Experience Benefits and Firm Organization*

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Abstract

A principal needs a worker for the production of a good. The worker can be hired as an internal agent (an employee), or an external agent under a contract. These two organizational modes correspond to in-house production and outsourcing, respectively. In each case, the agent earns *experience benefits*: future monetary returns from managing production, reputation, and enjoyment. The principal would like to extract experience benefits, and can do so when production is outsourced. However, the external agent earns information rent from private information about production costs. The principal cannot fully extract experience benefits when production is in-house because the internal agent must be provided with a minimum income, although the principal has full information on production costs. Our theory proposes a new trade-off, one between *information rent* under outsourcing and *experience rent* under in-house production. The principal chooses outsourcing when experience benefits are high, but her organizational choice may be socially inefficient.

Keywords and phrases: vertical integration, experience benefits, experience rents, informational rents.

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1 Introduction

A firm often chooses between producing a good in-house and outsourcing production to another firm. Ever since Coase's famous article (Coase, 1937), economists have sought to identify trade-offs between in-house production and outsourcing. Proposed theories are based on transactions costs (e.g., Williamson, 1975, 1985), property rights and inefficient *ex ante* investments (e.g., Grossman and Hart, 1986), the value of keeping a supplier at arm's length to commit to carrying out punishments (Crémer, 1995), communication costs between a firm's different hierarchical levels, (Antràs et al2008), and the development of firm-specific languages (Crémer, Garicano and Prat, 2007). In this paper, we propose a new and complementary theory, which centers on *experience benefits*. The following example illustrates the idea.

For some time, the Japanese auto manufacturer Toyota purchased 70% of its electronic car components from one independent supplier (called Denso), but this figure had declined to 50% by the end of the 1990's. Better access to cost information seems to have contributed to this change. According to Ahmadjian and Lincoln (2001) "an auto assembler [has] access to a supplier's cost structure and understand[s] intimately its manufacturing process.…[K]nowledge asymmetries between customer and supplier posed few problems when the technology behind the parts never strayed far from the assembler's core knowledge base…As electronics technology grew more complex and integral to automotive design and manufacturing, information asymmetries increased between Toyota and Denso.…Toyota was candid in interviews with us and with the Japanese press in saying that one factor in motivating its decision to manufacture electronics components was an interest in boosting bargaining leverage over Denso with a firm grasp of Denso's real costs." (Ahmadjian and Lincoln, 2001, p.688) But if in-house production gives a better grasp of real costs, why outsource at all? Our point here is that outsourcing may solve a problem that is due to experience benefits.

Experience benefits accrue to any individual engaged in production. Production may help a worker to accumulate human capital which then leads to a better future career. He may also gain reputation, or even derive private enjoyment from production. Understanding that a worker gains experience benefits, an employer will attempt to expropriate these gains by reducing wages.[1] However, a key aspect of experience benefits is that they are either non-monetary or in the form of future monetary rewards. Hence, an employer's attempt to extract experience benefits may be thwarted by the employee's inability to satisfy current liquidity requirements (Becker, 1964, Ritzen and Stern, 1991). Outsourcing may mitigate this problem because it potentially avoids the liquidity constraint.

[1]See Becker (1964), Ben-Porath (1967) and Rosen (1972) for the standard argument For recent analyses of firms' incentives to provide training, see Acemoglu and Pischke (1999), and Kessler and Lülfesmann (2006).

The obvious reason for firms finding in-housing production profitable is that an arms-length relationship introduces opportunistic behaviors, as the Toyota-Denso example has demonstrated. The firm will be unable to monitor the worker's decisions, or to obtain cost information. In-house production ameliorates such opportunistic behaviors (Williamson, 1975, 1985). We develop a model for the trade-off between extracting experience benefits through outsourcing, and eliminating private information through in-house production.

We analyze a model in which the principal decides between hiring an agent as an employee and outsourcing production to an outside agent. Employees and outside agents acquire experience benefits, and have the same reservation utility. There are two differences between the two contracting regimes.

First, the principal and the agent share the same cost information when the agent is an employee, but the agent has private cost information when he is not. This is a natural assumption: the owner of a firm has better access to information within the firm than information of contracted, outside agents.

Second, an agent must receive a *minimum income*, but there are two different types of agent. The first type can satisfy this minimum income requirement on his own; the second type cannot. Such a difference may exist for many reasons. First, some agents simply are wealthier than others. Second, some agents may have multiple jobs, so have higher earned income. Third, some agents may have working spouses, so their household incomes are higher.

In our setting, an agent hired as an outside contractor is of the type that can satisfy his liquidity needs by his own resources, and employees are of the other type. In order to be hired as an outside contractor, an agent must set up his own business, which requires sufficient liquidity. Such an assumption is consistent with some evidence. Evans and Jovanovic (1989) find that entrepreneurs are among the wealthier individuals in the population. Setting up a new business requires one to have some capital in order to circumvent credit constraints. If the taste for entrepreneurship is sufficiently widespread, wealthier individuals will typically be available as outside contractors rather than employees.[2] Individuals with tight liquidity constraints will have no choice but to work as employees. We make the simplifying assumption that all employees are liquidity constrained, but outside contractors are not.

The minimum income requirement allows the less wealthy agent to earn *experience rent* when he works as an employee. The principal is unable to drive the agent's utility all the way to the reservation utility. The drawback of in-house production is experience rent. The minimum income requirement is eliminated in outsourcing. However, the external agent has private cost information, and earns *information rent*. The drawback of outsourcing is information rent. This is the basic trade-off. The optimal contract under outsourcing implements the standard second best. The optimal contract under in-house production implements the first best when experience benefits are small, but

[2]Such a taste may be described by concepts proposed by psychologists such as the need for achievement (McClelland, 1961) or the locus of control (Shapero, 1975)

output is lower than first best when experience benefits are large.

In sum, we posit that a worker may face both reservation utility and minimum income constraints. The principal uses an external agent to eliminate the minimum income constraint, and his experience benefits are "monetized" and expropriated. However, the external agent earns information rent, so the reservation utility constraint is slack. When the principal uses an internal agent, the minimum income constraint may bind, but the reservation utility constraint may, too. Each of these two constraints may be more or less important in specific production and information parameter configurations.

The principal's organizational choice depends on the agent's marginal experience benefit as output increases. The principal chooses outsourcing if this marginal benefit is large enough, and in-house production if it is small enough. Notwithstanding, the difference between profits in in-house production and outsourcing is *nonmonotone*. At a low marginal experience benefit, in-house profit is first best or near first best, but outsourcing profit is always second best. Hence, when the marginal experience benefit is small, an increase in the marginal experience benefit raises the profit difference. The opposite is true when the marginal experience benefit is large. Then, the principal cannot extract any of the marginal experience benefit under in-house production due to the binding minimum income constraint, while she can capture some of it under outsourcing.

A higher minimum income makes in-house production less profitable. It may prompt the principal to switch from in-house production to outsourcing, but never the other way around. As the minimum income gets higher, the set of marginal experience benefits for which in-house production is superior to outsourcing shrinks.

We investigate welfare implications using a constrained or second-best approach. A social planner chooses the contractual arrangement, but must leave production decisions to the principal. When the social planner chooses the production mode to maximize social surplus, his choice is qualitatively similar to the principal's. However, the social planner's choices do not coincide with the principal's because the principal only captures a fraction of social surplus. The principal sometimes chooses outsourcing when in-house production is socially optimal, and the opposite may also be true. This latter situation is likely if the agent's minimum income requirement is modest.

Our model delivers new testable predictions, since experience benefits may depend, in a systematic manner, on market characteristics. First, *ceteris paribus*, outsourcing should be more common when the market for the agent's human capital is thicker.[3] This prediction is consistent with some empirical findings. In the literature on the effects of market thickness on vertical integration, Holmes (1999) studies the proportion of purchased inputs using U.S.

[3] There is strong empirical evidence that much of the accumulated human capital is indeed general, or at least sector-specific, rather than firm-specific; see, e.g., Neal (1995), as well as Altonji and Williams (2005) and the references therein.

manufacturing firm data. He finds that this proportion is significantly higher when plants are located in an area with a high own-industry employment; conversely, this proportion is lower when the employment in the same industry is low. Furthermore, in their analysis of U.S. auto industry data Masten et al. (1989) report that more firm-specificity of human capital is correlated with in-house production.[4]

Second, the (monetary) value of experience benefits may depend on the marketability of the produced good. González-Dìaz et al. (2000) use data from construction firms in Spain to build a measure of each firm's reliance on subcontractors. They find that reliance is higher for firms producing output with greater marketability.[5]

To the best of our knowledge, the experience-benefit-information-rent trade-off has not been considered in a theory of the firm. The most closely related paper is by Lewis and Sappington (1991). In their principal-agent setting, transferability of a subcontractor's skills determines the subcontractor's outside option. However, Lewis and Sappington do not consider the transferability of skills that would be acquired during production. Moreover, they assume that costs are lower when production is subcontracted. In our model, costs are identical whether production is in-house or outsourced.

Our model is also related to the literature of career concerns, where individuals acquire experience benefits (Holmström, 1999, and Gibbons and Murphy, 1992). However, that literature does not consider the principal's choices between hiring agents as employees and independent contractors, as we do. Instead, the focus is on how experience benefits may mitigate moral hazard.

The paper proceeds as follows. We describe the model and the first best in Sections 2 and 3, respectively. In Section 4, we derive the optimal contract under outsourcing. The optimal contract under in-house production is presented in Section 5. Next, in Section 6, we study whether the principal's choices between the two organizational modes are socially efficient. The final section draws some conclusions. All the proofs are in the Appendix.

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[4]Theories of the firm involving transactions costs (e.g., Williamson, 1975, 1985), and property rights (e.g., Grossman and Hart, 1986) have also studied the relationship between asset specificity and firm organization. The interpretation, however, is different. These theories show that vertical integration is more beneficial when assets are more specific to the relationship, and there is a hold-up problem when contracting is imperfect. By contrast, our theory implies that the benefit of vertical *separation* is larger when there is more non-specific human capital and employees are credit constrained.

[5]See also Pirrong (1993) and Hubbard (2001) for analyses of shipping industries, and references cited in Klein (2005).

2 The Model

A principal would like to produce a good to sell to consumers at a price normalized to 1. He needs an agent to carry out the production. Let q denote the quantity of the good produced. The (variable) cost is $\gamma c(q)$, where c is twice continuously differentiable, strictly increasing and strictly convex, with $c(0) = 0$, $c'(0) = 0$, and $\lim_{q \to +\infty} c'(q) = +\infty$. The cost parameter γ is a random variable distributed on $[\underline{\gamma}, \overline{\gamma}]$, where $\underline{\gamma} > 0$, with distribution and density functions F and f, respectively. We assume that $f(\gamma) > 0$ for all $\gamma \in [\underline{\gamma}, \overline{\gamma}]$. We define the function h by $h(\gamma) \equiv \frac{F(\gamma)}{f(\gamma)}$, and assume that it is strictly increasing in $\gamma \in [\underline{\gamma}, \overline{\gamma}]$. Only the agent observes the realized value of γ.

We assume that the agent gets *experience benefits* βq from production, where $\beta \in \Re^+$ is an exogenously given parameter.[6] The value of β is common knowledge. Examples of such experience benefits include enjoyment, reputation, or expected future returns from the experience acquired through production. If βq is interpreted as the agent's experience and human capital accumulation from working for this principal, the value of β can be regarded as the degree of specificity: a higher value of β means that the experience return can be used more readily in another project.

Time is not explicitly modeled here, although the experience benefits can be regarded as future returns from working for other principals. A more complete model would let experience benefits be dependent on the agent's termination decision. If the principal can commit, she may offer the agent a future opportunity to take advantage of the experience benefits.[7] Nevertheless, our modest purpose is to show that experience benefits generate a trade-off between in-house production and outsourcing, so we disregard any dynamic considerations.

The principal makes a take-it-or-leave-it contract offer to the agent. We consider two contracts, described below. Under each contract, the principal's utility is the revenue q, minus any transfer it may give to the agent, and the agent's utility is $\beta q - \gamma c(q)$ plus any transfer from the principal. The agent's reservation utility is $U > 0$.[8]

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[6]We can consider a more general benefit function such as $V(q;\beta)$ with V increasing in each argument, and a positive cross-partial derivative. We simply have taken $V(q;\beta)$ to be βq. Using a more general function only leads to more notation but does not raise conceptually new issues.

[7]In a long term relationship there may be scope for the principal to exploit experience benefits even if the human capital accumulation is relational specific (see e.g. Becker, 1962, or Salop and Salop, 1976).

[8]An alternative approach would be to analyze an economy where many principals and many agents interact. A contract can be developed once a principal and an agent are matched. The agent's reservation utility depends on alternative offers. We leave such an

The two contracts we consider are *outsourcing* and *in-house production*. There are two differences. First, according to laws governing employment and non-employment contractual relationships, the principal should have better access to information under in-house production than under outsourcing, as shown by the following quotes of legal texts (found in Masten, 1988, p.186):[9]

> 'one party to a business transaction is not liable to the other for harm caused by his failure to disclose to the other facts of which he knows the other is ignorant and which he further knows the other, if he knew them, would regard as material in determining the course of his action in the transaction in question' (Restatement (2nd) of Torts, §51; also see Restatement of Contracts (2nd), §303). [...]

By contrast, an employee is obliged

> 'to communicate to [his employer] all facts which he ought to know' (56 CJS 67 [...]).

Accordingly, we assume that the agent fully and freely reveals the cost information to the principal under in-house production, but that the cost information remains the agent's private information under outsourcing.[10]

Second, the agent must receive a minimum income $M \in [-\infty, U]$. This minimum income differs from the reservation utility. An agent can be one of two types. The wealthy type has sufficient personal resources to cover the minimum income requirement; the less wealthy type does not. The latter type of agent may not be hired as an outside contractor because he does not have enough funds to start his own business. The principal is therefore certain to hire a wealthy agent if she resorts to outsourcing. By contrast, if she hires an employee, she hires an agent who must be liquidity constrained.[11]

We now formally define extensive forms. A contract is denoted by $\mathcal{C} \equiv \{[q(\gamma), t(\gamma)], \gamma \in [\underline{\gamma}, \overline{\gamma}]\}$, where $q(\gamma)$ is the output and $t(\gamma)$ is the transfer from

analysis for future research.

[9]Even absent legal constraints, a firm may develop a specific language that makes information flows less costly within the firm than with other firms, as suggested by Crémer et al(2007).

[10]Loyalty towards the employer may also explain why an individual might want to reveal information honestly to an employer, as suggested by Alger and Renault (2007) and the references cited therein.

[11]Our qualitative results may hold if the principal faces a population of wealthy and poor agents, and uses a screening mechanism. Indeed, the principal does not know if those who apply to be an internal agent are wealthy or not, but she knows that external agents must be wealthy. This implies an information rent for an internal agent. This rent may be lower than what a wealthy agent earns when he is an external agent, who gains private information about cost. In this scenario, wealthy agents choose to be external, while not-so-wealthy agents choose to be employees.

the principal to the agent when the cost parameter is γ. Under outsourcing, the agent possesses private information about γ. Without loss of generality, we then let a contract be a direct revelation mechanism where the production levels and compensations are functions of the agent's report on γ, and where the agent reports γ truthfully. Under in-house production, the principal and the agent have perfect information about the cost parameter γ so the contract is well-defined.

Under *Outsourcing*, the extensive form is:[12]

Stage 1: The agent observes γ, but the principal does not.

Stage 2: The principal offers a contract $\mathcal{C} \equiv \{[q(\gamma), t(\gamma)], \gamma \in [\underline{\gamma}, \overline{\gamma}]\}$ (a revelation mechanism) to the agent, and the agent then chooses between accepting and rejecting it.

Stage 3: If the agent accepts, the agent reports γ, production takes place, and is paid according to the contract.

Under *In-house production*, the extensive form is:

Stage 1: The agent observes γ and reveals this to the principal.

Stage 2: The principal offers a contract $\mathcal{C} \equiv \{[q(\gamma), t(\gamma)], \gamma \in [\underline{\gamma}, \overline{\gamma}]\}$ to the agent, and the agent then chooses between accepting and rejecting it.

Stage 3: The terms of the contracts are executed if the agent has accepted the contract $\mathcal{C}$.

Under both contractual forms the contract must give the agent a *utility* of at least U. Under in-house production there is also a minimum income constraint, which states that the *(net) monetary compensation* from the principal must be at least M.

3 First best

We begin by deriving the first best, which would obtain if the principal observed the cost parameter γ and the agent did not face a minimum income constraint. This, in fact, corresponds to in-house production with an agent

[12] Here we let the agent observe the cost parameter before contracting. Because the agent is risk neutral, the principal may "sell the firm" to the agent at the first-best (expected) price if a contract can be offered before the agent acquires any cost information. We wish to consider the effect of asymmetric information, hence disallowing contracts that are signed before information acquisition.

who does not have a minimum income constraint (or whose minimum income is $M = -\infty$).

For cost parameter γ, the first best is defined by a production level q and a transfer t that maximize $q - t$ subject to the agent's reservation utility constraint $\beta q + t - \gamma c(q) \geq U$. Clearly, the principal extracts all surplus, including the benefit βq, by the transfer $t = U - \beta q + \gamma c(q)$. It follows that the principal's objective is to choose q to maximize the social surplus

$$(1) \qquad (1+\beta)q - \gamma c(q) - U.$$

The social surplus (1) takes into account *both* the principal's and the agent's benefit from the output, $(1+\beta)q$. The first-best quantity therefore equates social marginal benefit $1+\beta$ and marginal cost $\gamma c'(q)$.

It will be useful to define a function $\tilde{q} : \Re^{++} \to \Re^{++}$ as follows:

$$(2) \qquad \tilde{q}(x) = \arg\max_{q} q - xc(q), \qquad \text{or} \qquad c'(\tilde{q}(x)) = \frac{1}{x}.$$

Because the second-order cross-partial derivative of $q - xc(q)$ is $-c'(q) < 0$ from the strict convexity of c, $\tilde{q}$ is strictly decreasing. Note also that $\lim_{x\to 0} \tilde{q}(x) = +\infty$ and $\lim_{x\to+\infty} \tilde{q}(x) = 0$.

We summarize the first best as follows.

Proposition 1 *The first best is the quantity-transfer pair* $((q^*(\gamma), t^*(\gamma))$*:*

$$q^*(\gamma) = \tilde{q}\left(\frac{\gamma}{1+\beta}\right)$$

$$t^*(\gamma) = U - \beta q^*(\gamma) + \gamma c\left(q^*(\gamma)\right).$$

The principal uses in-kind compensation $\beta q^*(\gamma)$ to substitute for monetary compensation. The in-kind compensation is increasing in quantity, and therefore decreasing in the cost parameter γ. Moreover, it is increasing in the experience benefit parameter β. Hence, in the first best, the net monetary compensation, $t^*(\gamma) - \gamma c(q^*(\gamma))$, is increasing in γ, and decreasing in β.

Taking expectation over the cost parameters in $[\underline{\gamma}, \overline{\gamma}]$, we obtain the first-best expected profit

$$(3) \quad \pi^*(\beta) = \int_{\underline{\gamma}}^{\overline{\gamma}} \left[(1+\beta)\tilde{q}\left(\frac{\gamma}{1+\beta}\right) - \gamma c\left(\tilde{q}\left(\frac{\gamma}{1+\beta}\right)\right)\right] f(\gamma)d\gamma - U.$$

The profit function (1) is strictly increasing and quasi-linear in β. Therefore, the first-best profit (3) is strictly increasing and strictly convex in β.

4 Optimal contract under outsourcing

From the revelation principle, an optimal contract is a pair $(q(\gamma), t(\gamma))$ that maximizes the principal's expected profit subject to the constraints that the agent obtains at least the reservation utility U, and that he reports γ truthfully:

$$\max_{q(\cdot),t(\cdot)} \int_{\underline{\gamma}}^{\overline{\gamma}} [q(\gamma) - t(\gamma)] f(\gamma) d\gamma \tag{4}$$

subject to

$$\beta q(\gamma) + t(\gamma) - \gamma c(q(\gamma)) \geq U \qquad \forall \gamma \in [\underline{\gamma}, \overline{\gamma}], \tag{5}$$

$$\beta q(\gamma) + t(\gamma) - \gamma c(q(\gamma)) \geq \beta q(\hat{\gamma}) + t(\hat{\gamma}) - \gamma c(q(\hat{\gamma})) \quad \forall (\gamma, \hat{\gamma}) \in [\underline{\gamma}, \overline{\gamma}]^2. \tag{6}$$

The solution is well-known (see, for example, Laffont and Martimort, 2001). The difference between the optimal contract under asymmetric information and the first best is Myerson's "virtual cost" adjustment. The agent's private information leads to an adjustment of the agent's cost function from γ to $\gamma + h(\gamma)$ (recall $h \equiv \frac{F}{f}$), so the optimal quantity maximizes

$$\int_{\underline{\gamma}}^{\overline{\gamma}} \left[(1+\beta) q(\gamma) - (\gamma + h(\gamma))\, c\,(q(\gamma))\right] f(\gamma) d\gamma - U.$$

Pointwise maximization implies that for each γ:

$$c'(q^e) = \frac{1+\beta}{\gamma + h(\gamma)}. \tag{7}$$

We state the following proposition, but omit its proof.

Proposition 2 *Under outsourcing, the optimal contract is the quantity-transfer pair* $(q^e(\gamma), t^e(\gamma))$*:*

$$q^e(\gamma) = \tilde{q}\left(\frac{\gamma + h(\gamma)}{1+\beta}\right),$$

$$t^e(\gamma) = U - \beta q^e(\gamma) + \gamma c(q^e) + \int_{\gamma}^{\overline{\gamma}} c(q^e(x)) dx.$$

At cost parameter γ, the term $\int_{\gamma}^{\overline{\gamma}} c(q^e(x))dx$ (the agent's utility less U) is the agent's *information rent*, due entirely to the private information about γ. The agent does not receive a direct benefit from βq.

From Proposition 2, under outsourcing the principal's optimal expected profit, $\pi^e(\beta)$, and the agent's expected rent, $R^e(\beta)$, are:

$$\begin{aligned}
\pi^e(\beta) &= \int_{\underline{\gamma}}^{\overline{\gamma}} (1+\beta)\tilde{q}\left(\frac{\gamma+h(\gamma)}{1+\beta}\right) f(\gamma)d\gamma \\
&\quad - \int_{\underline{\gamma}}^{\overline{\gamma}} (\gamma+h(\gamma))\, c\left(\tilde{q}\left(\frac{\gamma+h(\gamma)}{1+\beta}\right)\right) f(\gamma)d\gamma - U
\end{aligned} \tag{8}$$

$$R^e(\beta) = \int_{\underline{\gamma}}^{\overline{\gamma}} h(\gamma) c\left(\tilde{q}\left(\frac{\gamma+h(\gamma)}{1+\beta}\right)\right) f(\gamma)d\gamma. \tag{9}$$

From (9), the agent's direct benefit βq has been appropriated by the principal. There is, however, an indirect effect of β on the agent's rent through the quantity schedule q^e. Information rent is proportional to quantity, and since the optimal quantity is increasing in β, the agent's information rent is increasing in β.

Because the quantity q^e is distorted downward, the expected profit under outsourcing increases in β at a rate lower than the first best. Formally, by the Envelope Theorem:

$$\frac{d\pi^e(\beta)}{d\beta} = \int_{\underline{\gamma}}^{\overline{\gamma}} \tilde{q}\left(\frac{\gamma+h(\gamma)}{1+\beta}\right) f(\gamma)d\gamma < \int_{\underline{\gamma}}^{\overline{\gamma}} \tilde{q}\left(\frac{\gamma}{1+\beta}\right) f(\gamma)d\gamma = \frac{d\pi^*(\beta)}{d\beta}. \tag{10}$$

These results are summarized as follows.

Corollary 1 *In the optimal contract under outsourcing, the principal's expected profit is strictly increasing and strictly convex in β, while the agent's expected rent $R^e(\beta)$ is strictly increasing in β. Furthermore, for all $\beta \geq 0$, the expected profit is strictly below the first best: $\pi^e(\beta) < \pi^*(\beta)$.*

5 Optimal contract under in-house production

5.1 Optimal contract

Under in-house production the principal knows the cost parameter γ when offering a contract $[q(\gamma), t(\gamma)]$. The agent accepts a contract if it gives him a sufficiently high utility, and if it gives him a sufficiently high net monetary payoff. Given a minimum payment M, an experience benefit parameter β, and a cost parameter γ, the principal chooses (q, t) to maximize

$$q - t \tag{11}$$

subject to the reservation utility constraint

$$\beta q + t - \gamma c(q) \geq U, \tag{12}$$

and the minimum income constraint

$$t - \gamma c(q) \geq M. \tag{13}$$

Due to the benefit βq, there can be a tension between constraints (12) and (13). If βq is large, the principal may satisfy the participation constraint with a small, or even a negative, net payment $t - \gamma c(q)$. However, the minimum income constraint puts a lower bound on that. In the first-best contract the in-kind compensation βq is larger and the net payment smaller, the smaller the cost parameter γ. Hence, under in-house production the minimum income constraint will bind for small values of γ, and be slack for large values of γ. In the next proposition we refer to a critical threshold value $\hat{\gamma}$ defined by:

$$\beta \tilde{q}(\hat{\gamma}) + M = U. \tag{14}$$

Since $\tilde{q}$ is a strictly decreasing function mapping $\Re^{++}$ onto itself, (14) defines a unique $\hat{\gamma}$ for any $M < U$ and $\beta > 0$.

Proposition 3 *For each $\beta \in \Re^{+}$, $M \in [-\infty, U]$, and $\gamma \in [\underline{\gamma}, \overline{\gamma}]$,*

1. *if $\gamma \geq (1+\beta)\hat{\gamma}(\beta, M)$, reservation constraint (12) is the only binding constraint;*

2. *if $\hat{\gamma}(\beta, M) < \gamma < (1+\beta)\hat{\gamma}(\beta, M)$, reservation constraint (12) and minimum income constraint (13) are both binding;*

3. *if $\gamma \leq \hat{\gamma}(\beta, M)$, minimum income constraint (13) is the only binding constraint.*

Under in-house production the optimal contracts for the agent are correspondingly the following:

1. *if only reservation constraint (12) binds,*

$$\begin{aligned}[q^i(\gamma), t^i(\gamma)] &= [q^*(\gamma), t^*(\gamma)] \\ &= \left[\tilde{q}\left(\frac{\gamma}{1+\beta}\right), \gamma c\left(\tilde{q}\left(\frac{\gamma}{1+\beta}\right)\right) + U - \beta \tilde{q}\left(\frac{\gamma}{1+\beta}\right)\right];\end{aligned}$$

2. if reservation constraint (12) and minimum income constraint (13) both bind,

$$[q^i(\gamma), t^i(\gamma)] = \left[\frac{U-M}{\beta}, \gamma c\left(\frac{U-M}{\beta}\right) + M\right];$$

3. if only minimum income constraint (13) binds,

$$[q^i(\gamma), t^i(\gamma)] = [\tilde{q}(\gamma), \gamma c(\tilde{q}(\gamma)) + M].$$

Under in-house production the principal would like to extract surplus from the agent by using in-kind compensation, and to implement first-best production, $\tilde{q}\left(\frac{\gamma}{1+\beta}\right)$. When γ is larger than $(1+\beta)\hat{\gamma}(\beta, M)$, the in-kind compensation $\beta\tilde{q}\left(\frac{\gamma}{1+\beta}\right)$ is small, and the monetary compensation is sufficient to meet the minimum income requirement. Leaving no rent to the agent, the principal implements the first-best production level.

As γ becomes smaller than $(1+\beta)\hat{\gamma}(\beta, M)$, the net first-best monetary compensation drops below the minimum payment M, so the minimum income constraint becomes binding. The principal's profit is $q - \gamma c(q) - M$, which is maximized at $\tilde{q}(\gamma)$. When the cost is small enough ($\gamma \leq \hat{\gamma}(\beta, M)$), the quantity $\tilde{q}(\gamma)$ is large enough to satisfy the agent's reservation utility constraint. Hence, for $\gamma \leq \hat{\gamma}(\beta, M)$ only the minimum income constraint binds. The principal is unable to capture any of the agent's experience benefit, so implements first-best production corresponding to $\beta = 0$. In this case, the agent obtains *experience rents.*

However, for medium values of γ, the principal must produce more than $\tilde{q}(\gamma)$ to meet the reservation utility constraint. For γ between $\hat{\gamma}(\beta, M)$ and $(1+\beta)\hat{\gamma}(\beta, M)$, production quantity is constant and satisfies the reservation utility and the minimum income constraints.

Figure 1 illustrates the case where both thresholds, $\hat{\gamma}(\beta, M)$ and $(1+\beta)\hat{\gamma}(\beta, M)$, are in the interval $[\underline{\gamma}, \overline{\gamma}]$, by exhibiting the optimal quantity as a function of $\gamma \in [0.15, 0.5]$ for $U = 2$, $M = 1$, $\beta = 0.3$, and $c(q) = q^2/2$. When the cost parameter is outside of the interval bounded by the thresholds, the optimal quantities are decreasing, corresponding to the case of binding minimum income and reservation utility constraints. For medium values of the cost parameter, both constraints bind, and the optimal quantity and transfer remain constant. The threshold $\hat{\gamma}(\beta, M)$ is at the first kink in the q^i-curve.

5.2 Expected profit and expected rent

When choosing between in-house production and outsourcing, the principal does not yet know the value of γ, so she considers the expected profit. By

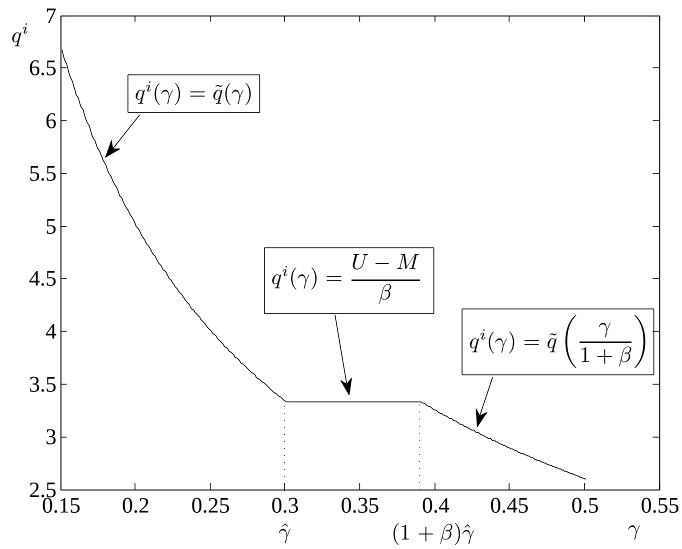

Figure 1: q^i as a function of $\gamma \in [0.15, 0.5]$ for $U = 2$, $M = 1$, $\beta = 0.3$, and $c(q) = q^2/2$.

Proposition 3, the expected profit is:

$$
\begin{aligned}
(15) \qquad \pi^i(\beta, M) = & \int_{\underline{\gamma}}^{\hat{\gamma}(\beta,M)} [\tilde{q}(\gamma) - \gamma c(\tilde{q}(\gamma)) - M]\, f(\gamma) d\gamma \\
& + \int_{\hat{\gamma}(\beta,M)}^{(1+\beta)\hat{\gamma}(\beta,M)} [(1+\beta)\tilde{q}(\hat{\gamma}(\beta, M)) - \gamma c\left(\tilde{q}(\hat{\gamma}(\beta, M))\right) - U]\, f(\gamma) d\gamma \\
& + \int_{(1+\beta)\hat{\gamma}(\beta,M)}^{\overline{\gamma}} \left[(1+\beta)\tilde{q}\left(\frac{\gamma}{1+\beta}\right) - \gamma c\left(\tilde{q}\left(\frac{\gamma}{1+\beta}\right)\right) - U\right] f(\gamma) d\gamma.
\end{aligned}
$$

Because $f(\gamma) = 0$ for any $\gamma \notin [\underline{\gamma}, \bar{\gamma}]$, we do not have to consider thresholds that are not in the interval $[\underline{\gamma}, \bar{\gamma}]$. The agent obtains experience rent if and only if $\gamma < \hat{\gamma}(\beta, M)$, so his expected rent is:

$$
(16) \qquad R^i(\beta, M) \;=\; \int_{\underline{\gamma}}^{\hat{\gamma}(\beta,M)} [\beta\tilde{q}(\gamma) + M - U] f(\gamma) d\gamma.
$$

We now derive properties of the principal's expected profit and the agent's expected rent for different regions of the parameter space defined by β and M. Three regions can be distinguished. First if M is small enough, then

$(1+\beta)\hat{\gamma}(\beta, M) < \underline{\gamma}$, which is equivalent to[13]

$$M < U - \beta\tilde{q}\left(\frac{\underline{\gamma}}{1+\beta}\right) \equiv \underline{m}(\beta). \tag{17}$$

By contrast, for M very large, $\hat{\gamma}(\beta, M) > \bar{\gamma}$ which happens if

$$M > U - \beta\tilde{q}(\bar{\gamma}) \equiv \overline{m}(\beta). \tag{18}$$

Finally, to describe the region for which the agent earns a strictly positive rent, we also identify values of M such that $\underline{\gamma} < \hat{\gamma}(\beta, M)$, or

$$M > U - \beta\tilde{q}(\underline{\gamma}) \equiv \widetilde{m}(\beta). \tag{19}$$

Each threshold takes the value U at $\beta = 0$. Furthermore, $\underline{m}(\beta) < \widetilde{m}(\beta) < \overline{m}(\beta)$ for all $\beta > 0$, and the three thresholds are strictly decreasing in β.

Corollary 2 *For any $\beta > 0$,*

- $\pi^i(\beta, M) = \pi^*(\beta)$ *if and only if* $M \leq \underline{m}(\beta)$ *(minimum income constraint (13) is slack for all* γ*).*
- $R^i(\beta, M) > 0$ *if and only if* $M > \widetilde{m}(\beta)$ *(reservation utility constraint (12) is slack for some* γ*).*
- $R^i(\beta, M) = \int_{\underline{\gamma}}^{\overline{\gamma}} \beta\tilde{q}(\gamma)f(\gamma)d\gamma + M - U > 0$ *if and only if* $M \geq \overline{m}(\beta)$ *(reservation utility constraint (12) is slack for all* γ*).*

Figure 2 depicts the functions $\underline{m}$, $\tilde{m}$, and $\overline{m}$ for the case where $[\underline{\gamma}, \overline{\gamma}] = [0.15, 0.5]$, $U = 2$, and $c(q) = q^2/2$.

The principal extracts more surplus when M is small. When the value of M is so low that it lies below the graph of $\underline{m}(\beta)$, the minimum income constraint is irrelevant, and the principal achieves the first best. Symmetrically, if the value of M is so high that it lies above the graph of $\overline{m}(\beta)$, the reservation utility constraint is irrelevant. The principal never achieves the first best, and the agent's experience benefit cannot be extracted. For medium values of M, those between $\underline{m}(\beta)$ and $\overline{m}(\beta)$, there are always some values of γ for which both the minimum income constraint and the reservation utility constraint bind. There may also be values of γ for which only one of them binds. The agent receives rent only if M is above $\tilde{m}(\beta)$, so that the reservation utility constraint is slack for some values of γ.

[13] The three following equivalence relations are formally established in the proof of Corollary 2 below.

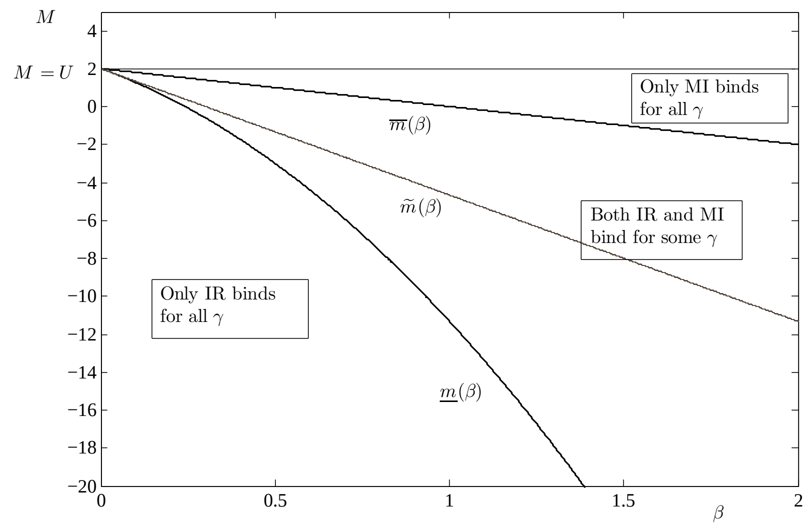

Figure 2: $\underline{m}(\beta)$, $\tilde{m}(\beta)$, and $\overline{m}(\beta)$ for $c(q) = q^2/2$, $U = 2$, $\underline{\gamma} = 0.15$ and $\bar{\gamma} = 0.5$. IR: participation constraint. MI: minimum income constraint.

5.3 Comparative statics

Given the cost parameter distribution, how do the principal's expected profit and the agent's expected rent change with respect to the minimum income M, and the marginal benefit β? We show that the principal's expected profit decreases in the minimum income M, whereas the internal agent benefits from an increase in minimum income M. Nevertheless, these monotonicities are not always strict.

Corollary 3 *For a given β and a given cost distribution F:*

- $\dfrac{\partial \pi^i(\beta, M)}{\partial M} \leq 0$, *with a strict inequality if and only if $M > \underline{m}(\beta)$.*
- $\dfrac{\partial R^i(\beta, M)}{\partial M} \geq 0$ *with a strict inequality if and only if $M > \widetilde{m}(\beta)$.*

Turning now to β, we first observe that a contract feasible for a given β is also feasible for a higher β. The principal cannot become worse off when β increases. Nevertheless, Proposition 3 identifies conditions where the principal cannot benefit from an increase in β.

Corollary 4 *For a given M and a given cost distribution F:*

- $\dfrac{\partial \pi^i(\beta, M)}{\partial \beta} \geq 0$, *with a strict inequality if and only if $M < \overline{m}(\beta)$.*

Furthermore $\pi^i(\beta, M)$ is first best, $\pi^i(\beta, M) = \pi^*(\beta)$, and therefore convex in β if $M < \underline{m}(\beta)$.

- $\dfrac{\partial R^i(\beta, M)}{\partial \beta} \geq 0$*, with a strict inequality if and only if* $M > \widetilde{m}(\beta)$.

The principal's expected profit is first best if the value of M is so small that the minimum income constraint never binds. In this case, the expected profit is convex in β. At the other extreme, if the minimum income constraint prevents the principal from extracting any of the agent's benefit, an increase in β has no effect on expected profit. Finally, an increase in β strictly benefits the internal agent as long as he earns some rent.

6 Principal's choice between outsourcing and in-house production

We now study the principal's choice between outsourcing and in-house production. This decision is made before the realization of the cost parameter γ. We first focus on how changes in the minimum payment M affects the principal's choice. If the agent faced no liquidity constraint, $M = -\infty$, the principal would always prefer in-house production because the agent would obtain private information only under outsourcing. The first proposition is a direct consequence of our previous results.

Proposition 4 *There exists $\beta_U > 0$ such that:*

- *if $\beta \leq \beta_U$, the principal strictly prefers in-house production to outsourcing for all $M \leq U$;*
- *if $\beta > \beta_U$, there is a minimum income threshold $\widehat{M}(\beta) \in (\underline{m}(\beta), U)$ such that the principal prefers in-house production to outsourcing if $M < \widehat{M}(\beta)$, and* vice versa *if $M > \widehat{M}(\beta)$.*

When M is small, experience rent is low and there is little or no distortion away from the first best under in-house production, so the principal prefers in-house production. Conversely, when M is large, the agent's experience benefit and experience rent are high, and there are large distortions under in-house production, so the principal prefers outsourcing.

Interestingly, Proposition 4 implies that when β is small enough ($\beta < \beta_U$), in-house production dominates outsourcing even as M tends to U. This is explained as follows. For M close to U the minimum income constraint always binds, and the quantity under in-house production is always below the first best. However, when β is small the difference between first-best output and optimal output under in-house production, $q^*(\gamma) - q^i(\gamma)$, is small; moreover, the difference between the corresponding transfers, $U - \beta q^*(\gamma)$ in the first-best contract, and M under in-house production, is also small. The profit under in-house production is therefore close to the first-best profit, and outsourcing is dominated by in-house production.

By contrast, for any minimum payment $M \leq U$ there always exists a set of values of β such that the principal prefers in-house production, and a set of values of β for which the opposite is true, as stated in the following proposition.

Proposition 5 *Let $M \leq U$. Consider the difference between profits under in-house production and outsourcing, $\pi^i(\beta, M) - \pi^e(\beta)$:*

- *for β sufficiently close to zero, $\pi^i(\beta, M) - \pi^e(\beta) > 0$, and if $M < U$ it is increasing in β;*
- *for β sufficiently large, $\pi^i(\beta, M) - \pi^e(\beta) < 0$ and it is strictly decreasing in β.*

This proposition says that for any minimum payment M, there is an interval of small β at which in-house production is strictly more profitable than outsourcing, and there is an interval of large β at which the opposite is true. Under in-house production, and for a given minimum payment M, experience rent is zero when β is small, whereas the experience benefit accrues entirely to the agent when β is large. The principal therefore does not benefit from an increase in β when β is sufficiently large. By contrast, under outsourcing, the principal always leaves an information rent so that the profit is below the first best even when β is small; however, since the principal extracts any additional experience benefit, her profit is always increasing in β.[14]

The results in Proposition 5 imply that in-house production is not used when human capital is highly nonspecific (large β). However, if human capital is mostly firm-specific (β close to zero), in-house production is preferred. These empirical implications are similar to other theories of vertical integration (Williamson, 1975, and Grossman and Hart, 1986). Our model, however, allows us to enrich this prediction in two important ways.

First, from Proposition 5, a decrease in human capital specificity may *increase* the profit gap between in-house production and outsourcing when asset specificity is high. The in-house profit is first best for small β, and it increases faster than the second-best profit under outsourcing as β increases.

Second, the degree of human capital specificity *interacts* with the minimum income constraint to determine the optimality of in-house production or outsourcing. According to Proposition 4, an increase in M can lead the

[14]We do not know if this trade-off must lead to a unique cutoff in β at which the principal changes his preferences from in-house production to outsourcing. All the examples we have constructed do support a unique cutoff, however.

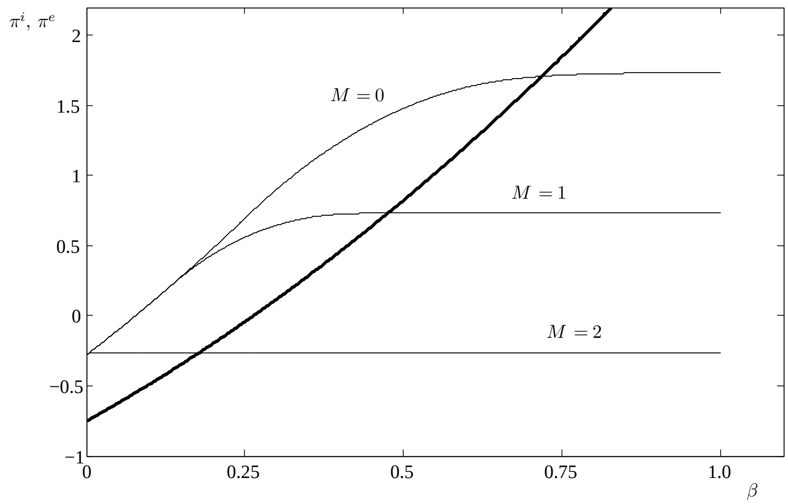

Figure 3: $\pi^e(\beta)$ (thick curve), and $\pi^i(\beta, M)$ as a function of β for $U = 2$, $c(q) = q^2/2$, $\gamma \in [0.15, 0.5]$, and $M = 0$ (upper thin curve), $M = 1$ (middle thin curve), and $M = 2$ (lower thin curve)

principal to switch from in-house production to outsourcing, but not the other way around. To see this, note that for $\beta < \beta_U$, in-house production is more profitable, while for $\beta > \beta_U$, the threshold value $\widehat{M}(\beta)$ is uniquely defined. Once $M > \widehat{M}(\beta)$, outsourcing is always optimal for that β. Hence, a tighter minimum income constraint narrows the range of β for which in-house production is optimal. Propositions 4 and 5 imply that a more relaxed minimum income constraint (a lower M) will likely result in vertical integration.

Figure 3 illustrates this by showing the expected profit under outsourcing (the thick curve), as well as the expected profit under in-house production for three different values of M, as a function of β, using the same parameter values as in Figure 2. For the values of M below U (in the example, $M = 0$ and $M = 1$), the profit under in-house production is increasing in β when β is small, and constant when β is large. For $M = U = 2$, the profit under in-house production is a constant. In all cases, in-house production dominates outsourcing when β is small, while the opposite is true when β is large. The threshold value for β is larger, the smaller the value of M.

7 Social Welfare

In this section we ask whether the principal's equilibrium choices lead to maximum social surplus. For given values of β and γ, soical surplus is $(1+\beta)q-c(q)$, which is divided between the principal and the agent. We therefore calculate expected social surplus by the sum of the principal's expected profit and the agent's expected rent. From (8), (9), (15), and (16), and after simplification, expected social surplus under outsourcing equals

$$
\begin{aligned}
(20) \qquad & S^e(\beta) = \pi^e(\beta) + R^e(\beta) \\
= \; & \int_{\underline{\gamma}}^{\overline{\gamma}} \left[(1+\beta)\tilde{q}\left(\frac{\gamma + h(\gamma)}{1+\beta}\right) - \gamma c\left(\tilde{q}\left(\frac{\gamma+h(\gamma)}{1+\beta}\right)\right)\right] f(\gamma)d\gamma - U,
\end{aligned}
$$

and under in-house production it is

$$
\begin{aligned}
(21) \qquad & S^i(\beta, M) = \pi^i(\beta, M) + R^i(\beta, M) \\
= \; & \int_{\underline{\gamma}}^{\hat{\gamma}(\beta,M)} \left[(1+\beta)\tilde{q}(\gamma) - \gamma c(\tilde{q}(\gamma))\right] f(\gamma)d\gamma \\
& + \int_{\hat{\gamma}(\beta,M)}^{(1+\beta)\hat{\gamma}(\beta,M)} \left[(1+\beta)\tilde{q}(\hat{\gamma}(\beta,M)) - \gamma c\left(\tilde{q}(\hat{\gamma}(\beta,M))\right)\right] f(\gamma)d\gamma \\
& + \int_{(1+\beta)\hat{\gamma}(\beta,M)}^{\overline{\gamma}} \left[(1+\beta)\tilde{q}\left(\frac{\gamma}{1+\beta}\right) - \gamma c\left(\tilde{q}\left(\frac{\gamma}{1+\beta}\right)\right)\right] f(\gamma)d\gamma - U.
\end{aligned}
$$

From earlier results, neither surplus expression above is typically first best. The principal distorts quantities in response to her inability to extract the full surplus. But there is also a second potential source of inefficiency: by taking only her own profits into account, the principal may not choose the socially efficient organizational form. Does the principal select the organizational form that yields the higher expected social surplus?

We begin by building on results in the preceding sections to derive comparative statics for the respective social surpluses. First, for the surplus under in-house production, we obtain:

Lemma 1

- $\frac{\partial S^i(\beta,M)}{\partial \beta} > 0$ *for all* $M \leq U$ *and* $\beta \geq 0$. *Furthermore,* S^i *is strictly convex in* β *if* $M \leq \underline{m}(\beta)$ *(only the reservation utility constraint (12) binds for each* $\gamma \in [\underline{\gamma}, \overline{\gamma}]$*), and* S^i *is linear in* β *if* $M \geq \overline{m}(\beta)$ *(only the minimum income constraint (13) binds for each* $\gamma \in [\underline{\gamma}, \overline{\gamma}]$*).*

- $\frac{\partial S^i(\beta,M)}{\partial M} \leq 0$ *for all* $M \leq U$*, with a strict inequality if and only if* $M \in (\underline{m}(\beta), \overline{m}(\beta))$ *(both the minimum income constraint (13) and the reservation utility constraint (12) bind for some* $\gamma \in [\underline{\gamma}, \overline{\gamma}]$*).*

Under in-house production, social surplus is always strictly increasing in β. This is in contrast to the principal's profit under in-house production, which is unaffected by changes in the benefit parameter β when it is large enough. Furthermore, while the principal's profit decreases in M, as long as the minimum income constraint binds for some γ, the social surplus is affected by an increase in M only if this affects the quantity chosen by the principal. Hence, social surplus is constant in M if the minimum income constraint binds for all γ ($M \geq \bar{m}(\beta)$).

For outsourcing, Propositions 1 and 2 along with Corollary 1 imply:

Lemma 2 *Under outsourcing, the expected social surplus is lower than the first best, $S^e(\beta) < S^*(\beta)$ for all $\beta \geq 0$, and it is strictly increasing in the agent's benefit parameter: $\frac{dS^e(\beta)}{d\beta} > 0$ for all $\beta \geq 0$.*

The principal implements the first best under in-house production when the experience benefit parameter β is small. Hence, in-house production then dominates outsourcing from a social point of view. Since the expected social surplus is always increasing in β, could it be that in-house production dominates outsourcing for all values of β? The next proposition shows that outsourcing dominates in-house production when β is large enough.

Proposition 6 *For any $M \leq U$:*

- *when β is sufficiently close to zero, in-house production is socially preferable to outsourcing;*
- *when β is sufficiently large, outsourcing is socially preferable to in-house production.*

The social ranking of in-house production and outsourcing sometimes may be aligned with the principal's ranking. This is obviously true if β is small enough because the principal can capture the entire social surplus by in-house production. As β increases, the principal may no longer capture the entire social surplus by first-best quantities. For sufficiently large values of β, the principal's profit under in-house production is unaffected by an increase in the agent's marginal private benefit. In other words, the principal does not adjust production, although it would be socially desirable to do so. However, the principal then chooses to switch to outsourcing so as to extract more experience rent from the agent. Proposition 6 shows that this yields a higher expected social surplus than in-house production.

Nevertheless, the principal's organizational choice will differ from the social optimum because she does not internalize her impact on the agent. Consider a combination of β and M at which in-house production and outsourcing are equally profitable. Then a slight increase in M makes in-house production less profitable. Hence, if in this parameter configuration the agent's expected rent is higher with in-house production than with outsourcing, the principal makes an excessive use of outsourcing. The reverse arises if the agent earns a higher expected rent under outsourcing for such parameter combinations.

A numerical example illustrates the divergence between the the principal's organizational choice and the social optimum. Figure 4 shows, for $c(q) = \frac{1}{2}q^2$,

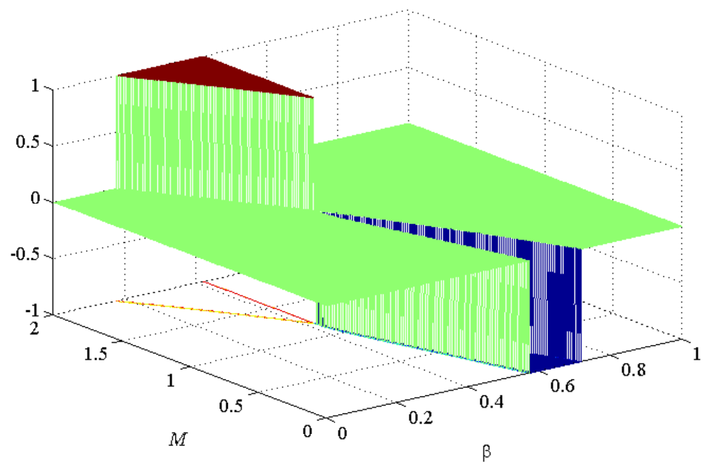

Figure 4: The principal chooses outsourcing although in-house production dominates socially when the dummy variable on the vertical axis takes the value 1; she chooses in-house production although outsourcing dominates socially when it takes the value -1.

$U = 2$, $\underline{\gamma} = 0.15$ and $\overline{\gamma} = 0.5$, whether the principal chooses the organizational form with the highest expected surplus, as a function of β and M. If the variable on the vertical axis takes a value 0, the principal's organizational choice is socially optimal; if it is 1 the principal chooses outsourcing while in-house production is socially optimal, and the opposite is true if the variable on the vertical axis is -1. This numerical example shows that the principal may choose an organizational mode, either in-house production or outsourcing, when it is socially inefficient.

In the numerical example there is too little outsourcing for small values of M. This result holds generally under fairly mild conditions, as the next proposition shows.

Proposition 7 *Assume that* $\dfrac{c'(q)}{c''(q)}$ *tends to infinity as* q *goes to infinity. For* M *sufficiently low, whenever outsourcing is chosen by the principal it is socially optimal, but there exist values of the parameter* β *at which the principal chooses in-house production while outsourcing is socially optimal.*

A low M makes in-house production more profitable for the principal and socially desirable than outsourcing unless β is very large. What drives the result is that for such very large β, and for a very convex cost function, the agent's rent is higher under outsourcing.

Figure 5 illustrates a case where the principal switches too late to outsourcing as β increases: in the figure, the upper curve is the difference between the principal's expected profit under in-house production and outsourc-

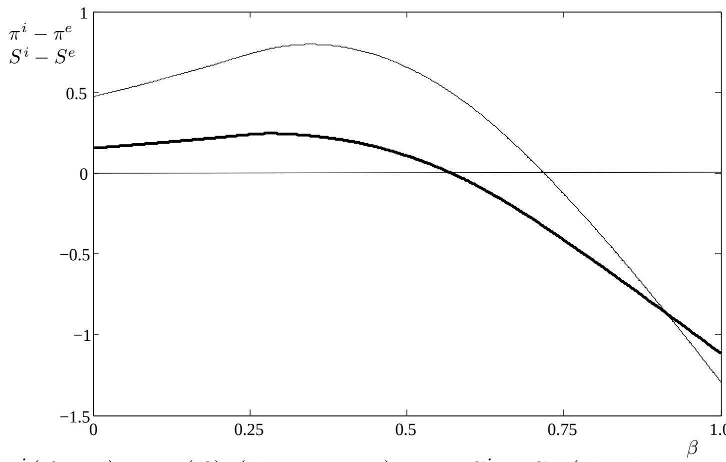

Figure 5: $\pi^i(\beta, M) - \pi^e(\beta)$ (thin curve) and $S^i - S^e$ (thick curve) as a function of β for $U = 2$, $M = 0$, $c(q) = q^2/2$, and $\gamma \in [0.15, 0.5]$

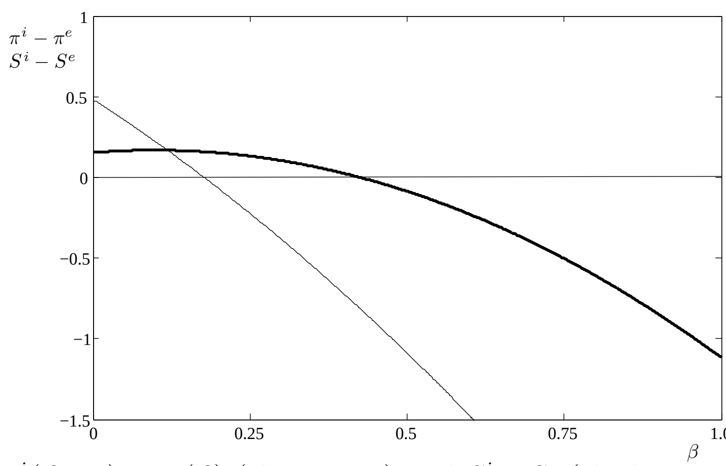

Figure 6: $\pi^i(\beta, M) - \pi^e(\beta)$ (thin curve) and $S^i - S^e$ (thick curve) as a function of β for $U = 2$, $M = 2$, $c(q) = q^2/2$, and $\gamma \in [0.15, 0.5]$

ing, $\pi^i(\beta, M) - \pi^e(\beta)$, whereas the lower curve is the difference between the expected social surpluses, $S^i - S^e$. When $M = 0$, the principal is able to extract the agent's surplus under in-house production for fairly large values of β; however, she fails to internalize the agent's rent under outsourcing, and sometimes chooses in-house production over outsourcing, but that choice is socially inefficient.

Next, consider Figure 6, which shows the same differences for $M = U$, so that the minimum income constraint is binding for all cost parameter realizations. Here, the principal fails to internalize the effect of an increase in β on the agent's rent under in-house production, and sometimes chooses outsourcing over in-house production but the choice is socially suboptimal.

8 Concluding remarks

For such reasons as legal requirements, accounting and auditing, and internal communication codes and systems, information asymmetries may be less within than between firms. In this paper we have shown that a firm may nonetheless forgo the information advantage of in-house production and resort to outsourcing. We have shown how an independent contractor's better access to other sources of revenues can actually benefit the firm. A relaxed liquidity constraint enables the firm to extract more experience benefits which an agent earns from production.

Our theory predicts that, for a given level of the employee's income need (M), the principal chooses outsourcing when experience benefits are large: although the principal leaves information rent to the agent under outsourcing, she may fully extract the agent's experience benefits. When these benefits are small, benefit extraction becomes less of a concern, and the principal chooses in-house production instead. Our prediction that a higher degree of human capital specificity (low β) should be associated with more in-house production, is consistent with other theories on the determinants of vertical integration, such as those in the transactions cost and the property rights literatures. Our theory complements these theories by proposing another reason for why human capital specificity may matter. It also enriches this theory, by suggesting that it is human capital *together with* liquidity constraints that determine a firm's choice of production mode.

In the model we focus on hidden information, and assume away hidden action. We also assume that the project is indivisible. Relaxing these assumptions would be useful. One can also extend our model to the case where the principal needs several agents. It would be interesting to see whether the principal sometimes resorts to a mixed solution, with some in-house production and some outsourcing, as firms sometimes do in practice.

Our aim here has been to point out and analyze a trade-off between experience rent under in-house production and information rent under outsourced production. In our model experience benefits and credit constraints are exogenous. Future research to endogenize experience benefits and credit constraints, as well as to consider general equilibrium aspects may well be fruitful.

Appendix

Proof of Corollary 1

From the Envelope Theorem

$$\frac{d\pi^e(\beta)}{d\beta} = \int_{\underline{\gamma}}^{\overline{\gamma}} q^e(\gamma) f(\gamma) d\gamma > 0,$$

which says that the expected profit is increasing in β. Because $q^e(\gamma) = \tilde{q}\left(\frac{\gamma+h(\gamma)}{1+\beta}\right)$, q^e is increasing in β. Therefore, as β increases, the derivative of π^e increases, and the convexity of π^e follows. The agent's expected rent is increasing in β because the optimal quantity q^e is increasing in β, and the cost function c increasing. *Q.E.D.*

Proof of Proposition 3

Consider a relaxed program which omits the minimum income constraint (13). Then the reservation constraint (12) must bind, and we have the first best:

$$q = \tilde{q}\left(\frac{\gamma}{1+\beta}\right) \qquad \text{and} \qquad t = \gamma c\left(\tilde{q}\left(\frac{\gamma}{1+\beta}\right)\right) + U - \beta\tilde{q}\left(\frac{\gamma}{1+\beta}\right).$$

The omitted minimum income constraint (13) is satisfied if and only if

$$t - \gamma c\left(\tilde{q}\left(\frac{\gamma}{1+\beta}\right)\right) = U - \beta\tilde{q}\left(\frac{\gamma}{1+\beta}\right) \geq M.$$

Since $\tilde{q}$ is strictly decreasing, this is equivalent to $\gamma \geq (1+\beta)\hat{\gamma}(\beta, M)$.

Consider a relaxed program which omits the reservation utility constraint (12). Then the minimum income constraint (13) must bind, and the solution is:

$$q = \tilde{q}(\gamma) \qquad \text{and} \qquad t = \gamma c(\tilde{q}(\gamma)) + M.$$

The omitted reservation utility (12) constraint is satisfied if and only if

$$\beta\tilde{q}(\gamma)) + t - \gamma c(\tilde{q}(\gamma)) = \beta\tilde{q}(\gamma)) + M \geq U.$$

Since $\tilde{q}$ is strictly decreasing, this is equivalent to $\gamma \leq \hat{\gamma}(\beta, M)$.

Finally, let $\hat{\gamma}(\beta, M) < \gamma < (1+\beta)\hat{\gamma}(\beta, M)$. From the preceding arguments, both reservation constraint (12) and minimum income constraint (13) must bind. These two equations uniquely determine the solution:

$$q = \frac{U-M}{\beta} \qquad \text{and} \qquad t = \gamma c\left(\frac{U-M}{\beta}\right) + M.$$

Q.E.D.

Proof of Corollary 2

From Proposition 3, the reservation constraint (12) is the only binding constraint for all $\gamma \in [\underline{\gamma}, \bar{\gamma}]$ if and only if $(1+\beta)\hat{\gamma}(\beta, M) \leq \underline{\gamma}$. Since $\tilde{q}$ is strictly decreasing, this is equivalent to

$$\tilde{q}(\hat{\gamma}(\beta, M)) \geq \tilde{q}\left(\frac{\underline{\gamma}}{1+\beta}\right). \tag{22}$$

From the definition of $\hat{\gamma}(\beta, M)$ this is equivalent to

$$\frac{U-M}{\beta} \geq \tilde{q}\left(\frac{\underline{\gamma}}{1+\beta}\right) \quad \Leftrightarrow \quad M \leq U - \beta\tilde{q}\left(\frac{\underline{\gamma}}{1+\beta}\right) = \underline{m}(\beta). \tag{23}$$

The minimum income constraint (13) is the only binding constraint for all $\gamma \in [\underline{\gamma}, \bar{\gamma}]$ if and only if

$$\bar{\gamma} \leq \hat{\gamma}(\beta, M) \quad \Leftrightarrow \quad \frac{U-M}{\beta} \leq \tilde{q}(\bar{\gamma}) \quad \Leftrightarrow \quad M \geq U - \beta\tilde{q}(\bar{\gamma}) = \overline{m}(\beta). \tag{24}$$

The reservation constraint (12) is slack for some $\gamma \in [\underline{\gamma}, \bar{\gamma}]$ if and only if

$$\underline{\gamma} < \hat{\gamma}(\beta, M) \quad \Leftrightarrow \quad \frac{U-M}{\beta} < \tilde{q}(\underline{\gamma}) \quad \Leftrightarrow \quad M > U - \beta\tilde{q}(\underline{\gamma}) = \widetilde{m}(\beta). \tag{25}$$

Q.E.D.

Proof of Corollary 3

Consider the maximization of (11) subject to (12) and (13) for each γ. Let $\bar{\pi}^i$ denote the optimized value at γ. The Lagrangean is

$$\mathcal{L}(q, t, \lambda, \mu, \gamma, U, M, \beta) = q - t + \lambda[\beta q + t - \gamma c(q) - U] + \mu[t - \gamma c(q) - M].$$

By the Envelope Theorem

$$\frac{\partial \bar{\pi}^i}{\partial M}(\gamma, \cdot) \quad = \quad \frac{\partial \mathcal{L}}{\partial M}(\gamma, \cdot) = -\mu(\gamma, \cdot). \tag{26}$$

Whether these multipliers λ and μ are strictly positive or zero are determined by whether the corresponding constraints are binding or slack. Proposition 3, and Corollary 2 state the relevant conditions.

From (26), the principal's expected profit is decreasing in M. It is strictly decreasing whenever the multiplier is strictly positive for some values of γ. This is the case when $M > \underline{m}(\beta)$.

The agent's rent is

$$R^i(\beta, M) = \int_{\underline{\gamma}}^{\hat{\gamma}} [\beta\tilde{q}(\gamma) + M - U] f(\gamma) d\gamma. \tag{27}$$

From (14), $\hat{\gamma}$ is increasing in M. Therefore, the expression in (27) is increasing in M. It is strictly increasing if $\hat{\gamma} > \underline{\gamma}$. This is the case when $M > \widetilde{m}(\beta)$. *Q.E.D.*

Proof of Corollary 4

Use the Lagrangean in the proof of Corollary 3. By the Envelope Theorem

$$\frac{\partial \bar{\pi}^i}{\partial \beta}(\gamma, \cdot) = \frac{\partial \mathcal{L}}{\partial \beta}(\gamma, \cdot) = \lambda(\gamma, \cdot) q,$$

which says that the principal's expected profit is increasing in β. This is strictly positive if and only if $\lambda > 0$ for some γ, which is the case when $M < \overline{m}(\beta)$.

Next, when $M < \underline{m}(\beta)$, the minimum income constraint (13) is slack for all γ so that the first best is achieved, so the principal's expected profit is convex in β.

Finally, from (27), the agent's expected rent is increasing in β. It is strictly increasing if $\hat{\gamma} > \underline{\gamma}$. This is the case when $M > \widetilde{m}(\beta)$. *Q.E.D.*

Proof of Proposition 4

Clearly $U \geq \overline{m}(\beta)$ for all $\beta \geq 0$, and Corollary 2 implies that $\pi^i(\beta, M)_{|M=U} = \pi^*(\beta)$ if and only if $\beta = 0$, while Corollary 4 implies that $\frac{\partial \pi^i(\beta, M)}{\partial \beta}_{|M=U} = 0$. Since $\pi^e(\beta)$ is strictly increasing in β, there is $\beta_U > 0$ such that $\pi^i(\beta, U) > \pi^e(\beta)$ if and only if $\beta < \beta_U$, while $\pi^i(\beta, U) < \pi^e(\beta)$ if and only if $\beta > \beta_U$.

Consider $\beta < \beta_U$. Since the profit from outsourcing $\pi^e(\beta)$ is independent of M, while $\pi^i(\beta, M)$ is decreasing in M, $\beta < \beta_U$ implies that $\pi^i(\beta, M) > \pi^e(\beta)$ for all $M \leq U$ for $\beta < \beta_U$.

Consider now $\beta > \beta_U$. Then, $\pi^i(\beta, M)_{|M=U} < \pi^e(\beta)$. Together with Corollary 2 and Corollary 4, and the continuity of $\pi^i(\beta, M)$, this implies that there exists $\widehat{M}(\beta) < U$ such that $\pi^i(\beta, M) > \pi^e(\beta)$ if and only if $M < \widehat{M}(\beta)$, and $\pi^i(\beta, M) < \pi^e(\beta)$ if and only if $M > \widehat{M}(\beta)$.

For (β, M) such that $\overline{m}(\beta) < M$, π^i is strictly decreasing in M and independent of β, whereas π^e is strictly increasing in β; this implies that for these values of (β, M), $\widehat{M}(\beta)$ is strictly decreasing in β.

Finally, since $\pi^i(\beta, M) = \pi^*$ for $M \leq \underline{m}(\beta)$, it must be that $\widehat{M}(\beta) > \underline{m}(\beta)$.
Q.E.D.

Proof of Proposition 5

First recall that $\underline{m}$ and $\overline{m}$ are strictly decreasing functions of β, and that $\underline{m}(0) = \overline{m}(0) = U$. Then the proposition follows from Corollary 1 and Corollary 4, which say that the expected profit under outsourcing is second-best, and increasing in β, whereas the expected profit under in-house production is first best for $M \leq \underline{m}(\beta)$, and independent of β for $M > \overline{m}(\beta)$. *Q.E.D.*

Proof of Lemma 1

Because $\overline{m}(\beta) > \widetilde{m}(\beta)$, any (β, M) must satisfy at least one of the following inequalities: $M < \overline{m}(\beta)$, $M > \widetilde{m}(\beta)$. Then Corollary 4 says that either π^i, or R^i, or both must be strictly increasing in β. We conclude that $S^i = \pi^i + R^i$ must be strictly increasing in β.

Next, if $M < \underline{m}(\beta)$, from Corollary 4, $\pi^i(\beta, M) = \pi^*(\beta)$, and from Corollary 2, $R^i(\beta, M) = 0$. Therefore $S^i(\beta, M) = \pi^*(\beta)$ and is strictly convex in β.

Now if $M \geq \overline{m}(\beta)$, from Corollary 4 $\pi^i(\beta, M)$ is constant in β and hence $\frac{\partial S^i}{\partial \beta}(\beta, M) = \frac{\partial R^i}{\partial \beta}(\beta, M)$. Also, if $M \geq \overline{m}(\beta)$, $\hat{\gamma}(\beta, M) \geq \overline{\gamma}$ so that from (16) the value of $R^i(\beta, M)$ is $\int_{\underline{\gamma}}^{\overline{\gamma}} \tilde{q}(\gamma) f(\gamma) d\gamma$. Hence, $\frac{\partial S^i}{\partial \beta}(\beta, M)$ is a constant independent of β.

Finally, to evaluate the derivative of S^i with respect to M, we use (21).

After simplification and by the definition of $\hat{\gamma}$ we have

$$\frac{\partial S^i}{\partial M}(\beta, M) = \int_{\hat{\gamma}(\beta,M)}^{(1+\beta)\hat{\gamma}(\beta,M)} [1+\beta-\gamma c'(\tilde{q}(\hat{\gamma}(\beta,M)))] \cdot \tilde{q}'(\hat{\gamma}(\beta,M)\frac{\partial\hat{\gamma}}{\partial M}(\beta,M)f(\gamma)d\gamma. \tag{28}$$

The function $\hat{\gamma}(\beta, M)$ is increasing in M, while the function $\tilde{q}$ is decreasing. Because $1+\beta-\gamma c'(\tilde{q}(\frac{\gamma}{1+\beta}) = 0$, from the definition of $\tilde{q}$, for any $\gamma \in [\hat{\gamma}(\beta, M), (1+\beta)\hat{\gamma}(\beta, M)]$, the term in the square bracket in (28) is strictly positive. We conclude that $\frac{S^i}{M} \geq 0$, and that the inequality is strict if and only if the lower or upper limit of the integral in (28) resides in the range $(\underline{\gamma}, \overline{\gamma})$, which is guaranteed by $M \in [\underline{m}(\beta), \overline{m}(\beta)]$. *Q.E.D.*

Proof of Lemma 2

From Corollary 1 both π^e and R^e are strictly increasing in β. Hence $\pi^e + R^e$ is strictly increasing. From (3) and (20)

$$\begin{aligned} S^*(\beta) - S^e(\beta) &= \int_{\underline{\gamma}}^{\overline{\gamma}} [(1+\beta)\left[\tilde{q}\left(\frac{\gamma}{1+\beta}\right) - \tilde{q}\left(\frac{\gamma+h(\gamma)}{1+\beta}\right)\right] \\ &\quad -\gamma\left[c\left(\tilde{q}\left(\frac{\gamma}{1+\beta}\right)\right) - c\left(\tilde{q}\left(\frac{\gamma+h(\gamma)}{1+\beta}\right)\right)\right]]f(\gamma)d\gamma, \end{aligned}$$

which is strictly positive since $\tilde{q}\left(\frac{\gamma}{1+\beta}\right)$ maximizes $(1+\beta)q - \gamma c(q)$. *Q.E.D.*

Proof of Proposition 6

$S^i(0, M) \geq \pi^i(0, M) \geq \pi^i(0, U) = \pi^*(0) = S^i(0, U) > S^e(0)$. Therefore, by the continuity of S^i and S^e, for β sufficiently small, $S^i(\beta, M) > S^e(\beta)$. The remainder of the proof consists in showing that for any $M \leq U$, $S^e > S^i$ for β large enough. To do this we study the derivatives of the social surpluses with respect to β.

Differentiating the surplus under outsourcing yields

$$\begin{aligned}
(29) \qquad \frac{dS^e(\beta)}{d\beta} &= \int_{\underline{\gamma}}^{\overline{\gamma}} \tilde{q}\left(\frac{\gamma+h(\gamma)}{1+\beta}\right) f(\gamma)d\gamma \\
&\quad + \int_{\underline{\gamma}}^{\overline{\gamma}} \left[1+\beta-\gamma c'\left(\tilde{q}\left(\frac{\gamma+h(\gamma)}{1+\beta}\right)\right)\right] \cdot \\
&\quad \tilde{q}'\left(\frac{\gamma+h(\gamma)}{1+\beta}\right)\left(-\frac{\gamma+h(\gamma)}{(1+\beta)^2}\right) f(\gamma)d\gamma.
\end{aligned}$$

From the principal's optimization problem under outsourcing we have

$$(30) \quad 1+\beta-\gamma c'\left(\tilde{q}\left(\frac{\gamma+h(\gamma)}{1+\beta}\right)\right) = h(\gamma)c'\left(\tilde{q}\left(\frac{\gamma+h(\gamma)}{1+\beta}\right)\right) > 0.$$

Using this and the fact that $\tilde{q}$ is a decreasing function, (29) implies

$$(31) \qquad \frac{dS^e(\beta)}{d\beta} \geq \int_{\underline{\gamma}}^{\overline{\gamma}} \tilde{q}\left(\frac{\gamma+h(\gamma)}{1+\beta}\right) f(\gamma)d\gamma.$$

Turning now to the surplus under in-house production, for any $M \leq U$, if β is so large that $\overline{m}(\beta) \leq M$, the reservation utility constraint is slack for all $\gamma \in [\underline{\gamma}, \bar{\gamma}]$ (see Corollary 2), and social surplus is a linear function of β with slope

$$(32) \qquad \frac{\partial S^i(\beta, M)}{\partial \beta} = \int_{\underline{\gamma}}^{\overline{\gamma}} \tilde{q}(\gamma) f(\gamma)d\gamma.$$

Hence, for such high values of β, the slope of the social surplus difference $S^e(\beta) - S^i(\beta, M)$ with respect to β is bounded below by

$$(33) \qquad \int_{\underline{\gamma}}^{\overline{\gamma}} \tilde{q}\left(\frac{\gamma+h(\gamma)}{1+\beta}\right) f(\gamma)d\gamma - \int_{\underline{\gamma}}^{\overline{\gamma}} \tilde{q}(\gamma) f(\gamma)d\gamma.$$

The desired result may then be proved by showing that the above expression goes to infinity as β goes to infinity, which we now do.

For all $\gamma \in (\underline{\gamma}, \bar{\gamma})$, $\frac{\gamma+h(\gamma)}{1+\beta}$ tends to zero as β tends to infinity, so that $\tilde{q}\left(\frac{\gamma+h(\gamma)}{1+\beta}\right)$ tends to infinity (since $\tilde{q}(x)$ tends to infinity as x tends to zero). Hence,

$$\int_{\underline{\gamma}}^{\overline{\gamma}} \tilde{q}\left(\frac{\gamma+h(\gamma)}{1+\beta}\right) f(\gamma)d\gamma$$

diverges to infinity as β tends to infinity. *Q.E.D.*

Proof of Proposition 7

We first show that for β large enough the agent's rent is larger under outsourcing than under in-house production for all $M \leq U$. To do this we compare the derivatives. Differentiating the agent's rent under outsourcing (9) yields

$$\frac{dR^e(\beta)}{d\beta} = \int_{\underline{\gamma}}^{\overline{\gamma}} h(\gamma)c'(q^e)\frac{dq^e}{d\beta}f(\gamma)d\gamma, \tag{34}$$

where q^e is defined in equation (7). Using equation (7) and the implicit function theorem we obtain

$$\frac{dq^e}{d\beta} = \frac{1}{(\gamma + h(\gamma))c''(q^e)}. \tag{35}$$

Since q^e tends to infinity as β tends to infinity (recall that $q^e(\gamma) = \tilde{q}\left(\frac{\gamma+h(\gamma)}{1+\beta}\right)$, and see the proof of Proposition 6), the divergence of $\dfrac{c'(q)}{c''(q)}$ as q goes to infinity implies that the derivative of the agent's rent under outsourcing tends to infinity as β tends to infinity.

Next, $R^i(\beta, M)$ is largest when $M = U$. Corollary 2 says that at $M = U$, $R^i(\beta, M)$ is a linear function of β with slope $\int_{\underline{\gamma}}^{\overline{\gamma}} \tilde{q}(\gamma)f(\gamma)d\gamma$. Hence, for β large enough, $R^e(\beta) > R^i(\beta, M)$ for all M.

Now consider the principal's organization choice. Define $\underline{\beta}$ as the value of β for which $\underline{m}(\beta) = M$. Therefore at M, from the definition of $\underline{m}$, $\underline{\beta}$ solves $\underline{\gamma}c'(\frac{U-M}{\underline{\beta}}) = 1 + \underline{\beta}$ (that is, from equations (17) and (2)). As M tends to $-\infty$, $c'(\frac{U-M}{\beta})$ tends to infinity for any $\beta > 0$, so that $\underline{\beta}$ must tend to ∞. For $\beta < \underline{\beta}$, in-house production is preferred by the principal since it yields the first-best profit. Hence for M small, the principal selects outsourcing only for values of β that are so large that $R^e(\beta) > R^i(\beta, M)$, implying that social surplus is higher with outsourcing than in-house production.

Furthermore, the first value of β at which profits are equal (denoted below by $\beta_0(M)$) must exceed $\underline{\beta}$ for all M ($\beta_0(M)$ exists from the intermediate value theorem since profits are continuous). Thus, for M very small, $\beta_0(M)$ is large enough for $R^e(\beta_0(M)) > R^i(\beta_0(M), M)$ to hold. Hence, by continuity, for β slightly less than $\beta_0(M)$, this inequality remains valid whereas profits are nearly equal. This implies that social surplus is higher with outsourcing while the principal selects in-house production. *Q.E.D.*

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