. The first-order condition is given by:

$$\frac{\partial \tilde{\pi}_i^h}{\partial y_i} = p - c_i^h - y_i = 0, \tag{5}$$

where $(h = V,O)$. Combining the reaction functions implied by the first order condition in Eq. (5) with the inverse demand function in Eq. (1), we obtain the (final-stage) Nash equilibrium in quantities:

$$y_i = \frac{a - 2c_i^h + c_j^k}{3}, \tag{6}$$

where $(h,k = V,O)$ and $(i,j = 1,2)$, with $(i \neq j)$.

3.2. Stage 3

In stage three of the game, firms will bargain over the wage with their firm-level unions. If they outsource, they will also simultaneously bargain with their supplier firm over the price of the intermediate.[19] If the firm is vertically integrated, then all the labour used in its production activities (assembly as well intermediate good production) is employed in-house. If it outsources, the firm's labour demand will only be made up of the workers employed in the production of the final good.

Firm i's firm-specific union's utility function is given by:

$$U_i^h = (w_i - \bar{w}) L_i^h \quad (h = V, O), \tag{7}$$

where $\bar{w}$ is the reservation wage of the union and $L_i^h = y_i \xi_i^h$ is the total employment of the downstream firm — where $\xi_i^O = \bar{l} - z_i$ and $\xi_i^V = \hat{r}_i + \bar{l} - z_i$ are the firm level per-unit employment in the two regimes. The wage is determined via the maximisation of the following Nash bargain:

$$B_i^h = \left[(w_i - \bar{w}) L_i^h\right]^{\beta} \left[\left(p - c_i^h\right) y_i^h\right]^{1-\beta} \quad (h = V, O), \tag{8}$$

where $\beta \in [0,1]$ is the bargaining power parameter. The larger is β the greater is the bargaining power of the union. Recalling that all fixed and investment costs are sunk at this stage, firms and unions take the firm level per unit employment ξ_i^h as given. Therefore, regardless of the mode-of-operation chosen by the firm, bargaining between a union-firm pair will result in a wage w_i such that: $w_i = \bar{w} - \frac{\beta/(2-\beta)}{\partial y_i/\partial w_i} y_i$. From Eqs. (2a), (2b) and (6) we can obtain $\partial y_i / \partial w_i = -(2/3)\xi_i^h$ and hence write the wage as:

$$w_i^h = \bar{w} + \frac{3}{2} \frac{\beta}{2-\beta} \frac{y_i}{\xi_i^h}. \tag{9}$$

Other things equal, and independently of the mode-of-operation of the firm, the wage increases in the bargaining power of the union. It also increases in the output of the downstream firm. Furthermore, as can be seen from $\partial y_i / \partial w_i$, the greater is the per-unit input

[17] G captures the costs – *à la* Williamson (1975, 1985) – of running a larger and more complex organisation. Governance costs, which can also be thought of as managerial incentive costs of integration, have been extensively discussed in the literature. See for instance McLaren (2000) and references therein.

[18] The relationship between upstream and downstream firms is a bilateral one. As discussed above, the intermediates are highly specific to a downstream firm and we assumed that each downstream firm chooses to outsource to a different upstream firm. We can rule out the possibility that more than one upstream firm compete to supply a downstream firm. One could think of there being ex ante many identical potential intermediate suppliers. However, *only* one firm will enter to supply a particular downstream firm in equilibrium since with more than one upstream firm, as a result of Bertrand competition, the intermediate price would be driven to the marginal production cost and the firms will be unable to cover their investment and fixed entry cost. Anticipating this, only one firm will enter to invest in and supply the firm-specific intermediate of any particular downstream firm.

[19] The purchase of intermediate components has sometimes been assumed to involve the combination of a fixed lump-sum payment and a price set at marginal cost. As highlighted by Spencer (2005), however, the transfer of rents through lump-sum payments is at odds with stylised facts about domestic and international transactions. Our paper recognizes that outsourcing contracts typically involve strictly positive prices that exceed marginal costs. The distribution of rents between intermediate supplier and final good producer – and hence the returns to the relationship-specific investment – is determined through Nash bargaining over the price after investment is sunk.

requirement of unionised labour ξ_i^h, the greater is the (negative) impact on the firm's output and operating profits of an increase in wage. Hence, unions will moderate their wage claims less the smaller is the per-unit input requirement of unionised labour. This is because the effect of union wages on the downstream firm's marginal cost is relatively less important when the dependence on unionised labour declines. Given that outsourcing can be expected to reduce domestic employment, this effect goes against conventional wisdom — which contends that outsourcing weakens unions.[20] This more aggressive behaviour by the union arises from a complementarity between upstream and downstream activities and hence between foreign and domestic employment under outsourcing. However, it would be premature to conclude from this that outsourcing raises wages. Changes in the mode of operation also affect y_i, the output of the downstream firm, and this will play a critical role in determining the rents that are available and thus, as is clear from Eq. (9), the union wage. However, y_i is determined by among other things the level of investment which itself depends on the mode-of-operation. As we show later, in many instances outsourcing leads to a lowering of y_i and, when this occurs, this effect works towards lowering the wage under outsourcing.

If firm i outsources, the price q_i of the intermediate is determined via the maximisation of the following Nash bargain:

$$N_i = \left[(q_i - r^m)y_i\right]^{\delta}\left[(p - c_i)y_i\right]^{1-\delta}, \tag{10}$$

where $\delta \in [0,1]$ is the bargaining power parameter. The larger is δ the greater is the bargaining power of the upstream firm. Bargaining between firms occurs at the same time as bargaining with unions and takes the level of investment as given; this yields:

$$q_i = r_i^m - \frac{\delta}{2-\delta}\frac{y_i}{\partial y_i/\partial q_i} = r_i^m + \frac{3}{2}\frac{\delta}{2-\delta}y_i. \tag{11}$$

Clearly, the price of the intermediate is ceteris paribus increasing in the bargaining power of the upstream firm and in the output of the downstream firm.

3.3. Stage 2

The firms choose their investment levels simultaneously in stage 2. If the intermediate is produced in-house, then K_i is chosen to maximise operating profits net of the investment cost, i.e. $\tilde{\pi}_i^V - K_i = y_i^2 - z_i^2$. Note that $(p - c_i^V)$ and K_i have been eliminated using Eq. (5) and $K_i = z_i^2$. We can model the firm as choosing the level of cost reduction (z_i), which simplifies the algebra somewhat. The resulting first-order condition is:

$$2\left(y_i\frac{dy_i}{dz_i} - z_i\right) = 0, \tag{12}$$

which implies: $z_i^V = \sqrt{K_i^V} = y_i(dy_i/dz_i)$. It will prove convenient to write this as:

$$z_i^V = \sqrt{K_i^V} = \theta^{Vk}y_i, \text{where } k = (V,O). \tag{13}$$

The first superscript in θ^{Vk} refers to the mode-of-operation of firm i, whilst the second one refers to the mode-of-operation of its rival. The expressions for θ^{Vk} in the different regimes are reported in Section I of Appendix A.

The θ parameters can be thought of as measures of investment-to-output ratios, with the 'aggressiveness' in investment increasing in θ. As shown in Section II of Appendix A, $\theta^{VV} > \theta^{VO}$ holds for any value of β and δ. This means that outsourcing by its rival tends to reduce firm i's investment-to-output ratio. Thus, outsourcing by one firm *softens* the behaviour of its rival, i.e. it reduces the latter's aggressiveness in investment. This results in a 'strategic motive' to outsource which is explored in more depth in Leahy and Montagna (2011).

If the intermediate is outsourced, then z_i is chosen to maximise the supplier's operating profit net of the investment cost; this is given by: $\mu_i = \frac{3}{2}\frac{\delta}{2-\delta}y_i^2 - z_i^2$, where we have made use of the fact that $(q_i - r_i^m) = \frac{3}{2}\frac{\delta}{2-\delta}y_i$ from Eq. (11) and we have eliminated K_i using $K_i = z_i^2$. At the optimum: $z_i^O = \frac{3}{2}\frac{\delta}{2-\delta}y_i(dy_i/dz_i)$. This expression for optimal investment is obviously similar to that in which firm i is vertically integrated. It differs only in that the right-hand side is now multiplied by $(3/2)[\delta/(2-\delta)]$. We can write it in compact form as:

$$z_i^O = \sqrt{K_i^O} = \theta^{Ok}y_i, \text{where } k = (V,O). \tag{14}$$

The expression for θ^{Ok} depends on the mode-of-operation chosen by the rival firm. As shown in Section II of Appendix A, $\theta^{OV} > \theta^{OO}$ holds for any value of β and δ. This means that outsourcing by a firm tends to reduce the other firm's investment-to-output ratio. So, as before, outsourcing by one firm 'softens' the behaviour of its rival, i.e. it reduces the latter's aggressiveness in investment.

Investment reduces the marginal costs of final good production — and these marginal cost reductions generate rents.[21] For $\beta > 0$ and $\delta \neq 1$, under both modes-of-operation, the investing agent (i.e. the final good producer under vertical integration or the upstream supplier under outsourcing) will appropriate only a share of these rents. Under vertical integration, the investor shares rents with the unions whilst, in the outsourcing case, the investor shares rents with the downstream firm. These considerations have implications for the aggressiveness of investment, as reflected in the magnitude of the θ parameters. It will be the case for all but very high values of both β and δ that $\theta^{VV} > \theta^{OV}$ and $\theta^{VO} > \theta^{OO}$, i.e. given the mode-of-operation choice of its rival, the investment-to-output ratio is higher when a firm vertical integrates than it is when it outsources (the proof is in Section III of Appendix A). The intuition for this rests on a key difference between the two mode-of-operation regimes, that is: under outsourcing the effectiveness of investment in reducing the marginal cost of producing the final good is lower than under vertical integration. This is because, as the marginal cost falls (and output increases), both the price of the intermediate (q) and the wage (w) rise endogenously under outsourcing, whilst only the wage rises under vertical integration. Note, however, that for sufficiently high bargaining powers of both the union and the supplier (as proved in Section III of Appendix A), the investment-to-output ratio is lower under vertical integration than under outsourcing (i.e. $\theta^{VV} \not> \theta^{OV}$ and $\theta^{VO} \not> \theta^{OO}$). The intuition for this reversal is that, in this instance, the vertically integrated firm must share the rents from investment with the unions to a greater extent, thus having a lower incentive to invest; however, at the same time, under outsourcing the upstream firm retains a greater share of the returns from investment. The fact that in this case the investment-to-output ratio is lower under vertical integration than under outsourcing would seem to suggest that by contracting out the development of the intermediate a firm might obtain a lower marginal cost of producing the final good, due to the higher input quality resulting from the higher investment under outsourcing. However, this is not the end of the story, because under

[20] Under some circumstances, outsourcing could actually increase the requirement of unionised labour per-unit of output. If $z^V - z^O > \hat{r}$, then the input requirement of unionised labour would actually rise under outsourcing. This case seems less plausible, however, since one would expect the direct effect of labour saving to dominate any indirect effects that operate through falls in productivity as a result of outsourcing. Hence, to avoid excessive taxonomy of cases, we will not discuss this case further.

[21] Whilst in Zhao (2001) and Zhao and Okamura (2010) the endogeneity of the cost of the intermediate rests ultimately on the presence of foreign unions, in our paper it results from the different incentives to invest in the intermediate's quality that exist under vertical integration and under outsourcing and from the bargaining with the supplier.

outsourcing the final good firm is now suffering from the effects of the rent extracting behaviour of two parties rather than one: the unions (on the remaining level of employment) and the upstream supplier. Hence, even when unions are very strong, the marginal cost under outsourcing may still be higher than under vertical integration — despite a higher investment-to-output ratios.[22]

3.4. Stage 1

The firms simultaneously choose their mode-of-operation in stage 1 of the game. To establish whether a firm will outsource or choose to be vertically integrated, we must compare its profits under the two regimes for a given behaviour of its rival. To this end, it proves useful to obtain an expression for the profits in terms of outputs and parameters only. Substituting from the first-order conditions for output in Eq. (5) and the expressions for optimal investment in Eq. (13) into Eq. (3a), we can rewrite the profit function under vertical integration as:

$$\pi_i^{Vk} = \left(y_i^{Vk}\right)^2\left[1-\left(\theta^{Vk}\right)^2\right]-G, \text{where } k=(V,O). \tag{15}$$

Using Eq. (5) in Eq. (3b), the profit function under outsourcing can be rewritten similarly as:

$$\pi_i^{Ok} = \left(y_i^{Ok}\right)^2, \text{where } k=(V,O). \tag{16}$$

Clearly, there are four possible candidate equilibrium regimes: (**V**,**V**), (**V**,**O**), (**O**,**V**), and (**O**,**O**), where the first letter refers to the mode-of-operation selected by firm 1 and the second letter refers to the mode-of-operation of firm 2. It is immediately obvious from Eqs. (15) and (16) that a sufficient condition for $\pi^{Ok}>\pi^{Vk}$ is that $y^{Ok}\geq y^{Vk}$. The term in square bracket is less than unity and so if outsourcing results in an increase in output then it clearly dominates vertical integration. However, if outsourcing raises marginal costs and hence lowers the output of the final goods firm sufficiently, then vertical integration will be the preferred strategy.

4. The mode-of-operation equilibria

We now turn to a discussion of the mode-of-operation equilibria. The actual equilibrium that arises depends on the parameter values. There are many potential asymmetries between firms both upstream and downstream. However, in order to focus on the interplay between unionisation and strategic interaction between firms, we will consider in detail only the case in which the firms at each stage of the production stage are ex-ante symmetric (thus, both downstream firms have identical exogenous cost parameters and so do both active upstream firms) and furthermore there is no underlying cost advantage or disadvantage from outsourcing. We shall briefly comment on other (ex-ante asymmetric) cases later in the section. Defining the underlying cost advantage from outsourcing as $\rho_i \equiv \bar{w}\hat{r}_i - r_i^m - t$ ($i=1,2$) (which is a measure of the ex-ante difference between the marginal production cost of the intermediate for the vertically integrated firm and that for the upstream supplier),[23] assuming symmetry implies $\rho_1=\rho_2=0$.

When firms are ex-ante symmetric and there is no underlying cost advantage from outsourcing, it can be shown (see Section V of Appendix A) that the ex-post (i.e. equilibrium) marginal cost is higher under outsourcing than under vertical integration. This result is robust to different values of the bargaining power parameters β and δ, even when, for values of both β and δ close to one, the investment-to-output ratio is higher under outsourcing than under vertical integration — a situation which, as we explained in Section 3, arises from the countervailing effects of the *double* source of rent-extraction (from both the union and the upstream supplier) in the case of outsourcing, as against the *single* source of rent extraction (the union) under vertical integration.

It can be shown that the pattern of equilibria depends on the level of governance cost, G. If G is sufficiently large, then both firms will choose to outsource (**O**,**O**). At $G=0$, both firms are vertically integrated and (**V**,**V**) is the unique subgame perfect equilibrium. At intermediate levels of G, there is multiple asymmetric equilibria (**V**,**O**) and (**O**,**V**). Further details are provided in Section VI of Appendix A.

The emergence of asymmetric equilibria can be explained by the existence of a negative interdependence between the firms' mode-of-operation decisions. As we said above, outsourcing is a higher marginal cost (in exchange for lower fixed cost) – and hence a lower output – strategy. As a result, outsourcing can be seen as a less aggressive business strategy than vertical integration. The relative incentive to choose vertical integration is larger the larger is a firm's expected output — because the lower marginal production cost then applies to a larger output. Faced with a vertically integrated rival exhibiting lower marginal cost, a firm will then have a lower anticipated market share and hence a lower incentive to vertically integrate than a firm that faces an outsourced rival. However, a firm facing an outsourcing (higher marginal cost) rival, will have a greater incentive to vertically integrate because it has a higher anticipated output (and hence will benefit more from a lower marginal production cost). Over a range of G, outsourcing is a best response to a rival's vertical integration but vertical integration is a best response to a rival's outsourcing. This result is analogous to that obtained by Leahy and Montagna (2011), in a model without unions and with an endogenous choice of the mode of internationalisation, who show how cost and strategic considerations are entwined in determining the mode-of-operation decision of firms.

It can be shown that whilst the order of equilibrium regions with respect to G is invariant to changes in the value of the bargaining power of unions (β) and of the upstream supplier (δ), the range of G over which outsourcing occurs in equilibrium increases in β and falls in δ. The effect of β is consistent with the conventional wisdom that strong union power may encourage outsourcing as a 'means-to-escape-unions' behaviour — even though this may result in higher wages for the workers who remain in domestic employment. The intuition for this lies in the endogeneity of the quality and price of the intermediate input (that results from the relationship-specificity of investment in the presence of contract incompleteness): given that outsourcing may result in a higher marginal cost and lower operating profits, it will reduce the rents that a stronger union can extract from domestic production. As a result, total profits under vertical integration are more sensitive to union bargaining power than they are under outsourcing and a higher bargaining power of unions increases the incentive to outsource. This prediction of the model contrasts with the negative relationship between union bargaining power and outsourcing found by Lommerud et al. (2009) — which is due to the fact that in their framework outsourcing unambiguously increases operating profits (and hence the rents that a more powerful union can extract from the remaining in-house production). As for the bargaining power of the supplier, a higher δ clearly reduces the share of rents available to the downstream firm under outsourcing and hence ceteris paribus increases incentives to vertically integrate.

When a small change in a parameter such as β, δ or G results in a firm switching its mode-of-operation, then this will result in a discrete change in that firm's output. This is because when the profits under the two mode-of-operation regimes are equal or close to equal (as they are in the neighbourhood of a switch), then the output under outsourcing is lower than it is under vertical integration. As we

[22] Clearly, the difference between the marginal costs in the two regimes will also depend on the underlying differences between downstream and upstream firms' costs as determined by technology and/or factor prices.

[23] The *underlying* (ex-ante) cost advantage from outsourcing depends only on exogenous parameters. There will of course be an ex-post cost difference between firms which will depend on endogenous variables such as w, z and q among other things.

have already seen, this follows from a comparison of Eqs. (15) and (16). By using Eq. (5) in $\tilde{\pi}_i^h = (p - c_i^h)y_i^h$, it is clear that a firm's operating profit can be written as $\tilde{\pi}_i^h = (y_i^h)^2$. It is straightforward to show that the greater is a firm's operating profitability, the higher is the total rent that its union can extract. Therefore, if a change in its mode-of-operation decreases the downstream firm's operating profits, as happens in the neighbourhood of a switch from vertical integration to outsourcing, then this will lead to lower total union rents. To see this, note that Eq. (10) implies that $(w_i^h - \bar{w})\xi_i^h = \frac{3}{2}\frac{\beta}{2-\beta}y^i$. Multiplying both sides of this by y_i^h, it follows that total union rents are: $(w_i^h - \bar{w})L_i^h = \frac{3}{2}\frac{\beta}{2-\beta}\tilde{\pi}_i^h$. We can see from this equation that, for given operating profits, a higher bargaining power is associated with higher union rents.[24] Perhaps surprisingly, however, this does not necessarily mean that a switch in the mode-of-operation that raises the downstream firm's profitability also necessarily raises the union wage. This is because the union rents per unit of labour $(w_i^h - \bar{w})$ are proportional to $\frac{\tilde{\pi}_i^h}{L_i^h} = \frac{y_i^h}{\xi_i^h}$ which is the *operating profit per unit of labour employed*. Hence, *if* output (y_i^h) were constant, then a change in the mode-of-operation that reduced the per-unit labour requirement (ξ_i^h) would raise the union wage. Outsourcing of the production of the intermediate would involve such a reduction in ξ_i^h and, as explained earlier, would lead to the union becoming more aggressive in its wage setting behaviour. However, as also explained earlier, it would also lead to a fall in y_i^h and so its effect on $(w_i^h - \bar{w})$ is unclear.

As we have seen, asymmetric equilibria can emerge in this model, even when firms are ex-ante symmetric. A clear implication of this is that in this instance wages will differ between firms. In such an asymmetric equilibrium in which one firm is vertically integrated and the other is outsourcing, the former will have the larger output due to its lower marginal production cost; this works towards a higher wage for the vertically integrated firm. This result is consistent with the stylised fact emerging from the empirical literature that lower cost firms pay higher wages. Clearly, as is captured by the model, outsourcing typically reduces the per-unit input requirement of domestic labour; when this effect is sufficiently strong, the wage of the outsourcing firm is actually higher than that of the vertically integrated firm. Thus, the model predicts that the nature of the inter-firm wage dispersion depends on whether or not the firm-efficiency effect – which works through y_i – dominates the countervailing effect arising from the greater aggressiveness of unions under outsourcing (the Horn and Wolinksy effect), which works through ξ_i.

In this section we have assumed ex-ante technological symmetry both between downstream firms and also between upstream and downstream firms. It is straightforward to show that when the supplier has an underlying cost advantage in producing the intermediate over the downstream firm (i.e. $\rho_i > 0$), outsourcing becomes ceteris paribus more attractive. In this case, trade liberalisation reduces the cost of acquiring the input from abroad and works towards more outsourcing. Ex-ante asymmetries between downstream firms can be shown to expand the asymmetric equilibria regions.[25]

5. Concluding remarks

We have developed a unionised oligopoly model to examine how the strategic interaction between firms and between firms and unions determine the effects of unionisation on the incentive to outsource and the effect of outsourcing on investment and firms' efficiency.

We found that outsourcing can increase the union wage when not all unionised production tasks are outsourced. The reason for this is that the impact of domestic wages on a firm's marginal cost is relatively less important when the firm outsources part of its production abroad, because reliance on domestic labour is lower. Thus, an increase in outsourcing tends to make unions more aggressive in the wage negotiations covering the (remaining) domestically employed labour. However, outsourcing will also tend to reduce the available rents that firms and unions bargain over and this works towards reducing the union wage. The overall effect of outsourcing on the union wage is ambiguous. In addition to its effect on the wages that a downstream firm must pay, outsourcing exposes a firm to a second hold-up problem due to its dependence on its upstream supplier. As a result, outsourcing is likely to lead to an increase in the marginal production cost of the downstream firm — even if there are substantial underlying cost advantages of the foreign supplier in producing the intermediate or when the investment-to-output ratios are higher under outsourcing than under vertical integration (as is the case for very high bargaining powers of unions and of the upstream supplier). Thus, if marginal costs are higher under outsourcing, firms' mode-of-operation choice involves a trade-off between this and the higher governance cost associated with vertical integration. However, consistent with the evidence that the internationalisation of firms has been accompanied in most countries by a reduction in the bargaining power of unions and with the view that foreign procurement of intermediate inputs may be used as a means to escape powerful unions, we find that an increase in the bargaining power of unions will result in more outsourcing.

We also showed that by reducing the relative cost of procuring intermediates abroad, trade liberalisation increases the degree of outsourcing. Depending on the level of governance costs, it can change the equilibrium from one in which all firms vertically integrate, to an asymmetric one in which firms choose different modes-of-operation, to an equilibrium in which all firms outsource.

Finally, we showed that asymmetric equilibria (in which firms choose different modes-of-operation) emerge even when firms are ex-ante identical.

Our model suggests that labour market deregulation policies aimed at reducing unions' power may result in less outsourcing. Our results provide a rationale for the stylised fact that, as highlighted in the introduction, outsourcing does not unambiguously lead to a reduction of a firm's marginal costs. They also help to explain why – even within the same industry – technologically similar firms adopt different modes-of-operation (for instance, in the highly oligopolistic aerospace industry, outsourcing, though increasing at Airbus, still lags behind that of its rival Boeing). This, in turn, helps to rationalise the observed within-industry wage dispersion.

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Appendix A

I. The parameter θ in the different regimes

From Eqs. (13) and (14), it is clear that the optimal z is proportional to output. So, it is possible to write the expression for investment in a general form as:

$$z_i^{hk} = \theta^{hk} y_i^{hk}, \ (i = 1, 2, h = V, O \text{ and } k = V, O). \tag{A1}$$

[24] This also helps to explain why a switch to outsourcing results in a reduction in the responsiveness of rents to union power and thus reduces the sensitivity of a firm's profits to the bargaining power of unions.

[25] Both these cases are analysed in the discussion paper version of the paper (Leahy and Montagna, 2010).

where here and in the remainder of the appendix when there are double superscripts the first refers to the mode-of-operation of firm i and the second refers to the mode-of-operation of its rival. The parameter θ takes on a different value depending on the mode-of-operation of the firm and that of its rival. When firm i is vertically integrated, we have $\theta^{Vk}=dy_i^{Vk}/dz_i$ for $(k=V,O)$ and when firm i is outsourcing we get $\theta^{Ok}=(3/2)[\delta/(2-\delta)]dy_i^{Ok}/dz_i$ for $(k=V,O)$.

To obtain an expression for dy_i/dz_i, differentiate Eq. (6) to get:

$$\frac{dy_i^{hk}}{dz_i}=\frac{1}{3}\left(-2\frac{dc_i^h}{dz_i}+\frac{dc_j^k}{dz_i}\right)(i,j=1,2 \text{ and } i\neq j, h=V,O \text{ and } k=V,O). \tag{A2}$$

When firm i is vertically integrated we can use Eq. (2) and (9) and differentiate with respect to z_i to obtain:

$$\frac{dc_i^V}{dz_i}=-\bar{w}+\frac{3}{2}F^V\frac{dy_i^{Vk}}{dz_i}, \text{where } F^V\equiv\frac{\beta}{2-\beta} \text{ and } (k=V,O). \tag{A3}$$

When firm i is involved in outsourcing, we must eliminate q_i in Eq. (2b) using Eq. (11) and eliminate w_i using Eq. (9). Differentiation of the marginal cost with respect to z_i then yields:

$$\frac{dc_i^O}{dz_i}=-\bar{w}+\frac{3}{2}F^O\frac{dy_i^{Ok}}{dz_i}, \text{where } F^O\equiv\frac{\beta}{2-\beta}+\frac{\delta}{2-\delta} \text{ and } (\mathbf{k}=\mathbf{V},\mathbf{O}). \tag{A4}$$

So, in general, we can write: $dc_i^h/dz_i=-\bar{w}+\frac{3}{2}F^h(dy_i^{hk}/dz_i)$ for $(h, k=V,O)$. Similarly, the general expression for the effect of z_i on the rival firm's costs is: $dc_j^k/dz_i=\frac{3}{2}F^k\left(dy_j^{hk}/dz_i\right)$, $i,j=1,2$ with $i\neq j$, and $(h,k=V,O)$.

I.1. Firm i is vertically integrated

To find θ^{Vk}, we first need to find (dy_i^{Vk}/dz_i) for $k=(V,O)$. Substitution of Eq. (A3) and the general expression for dc_j^k/dz_i into Eq. (A2) yields:

$$\begin{aligned}\frac{dy_i^{Vk}}{dz_i}&=\frac{1}{3}\left\{-2\left(-\bar{w}+\frac{3}{2}F^V\frac{dy_i^{Vk}}{dz_i}\right)+\frac{3}{2}F^k\frac{dy_j^{Vk}}{dz_i}\right\}\\&=\frac{2}{3}\bar{w}-F^V\frac{dy_i^{Vk}}{dz_i}+\frac{1}{2}F^k\frac{dy_j^{Vk}}{dz_i}. (ij=1,2 \text{ and } i\neq j).\end{aligned} \tag{A5}$$

We also need an expression for dy_j^{Vk}/dz_i. Adopting an approach analogous to that we used to derive Eq. (A5), it is straightforward to show that:

$$\frac{dy_j^{Vk}}{dz_i}=-\frac{1}{3}\bar{w}-F^k\frac{dy_j^{Vk}}{dz_i}+\frac{1}{2}F^V\frac{dy_i^{Vk}}{dz_i}. \tag{A6}$$

Combining Eqs. (A5) and (A6) yields:

$$\theta^{Vk}=\frac{dy_i^{Vk}}{dz_i}=\frac{\frac{2}{3}+\frac{1}{2}F^k}{1+F^V+F^k+\frac{3}{4}F^VF^k}\bar{w}. \tag{A7}$$

I.2. Firm i is outsourcing

When firm i is outsourcing we need an expression for dy_i^{Ok}/dz_i $(k=V,O)$. To obtain such an expression, use Eq. (A4) and the general expression for dc_i^h/dz_i in Eq. (A2) to get:

$$\frac{dy_i^{Ok}}{dz_i}=\frac{2}{3}\bar{w}-F^O\frac{dy_i^{Ok}}{dz_i}+\frac{1}{2}F^k\frac{dy_j^{Ok}}{dz_i} \quad (i,j=1,2 \text{ and } i\neq j). \tag{A8}$$

This is clearly analogous to Eq. (A5) with O replacing V in the expression. So, following the same procedure as before, combine this with: $\frac{dy_j^{Ok}}{dz_i}=-\frac{1}{3}\bar{w}-F^k\frac{dy_j^{Ok}}{dz_i}+\frac{1}{2}F^O\frac{dy_i^{Ok}}{dz_i}$ and substitute into $\theta^{Ok}=(3/2)[\delta/(2-\delta)]dy_i^{Ok}/dz_i$ to get:

$$\theta^{Ok}=\frac{dy_i^{Ok}}{dz_i}=\frac{3}{2}\frac{\delta}{2-\delta}\left(\frac{\frac{2}{3}+\frac{1}{2}F^k}{1+F^O+F^k+\frac{3}{4}F^OF^k}\right)\bar{w}. \tag{A9}$$

II. Outsourcing by a firm lowers the investment-to-output ratios of its rival

Demonstrating that $\theta^{VV}>\theta^{VO}$ and $\theta^{OV}>\theta^{OO}$ hold for all values of β and δ is straightforward. Use Eq. (A7) to get an expression for $(\theta^{VV}-\theta^{VO})$. It is convenient to simplify the notation and write: $(1/\bar{w})\theta^{VV}=R/S$, where $R=\frac{2}{3}+\frac{1}{2}F^V$ and $S=1+2F^V+\frac{3}{4}\left(F^V\right)^2$. Similarly, using this notation, we can write: $(1/\bar{w})\theta^{VO}=\left[R+\frac{1}{2}D\right]/\left[S+D\left(1+\frac{3}{4}F^V\right)\right]$, where $D=\frac{\delta}{2-\delta}$. Then:

$$(1/\bar{w})\left(\theta^{VV}-\theta^{VO}\right)=D\frac{R\left(1+\frac{3}{4}F^V\right)-\frac{1}{2}S}{S\left[S+D\left(1+\frac{3}{4}F^V\right)\right]}. \tag{A10}$$

The denominator of Eq. (A10) and the parameter D are clearly positive and the numerator reduces to $R\left(1+\frac{3}{4}F^V\right)-\frac{1}{2}S=\left(\frac{2}{3}+\frac{1}{2}F^V\right)\left(1+\frac{3}{4}F^V\right)-\left(\frac{1}{2}+F^V+\frac{3}{8}\left(F^V\right)^2\right)=\frac{1}{6}>0$. From Eq. (A9), analogous calculations can be used to demonstrate that $(1/\bar{w})\left(\theta^{OV}-\theta^{OO}\right)>0$.

III. Investment-to-output ratios are lower under outsourcing except for high β and δ

We need to compare $\theta^{Vk}$and θ^{Ok}. As above, it is helpful to simplify the notation and write: $(1/\bar{w})\theta^{Vk}=R'/S'$ where $R'=\frac{2}{3}+\frac{1}{2}F^k$ and $S'=1+F^V+F^k+\frac{3}{4}F^VF^k$. Similarly, we can write: $(1/\bar{w})\theta^{Ok}=\frac{3}{2}(DR')/\left[S'+D\left(1+\frac{3}{4}F^k\right)\right]$ where $D=\frac{\delta}{2-\delta}$. Then:

$$(1/\bar{w})\left(\theta^{Vk}-\theta^{Ok}\right)=R'\frac{S'\left(1-\frac{3}{2}D\right)+D\left(1+\frac{3}{4}F^k\right)}{S'\left[S'+D\left(1+\frac{3}{4}F^k\right)\right]}. \tag{A11}$$

The denominator of Eq. (A11) and the parameter R' are clearly positive and the numerator is guaranteed to be positive for $D\geq\frac{2}{3}$ or, equivalently, $\delta\geq\frac{4}{5}$. Even if $\delta=1$, θ^{Vk} is still larger than θ^{Ok} unless β is also very high. To see this, let $\delta=1$. Then it follows that $D=1$, and the numerator becomes: $\left(\frac{1}{2}+\frac{1}{4}F^k\right)-F^V\left(\frac{1}{2}+\frac{3}{8}F^k\right)$ which is positive if and only if: $F^V\leq\frac{\left(1+\frac{1}{2}F^k\right)}{\left(1+\frac{3}{4}F^k\right)}$. Since F^k cannot exceed 2 by definition, a value of F^V close to unity – and thus a value of β close to unity – is required for θ^{Ok} to exceed θ^{Vk}. But note that if both β and δ are unity, then $F^V=1$ but $\left(1+\frac{1}{2}F^k\right)/\left(1+\frac{3}{4}F^k\right)<1$ and so in that interesting case: $\theta^{Ok}>\theta^{Vk}$.

IV. Reduced form equilibrium output expressions in the different regimes

Combining Eqs. (5) and (1), the first-order condition for output of a typical firm can be written in general form as:

$$a-c_i^{hk}-2y_i-y_j=0 \quad (i,j=1,2 \text{ and } i\neq j, h=V,O \text{ and } k=V,O), \tag{A12}$$

where c_i^{hk} is the marginal cost for firm i when it chooses mode-of-operation $h=(V,O)$ and its rival chooses mode-of-operation $k=(V,O)$.

From the expression for the wage in Eq. (9), the labour component of firm i's marginal cost is: $w_i^h \xi_i^h = \bar{w}\xi_i^h + \frac{3}{2}\frac{\beta}{2-\beta} y_i$ and from Eq. (11) the intermediate good's price it must pay under outsourcing is: $q_i = r_i^m + \frac{3}{2}\frac{\delta}{2-\delta} y_i$. Both of these depend on the firms' outputs. Making use of these relationships and the expression for investment in Eq. (A1), we can rewrite the first-order condition for firm i in general form as:

$$A_i^h - 2y_i - y_j + \eta^{hk} y_i = 0, \tag{A13}$$

where $\eta^{Vk} \equiv \bar{w}\theta^{Vk} - \frac{3}{2}F^V$ and $\eta^{Ok} \equiv \bar{w}\theta^{Ok} - \frac{3}{2}F^O$, with the first superscript referring to the mode-of-operation (V,O) of firm i and the second superscript to that of its rival. The parameters $A_i^V = a - \bar{w}(\hat{r}_i + \bar{l})$ and $A_i^O = a - (r_i^m + \bar{w}\bar{l} + t)$ only depend on the firm's own mode-of-operation. In the text we focus on the case of ex-ante symmetry; however, in this appendix we allow for more general cases. To that end it is useful to use $\rho_i = \bar{w}\hat{r}_i - r_i^m - t$ $(i = 1,2)$ and define $\varphi \equiv \bar{w}(\hat{r}_2 - \hat{r}_1)$ as the ex-ante marginal cost advantage of firm 1. Making use of these, we can then write: $A_1^O = A_1^V + \rho_1$, $A_2^V = A_1^V - \varphi$ and $A_2^O = A_1^V - \varphi + \rho_2$. From the equations for firm i and j in Eq. (A13), we can obtain the reduced form equilibrium output expressions for the two firms:

$$y_i^{hk} = \frac{\left(2 - \eta^{kh}\right)A_i^h - A_j^k}{3 - 2\left(\eta^{hk} + \eta^{kh}\right) + \eta^{hk}\eta^{kh}}. \tag{A14}$$

The reduced form expression for industry output is thus:

$$\bar{y}^{hk} = \frac{\left(1 - \eta^{kh}\right)A_i^h + \left(1 - \eta^{hk}\right)A_j^k}{3 - 2\left(\eta^{hk} + \eta^{kh}\right) + \eta^{hk}\eta^{kh}}. \tag{A15}$$

V. Demonstrating that marginal costs are higher under outsourcing than under vertical integration

Since in the paper we examine the case in which firms are ex-ante symmetric and furthermore there is no underlying cost advantage or disadvantage from outsourcing, we can write $A_i^h = A_j^k$. Then industry output reduces to $\bar{y}^{hk} = \frac{(2-\eta^{kh}-\eta^{hk})A_i^h}{3-2(\eta^{hk}+\eta^{kh})+\eta^{hk}\eta^{kh}}$. It is straightforward to show that this is increasing in η^{hk} and η^{kh} for all values of η consistent with stable interior solutions. Since $\eta^{VV} > \eta^{VO} > \eta^{OV} > \eta^{OO}$, it follows that $\bar{y}^{VV} > \bar{y}^{VO} = \bar{y}^{OV} > \bar{y}^{OO}$ regardless of the level of β and δ. Now, using Eq. (6) we find that: $\bar{y}^{hk} - \bar{y}^{rs} = \frac{1}{3}\left\{\left(c_1^{rs} - c_1^{hk}\right) + \left(c_2^{rs} - c_2^{hk}\right)\right\}$ for $(h,k = V,O)$ and $(r, s = V,O)$. It is then easy to show that: $2c_1^{VV} = 2c_2^{VV} \flat \left(c_1^{VO} + c_2^{VO}\right) \flat 2c_1^{OO} = 2c_2^{OO}$ (here the first superscript refers to firm 1 and the second to firm 2). Combining this with the fact that $c_1^{VO} \flat c_2^{VO}$, it then follows that $c_i^{OO} > c_i^{VV}$, $c_i^{OO} > c_i^{VO}$, $c_i^{OV} > c_i^{VV}$ and $c_i^{OV} > c_i^{VO}$ (for $i = 1,2$). Hence, ex-post equilibrium marginal costs are higher under outsourcing than under vertical integration.

VI. Equilibria

Since firms are ex ante symmetric and there is no underlying cost advantage from outsourcing, both firms choosing to vertically integrate is the unique subgame perfect Nash equilibrium at $G = 0$. Using Eqs. (15) and (16), it is clear that this requires that:

$$\left(y_i^{Vk}\right)^2 \left[1 - \left(\theta^{Vk}\right)^2\right] > \left(y_i^{Ok}\right)^2 k = (V,O). \tag{A16}$$

Taking the square root of both sides and making use of the reduced form expressions for output in Eq. (A14), this condition becomes:

$$\frac{\sqrt{1 - \left(\theta^{Vk}\right)^2}\left(1 - \eta^{kV}\right)A}{3 - 2\left(\eta^{Vk} + \eta^{kV}\right) + \eta^{Vk}\eta^{kV}} - \frac{\left(1 - \eta^{kO}\right)A}{3 - 2\left(\eta^{Ok} + \eta^{kO}\right) + \eta^{Ok}\eta^{kO}} > 0, \tag{A17}$$

where $A_i^V = A_j^V = A_i^O = A_j^O = A$, as $\rho_i = \rho_j = 0$ $(i,j = 1,2$ and $i \neq j)$. It can be shown that the condition in Eq. (A17) holds for all parameters consistent with stable interior solutions in all equilibria. It can also be shown that the difference in Eq. (A17) is strictly larger when the rival firm outsources. Hence, at any given G, the gain in profit from vertical integration relative to outsourcing is larger when the rival is outsourcing.

Thus, there exists a non-empty set of G such that:

$$\left(y_i^{VO}\right)^2 \left[1 - \left(\theta^{VO}\right)^2\right] - \left(y_i^{OO}\right)^2 > G > \left(y_i^{VV}\right)^2 \left[1 - \left(\theta^{VV}\right)^2\right] - \left(y_i^{OV}\right)^2 > 0. \tag{A18}$$

For levels of G within this range, a firm will find it more profitable to be vertically integrated if its rival is outsourcing, but more profitable to be outsourcing if its rival is vertically integrated. Hence, for this region of G there are multiple asymmetric equilibria (**V**,**O**) and (**O**,**V**). Clearly, for $G > (y_i^{VO})^2[1 - (\theta^{VO})^2] - (y_i^{OO})^2$, firms will always wish to outsource; hence (**O**,**O**) is the unique equilibrium.

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