Experience Benefits and Firm Organization*

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Abstract

A principal requires a manager for production. He can use an internal manager, or contracts with an external manger. In each case, the manager obtains experience benefits from production. When the principal uses an internal manager, both parties share cost information. When the principal contracts with an external manager, only the external manager acquires cost information. The internal manager has limited access to the credit market; he has a minimum income constraint. The external manager has adequate access and has no minimum income constraint. The principal faces a tradeoff. Hiring an internal manager eliminates asymmetric information, but extracting experience rent is more difficult due to the minimum income constraint. Hiring an external manager means giving up information rent, but extracting experience rent is feasible. Whether the principal uses an internal or an external manager depends on the tightness of the minimum income constraint and the magnitude of the experience benefit. The principal's optimal choice may not be socially efficient.

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1 Introduction

We present a new theory on how a firm should organize its production activity. A principal must use an agent for production. Should an internal manager, an employee of the firm, be this agent? Or should an external manager, an outside party, be this agent? In other words, should the firm use in-house production, or should it out-source?

The key element in our theory is that a manager acquires benefits from production, in addition to payments received from the principal. We call these *experience benefits.* They can be the manager's higher future returns of human capital in the labor market, gain in reputation, as well as private enjoyment. Even under low-powered pay incentives, employees often take production decisions seriously because they may garner experience benefits in the form of higher future returns in the labor market. Success in a current job will be rewarded in the future, because it enhances human capital. A standard argument in the literature on human capital, starting with Becker (1964), is that employers will attempt to expropriate an employee's experience benefits by paying lower wages.[1] Such attempts may, however, be thwarted by the employee's credit constraints (Becker, 1964, Ritzen and Stern, 1991). In this paper we show that the principal may resort to external production instead.

The second element in our theory is that an internal manager has no access to the credit market, but an external manager has. Neither kind of manager can use experience benefits as collateral. However, production requires a complementary asset, which may be used as collateral. The principal is the owner of this asset when she uses an internal manager.[2] Without any collateral, the internal manager cannot borrow. By contrast, when the principal uses an external manager, the complementary asset belongs to the external manager, who can use it as collateral to borrow. The financing of the asset *per se* is covered by the principal's payment. Hence the principal's ability to extract the manager's experience benefits is enhanced with an external manager, who is not

[1]This point was picked up by Ben-Porath (1967) and Rosen (1972a). For recent analyses of firms' incentives to provide training, see Acemoglu and Pischke (1999), and Kessler and Lülfesmann (2006).

[2]Throughout we define a firm as the collection of assets that are owned by the same set of individuals, together with these owners. This is consistent with the legal definition, "a corporation is a legal person that may own property, but a division or branch of the corporation may not" (Iacobucci and Triantis, 2007, p.518), and with the property rights literature (Grossman and Hart, 1986).

liquidity constrained.

The third element of our theory is information asymmetry. The principal may have better access to information when using an internal manager than an external manager. Laws governing employment and non-employment contractual relationships support this idea. For example, Masten (1988, p.186) quotes the following legal texts:

> '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 [...]).

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, Garicano and Prat (2007). We assume complete cost information in internal contracting, but asymmetric cost information in external contracting.

We analyze a principal-agent model that incorporates the above three elements. The principal first chooses between internal and external production, and then offers a contract to the manager. In either case the manager gets information about production costs. With an external manager, production costs are his private information. With an internal manager production cost information is contractible.

A manager evaluates a contract both in terms of the renumeration from the principal, and the experience benefits. These benefits are increasing in the size of the operation that is under the manager's responsibility, which in our setting is measured by production.[3] Each manager has a reservation utility constraint. For the external manager, this is the only concern; he accepts the

[3] This modeling of experience benefits is in line with Ben-Porath (1967) and Rosen (1972a,b).

contract when he can obtain the reservation utility. For the internal manager, there is, in addition, a *minimum income constraint*; he accepts the contract when he can obtain the reservation utility *and* when the net monetary payment exceeds a minimum income level. The internal manager's minimum income constraint is due to his lack of collateral to access the credit market.

The basic tradeoff for the principal when choosing an organization is between limiting information rent and extracting experience benefits. Using an internal manager avoids asymmetric information in production cost, but the principal may be prevented from extracting experience benefits. Using an external manager results in asymmetric cost information, but the principal extracts experience benefits. This tradeoff in turn depends critically on the magnitude of the manager's experience benefits, and on the internal manager's minimum income.

The optimal contract for the external manager trades off information rent and efficiency, and implements the standard second best. The optimal contract for the internal manager depends on the principal's ability to extract the manager's experience benefits. When these benefits are small the principal may fully capture them despite the manager's liquidity constraint, and implements the first-best outcome. When the experience benefits are large the principal does not fully capture them, and selects an inefficiently low output.

We study how the principal's organizational choice depends on the manager's marginal experience benefit associated with an increase in production. The principal chooses an external manager if this marginal benefit is large enough, and an internal manager if it is small enough. For a low marginal experience benefit, profit is first best or near first best with an internal manager, whereas it is always second best with an external manager. By contrast, for a large enough marginal benefit the principal would not profit from an increase in experience benefits with internal contracting, while she always captures experience benefits at the margin with an external manager.

Our analysis also yields implications on how the manager's minimum income may affect the organizational choice. An increase in the minimum income makes an internal manager less attractive. It may prompt the principal to switch from an internal to an external manager, but not the other way around. This in turn implies that the range of values of the marginal experience benefit for which the internal manager is chosen shrinks as the minimum income increases.

We complete our analysis by investigating welfare implications. We adopt a second-best view whereby a social planner may only choose the contractual arrangement while leaving production decisions to the profit-maximizing principal. The social planner then picks the solution that offers the higher social surplus. We find that the planner's choice is qualitatively similar to that of the principal. The planner chooses external management when the manager's marginal experience benefits are high, or if the internal manager has a tight liquidity constraint. However, the two choices do not always coincide because the principal only captures a fraction of social surplus. The principal sometimes chooses the external manager when using the internal manager is socially optimal, and the reverse situation may also arise. The latter situation is likely to arise if the internal manager faces a very relaxed liquidity constraint.

Experience benefits correspond to some human capital that is accumulated within the firm, and that may be sold in the market. This human capital is not specific to the firm. 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. Our analysis has a number of empirical implications in this respect.

First, firms should be expected to resort more to external contracting in sophisticated trades where there is a higher potential for marketable on-the-job learning. Rosés (2009) finds that the vertical concentration in the Spanish cotton industry in the 19th century had a limited impact on high quality textile production.

Second, external contracting should be more common where there is a thicker market for the manager's human capital. This prediction is consistent with the literature on the effects of market thickness on vertical integration. Using data on U.S. manufacturing firms, Holmes (1999) studies the proportion of purchased inputs. He finds that this proportion is significantly higher for plants located in an area with a high own-industry employment than for similar plants located in an area where the employment in the same industry is low.

Relatedly, the market value of production management experience 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 it is higher for firms producing output with greater marketability.[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 somewhat 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 not perfect. 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.

Our approach is close to Lewis and Sappington (1991), who also consider a principal-agent setting. Transferability of a subcontractor's skills determines the value of his outside option. However, they do not consider the transferability of skills that would be acquired while performing the task, which is our prime focus. Moreover, they assume that costs are lower when production is subcontracted. Crémer (1995) also uses a principal-agent setting, where the principal sometimes chooses to forego better access to information; by doing so, the principal is able to commit to punishing the agent in case of failure.

The paper is structured as follows. We first describe the model and the first best. We derive the optimal contract when the principal contracts with an external manager. Next, we derive the optimal contract when on the principal hires an internal manager. We then use these results to determine the principal's preferences between the internal manager and the external manager. We analyze whether the principal's optimal choice is socially efficient. The final section draws some concluding remarks.

2 The Model

A principal needs a manager to produce some outputs. The principal may either hire an internal manager as an employee, or contract with an external manager. Besides the manager, production also requires some physical capital or asset, which amounts to an observable fixed cost. If the

[4]See also Pirrong (1993) and Hubbard (2001) for analyses of shipping industries, and references cited in Klein (2005). In their analysis of data from the U.S. auto industry Masten et al. (1989) report that a higher degree of human capital specificity is correlated with a higher degree of in-house production.

principal uses an internal manager, she acquires the physical capital and lets the employee use it for production. If the principal uses an external manager, she lets that manager acquire the physical capital. Because the physical capital is observable, the principal directly reimburses the external manager's fixed cost. The principal owns the physical capital when she hires an internal manager, but an external manager owns the physical capital.

Turning now to variable costs, we let q denote the output and $\gamma c(q)$ the variable cost. The function 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 $\gamma \in [\underline{\gamma}, \overline{\gamma}]$.

The principal is risk neutral and owns the contractible outputs, with price normalized to 1. The principal's utility, net of the fixed capital cost, is $q - t$, where t is the transfer from the principal to the manager.

The internal and external managers are risk neutral and have identical preferences. Each manager has a reservation utility $U > 0$. Bearing production cost initially, a manager's utility is $\beta q + t - \gamma c(q)$. The parameter $\beta \in \Re^+$ is what sets our model apart from the standard principal-agent model.[5] A manager benefits from the output he helps to produce for the principal. These benefits are increasing in the output level, and include enjoyment, reputation, and future returns.

If βq is interpreted as the manager's experience and human capital accumulation from working for this principal, the value of β can be regarded as the degree of the asset specificity of this accumulation. A higher value of β means that the experience return can be used more readily in another project. The value of β is common knowledge.

A manager gets to observe the cost parameter γ. If the principal hires an internal manager, she also observes γ. The employment relationship entitles the principal access to the relevant cost information; an internal accounting or audit system may be in place for discovery. On the contrary,

[5] 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 different issues.

if the principal uses an external manager, the cost parameter remains the private information of that manager. The principal simply is not privy to that information.

Internal and external managers differ with respect to asset ownership. Being the owner of a capital asset and having a collateral, the external manager is assumed to have access to the credit market. Without asset ownership, the internal manager has a limited access to the credit market. We model this difference by assuming that the internal manager's (net) monetary compensation from the principal must be at least M, which defines a liquidity or minimum income constraint. The external manager does not face any such constraint. Because the managers are assumed to be risk neutral, the maximum liquidity needs should not be above the reservation utility U, so we let $M \in [-\infty, U]$.

Next, we define the contracts that the principal offers a manager. 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 his payment when the cost parameter is γ. If an internal manager is hired, the principal and the manager have perfect information about the cost parameter γ so the above is well-defined. If an external manager is used, the manager possesses private information about γ. Without loss of generality, we let a contract be a direct revelation mechanism where the production level and compensation are functions of the manager's report on γ, and where the manager reports γ truthfully.

Under *External Contracting* the extensive form is:

Stage 1: The external manager 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 manager, and the manager then chooses between accepting and rejecting it.

Stage 3: The manager reports a value of γ and the terms of the contracts are executed if the manager has accepted the contract $\mathcal{C}$.

Under *Internal Contracting* the extensive form is:

Stage 1: The internal manager and the principal observe γ.

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

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

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

We now derive the first best. This would be the outcome if the principal were able to hire an internal manager who did not have a minimum income constraint. 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 manager'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 manager's benefit from the output, $(1+\beta)q$. It is as if the cost $\gamma c(q)$ generated a total 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, $t^* - \gamma c(q^*(\gamma))$, 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

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

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.

3 Optimal Contract for External Manager

From the revelation principle, and without a minimum income constraint, an optimal contract is a pair $(q(\gamma), t(\gamma))$ that maximizes the principal's expected profit subject to the constraints that the external manager 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

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

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

The solution is well-known (see for example Laffont and Martimort, 2003). The difference between the optimal contract under asymmetric information and the first best is Myerson's "virtual cost" adjustment. The manager's private information leads to an adjustment of the manager's cost function from γ to $\gamma + h(\gamma)$ (recall $h \equiv \frac{F}{f}$), so the optimal quantity maximizes

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

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 *The optimal contract for the external manager 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 manager's utility less U) is the external manager's *information rent*, due entirely to the private information about γ. The manager does not receive a direct benefit from βq.

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

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

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

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

Because the quantity q^e is distorted downward, the expected profit under external contracting 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 for the external manager, the principal's expected profit is strictly increasing and strictly convex in* β*, while the manager'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 one:* $\pi^e(\beta) < \pi^*(\beta)$*.*

4 Optimal Contract for Internal Manager

4.1 Optimal contract

Under internal contracting the principal knows the cost parameter γ when offering a contract $[q(\gamma), t(\gamma)]$. The manager 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

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

Constraints (12) and (13) both concern the net payment $t - \gamma c(q)$. In the first-best contract the net payment is smaller, and the in-kind compensation βq is larger, the smaller is the cost parameter γ. Hence, with an internal manager requiring a net payment of at least M, the minimum income constraint will tend to 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 $\beta > 0$.[6]

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

[6] Note that (14) has no solution in γ when $M = U$ since $\tilde{q}$ is never zero, or when $\beta = 0$. More formally, then, let $\hat{\gamma} : \Re^+ \times (-\infty, U] \rightarrow \Re^+$ be the function that for any $\beta > 0$ and $M < U$ associates the solution to (14), that for any $M \leq U$ and $\beta = 0$ associates the value 0, and that for any $\beta > 0$ and $M = U$ associates the value $2\overline{\gamma}$. Note that $\hat{\gamma}(\beta, M)_{|\beta=0} = 0$ simply assigns the value of the limit of the solution to (14) as β tends to zero. The exact value of $\hat{\gamma}(\beta, M)_{|M=U}$ is irrelevant as long as it is strictly above $\overline{\gamma}$ so Proposition 3 is correct even when $M = U$.

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.*

The optimal contracts for the internal manager are correspondingly the following:

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

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

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,*

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

The principal would like to extract surplus from the internal manager 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. Hence, the principal implements first-best production and leaves no rent to the internal manager.

As γ becomes smaller than $(1+\beta)\hat{\gamma}(\beta, M)$, the net monetary compensation in the first-best solution 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 manager'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 manager's experience rent, so she implements production at the first-best level corresponding to $\beta = 0$. However, for intermediate levels 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 low, or high, the optimal quantities are decreasing, corresponding to the case of binding minimum income and reservation utility constraints, respectively. 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.

[Figure 1 about here]

4.2 Expected profit and expected rent

When choosing between internal and external contracting, the principal does not yet know the value of γ. Using Proposition 3, for a given interval of cost parameter values $[\underline{\gamma}, \overline{\gamma}]$ the expected profit may be written:

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

The fact that $f(\gamma) = 0$ for any $\gamma \notin [\underline{\gamma}, \bar{\gamma}]$ takes care of cases where one of the thresholds is not in the interval $[\underline{\gamma}, \bar{\gamma}]$. The manager obtains some experience rent if and only if $\gamma < \hat{\gamma}(\beta, M)$, so that 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 manager'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[7]

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

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

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 manager 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. Then:

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) slack for all γ).*
- *$R^i(\beta, M) > 0$ if and only if $M > \widetilde{m}(\beta)$ (reservation utility constraint (12) 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) slack for all γ).*

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

[Figure 2 about here]

The principal extracts more surplus the smaller M is. When the value of M is so low that it lies below the graph of $\underline{m}(\beta)$, the minimum income constraint is irrelevant. 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 manager's experience rent cannot be extracted. For intermediate 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 manager receives rent only if M is above $\tilde{m}(\beta)$, so that the reservation utility constraint to be slack for some values of γ.

4.3 Comparative statics

Given the cost parameter distribution, how do the principal's expected profit and the manager'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 manager 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 manager's benefit, an increase in β has no effect on expected profit. Finally, an increase in β strictly benefits the internal manager as long as he earns some rent.

5 Principal's Choice Between External and Internal Contracting

We now turn to the principal's choice between external and internal contracting. 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. The first proposition is an immediate consequence of our previous results.

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

- *if $\beta \leq \beta_U$ the principal strictly prefers internal to external contracting 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 internal to external contracting 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 internal contracting. The principal then prefers to use internal contracting. Conversely, for large values of M, the internal manager's experience benefit and experience rent are high. Moreover, there are large distortions under internal contracting. The principal then prefers to use external contracting.

Interestingly, Proposition 4 implies that when β is small enough ($\beta < \beta_U$) internal contracting dominates external contracting even as M tends to U so that the minimum payment constraint is binding for all cost parameter realizations. This is explained as follows. For M close to U the minimum income constraint is binding for all cost parameter realizations, and the quantity implemented under internal contracting is always below the first-best quantity. However, when β is small the difference between first-best output and optimal output under internal contracting, $q^*(\gamma) - q^i(\gamma)$, is small; moreover, the difference between the corresponding transfers, $U - \beta q^*(\gamma)$ in the first-best contract, and M under internal contracting, is also small. The profit under internal contracting is therefore close to the first-best profit, and external contracting is dominated.

By contrast, for any minimum payment $M \leq U$ there always exists a set of values of β such that the principal prefers internal contracting, 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 in internal and external contracting, $\pi^i(\beta, M) - \pi^e(\beta)$:*

- *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 internal production is strictly more profitable than external production, and there is an interval of large β at which the opposite is true. Under internal contracting, and for a given minimum payment M, experience rent is zero when β is small, whereas the experience benefit accrues entirely to the manager when β is large. The principal therefore does not benefit from an increase in β when β is sufficiently large. By contrast, under external contracting 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.[8]

The results in Proposition 5 imply that internal contracting is never used when human capital is highly nonspecific (large β), while if it is mostly firm-specific (β close to zero) internal contracting 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 internal and external contracting when asset specificity is high. The internal contracting profit is first best for small β, and it increases faster than the second-best profit under external contracting as β increases. If other factors, such as different fixed costs associated with internal and external contracting, are relevant, our model suggests that more human capital specificity may lead to more external contracting.

Second, the degree of human capital specificity *interacts* with credit market constraints to determine the optimality of internal or external production. According to Proposition 4 an increase in M can lead the principal to switch from internal to external contracting, but not the other way around. To see this, note that for $\beta < \beta_U$, internal production is more profitable, while for $\beta > \beta_U$, the threshold value $\widehat{M}(\beta)$ is uniquely defined. Once $M > \widehat{M}(\beta)$, external production is always optimal for that β. Hence tighter minimum income constraint narrows the range of β for which

[8] We do not know if this tradeoff must lead to a unique cutoff in β at which the principal changes his preferences from internal contracting to external contracting. All the examples we have constructed do support a unique cutoff, however.

internal contracting is optimal. Absent any prior information about human capital specificity Propositions 4 and 5 imply that a looser credit constraint in the form of a decrease in M will lead to more vertical integration.

Figure 3 illustrates this by showing the expected profit under external contracting (the thick curve), as well as the expected profit under internal contracting 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 internal contracting is increasing in β when β is small, and independent of β when β is large. For $M = U = 2$ the profit under internal contracting is a constant. In all the cases, internal contracting dominates external contracting when β is small, while the opposite is true when β is large. The threshold value for β is larger, the smaller M is.

[Figure 3 about here]

6 Social Welfare

In this section we ask whether the principal's and the manager's equilibrium actions lead to socially efficient outcomes, which maximize total surplus. For a given experience benefit parameter β, and a given value of the cost parameter γ, total surplus is $(1+\beta)q - c(q)$. In our model total surplus is divided between the principal and the manager, and hence expected total surplus can be calculated as the sum of the principal's expected profit and the manager's expected rent. Hence, from expressions (8), (9), (15), and (16), and after simplification, expected total surplus under external contracting equals

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

and under internal contracting it is

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

From earlier results, typically neither surplus expression above is 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. Here we ask whether the principal selects the organizational form that yields the higher expected surplus, assuming that quantities and transfers are selected by the principal. We do this by comparing (20) and (21).

We first build on results in the preceding sections to derive comparative statics for the respective social surpluses. First, for the surplus under internal contracting, 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 internal contracting the social surplus is always strictly increasing in β. This is to be contrasted with the principal's profit under internal contracting, 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 constraints 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 external contracting, Propositions 1 and 2 along with Corollary 1 imply:

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

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

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

- *for β sufficiently close to zero, internal contracting is socially preferable to external contracting;*
- *for β sufficiently large, external contracting is socially preferable to internal contracting*

This proposition shows that the ranking of internal and external contracting from a social point of view is somewhat aligned with the principal's ranking. This is obviously the case when β is small enough that, with internal contracting, the principal may capture the entire first-best social surplus. Then external contracting, which involves distortions in production, is dominated both privately, and socially. As the manager's private benefit parameter increases, the principal may no more capture total surplus while implementing first-best production. For sufficiently large values of β the principal's profit under internal contracting is unaffected by an increase in the manager's marginal private benefit, so that she does not adjust production to such an increase while it would be socially desirable to do so. However, the principal then chooses to switch to external contracting so as to extract more experience rent from the manager. Proposition 6 shows that this yields a higher expected social surplus than internal production would.

Still, the principal's organizational choice will not systematically coincide with the socially optimal organization because the principal does not entirely capture social surplus. The intuition is that the principal does not take into account the externality imparted on the manager. Consider a combination of β and M at which internal and external contracting are equally profitable. Then a slight increase in M makes internal production less profitable. Hence, if in this parameter configuration the manager's expected rent is higher with internal than external contracting, the principal makes an excessive use of external contracting. The reverse arises if an external manager earns a higher expected rent for such parameter combinations.

A numerical example illustrates how the organizational choice of the principal may differ from that which maximizes total surplus. Figure 4 shows, for $c(q) = \frac{1}{2}q^2$, $U = 2$, $\underline{\gamma} = 0.15$ 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 external contracting while internal contracting would be socially optimal, and the opposite is true if the variable on the vertical axis is -1. This numerical example shows that the bias in the principal's decision may be extensive: she may choose external contracting when it is socially dominated, or choose internal contracting when external contracting would have been socially optimal, depending on parameter values.

[Figure 4 about here.]

In the numerical example there is too little external contracting 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. Then for* M *sufficiently low, whenever external contracting is chosen by the principal it is socially optimal, and there exists* β *such that the principal chooses internal contracting while external contracting is the socially optimal institutional arrangement.*

A low M makes internal production more profitable for the principal and socially desirable than external contracting unless β is very large. What drives the result is that for such very large β, and for a very convex cost function, the manager's rent is higher under external contracting.

Figure 5 illustrates a case where the principal switches too late to external contracting as β increases: in the figure the upper curve is the difference between the principal's expected profit under internal and external contracting, $\pi^i(\beta, M) - \pi^e(\beta)$, 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 all of the manager's surplus under internal contracting for fairly large values of β; however, she fails to internalize the manager's rent under external contracting, and sometimes inefficiently chooses internal over external contracting. Now, 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 internal manager's rent, and she ends up sometimes choosing external over internal in a suboptimal manner.

[Figure 5 about here.]

[Figure 6 about here.]

We are unable to derive a clear-cut result about the nature of the principal's inefficient choice of organization when M is close to U, which would parallel that of Proposition 7. The next proposition however shows that the principal makes a suboptimal organizational choice for some non zero measure of values of β when M is close to U.

Proposition 8 *Suppose that $M > \overline{m}(\beta)$ (so that the reservation utility constraint is slack for all cost parameter γ in internal contracting). There is a non-empty set of (β, M) for which the principal chooses the organizational mode that yields the lower expected social surplus.*

In the parameter region where the minimum income constraint binds for all cost realizations ($M > \overline{m}(\beta)$), under internal contracting an increase in M means that the principal makes a larger transfer to the manager. However, the surplus is unaffected since the quantities are unaffected.

7 Concluding remarks

A firm must decide whether to make or buy its inputs, and it is important to understand the reasons behind this choice. The change undergone by Toyota in its obtention of electronic car components provides an illustration. According to Ahmadjian and Lincoln (2001) Toyota used to purchase 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 information about cost seems to have been a critical determinant of this change.[9] But if in-house production gives a

[9]For most auto parts "an auto assembler [has] access to a supplier's cost structure and understand intimately its manufacturing process. (...) [K]nowledge asymmetries between customer and supplier posed few

better grasp of real costs, why outsource at all? In this paper we argue that a firm may want to forgo the information advantage of internal production, to benefit from a less stringent liquidity constraint faced by an external manager who owns collaterizable production assets. A relaxed liquidity constraint enables the firm to extract more of the experience benefits that a manager derives from overseeing production.

Our theory predicts that, for a given tightness of the internal manager's liquidity constraint, the principal chooses external production when the manager's experience benefits are large: although the principal leaves information rent to an external manager, she may fully extract the manager's experience benefits. When these benefits are small, benefit extraction becomes less of a concern relative to information rent extraction, and the principal chooses internal production instead. Our prediction that a higher degree of human capital specificity should be associated with more internal production is consistent with other theories on the determinants of vertical integration, such as the transactions cost and the property rights literatures. Our theory complements these literatures, by proposing an alternative reason for why asset specificity may matter. It also enriches this theory, by suggesting that it is asset specificity *together with* liquidity constraints that determines 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 managers. It would be interesting to see whether the principal sometimes resorts to a mixed solution, with some internal and some external production, as firms sometimes do in practice.

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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)

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 external manager'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 manager's rent is

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

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

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

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 manager'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 external contracting $\pi^e(\beta)$ 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 external contracting is second-best, and increasing in β, whereas the expected profit under internal contracting 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

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

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 external contracting yields

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

From the principal's optimization problem under external contracting we have

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

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

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

Turning now to the surplus under internal contracting, 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

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

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

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

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 manager's rent is larger under external than under internal contracting for all $M \leq U$. To do this we compare the derivatives. Differentiating the manager's rent under external contracting (9) yields

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

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 manager's rent under external contracting 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 $\beta < \underline{\beta}$, internal contracting is preferred by the principal since it yields the first-best profit. Hence for M small, the principal selects external contracting only for values of β that are so large that $R^e(\beta) > R^i(\beta, M)$, implying that social surplus is higher with external contracting than internal contracting.

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 external contracting while the principal selects internal contracting. *Q.E.D.*

Proof of Proposition 8

For the principal's choice of organizational mode to coincide with the organizational mode that yields the higher surplus at any (β, M), $\pi^i(\beta, M) = \pi^e(\beta)$ must imply $S^i(\beta, M) = S^e(\beta)$, and conversely. We now show that this is not true for some values (β, M) where $M > \overline{m}(\beta)$.

From Proposition 4, for any $\beta < \beta_U$ and any $M \leq U$, we have $\pi^i(\beta, M) > \pi^e(\beta)$. Consider $\widehat{M}(\beta)$, at which $\pi^e(\beta) = \pi^i(\beta, \widehat{M}(\beta))$. The graph $(\beta, \overline{m}(\beta))$ begins at $(0, U)$ and is negatively sloped, while the graph $(\beta, \widehat{M}(\beta))$ begins at (β_U, U), so there exists a set of β where $\widehat{M}(\beta) > \overline{m}(\beta)$.

There are two cases. First, suppose that there exists no (β, M), $M > \overline{m}(\beta)$, where $\pi^i(\beta, M) = \pi^e(\beta)$ and $S^i(\beta, M) = S^e(\beta)$. In this case, the proposition is true.

Second, suppose there exists (β, M), $M > \overline{m}(\beta)$, where $\pi^i(\beta, M) = \pi^e(\beta)$ and $S^i(\beta, M) = S^e(\beta)$. We show that there are points nearby at which these two equalities cannot hold simultaneously.

By definition, $\pi^e(\beta) = \pi^i(\beta, \widehat{M}(\beta))$, so suppose that $S^i(\beta, \widehat{M}(\beta)) = S^e(\beta)$. Because $\widehat{M}(\beta) > \overline{m}(\beta)$, from Lemma 1, $\frac{\partial S^i(\beta, M)}{\partial M} = 0$. This means that $S^i(\beta, M) = S^e(\beta)$ for any M near $\widehat{M}(\beta)$. By contrast, $\pi^i(\beta, M) < \pi^e(\beta)$ for $M > \widehat{M}(\beta)$, and $\pi^i(\beta, M) > \pi^e(\beta)$ for $M < \widehat{M}(\beta)$. Hence, for values of (β', M) near $(\beta, \widehat{M}(\beta))$, $S^i(\beta', M) = S^e(\beta')$, but $\pi^i(\beta', M) \neq \pi^e(\beta')$. *Q.E.D.*

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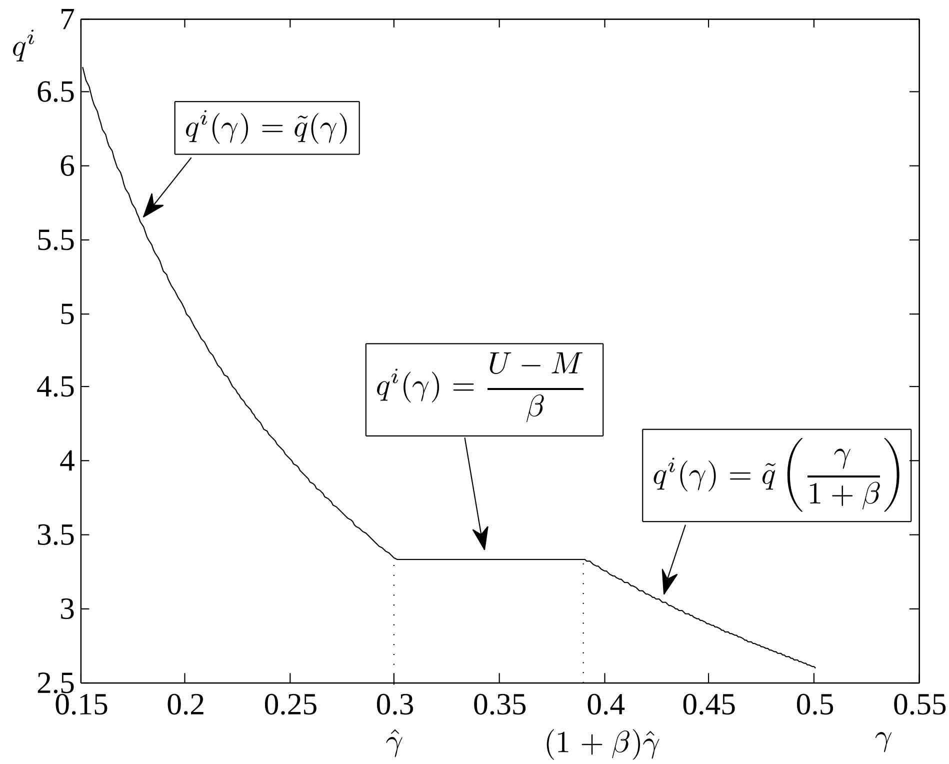

Figure 1: q^i as a function of $\gamma \in [0.15, 0.5]$ for $U = 2$, $M = 1$, $\beta = 0.3$, and $c(q) = \dfrac{q^2}{2}$.

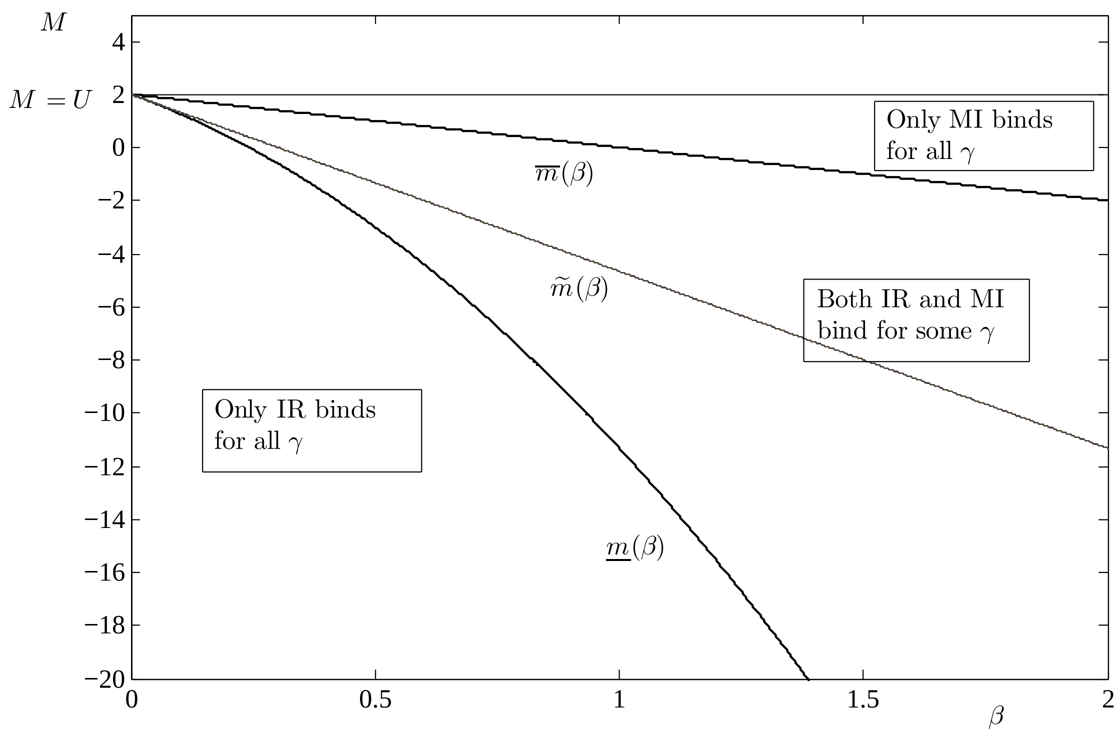

Figure 2: $\underline{m}(\beta)$, $\tilde{m}(\beta)$, and $\overline{m}(\beta)$ for $c(q) = \dfrac{q^2}{2}$, $U = 2$, $\underline{\gamma} = 0.15$ and $\bar{\gamma} = 0.5$. IR: reservation utility constraint. MI: minimum income constraint.

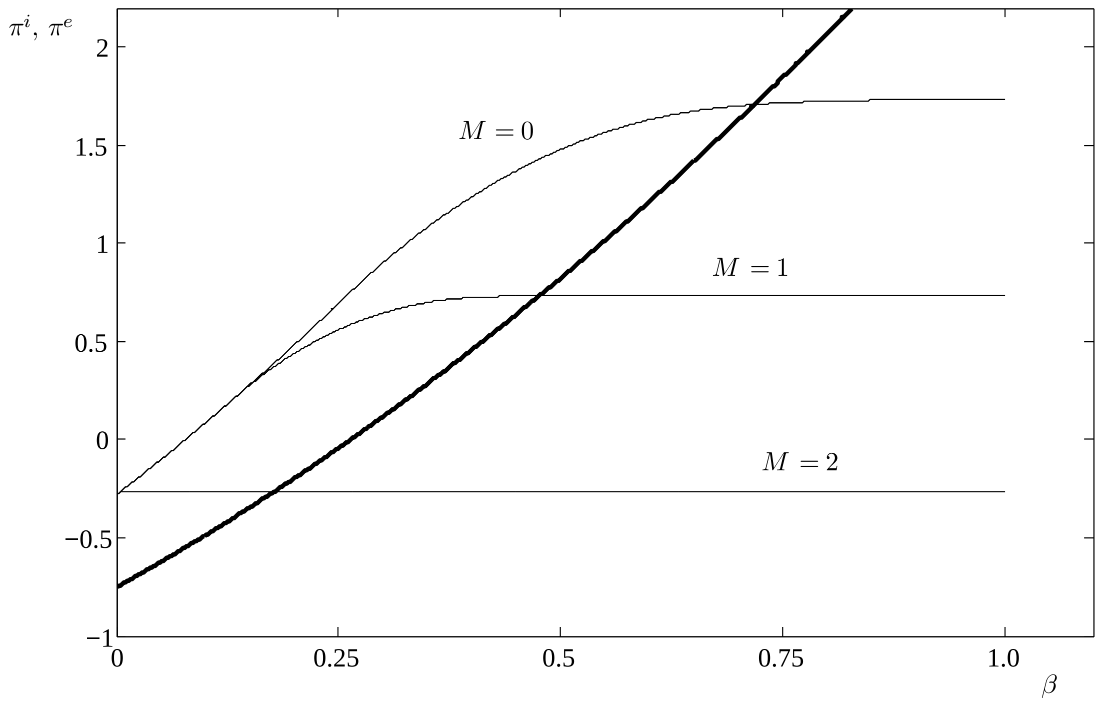

Figure 3: $\pi^e(\beta)$ (thick curve), and $\pi^i(\beta, M)$ as a function of β for $U = 2$, $c(q) = \dfrac{q^2}{2}$, $\gamma \in [0.15, 0.5]$, and $M = 0$ (upper thin curve), $M = 1$ (middle thin curve), and $M = 2$ (lower thin curve)

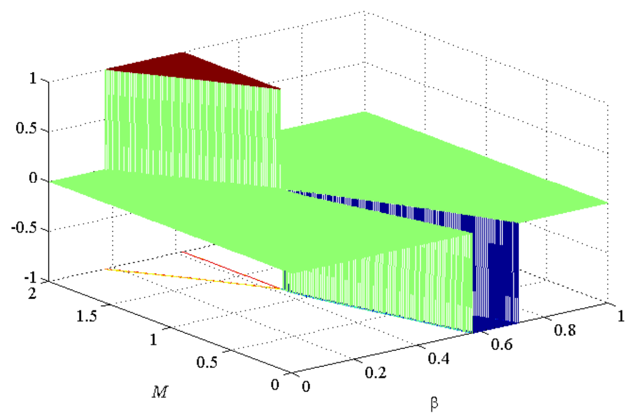

Figure 4: The principal chooses external contracting although internal contracting dominates socially when the dummy variable on the vertical axis takes the value 1; she chooses internal contracting although external contracting dominates socially when it takes the value -1.

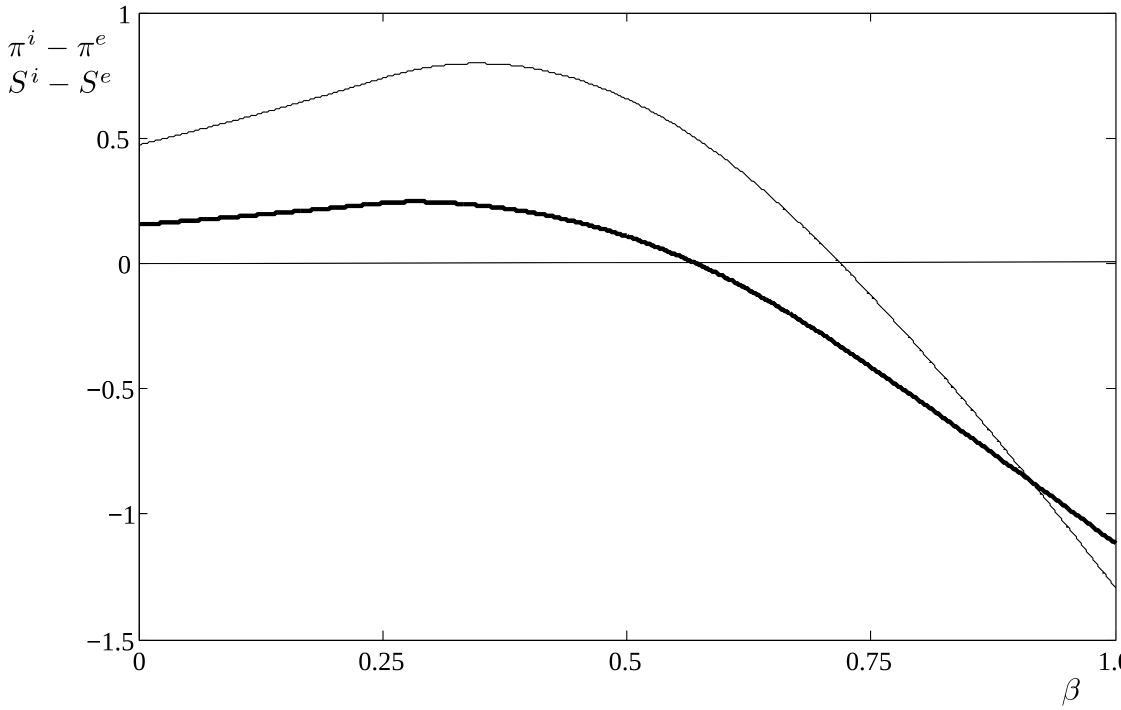

Figure 5: $\pi^i(\beta, M) - \pi^e(\beta)$ (thin curve) and $S^i - S^e$ (thick curve) as a function of β for $U = 2$, $M = 0$, $c(q) = \dfrac{q^2}{2}$, and $\gamma \in [0.15, 0.5]$

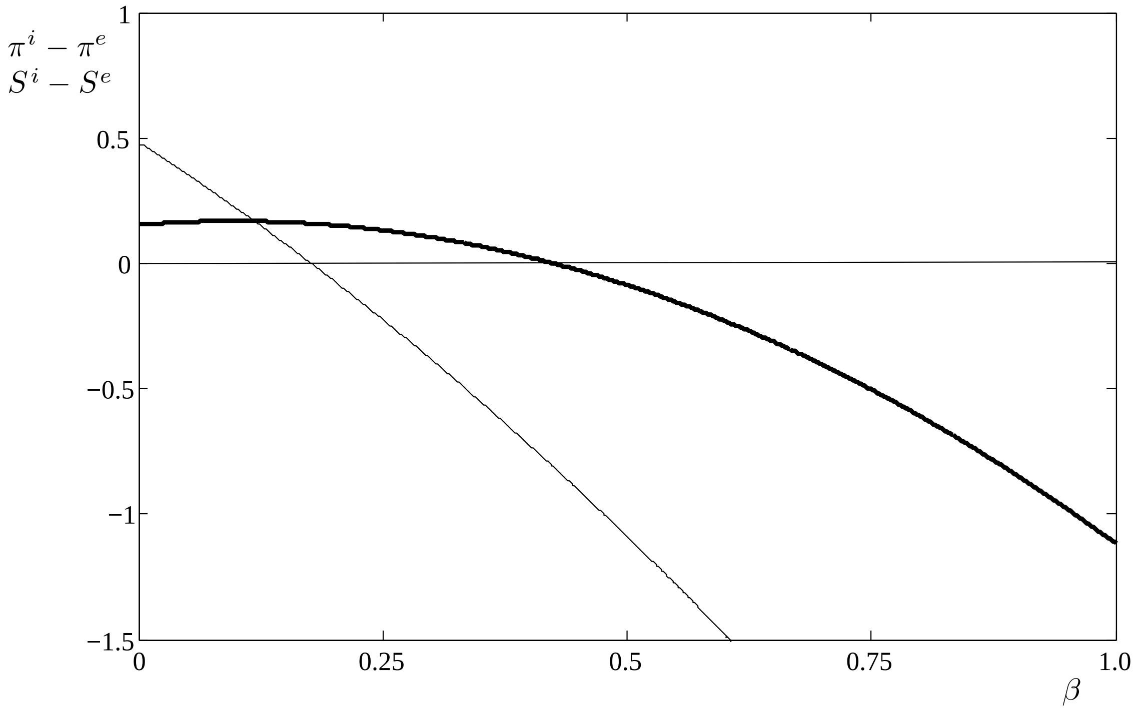

Figure 6: $\pi^i(\beta, M) - \pi^e(\beta)$ (thin curve) and $S^i - S^e$ (thick curve) as a function of β for $U = 2$, $M = 2$, $c(q) = \dfrac{q^2}{2}$, and $\gamma \in [0.15, 0.5]$