Vertical integration,
information flows
and
the power of incentives

Very preliminary and incomplete
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Introduction

-So, you are getting more responsiveness from outsider than you got from insiders?
   -Right.
   -Doesn't that mean that you didn't have the proper incentives for the insiders?
   -Probably. But I am not sure you can duplicate those incentives internally.[1]

It is generally accepted that vertical integration leads to less powerful incentives, but improves the information available for taking decisions. This paper proposes a model to explain this tradeoff. It computes the optimal contract between a manager of a firm, a client and an owner. It shows that when monitoring costs are low, there will be vertical integration, low powered incentives and lots of information available to take decisions; on the other hand, when monitoring costs are high, there is no vertical integration, high powered incentives and little information.

It may be worthwhile noticing three features that distinguish this model from other models in the literature. First, there is separation of ownership and management even in the absence of vertical integration. All incentive based models of vertical integration of which I am aware compare a situation in which the upstream firm is managed by its owner to a situation in which it is managed by the owner of the downstream firm. In these models vertical integration has two effects that should be differentiated for analytical purposes: to separate ownership and management in the upstream firm, and to unify the ownership of the two firms. Second, ownership is defined simply as the right to a profit stream, not, as in Grossman and Hart (1986), as the possession of the residual rights of control over specific assets used in production, or, as in Riordan (1990), as control of the accounting system. Third, the results do not rely on the incompleteness of contracts.

The model which develops these themes is presented in sections 1 to 5. Alas its main conclusions are at variance with recent evidence. In the last few decades, information costs have decreased, but there has been a strong increase in the amount of vertical disintegration: firms are able to set up complex networks of outside suppliers. I tackle this puzzle in section 6. I introduce the possibility for the firm to have information available without any cost. I show that as this information improves, vertical integration becomes less attractive. The final version of the paper will have a fuller explanation of the consequences of this result.

The results presented below were already presented in a working paper entitled "A theory of vertical integration based on monitoring costs". Although the basic intuition of that previous paper was correct, it contained some rather embarrassing mistakes, and I hope that nearly all of them will be corrected in the final version of this one.

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[1] *This dialog between Bennet Stewart and Richard Huber, CEO of Continental Bank, is quoted from the Journal of Applied Corporate Finance.*

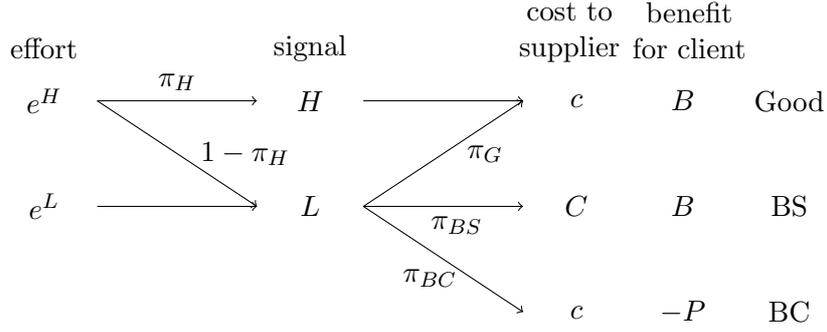|	effort		signal		cost to supplier	benefit for client	

Figure 1: The structure of production.

1 The model

We use a very simple model based on the project paradigm which has been used extensively in the recent literature on organization theory.

1.1 Production

The structure of production is illustrated in figure 1.

There are two possible level of efforts, two signals, which provide information about the likely outcome, and three outcomes, "Good", "BS", and "BC". The reader may think of the construction of a special component, with the signal being the quality of a prototype.

The manager of the upstream firm can either provide a high effort, which lowers his utility as much as a monetary loss of e^H, or a low effort, which "costs" him $e^L \equiv 0$. A high effort is associated with higher probabilities of the good outcome.

After the effort has been chosen, but before the decision to proceed with the project is irreversible, a signal of the outcome of the project is available. If the signal is H, then it is known that the outcome will be good. Continuing will provide a benefit equal to B to the client and the cost to the supplier will be c. I will assume that B is much larger than c.

If the signal is L, three outcomes are possible, the good outcome defined in the previous paragraph and two bad outcomes. The good outcome arises with probability $\pi_G > 0$. Outcome "BS", which stands for "Bad for the Supplier", is observed with probability $\pi_{BS} > 0$. In our example of a specific component, this would correspond to high costs of production, for instance because greater use of machinery or of engineering time is required. In this outcome, the benefit to the client is B but the cost to the firm is C, which will be assumed to be very large. More precisely, we assume that

$$(1 - \pi_H)\pi_{BS}\, C \geq [\pi_H + (1 - \pi_H)(\pi_G + \pi_{BS})]B. \qquad (1)$$

This implies that even if both c and P were both equal to zero, it would not be profitable to start production in the absence of any information.

The outcome "BC", which stands for "Bad for the Client", is observed with probability $\pi_{BC} > 0$. In this outcome, the cost to the firm is c, as in the good outcome, but the benefits to the client is $-P$, where P is positive and large. For a specific component, one can think of an outcome where its final version is not satisfactory and the client must either abandon the production of the final product or use a less satisfactory standard component. We assume

$$(1 - \pi_H)\pi_{BC}\, P \geq [\pi_H + (1 - \pi_H)(\pi_G + \pi_{BS})]B, \tag{2}$$

which states that even if c and C were both equal to zero, it would not be profitable to start production in the absence of any information.

I introduce two bad outcomes because the theory relies crucially on the conflicts of interest between the supplier and the client.

The costs c and C should be interpreted as the effect on the discounted profits of the supplier of continuation of the project. They can include wages, foregone profits from other projects that could be undertaken, capital depreciation, and so on. Similarly, B and $-P$ represent the benefit for the client of continuation of the project with that particular supplier.

The signal is a sufficient statistic for the outcome, and to finish the presentation of the model we only need to specify the probabilities of the signals as a function of the effort produced. With low effort, the signal will always be L; with high effort it will be H with probability π_H and L with probability $1 - \pi_H$. The parameters of the model are such that it is optimal to induce the manager of the upstream firm to produce a high effort.

The signal is important because, after it is observed, it is possible to discontinue the project at no cost (but at this point the effort is already sunk).

The information structure which we have described in very specific, but section 8 shows that our results are robust to richer information structure.

1.2 Information and contracts

At the outset, information is symmetric and all parties know the structure of the game. The manager chooses an effort that he alone can observe. The signal is observed by the owner and the client.

At the same time[2] that the effort is chosen by the manager, interested parties can set up a monitoring system, at a cost μ. When the signal is L any party who has set up a monitoring system knows the state of nature, and can observe the outcome if the product is continued. The information provided by this monitoring is soft: if there are conflicts of interest, a party cannot commit to transmit without modification the information it has received.

For most of the paper, we assume that incurring the monitoring cost enables the agent to observe exactly the outcome. It seems more realist to assume that the cost to an agent

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[2] It may seem more natural to assume that the decision to monitor is taken after the signal has been observed. This creates some modeling difficulties, which are detailed in footnotes 6 and 8. Solving them would complicate the paper and add little insight on the economics of the situation.

who wishes only to make sure that, let us say, outcome BC has not occurred would be lower than the cost to an agent who wishes to make sure that the Good outcome has occurred. We could for instance assume that the cost of observing both the cost to the supplier and the benefit to the client is μ whereas the cost of observing one of these quantities is $\alpha\mu$ with $\alpha \in (1/2, 1)$, whereas the text assumes $\alpha = 1$, except in the notes in footnotes 10 and 11. This alternate specification would not affect the results in any significant way.

The cost and benefit of pursuing the project to the end are private, and unobservable by a court. Two features of real world situations are reflected in this assumption. First, the supplier can have several clients, and it is difficult to disentangle the contribution of each to the costs that it incurs. Second, some of the costs, such as depreciation, and some of the benefits, such as acquisition of know-how, have difficult to measure long run consequences.

Furthermore I will assume that monitoring by any party is not observable by a third party (this is justified by the fact that it is very easy to fake monitoring[3]). These assumptions have been built in the model to ensure that in the absence of vertical integration the owner and the client cannot find ways to delegate monitoring to each other.

It is now possible to state precisely the condition, mentioned above, that $B - c$ is large enough:

$$B - c > \frac{2\mu + e^H}{\pi_H(1 - \pi_H)\pi_G(1 - \pi_G)}. \tag{3}$$

This condition, which is substantially stronger than needed, will ensure that the payoffs of the different parties are always positive in the optimal contracts that we compute. It states that the benefit of production is large compared to the costs of monitoring and effort.

1.3 The objectives of the agents

The objectives of the stockholders of the upstream firm and those of the client are easily described: they try to maximize expected profits.

In the text of the paper, we assume that the payments to the manager are always positive. This can be interpreted as a no slavery condition — the manager can leave the firm at any time if the expected utility that he derives from continued employment is negative. It can also be interpreted as a degenerate form of risk aversion — the utility derived by the manager from a payment of X is equal to X if $X \geq 0$ and to $-\infty$ if $X < 0$.

In appendix A, we show that this assumption, which simplifies the exposition, is not necessary and that the results hold with hardly any modifications if we simply assume

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[3]There is a cost to faking monitoring: even though one does not seriously study the evidence, one must pretend to collect it seriously. These activities could be introduced in the model.This would imply that a cost must be incurred if monitoring is included in the contract but not really conducted. I do not believe that the results would be modified. See Khalil (1997) for a deeper discussion of the observability of monitoring.

that the manager has a smooth concave utility function or even is risk neutral.

2 Vertical integration

In this section, we study the optimal contract under vertical integration. In the next section, we will study the consequence of vertical 'disintegration", and compare the two property structures in section 4.

Under vertical integration, the client and the owner are the same entity. The decomposition of the cost and benefit of pursuing the project to the end in a capital cost and a production benefit is irrelevant: the only relevant number is their sum. For instance if $B - c = -P - c$, outcomes BS and BC are totally equivalent.

The structure of the game is very simple:

1. The client/owner offers a contract to the agent. This contract promises a payment conditional on the decision to continue or discontinue the project.[4] The manager chooses to accept or refuse the contract.

2. The client/owner chooses whether or not to monitor; the manager chooses his level of effort.

3. After the signal is observed, the project is continued if either of the following three possibilities arise:

   - if the contract in force calls for its continuation;
   - if the contract gives one party the right to decide on continuation and this party chooses continuation;
   - if the contract calls for joint determination of the decision to continue, and this leads indeed to a decision to continue.

There is clearly no point in letting the manager have any say in the decision to continue: in order to incite him to provide a high effort, the contract has to give some surplus if the decision to continue is taken. Given that he does not incur any cost after this decision, he will always choose continuation. Any decision that takes into account the signal will depend only on the owner/client.

In order to solve for the optimal contract, we go through three steps. First, we compute the optimal contract among those that do not induce monitoring; second, we compute the optimal contract among those that do induce monitoring. We then compare these two optimal contracts.

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[4]It is actually possible to do a bit better, but I will keep this assumption which makes the analysis much simpler.

2.1 Contracts that do not induce monitoring

The assumptions on the values of the parameters ensure that it is optimal to offer contracts that induce the agent to produce a high effort. Because there is no monitoring, if the signal is L, the project whose expected value is

$$\pi_G(B - c) + \pi_{BS}(B - c) + \pi_{BC}(-P - c)$$

will be discontinued, as either one of equations (1) or (2) imply

$$B < c + \frac{\pi_{BS}(c - B) + \pi_{BC}(P + c)}{\pi_G}.$$

The payoff of the owner/client is therefore

$$\pi_H(B - c - w) - (1 - \pi_H)w^S, \tag{4}$$

where w is the wage conditional on continuation and w^S the wage if the project is discontinued.

The manager will provide a high effort if

$$\pi_H w + (1 - \pi_H)w^S - e^H \geq w^S,$$

that is if

$$w - w^S \geq \frac{e^H}{\pi_H}. \tag{5}$$

Equation (5) describes the incentive compatibility constraint of the agent. Because monitoring is not observable, we also need one incentive compatibility constraint for the the owner/client. He will not monitor if

$$\pi_H(B - c - w) + (1 - \pi_H)\left[\pi_G(B - c - w) + (1 - \pi_G)(-w^S)\right] - \mu$$
$$\leq \pi_H(B - c - w) + (1 - \pi_H)(-w^S). \tag{6}$$

The left hand side represent the net expected payoff with monitoring. If the signal is H the project is known to be good, and is continued. If the signal is L, the project is good and continued with probability π_G. The right hand side represent the net expected payoff without monitoring: in this case the project is continued if and only if the signal is H. Equation (6) is equivalent to

$$w - w^S \geq B - c - \frac{\mu}{\pi_G(1 - \pi_H)}. \tag{7}$$

From equations (4) and (7), and from the no slavery assumption, we can write the problem of the owner/client as follows:

$$\max_{w, w^S} \quad \pi_H(B - c - w) - (1 - \pi_H)w^S$$
$$\text{subject to} \quad w - w^S \geq e^H/\pi_H, \qquad \qquad (\text{ high effort})$$
$$w - w^S \geq (B - c) - \frac{\mu}{\pi_G(1 - \pi_H)}, \quad (\text{no monitoring})$$
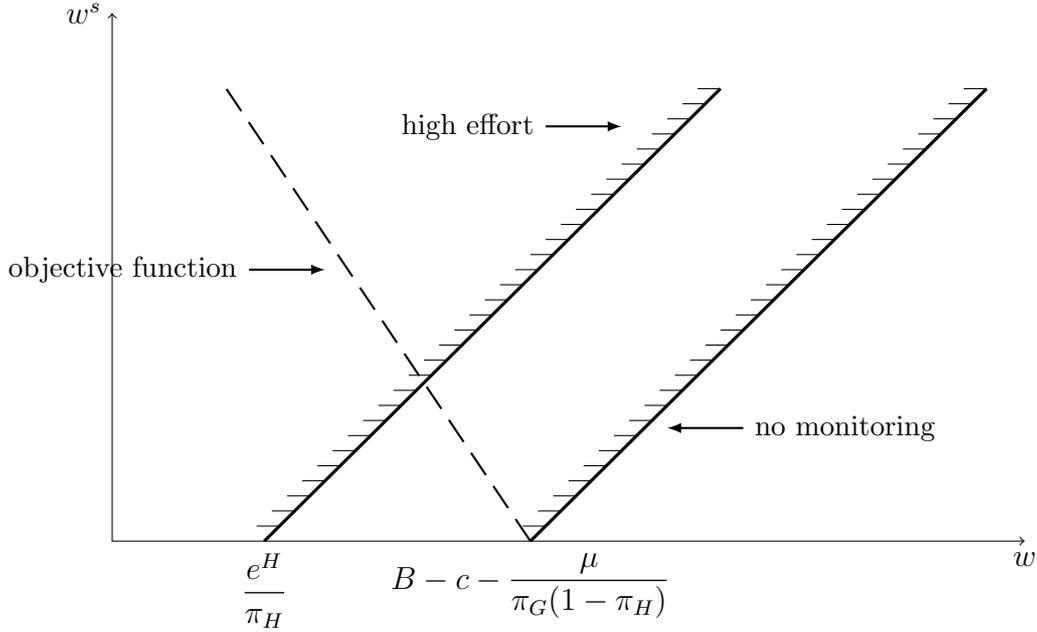$$w^S \geq 0.$$

Figure 2: The optimal no monitoring contract under vertical integration. The "isoobjective" line corresponding to the optimal solution is dotted. The two constraints are represented by solid lines with the dashes on the *outside* of the feasible set.

(The solution to this problem will satisfy $w \geq 0$.)[5]

We are mostly interested in the variation of this solution when μ varies. Two cases must be distinguished.

- $\mu \leq (1 - \pi_H)\pi_G[B - c - e^H/\pi_H]$. The situation is represented on figure 2. The optimal solution satisfies $w^S = 0$ and

$$w = B - c - \frac{\mu}{\pi_G(1 - \pi_H)}.$$

The profit of the owner/manager is

$$\frac{\mu \, \pi_H}{\pi_G(1 - \pi_H)}.$$

- $\mu \geq (1 - \pi_H)\pi_G[B - c - e^H/\pi_H]$. The no monitoring constraint is to the left of the high effort constraint, which is binding. The optimal solution is $w^S = 0$ and $w = e^H/\pi_H$. The profit of the owner/manager is $\pi_H(B - c - e^H/\pi_H)$.

In figure 3, I represent the variation of the payoff of the owner/manager as a function of μ. Although μ is a cost, this function is increasing, and strictly increasing when the

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[5]As mentioned in 1.3, I discuss in Appendix A (not included) more general forms of the individual rationality constraint and of the utility function of the manager.
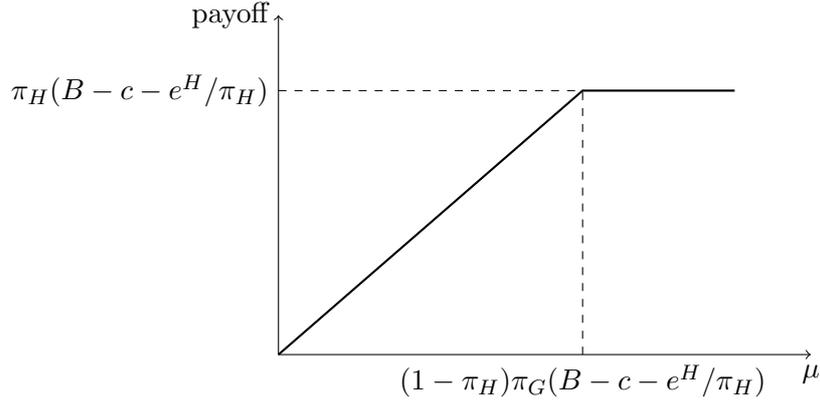
Figure 3: Payoff of the owner/client as a function of μ with contracts that do not induce monitoring.

no monitoring constraint is binding. Indeed, the larger μ the easier it is to induce the owner/client not to monitor.

2.2 Contracts that induce monitoring

Let us now examine the contracts that induce monitoring. If there is monitoring, the owner/client will choose to continue the project in the good state of nature. His payoff will be

$$\pi_H(B - c - w) + (1 - \pi_H)[\pi_G(B - c - w) + (1 - \pi_G)(-w^S)] - \mu. \tag{8}$$

In order to induce high effort from the manager we must have

$$[\pi_H + (1 - \pi_H)\pi_G]w + (1 - \pi_H)(1 - \pi_G)w^S - e^H$$
$$\geq \pi_G w + (1 - \pi_G)w^S.$$

The left hand side represents the manager's expected utility with high effort, the right hand side his expected utility with low effort. This is equivalent to

$$w - w^S \geq \frac{e^H}{\pi_H(1 - \pi_G)}. \tag{9}$$

Comparing this equation to equation (5), one observes that the owner/client needs to give the manager a higher premium for continuation when there is monitoring than when there is no monitoring. Improving information does reduce incentives.

Finally, the owner/client will monitor if

$$\pi_H(B - c - w) + (1 - \pi_H)[\pi_G(B - c - w) + (1 - \pi_G)(-w^S)] - \mu$$
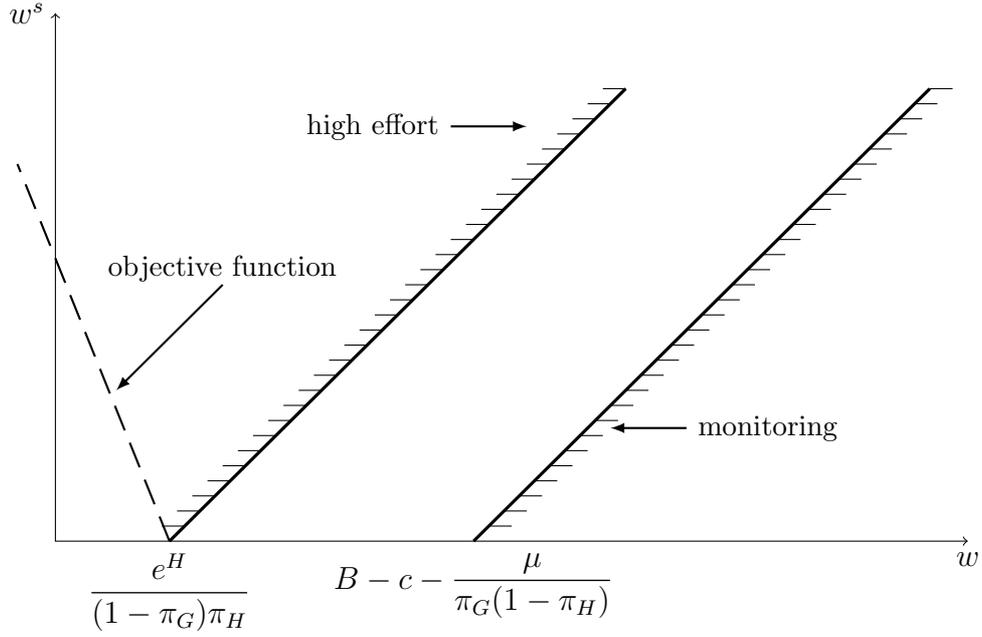$$\geq \pi_H(B - c - w) + (1 - \pi_H)(-w^S).$$

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Figure 4: The optimal contract with monitoring under vertical integration.

The left hand side is expression (8) and represents his expected payoff if he monitors, while the right hand side represents the expected payoff if he does not monitor. This is equivalent to

$$\pi_G(B - c - w) + (1 - \pi_G)(-w^S) - \frac{\mu}{(1 - \pi_H)} \geq -w^S. \tag{10}$$

From equations (8), (9) and (10), we can write the problem of the owner/client as follows:

$$\max_{w,w^S} \quad -w[\pi_H + (1 - \pi_H)\pi_G] - w^S(1 - \pi_H)(1 - \pi_G)$$
$$+(B - c)[\pi_H + (1 - \pi_H)\pi_G] - \mu$$
$$\text{s.t.} \quad w - w^S \geq \frac{e^H}{\pi_H(1 - \pi_G)} \quad \text{(high effort)},$$
$$w - w^S \leq B - c - \frac{\mu}{\pi_G(1 - \pi_H)} \quad \text{(monitoring)},$$
$$w^S \geq 0.$$

The shape of the resulting problem is represented on figure 4. The feasible set is represented by the band between the two diagonal lines. If

$$\frac{e^H}{\pi_H(1 - \pi_G)} \leq B - c - \frac{\mu}{\pi_G(1 - \pi_H)}, \tag{11}$$
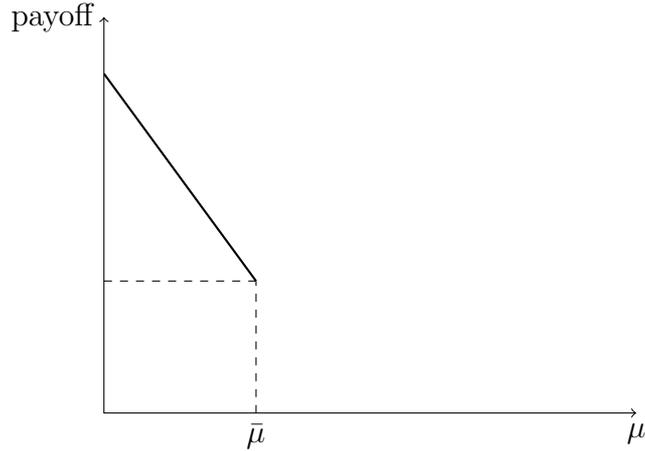
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Figure 5: Payoff of the owner/client as a function of μ with contracts that induce monitoring.

the optimal contracts sets $w^S = 0$ and $w = e^H / [(1 - \pi_G)\pi_H]$. The payoff of the owner/client is

$$[\pi_H + (1 - \pi_H)\pi_G] \left[B - c - \frac{e^H}{(1 - \pi_G)\pi_H} \right] - \mu. \tag{12}$$

If inequality (11) does not hold, that if if

$$\mu > (1 - \pi_H)\pi_G \left[B - c - \frac{e^H}{(1 - \pi_G)\pi_H} \right] \overset{\text{def}}{=} \bar{\mu},$$

there is no solution: it is impossible to at the same time induce the agent to provide a high effort (which requires a high w) and to induce the owner/client to monitor (which requires that w be not too high, so that continuation is worthwhile). The resulting shape of the payoff as a function of μ is represented on figure 5.

2.3 The optimal contract

When the cost of monitoring is $\bar{\mu}$ the payoffs are equal with and without monitoring. It is therefore clear that the optimal contract induces monitoring for $\mu < \bar{\mu}$, and does not induce monitoring for $\mu > \bar{\mu}$. The general shape of the payoff to the client/owner as a function of μ is represented on figure 6, which is obtained by combining figures 3 and 5. It is decreasing for $\mu < \bar{\mu}$, and increasing for $\mu > \bar{\mu}$.

We have shown this property in a very simple example, but the economic intuition is robust enough that one can be confident that it should hold in much more general setting. Indeed, it should be generally true that when one monitors, an increase in μ decreases profits; that when one needs to provide incentives not to monitor, an increase in μ increases profit; and that one monitors when μ is small.
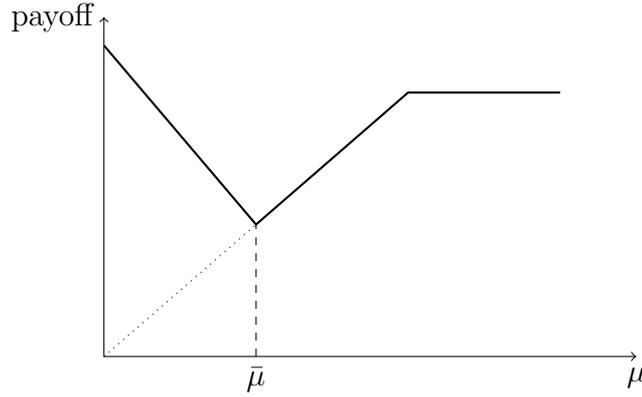
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Figure 6: Payoff of the owner/client as a function of μ.

2.4 Renegotiation proofness

The only time at which renegotiation could occur would be after the signal has been observed. The manager could accept a lower w in order to encourage continuation.[6] If monitoring has taken place, this is clearly not feasible: continuation already takes place in every state of nature where it is optimal. If monitoring has not taken place, because, by equations (1) and (2), B is much smaller than either c and P, the owner/client will refuse to continue even if $w = 0$.

3 No integration

In this section we revisit the model of the previous section when the client and the owner of the upstream firm are two different parties.

Intuition tells us that because monitoring information is soft, neither of these two parties can delegate to the other the task of monitoring. If, for instance, the owner is in charge of monitoring, he will accept continuation if he observes the state BC, which is not in the interest of the client. As a first approximation, vertical disintegration should therefore equivalent to a doubling of the cost of monitoring. However, this is not generally true without more assumptions. Indeed, it is possible to find contracts through which monitoring is nearly completely delegated to one of the parties. These contracts work in the following way. Assume that we want to have the owner do the monitoring. We ask the customer to monitor with a small probability. After monitoring has taken place, the owner and the customer announce whether or not they have monitored and, if they have monitored, they announce what they have observed. They pay a high penalty if they announce different results from their monitoring. It is possible to choose penalties

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[6]If the decision to conduct monitoring were taken after the signal is observed, this discussion would be much more complex. The manager would know his effort, and renegotiation would be taking place under asymmetric information.

high enough that the only equilibrium is a truthful equilibrium. In the sequel we assume away the possibility of such contracts, by focussing on pure strategy equilibria.[7]

The rest of this section is dedicated to making more precise the statement that the fact that we need to induce the owner and the client to monitor is equivalent to a doubling of the monitoring cost.

Our first task is to model the games between the three parties: the owner, the client and the manager. Both the owner and the client are risk neutral and income is transferable between the two of them; there is therefore no difference between giving one or the other the first mover advantage, and it does not make any difference which one of the two offers the contract to the other. We will therefore simply assume that in the first stage of the game they agree on a contract that maximizes the sum of their profits.

3.1 Contracts that induce monitoring

Contrary to the case of vertical integration, it is easier to study first the contracts that induce monitoring. The only contracts that induce both parties to monitor must condition continuation of the project on the agreement of both the owner and the client. In particular, it is impossible to have only one[8] of these two parties monitor. For this party, once it has observed the state of nature the only undominated strategy is to choose continuation whenever the state of nature is not unfavorable to its own interests. For instance, the client will choose to continue in the state BS. Ex-ante this is inefficient if c is large enough. Therefore, we study contracts in which both parties monitor, and in which joint approval is required for continuation.[9]

The objective is to maximize the sum of the profits of the owner and the client. The objective function is therefore

$$\pi_H(B - c - w) + (1 - \pi_H)[\pi_G(B - c - w) + (1 - \pi_G)(-w^S)] - 2\mu. \qquad (13)$$

This equation is exactly similar to (8) except for the fact that μ has been replaced by 2μ.

The incentives of the manager are the same as in the integrated case and he will provide high effort if inequality (9) holds.

The client will monitor if t, his payment to the owner in case of continuation, and t^s,

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[7]Another possibility would be to assume that there is one investment in monitoring cost which is used for many projects. If a party had not invested, there is a probability that this would be observed by the other one at the occasion of one of the first projects. In subsequent projects, the party who has invested would be able to take advantage of the situation to extract large rents.

[8] If we had assumed, as suggested in footnote 2, that the decision to monitor is taken after the signal is observed, we would have to take into account the possibility that one party monitors only if the other one has done so, and has agreed to continuation.

[9]Whatever the contract which is signed, an equilibrium without monitoring exists. A party that does not monitor will always refuse continuation. Therefore, if the owner expects the client not to monitor he has no incentive to monitor, as the project will in any case be discontinued when L is observed. In the analysis which precedes I assume that the agents coordinate on the efficient equilibrium.
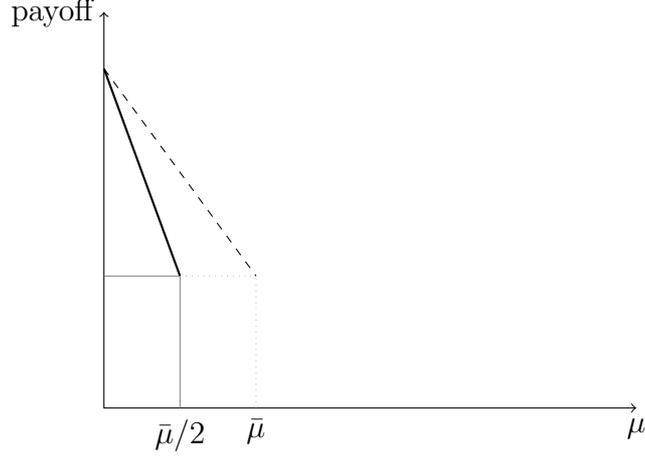
Figure 7: Aggregate payoff of the owner and the client as a function of μ with contracts that induce monitoring.

his payment if the project is stopped, satisfy

$$\pi_H(B-t) + (1-\pi_H)[\pi_G(B-t) + (1-\pi_G)(-t^s)] - \mu$$
$$\geq \pi_H(B-t) + (1-\pi_H)(-t^s), \quad (14)$$

where the left hand side represents his payoff in case of monitoring (assuming that the owner also monitors) and the right hand side his payoff without monitoring (in this case, he stops the project every time the signal L is observed). This is equivalent to

$$t - t^s \leq B - \frac{\mu}{\pi_G(1-\pi_H)}. \quad (15)$$

The owner receives t from the client and pays w to the manager if the project is continued. If the project is terminated he receives t^s and pays w^S. Given that the client monitors, he will monitor if

$$\pi_H(t-w-c) + (1-\pi_H)[\pi_G(t-w-c) + (1-\pi_G)(t^s-w^S)] - \mu$$
$$\geq \pi_H(t-w-c) + (1-\pi_H)(t^s-w^S), \quad (16)$$

which is equivalent to

$$(t-w) - (t^s-w^S) \geq c + \frac{\mu}{\pi_G(1-\pi_H)}. \quad (17)$$

In the resulting problem, we can without loss of generality set $t - t^s$ equal to the right hand side of equation (15). Then, equation (17) becomes

$$w - w^S \leq B - c - \frac{2\mu}{\pi_G(1-\pi_H)}, \quad (18)$$

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which is equivalent to the monitoring constraint of the problem of subsection 2.2 with μ replaced by 2μ. Hence, modulo this replacement, the two problems are exactly equivalent. For contracts that induce monitoring, the absence of vertical integration is equivalent to increasing the cost of monitoring. We can therefore recycle the analysis of the preceding section. The variation of the payoff as function of μ is given in figure 7.

3.2 Contracts that do not induce monitoring

The reasoning of footnote 9 shows that it is straightforward to write a contract that does not induce monitoring: choose the terms as you wish, and just write down that no monitoring takes place. It is then a Nash equilibrium of the game played between the owner and the client that neither of them conducts monitoring. Our main results go through if we admit, as this story suggests, that any contract can discourage monitoring, but we can find a more interesting story by focussing on renegotiation proof contracts.

We will assume that after the contract has been signed the owner and the client can renegotiate the transfers t and t^s, and that if there are several equilibria in the first stage game where they each choose whether or not to monitor they coordinate on a Pareto optimal one. It is then easy to show that if

$$w - w^S \geq B - c - \frac{2\mu}{\pi_G(1 - \pi_H)}, \tag{19}$$

there exist no couple of transfers (t, t^s) such that the owner and the client will be induced to monitor. If such transfers existed they would have to satisfy inequality (14) and (16). This would imply that equation (18) holds, a contradiction.

On the other hand, from the reasoning of 3.1 it is clear that (19) is necessary for the non existence of transfers such that monitoring is strictly Pareto superior for owner and client.

Because the incentives of the manager have not changed because of the change in ownership structure, the analysis is exactly similar to the analysis of contracts that do not induce monitoring in the case of vertical integration conducted in 2.1, as long as μ is replaced by 2μ.

3.3 Coalition proofness of the contracts

The equilibria of the games described in this section are robust to coalitions. This is clearly the case for coalitions composed of the client and the owner: the contracts that are signed when aggregated together form the contract that a single party whose cost of monitoring would be 2μ would sign. Given that they cannot lower the total cost of monitoring below this amount, they cannot renegotiate between themselves. Therefore the only possible successful coalitions are those composed of the manager and either the owner or the client.

These coalitions cannot form when the contract calls for no monitoring. There is no reason to induce monitoring by one party, and if the incentives to do monitoring are not

changed, the interests of the manager are only to have his salary increased, but there is nothing he can give in exchange to a coalition partner.

We are therefore left with the possibility of a coalition when the optimal contract calls for monitoring. By the reasoning of the previous paragraph, such a coalition can only be successful if it changes the incentives to monitor. However, if there is less monitoring the manager will be worse off, as the probability or receiving the wage w decreases. Hence, his partner must provide side payments whose expected value is strictly positive. In exchange for these side payments, he would be able not to monitor, but he can choose not to monitor totally independently without incurring any costs. Therefore forming a coalition can never be Pareto optimal.[10]

4 Choosing the ownership structure

With the analysis of the preceding sections in mind, we can compare the payoffs under the two organizational structures. From the analysis of the preceding section, it is clear that the payoff without vertical integration when the cost of monitoring is μ is equal to the payoff with vertical integration when the cost of monitoring is 2μ. The variations of the resulting payoffs as a function of μ are represented on figure 8. We obtain immediately the following proposition, which is our main result:

Proposition 1 *There exist a value μ^v such that vertical integration is preferred if and only if $\mu \leq \mu^v$.*
Under vertical integration, there always is monitoring. Without vertical integration, there is never any monitoring.

The function that links payoffs to monitoring cost is (basically) U-shaped. If this cost were a choice variable, it would be chosen either very small or very large. This choice cannot be made directly, but only through the indirect instrument of the ownership structure, which is chosen so as to facilitate the drawing of a contract that provides the correct incentives to conduct monitoring.[11]

---

[10]With contracts that induce monitoring, there exists another deviation from the equilibrium path described above that should be discussed. The owner could decide not to monitor, and to offer to sell the firm to the client — who must have monitored along the equilibrium path — when he announces that he would accept continuation. Difficult issues of renegotiation under asymmetric information arise, but we can eliminate this equilibrium naturally with the alternative assumption on monitoring costs described in the note on page 4. If $\alpha < 1$, neither the client nor the supplier will have an incentive to monitor both variables. When the signal is observed it is too late to set up the monitoring system, hence the deviation discussed above cannot occur. As discussed at the end of section 4, the results of the paper still hold with this assumption. Of course, the analysis that has been presented above is a very good approximation if α is very close to 1.

[11] The results would still hold with the alternative assumption on monitoring costs discussed on page 4 and in footnote fo monitoring costs 2. The only difference would be that vertical integration would decrease the costs of monitoring by less than half: for all formulas in section 3 we would have to replace 2μ by $2\alpha\mu$. Therefore the curve "with vert. int." on figure 8 would be steeper (closer in shape to the curve "without vert. int."), and μ^v would be smaller.
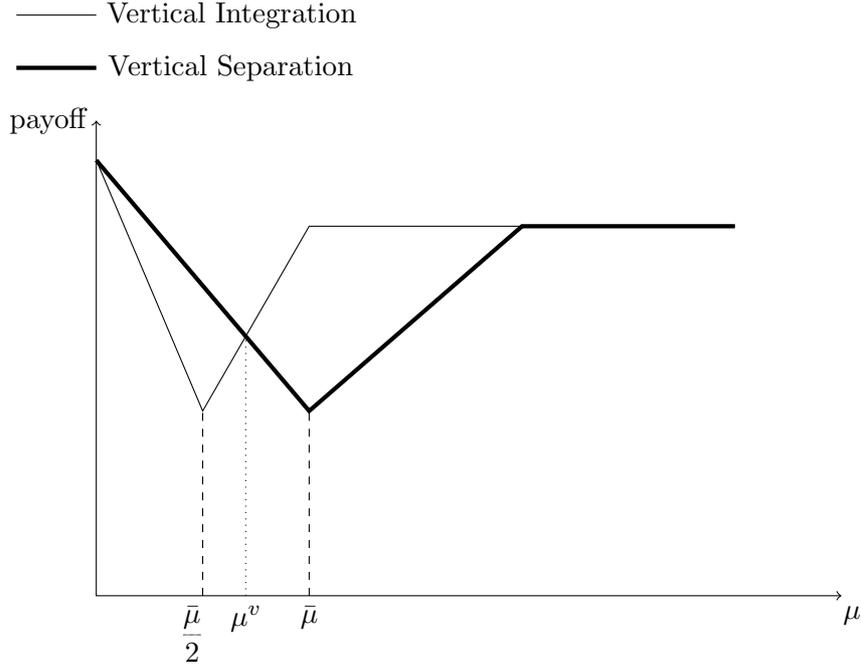
Figure 8: Comparison of the payoffs with and without vertical integration

5 Does vertical integration lower the amount of effort?

In the previous section, we have studied the choice between vertical integration and disintegration in a framework in which the level of effort was, by hypothesis, the same in both cases. If we keep this hypothesis, it is clear that the same results will hold in more general setups. The function that represents the payoff of the owners as a function of μ will always have the general shape represented on figure 8. Indeed, for small values of μ, monitoring will always be optimal, and an increase in its cost will decrease the profits. At some point, no monitoring will become optimal, and an increase in its cost will increase profits as it will make it easier to induce the owner and client not to monitor.

What happens on the other hand, if the level of effort varies with the organizational structure? As discussed in the introduction, intuition suggests that effort will be lower with vertical integration. We proceed to confirm this hypothesis on a simple generalization of the model used in sections 1 to 4, and I will show that it is actually the implicit decrease in the cost of monitoring due to vertical integration that induces a decrease in the level of effort.

There are still two possible signals H and L, and the probabilities of the different outcomes, given these signals, are the same as on figure 1. The only difference with the previous setup is that the manager can influence the probability $q \in [0,1)$ with which H will be observed by making the effort $e(q)$. I assume that the first *three* derivatives of

the function e are positive, with the first two strictly positive for $q > 0$, and

$$e(0) = e'(0) = 0,$$
$$\lim_{q \to 1} e'(q) = +\infty.$$

5.1 Contracts with monitoring under vertical integration

As above it will be clear that in the optimal contract $w^s = 0$. We therefore dispense with this variable. The manager maximizes

$$[q + (1 - q)\pi_G]w - e(q),$$

and given w chooses q such that

$$e'(q) = (1 - \pi_G)w. \tag{20}$$

The owner/client monitors if

$$[q + (1 - q)\pi_G](B - c - w) - \mu \geq q(B - c - w).$$

Substituting w computed from (20), we obtain

$$\mu \leq (1 - q)\pi_G(B - c - \frac{e'(q)}{1 - \pi_G}). \tag{21}$$

The payoff of the owner/client is

$$[q + (1 - q)\pi_G](B - c - w) - \mu = [q + (1 - q)\pi_G](B - c - \frac{e'(q)}{1 - \pi_G}) - \mu \overset{def}{=} h(q), \tag{22}$$

and his problem is to find the q that maximizes $h(q)$ subject to the constraint (21). Because the third derivative of e is positive, the function h is concave. If the monitoring constraint (21) is not binding, the optimal probability q^a satisfies $h'(q^a) = 0$, that is

$$(B - c)(1 - \pi_G) - e'(q^a) - [\pi_G + q^a(1 - \pi_G)]\frac{e''(q^a)}{1 - \pi_G} = 0. \tag{23}$$

From (21), the monitoring constraint is binding if

$$\mu > (1 - q^a)\pi_G(B - c - \frac{e'(q^a)}{1 - (1 - \pi_G)}),$$

and in this case the probability q of observing H is solution of

$$\mu = (1 - q)\pi_G(B - c - \frac{e'(q)}{1 - (1 - \pi_G)}). \tag{24}$$

The right hand side of this equation is the product of two positive functions that are decreasing in q and therefore it is also decreasing in q. Hence q decreases when μ increases. This makes economic sense: when μ increases, in order to encourage monitoring one increases the probability of L. We therefore obtain the following lemma:

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Lemma 1 *With monitoring, for all μ the optimal q is smaller than or equal to q^a, where q^a is the solution of equation (23).*

The right hand side of equation (24) reaches a maximum for some q. This determines a maximum μ for which one can incite the owner/client to conduct monitor, which we will call $\bar{\mu}$ by analogy with section 2.2. For $\mu > \bar{\mu}$ there is no feasible contract such that monitoring takes place.

5.2 Contracts without monitoring under vertical integration

With contracts that do not induce monitoring, the manager will receive a wage w if and only if the signal is H. He will choose q to maximize

$$qw - e(q),$$

and q will satisfy $e'(q) = w$. Note that, here also, it is easier to induce effort without monitoring: comparing with equation (20), for the same w, the effort q produced by the manager is higher. The profit of the owner/client is

$$q(B - c - w) = q(B - c - e'(q)).$$

The right hand side of this equation is a strictly concave function in q. When the no monitoring constraint is not binding the owner/client chooses the unique q^n that satisfies

$$e'(q^n) + q^n e''(q^n) = B - c. \tag{25}$$

The no monitoring constraint is written

$$\mu \geq \pi_G(1 - q)(B - c - w),$$

where the left hand side represents the cost of monitoring and the right hand side its benefit (with probability $\pi_G(1 - q)$ monitoring yields a payoff of $B - c - w$). Therefore if

$$\mu \geq \pi_G(1 - q^n)(B - c - e'(q^n)),$$

the no monitoring constraint is not binding, and q^n is the solution of the problem of the owner/client.

On the other hand, if the constraint is binding the optimal q is solution of the equation

$$\mu = \pi_G(1 - q)(B - c - e'(q)).$$

Because the right hand side is decreasing in q, the optimal q will once again be a decreasing function of μ. Again, this makes economic sense. As μ increases a smaller distortion in the probability of L is sufficient to deter monitoring. A solution exist for any μ such that the constraint is binding (with $\lim_{\mu \to 0} e'(q) = B - c$).

We have therefore proved the following lemma:

Lemma 2 *Without monitoring, for all μ the optimal q is greater than or equal to q^n, solution of equation (25).*

5.3 Comparing the levels of effort

We have

$$h'(q^n) = (B-c)(1-\pi_G) - e'(q^n) - [\pi_G + q^n(1-\pi_G)]\frac{e''(q^n)}{1-\pi_G}$$

$$= -\pi_G(B-c) - e''(q^n)\frac{\pi_G}{1-\pi_G} < 0.$$

Because $h'(q^a) = 0$ and h is strictly concave, $q^n > q^a$. By lemmas 1 and 2, *effort with monitoring is always lower than effort without monitoring.*

It is clear that the analysis of the choice of vertical integration will follow exactly the same path than in section 4; the only difference could be a discontinuity at $\bar{\mu}$, but this would not affect the results. From the second part of Proposition 1 it follows that the effort associated to any μ such that vertical integration is the optimal choice will be smaller than the effort associated to any μ such that non-integration is the optimal choice.

6 Information available without cost

In the model so far, we have assumed that improvement in information technology implied that the cost of monitoring decreased. This implies that improved information leads to more vertical information. However, in recent years we have had on average better information and *less* vertical information. In this section, we extend the model to show that this conclusion depends on the type of information that becomes more easily available when information technology improves.

In order to explore this question, we change the information structure, as represented on figure 9. With probability $1 - \phi$ the principal sees the same signal as above; with probability ϕ, he receives information about the true state of nature. Monitoring gives information to the principal; hence if the principal has decided to do monitoring, the fact that he would have received some information even without monitoring does not change his payoff. On the other hand, there are some values of μ for which it would have been possible to provide incentives for the principal to monitor for which it is not possible to do so when he can have access to "free" information. This is represented on figure 10, which should be compared to figure 5. We also obtain the following results:

- Without monitoring by the principal, his payoff is increasing in ϕ, for given w..

- Without monitoring by the principal, the incentives of the agent are increasing in ϕ: one need pay the agent less to to obtain high effort, as the incentive compatibility constraint of the agent is written

$$[(1-\phi)\pi_H + \phi(\pi_H + (1-\pi_H)\pi_G)]w \geq e^H$$

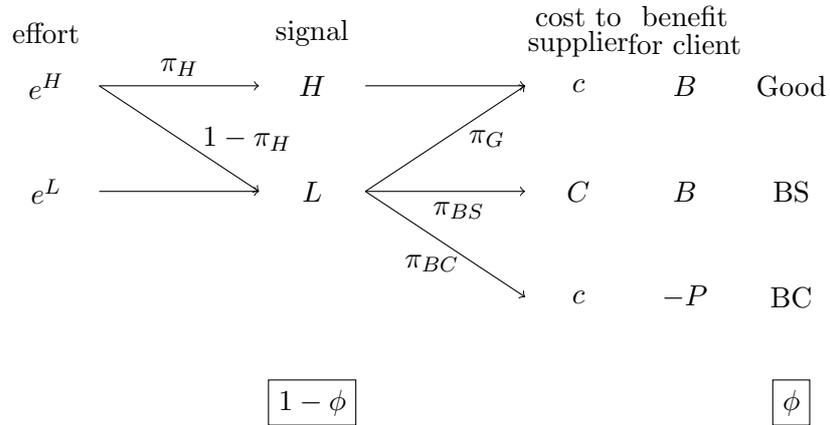$$\iff [\pi_H + \phi(1-\pi_H)\pi_G]w \geq e^H.$$

Figure 9: This figure represents the information structure when some information is available without cost.
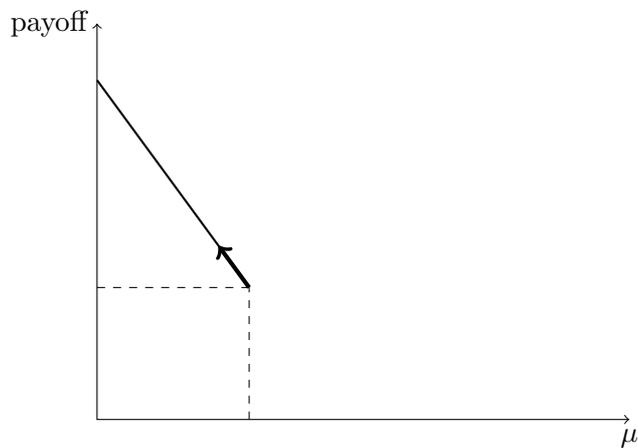

Figure 10: Payoff of the owner/client as a function of μ with contracts that induce monitoring when some information is available with cost.

- When ϕ increases, the incentives of the principal to monitor decrease — it is easier to convince him *not* to monitor.

- Overall, payoff of principal when it does not monitor increases when ϕ increases.

It is then possible to show that an increase in ϕ makes vertical information more desirable. Therefore if an improvement in information technology increases vertical information.

These results highlight the fact that improvements in information technology can make vertical information more or less valuable depending on the type of information that it provides.

7 Freely available information

Let us assume now that with probability ϕ, information is ϕreely available to the principal: whether or not he has monitored, once he observes the signal, he knows the true state of nature. We reproduce the analysis of the paper.

7.1 Contracts that do not induce monitoring

The project is continued if a) signal H is observed or b) if L is observed and free information is available. It is easy to show that as in the previous model $w^s = 0$, and, in order to simplify notation, we take this as given. The payoff of the owner/client is

$$
\begin{aligned}
\pi_H(B - c - w) + (1 - \pi_H)\phi\pi_G(B - c - w) \\
= (B - c - w)(\pi_H + \phi(1 - \pi_H)\pi_G) \\
= (\pi_H(1 - \phi\pi_G) + \phi\pi_G)(B - c - w). \quad (26)
\end{aligned}
$$

When the manager has provided high effort, the project will be continued if a) the signal is H or b) the signal is L, free information is available and the continuation state is good. On the other hand, if the manager provides low effort, the project will be continued only if free info is available and continuation value is good. Hence, to obtain high effort the wage must satisfy

$$
\pi_H w + (1 - \pi_H)\phi\pi_G w - e^H \geq \phi\pi_G w \Longleftrightarrow w \geq \frac{e^H}{\pi_H(1 - \phi\pi_G)}. \quad (27)
$$

Note that a higher ϕ implies that a higher wage is required in order to induce the agent to work as there is a greater probability that the project will continue even with low effort.

For given wages and given effort from the agent, the payoff of the principal under monitoring is the same as when $\phi = 0$: the freely available information plays no role. Therefore the principal will not monitor if

$$
(B - c - w)(\pi_H + (1 - \pi_H)\pi_G) - \mu \leq (B - c - w)(\pi_H + (1 - \pi_H)\phi\pi_G)
$$

which is equivalent to

$$w \geq B - c - \frac{\mu}{\pi_G(1 - \pi_H)(1 - \phi)}. \tag{28}$$

Equation (28) (as opposed to (27)) is binding if

$$B - c - \frac{\mu}{\pi_G(1 - \pi_H)(1 - \phi)} \geq \frac{e^H}{\pi_H(1 - \phi\pi_G)}$$

$$\Longleftrightarrow \mu \leq (1 - \pi_H)\pi_G(1 - \phi)\left[B - c - \frac{e^H}{\pi_H(1 - \phi\pi_G)}\right]$$

In this case, the profit of the owner/manager is

$$\frac{\pi_H + (1 - \pi_H)\phi\pi_G}{\pi_G(1 - \pi_H)(1 - \phi)}\mu. \tag{29}$$

Notice that the slope of function that gives us the payoff as a function of μ is increasing in ϕ: free monitoring makes effort more costly for the principal, but increases the probability of continuing the project when it should be continued — this second effect dominates.

On the other hand if

$$\mu \geq (1 - \pi_H)\pi_G(1 - \phi)\left[B - c - \frac{e^H}{\pi_H(1 - \phi\pi_G)}\right],$$

the no monitoring constraint is not binding anymore and the payoff does not depend on μ. The wage is determined by (27) and the payoff is

$$[\pi_H(1 - \phi\pi_G) + \phi\pi_G]\left[B - c - \frac{e^H}{\pi_H(1 - \phi\pi_G)}\right].$$

It is not obvious whether this thing is increasing in ϕ or not.

7.2 Contracts that induce monitoring

With monitoring the payoff of the principal is

$$(B - c - w)[\pi_H + (1 - \pi_H)\pi_G] - \mu, \tag{30}$$

independent of ϕ. For given w, this payoff is independent of ϕ.

Because the monitoring provides all the information to the manager, and outside information is irrelevant, and the condition for effort is the same as with no outside info:

$$[\pi_H + (1 - \pi_H)\pi_G]w - e^H \geq \pi_G w \Longleftrightarrow w \geq \frac{e^H}{\pi_H(1 - \pi_G)}. \tag{31}$$

The owner/client will monitor if

$$(B - c - w)[\pi_H + (1 - \pi_H)\pi_G] - \mu \geq (B - c - w)(\pi_H + \phi(1 - \pi_H)\pi_G).$$

$$[\pi_H(1-\phi\pi_G)+\phi\pi_G]\left[B-c-\frac{e^H}{\pi_H(1-\phi\pi_G)}\right]$$

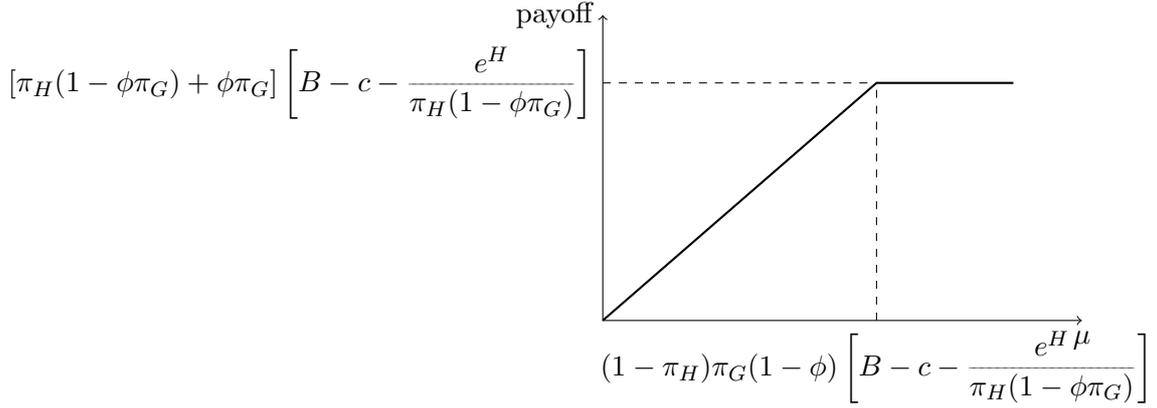$$(1-\pi_H)\pi_G(1-\phi)\left[B-c-\frac{e^H\mu}{\pi_H(1-\phi\pi_G)}\right]$$

Figure 11: Payoff of the owner/client as a function of μ with contracts that do not induce monitoring.

(The left hand side is expression (30).) This is equivalent to

$$w \leq B - c - \frac{\mu}{\pi_G(1-\pi_H)(1-\phi)}. \tag{32}$$

Note that the range of w for which monitoring can be induced is reduced by the presence of outside information: this makes sense as the outside information is a substitute for monitoring.

Monitoring will be feasible if (31) and (30) are compatible, which is if

$$\frac{e^H}{\pi_H(1-\pi_G)} \leq B - c - \frac{\mu}{\pi_G(1-\pi_H)(1-\phi)}$$

$$\Longleftrightarrow \mu \leq \pi_G(1-\pi_H)(1-\phi)\left[B-c-\frac{e^H}{\pi_H(1-\pi_G)}\right] \overset{\text{def}}{=} \mu(\phi). \tag{33}$$

Of course, we have $\bar\mu = \mu(0)$.

The payoff of the owner/client is given by (30), with w equal to the left hand side of (31) — that is, at given μ, the same payoff as in the case where $\phi = 0$,

$$[\pi_H+(1-\pi_H)\pi_G]\left[B-c-\frac{e^H}{(1-\pi_G)\pi_H}\right]-\mu. \tag{34}$$

The only difference is that the range of μs for which it is possible to do monitoring is smaller and given by (33). As a consequence, the figure that represents the payoff as a function of μ becomes figure 12. Substituting the value of μ from (33) into (34), we obtain the lowest possible value of the payoff of the principal when there is monitoring,

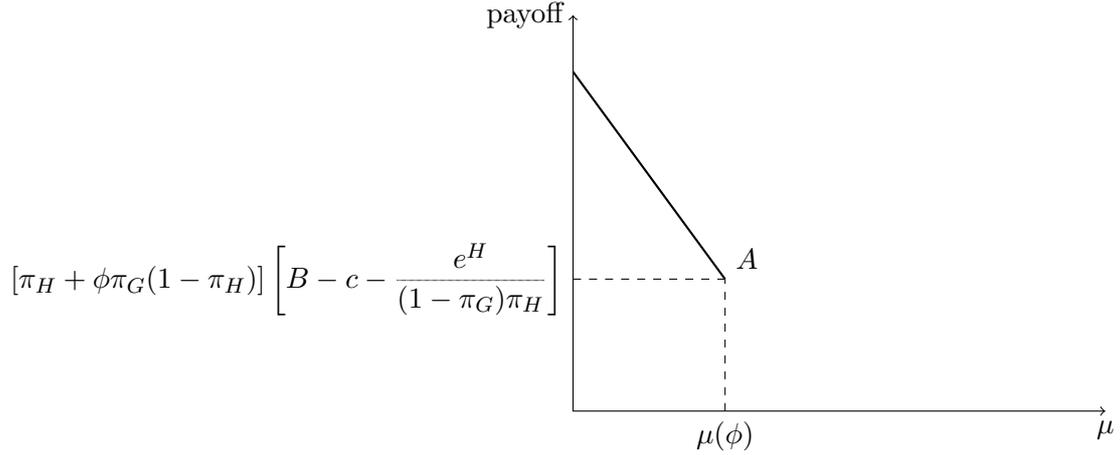$$[\pi_H+\phi\pi_G(1-\pi_H)]\left[B-c-\frac{e^H}{(1-\pi_G)\pi_H}\right]. \tag{35}$$

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Figure 12: Payoff of the owner/client as a function of μ with contracts that induce monitoring.

(See figure 12.)

I now show that point A in figure 12 is on the ascending part of figure 12. To see this we plug the value of μ from (33) in (29) to obtain

$$\frac{\pi_H + (1 - \pi_H)\phi\pi_G}{\pi_G(1 - \pi_H)(1 - \phi)} \times \pi_G(1 - \pi_H)(1 - \phi)\left[B - c - \frac{e^H}{\pi_H(1 - \pi_G)}\right]$$
$$= [\pi_H + (1 - \pi_H)\phi\pi_G]\left[B - c - \frac{e^H}{\pi_H(1 - \pi_G)}\right],$$

which is equal to (35), which proves the result.

7.3 The consequences of outside information for vertical integration

Figure 13 shows how the presence of outside information affect the profits of the principal/owner. The profits are not affected for small values of μ, when the principal offers a contract that induces monitoring, but they are larger when the contract induces monitoring.

The consequences for the choice of vertical integration can be seen on figure 14.

Think of outside information as the result of an investment by the owner/principal: if he invests γ he obtains information without monitoring with probability ϕ. Then, for given μ, he will of course choose the investment for small γ. This implies that the choice between vertical integration and disintegration will be as represented on figure 15.
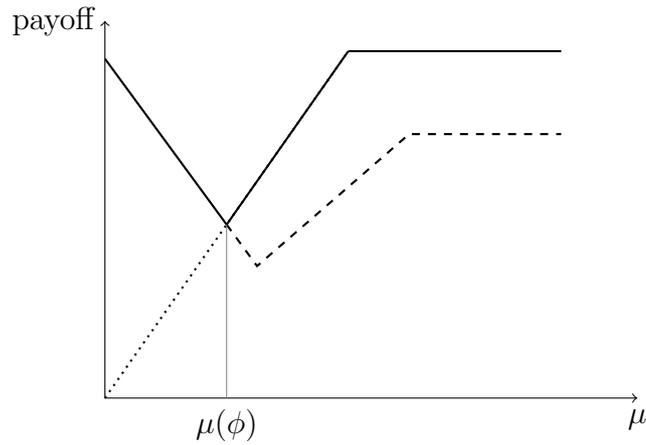
Figure 13: The payoff of the principal with and without outside information. The solid
line represents the payoff of the principal as a function of μ when $\phi > 0$, while
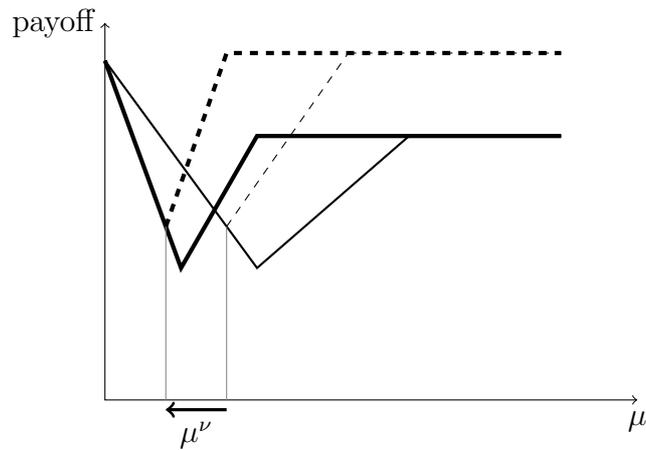the dashed line represents the payoff with no outside information.

Figure 14: Comparing payoffs with and without vertical integration. The thin line rep-
resents the payoff of the owner/principal when $\phi = 0$ and the thick lines
represent this payoff for $\phi > 0$. The solid lines represent the payoffs without
vertical integration and the dashed lines the payoff with vertical integration.
The cutoff value of μ for vertical integration to be profitable is smaller for
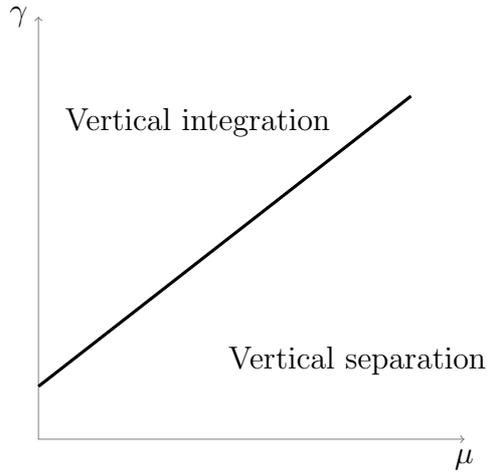positive ϕ.

Figure 15: The choices between vertical integration and disintegration as a function of μ and γ.

8 The R signal

Referee II of "A theory of vertical integration based on monitoring costs" suggests a modification of the model. There are three possible signals, H, L and R (I am renaming them to make the parallelism to present paper more obvious):

- after signals have been observed:
  - after H and L same as in paper;
  - after R one of the bad outcomes will certainly prevail;
- probabilities of outcomes depending on efforts:
  - if e_H same as in paper;
  - if e_L outcome R with probability π_R and L with probability $1 - \pi_R$.

The referee states that if $\pi_R > \pi_H$ then the curve of payoffs as a function of μ is not U-shaped and therefore the results do not hold anymore, more monitoring is always better. He is right, as we will show below, but there is a problem with the conclusion: if $\pi_R > \pi_H$ then no effort is optimal, and the problem of incentives diminish.

Actually, the case $\pi_R > 0$ yields quite interesting comparative statics which we explore.

The new model is represented on figure 16. When signal R is observed, the principal knows that the state of nature is bad. Assume that the probability that the state is BC is $\pi_{BC}^R \equiv \pi_{BC}/(\pi_{BC} + \pi_{BS})$, and the probability that the state is BS $\pi_{BS}^R \equiv \pi_{BS}/(\pi_{BC} + \pi_{BS})$.

To solve the problem, we study the shape of the payoff function when there is only one principal. Notice first that nothing is changed in the problem without monitoring.
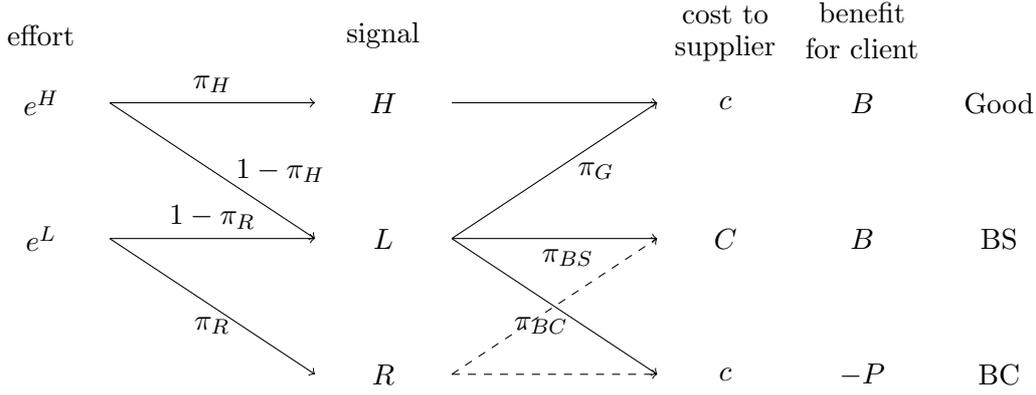
Figure 16: The model with signal R.

Given that the principal does not monitor, L and R are equivalent from the viewpoint of incentives of the agents: if any one of them is observed, the project is stopped. Given that the agent makes a high effort, the principal will never observe R, which plays therefore no role in the problem.

On the other hand, the problem with monitoring is changed. Given that the agent does an high effort, the incentives of the principal to monitor are not changed, and the monitoring constraint remains

$$\pi_H(B - c - w) + (1 - \pi_H)\pi_G(B - c - w) - \mu \geq \pi_H(B - c - w).$$

This implies

$$w \leq \pi_G(B - c) - \frac{\mu}{\pi_G(1 - \pi_H)}. \tag{36}$$

The agent has smaller incentives to shirk when $\pi_R > 0$: indeed this increases the probability that the project fails. The high effort constraint becomes

$$[\pi_H + (1 - \pi_H)\pi_G]w - e^H \geq (1 - \pi_R)\pi_G w \iff w \geq \frac{e^H}{(1 - \pi_G)\pi_H + \pi_R\pi_G}.$$

On figure 4 the coordinate the high effort constraint intersects the horizontal axis for $w = e^H/((1 - \pi_G)\pi_H + \pi_R\pi_G)$ and therefore the payoff of the owner client is

$$[\pi_H + (1 - \pi_H)\pi_G]\left[B - c - \frac{e^H}{(1 - \pi_G)\pi_H + \pi_R\pi_G}\right] - \mu, \tag{12-R}$$

which is to be compared to (12).

Equation (11) is rewritten

$$\frac{e^H}{\pi_H(1 - \pi_G) + \pi_R\pi_G} \leq B - c - \frac{\mu}{\pi_G(1 - \pi_H)}, \tag{11-R}$$

which, together with (12-R), implies that at the limit μ the payoff is independent of μ. Figure 5 can therefore be redrawn as figure 17. As π_R increases, the function shifts upwards, as shown by the dotted line.
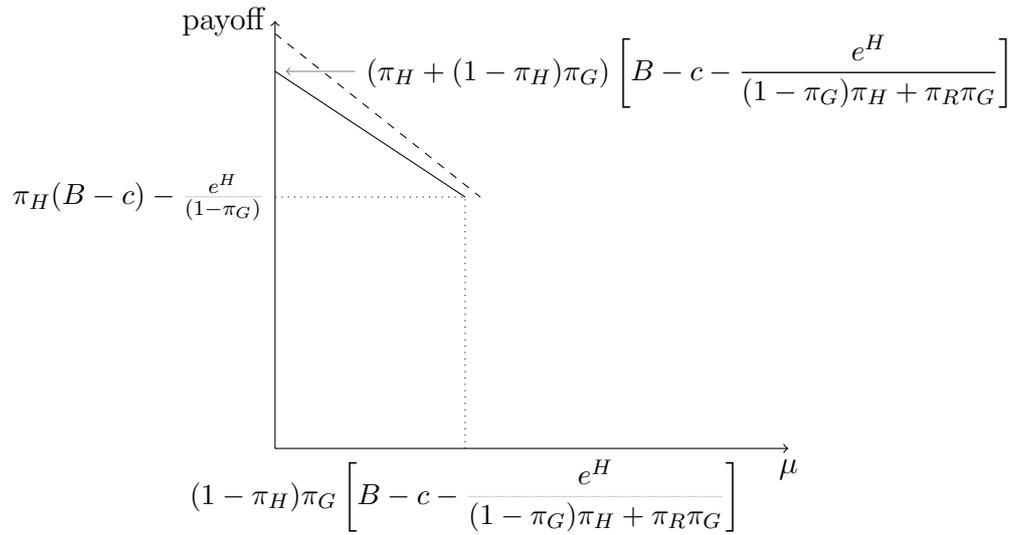
Figure 17: Payoff of the owner/client as a function of μ with contracts that induce monitoring.

The consequences for comparison of vertical structures is seen on figure 18. A small increase in μ shifts the curve to the lowest dashed line, and favors vertical integration with the theory staying sensibly similar. If $\pi_R > \pi_G$, the new payoff function corresponds to the highest dashed curve. There will be monitoring for low values of μ and no monitoring for high values of μ — in that latter case, the no monitoring constraint is not binding.
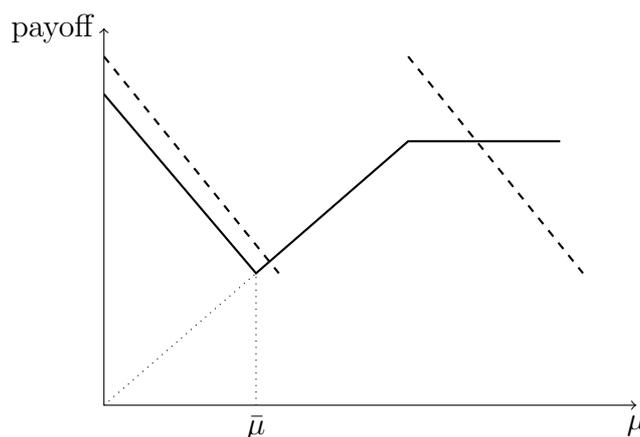
Figure 18: The payoff as a function of μ.

9 Conclusion

The aim of this paper has been to present a simple model where the allocation of the right to the profit stream of the firm induces changes in the incentives of the different parties to gather information, and determines through that channel the costs and benefits of vertical integration. A number of extensions come to mind.

The same theoretical framework could probably be applied to the theory of privatization. Schmidt (1996) assumes that the owner of the firm, government or stockholder, is the informed party. In the spirit of the present paper, one should study his incentives to become informed, and the incentives of government or civil service are very different from those of private owners. Hence, it might be possible to obtain a theory that discriminates better between nationalization and the effect of integration of two private firms.

The insights could maybe also be applied to conglomerates. In his discussion in *Markets and Hierarchies*, Williamson (1976) assumes that the "elite staff" is better informed than the financial markets could ever become about the prospects of the subsidiaries. It would be interesting to rethink through the issues while integrating the incentives of that staff to gather this information, and to use it to the benefit of the firm.

Expanding the analysis, one could think through the consequences of the fact that information is actually multidimensional. A stockholder and a client are not interested in the same dimension. This might enable us to speak of long run relationships between suppliers and buyers, and in particular to develop the links between the approach taken here and approaches based on the presence of specific capital.

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Appendix A:
Risk aversion.

In this appendix, I explore the consequences of more general assumptions on the utility function of the manager. I assume that he judges uncertain payments according to a strictly concave[12], increasing, von Neuman-Morgenstern expected utility function v defined on $(-\infty, +\infty)$ which satisfies

$$v(0) = 0, \tag{A.1}$$

$$\lim_{w \to -\infty} v(w) = -\infty, \tag{A.2}$$

$$\lim_{w \to +\infty} v(w) = +\infty. \tag{A.3}$$

$$\tag{A.4}$$

Rather than working directly with w and w^s, it will be easier to work with $u = v(w)$ and $u^s = v(w^s)$. I will therefore use the following properties of the strictly increasing convex function $\phi(u) = v^{-1}(u)$, properties which can be very simply derived from equations (A.1) to (A.3):

$$\phi(0) = 0, \tag{A.5}$$

$$\lim_{u \to -\infty} \phi(u) = -\infty, \tag{A.6}$$

$$\lim_{u \to +\infty} \phi(u) = +\infty. \tag{A.7}$$

$$\tag{A.8}$$

In order to ensure that the benefits of production are large enough to warrant extracting high effort from the manager at least for small values of μ, it is necessary to put a lower bound on the net benefits of the good state:

$$\phi\left(\frac{e^H}{\pi_H}\right) - \phi\left(-\frac{\pi_G e^H}{\pi_H(1 - \pi_G)}\right) < B - c \tag{A.9}$$

where

$$P_G = \pi_H + (1 - \pi_H)\pi_G$$

is the probability that the project will be continued with monitoring. Note that the left hand side of (A.9) is *greater than* $\phi(e^H/\pi_H)$.

I will first assume that there is vertical integration and show that the variation of the payoff of the owner/client as a function of μ has the shape depicted on figure **??**. The consequences for the choice between integration and no integration will then be quickly explored.

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[12]Risk neutrality of the manager does not substantially affect the results. See the end of this appendix for a discussion of its consequences.

A.1 Contracts that induce monitoring

We will begin by studying the contracts that induce monitoring. The payoff of the client/owner, $\text{Payoff}^m(\mu)$, is the value of the following problem

$$
\min_{u,u^s} \quad P_G(B-c) - [P_G\phi(u) + (1-P_G)\phi(u^s)] - \mu
$$

$$
\text{subject to} \quad u - u^s \geq \frac{e^H}{\pi_H(1-\pi_G)} \qquad \text{(high effort)}
$$

$$
P_G u + (1-P_G)u^s \geq e^H \qquad \text{(individual rationality)}
$$

$$
\phi(u) - \phi(u^s) \leq B - c - \frac{\mu}{\pi_G(1-\pi_H)} \qquad \text{(monitoring)}
$$

The straightforward individual rationality constraint replaces the non-negativity of w^s. The other constraints are similar to those of problem (**??**)

In the plane (u, u^s) the straight line of equation

$$
u - u^s = \frac{e^H}{\pi_H(1-\pi_G)}
$$

intersects only once the curve containing the points that satisfy

$$
\phi(u) - \phi(u^s) = B - c - \frac{\mu}{\pi_H(1-\pi_G)}.
$$

Indeed, it is easy to check that there is at least one intersection point[13] and that for $u > u^s$ this second curve has slope greater[14] than 1.

Therefore, when it is not empty, that is when μ is small enough, the feasible set has the shape represented on figure **??**. (I will explain the position of the optimal solution shortly.)

The point at the intersection of the individual rationality and incentive compatibility constraint has coordinates

$$
(u, u^s) = \left(\frac{e^H}{\pi_H}, -\frac{\pi_G e^H}{\pi_H(1-\pi_G)} \right). \tag{A.10}
$$

---

[13]The straight line and the curve intersect for a value of u^s such that

$$
\phi\left(u^s + \frac{e^H}{\pi_H(1-\pi_G)}\right) - \phi(u^s) = B - c - \frac{\mu}{\pi_H(1-\pi_G)}.
$$

From equations (A.1) to (A.3) and the strict convexity of the function ϕ this equation has exactly one solution.

[14]We have $\phi(u) - \phi(u^s) = C^{\text{ste}}$. Hence along the curve

$$
\frac{du^s}{du} = \frac{\phi'(u)}{\phi(u^s)} > 1.
$$

From (A.9), this point satisfies $\phi(u) - \phi(u^s) < B - c$, and therefore when $\mu = 0$ it belongs to the feasible set. As μ increases, the monitoring constraint moves to the left, and the feasible set shrinks, until it eventually becomes empty.

I now show that the solution of problem (**??**) lies as indicated on figure **??**. The objective function is decreasing in u and u^s, and the solution is therefore on the individual rationality constraint. A small movement along this constraint satisfies

$$P_G du + (1 - P_G) du^s = 0,$$

and changes the objective function by

$$P_G \phi'(u) du + (1 - P_G) \phi'(u^s) du^s = (1 - P_G)(\phi'(u^s) - \phi'(u)) du^s. \qquad (A.11)$$

The coefficient of du^s in the right hand side of this equation is negative. The solution will make it as small as possible, and this proves the result. This implies:

$$\text{Payoff}^m(\mu) = P_G(B - c) - P_G \phi(\frac{e^H}{\pi_H}) - (1 - P_G)\phi(-\frac{\pi_G e^H}{\pi_H(1 - \pi_G)}) - \mu. \qquad (A.12)$$

From (A.9), $\text{Payoff}^m(0) > 0$. Therefore, while the feasible set is not empty, $\partial \text{Payoff}^m(\mu)/\partial\mu = -1$, as in the main text. The graph of the payoff as a function of μ will therefore be similar to that of figure **??**, except for the formula determining the upper bound of μ. This upper bound will be

$$\mu^m = \left[B - c - \phi(\frac{e^H}{\pi_H}) + \phi(-\frac{\pi_G e^H}{\pi_H(1 - \pi_G)}) \right] \pi_G(1 - \pi_H) > 0, \qquad (A.13)$$

and by (A.9):

$$\text{Payoff}^m(\mu^m) = \pi_H[B - c - \phi(\frac{e^H}{\pi_H})] - (1 - \pi_H)\phi(-\frac{\pi_G e^H}{\pi_H(1 - \pi_G)}), \qquad (A.14)$$

which is also strictly positive.

A.2 Contracts that do not induce monitoring

I now turn to the study of the contracts that do not induce monitoring, and will show that for these contracts the payoff increases with μ.

The payoff of the client/owner, $\text{Payoff}^{nm}(\mu)$, is the value of the following problem:

$$\max_{u, u^s} \quad \pi_H(B - c - \phi(u)) - (1 - \pi_H)\phi(u^s)$$

$$\text{subject to} \quad u - u^s \geq \frac{e^H}{\pi_H} \qquad \qquad \text{(high effort)}$$

$$\pi_H u + (1 - \pi_H)u^s \geq e^H \qquad \text{(individual rationality)}$$

$$\phi(u) - \phi(u^s) \geq B - c - \frac{\mu}{\pi_G(1 - \pi_H)} \quad \text{(no monitoring)}$$

When μ is small enough, we find ourselves in the configuration of figure **??**. By a reasoning similar to the one leading to equation (A.11), one can show that the optimal solution is at the intersection of the no monitoring and the individual rationality constraints. When μ becomes larger, the optimal solution is at the intersection[15] of the incentive compatibility and individual rationality constraints, whose coordinates are

$$(u, u^s) = (\frac{e^H}{\pi_H}, 0),$$

and the payoff to the owner/client becomes independent of μ.

It follows that the graph of the payoff to the owner/client as a function of μ is an increasing function, strictly increasing when μ is small, and constant after it reaches the value

$$\mu^{nm} = \pi_G(1 - \pi_H)[B - c - \phi(\frac{e^H}{\pi_H})], \tag{A.15}$$

at which point the payoff is equal to

$$\text{Payoff}^{nm}(\mu^{nm}) = \pi_H[B - c - \phi(\frac{e^H}{\pi_H})]. \tag{A.16}$$

The shape of the graph is basically similar to that of figure **??**, except for the fact that $\text{Payoff}^{nm}(0) > 0$.

A.3 Choosing vertical integration

From equations (A.13) and (A.15):

$$\mu^{nm} > \mu^m. \tag{A.17}$$

From equations (A.14) and (A.16):

$$\text{Payoff}^{nm}(\mu^{nm}) < \text{Payoff}^m(\mu^m). \tag{A.18}$$

On figure **??**, I have drawn the shape of the payoffs as a function of μ in the integration case. As can easily be seen, we obtain the same qualitative result than in the main text: for small μ vertical integration is preferable, for large μ it is preferable not to integrate. However, there is one difference in interpretation: vertical integration is always preferable as long as monitoring is feasible. When it is not, no integration is feasible. In the model of the main text, one could prefer no integration even when monitoring would have been optimal under integration.

A.4 Risk neutrality

Modulo some minor differences of presentation (for instance, the monitoring constraint would not intersect the high effort constraint exactly once, but would either not intersect it at all or would be identical to it), all the results go through if the manager is risk neutral. The only difficulty is a difficulty of interpretation: why is it not optimal to sell him the two firms?

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[15]When $\mu = 0$ this point does not belong to the feasible set, because (A.9) implies $\phi(u) < B - c$.