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EMPLOYEE OPPORTUNISM AND REDUNDANCY IN FIRMS*

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Firms who share specialized information or client connections with their employees expose themselves to the risk of opportunism, in which their workers leave the firm and go into business for themselves. Legal and contractual solutions to the problem of employee opportunism are not always viable. Instead, firms may organize themselves so as to discourage opportunism. We study an organizational scheme called internal redundancy: the practice of assigning employees to overlapping tasks so that they are less likely to possess sole access to trade secrets or customers, and therefore, less likely to profit if they leave the firm.

1. Introduction

Many economic activities require firms to share valuable information with their employees. For example, a research scientist working on an R&D project will inevitably learn production and design techniques that he could never have acquired on his own. Similarly, partners in legal, investment, and consulting enterprises establish valuable connections with their companies' clients.

In such cases as these, firms are exposed to the risk of opportunistic behavior by their employees; behavior which has been described in other contexts by Williamson (1975, 1979). A research scientist who has received specialized training, and perhaps gained access to proprietary 'trade secrets', may quit his job and go into business for himself. Similarly, a lawyer may leave his partnership, anticipating that the big clients whose accounts he has been handling will come along with him. Such oportunism has its real

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economic costs, since firms exposed to it may be unwilling to invest in training their employees.

There are two ways in which firms can seek to protect themselves from employee opportunism. The first is legal. Patents grant firms sole ownership of innovations, and post-employment restraints can be written into employment contracts to prevent employees from competing with their current employer in the future. Unfortunately, such legal measures are often difficult to interpret and enforce in court, and can be economically inefficient. Blake (1960) argues that the boundary between firms' trade secrets and employees' personal skills is ambiguous: 'In modern laboratories, design centers, and planning conferences, where do trade secrets begin and the employee's intellectual tools of trade end?' And Trebilcock (1985) notes that post-employment restraints are often shunned in practice, as they can be too sweeping – limiting not only opportunism, but also economically efficient job mobility and valued personal freedom.

When legal measures are not a feasible solution to the problem of opportunism, firms may wish to resort to another tactic – organizing themselves internally in such a manner as to lessen the incentives for opportunistic behavior. There are a variety of ways in which this can be done. One possibility suggested by Trebilcock is the 'fragmentation' scheme: organizing in such a way that no single employee has access to enough information to profitably leave the firm. Clearly, such a tactic will be more effective in some circumstances than in others, and may be infeasible when a firm's activities require a group leader or supervisor.

We focus on another organizational scheme through which firms might try to cope with opportunism: the practice of assigning employees to partially overlapping tasks, which we call internal redundancy. A researcher will be less tempted to strike out on his own if there is a chance that the project he is working on, or the skills he has acquired, will be duplicated by someone else, thereby preventing him from possessing monopoly power over any products which he develops. Similarly, a lawyer will be less likely to leave his partnership if he has not had exclusive dealings with his clients, since it is possible that these clients will remain with the existing partnership.

Since it deters opportunism, redundancy will be used even when it is inefficient from the standpoint of production. As we show in what follows, the magnitude of this distortion depends on a variety of factors. One important determinant is the degree to which firms can monitor the progress of their workers' activities. Imperfect monitoring of worker progress not only hampers a firm's ability to provide risk-sharing [a familiar result – see Hart (1983)], but leads to increased use of redundancy as well.

The concept of redundancy has arisen in other contexts in the literature. Nalebuff and Stiglitz (1983) suggests that assigning workers to redundant tasks and paying them based on relative performance can induce increased worker effort. Downs (1967) points out that the redundancy of information collection channels can ameliorate Tullock's 'control loss' inefficiency, the tendency for information to become distorted as it passes up and down a vertical hierarchy. From another point of view, our work connects the 'ex-post opportunism' inefficiency which has been stressed by Williamson (1975, 1979) to the theory of the firm, pioneered by Coase (1937), and extended by Alchian and Demsetz (1972) and others: we start from the premise that opportunism can not only arise amongst agents contracting in the market, but also amongst agents brought together into a firm for production reasons.

The analysis proceeds as follows: section 2 introduces the formal model we will use; section 3 specifies the type of contractual arrangements that will emerge between firms and their employees; and section 4 presents our theoretical results. Section 5 provides a brief summary of the main points, and the Appendix contains technical proofs.

2. Model of a research firm

In this section we develop a formal model of a research firm which faces the problem of employee opportunism.[1] At date 0, the firm hires employees, trains them, and assigns them to specific projects. An 'inside' project refers to one that the worker starts on while employed at the firm – a worker cannot begin such a project without the benefit of the specific training and capital the firm can supply. In contrast, 'outside' project refers to an opportunity which requires less training and capital and can be directly undertaken by workers, outside the firm. After date 0, the worker no longer has the option of signing on with firm, because research training has already begun. The outside project begins at date 1; therefore, workers who sign on with the firm at date 0 have the option of leaving to pursue the outside project at this time.

By date 1, hired research workers have acquired substantial specialized information about their inside project – this information may take the form of partially developed design techniques, future research leads, or the like. If a researcher chooses to, he can leave the firm at this time and continue trying to develop the inside project on his own – behavior which we call 'opportunism'. His behavior is opportunistic because, if he does leave at this time, and later successfully develops products, he will possess full ownership rights – the project is still in progress, and the firm cannot enforce patents or property rights over any tangible products produced at a later date.

All payoffs occur at date 2. At this date, the project is completed. We

[1]The formal model we describe in this section applies more literally to the R&D case discussed above than it does to the client connections problem. However, with slight modifications in interpretation, the basic points carry over to the latter.

assume that when a single individual or firm possesses exclusive ownership over a successful project, he can market the project as a monopolist, and the project pays off one unit of income. However, if a project has been developed independently by more than one owner, competition in the product market reduces the profits each owner can earn; we discuss this further shortly. An unsuccessful project pays off zero units at date 2 in all cases. If the researcher has remained with the firm at date 1, the firm receives the income from a successful project. If the researcher has left at date 1 to pursue the inside project independently, he receives the income. Workers who remain inside the firm receive a wage payment x and utility $U(x)$; we normalize U so that $U(0)=0$ and $U(1)=1$. If the worker has left the firm to pursue his outside project, he receives an expected utility of z.

Some inside research projects progress better than others, and we would expect opportunism to be more of a problem amongst workers whose projects are progressing particularly well. To model this phenomenon, we assume that at date 1 each researcher inside the firm receives a signal telling him the probability of his project being successful at date 2. If the researcher receives the signal 'good', the probability is p that the project will be successful, and $1-p$ that it will fail. If the researcher receives the signal 'bad', the probability is 0 that the project will be successful.[2] We assume that p is $>z$, so that projects with a good signal are typically more attractive to a researcher than the outside opportunity, whereas projects with a bad signal are less attractive.

We define g to be the probability, as of date 0, that the worker will receive a good signal at date 1. As of date 0, the expected payoff to an inside project which is marketed monopolistically is then gp.

Given the research process which we have described above, the firm faces a dilemma. It must bear the cost of training workers so that they can pursue the inside project; however, once they are trained, they have incentive to leave the firm. Ex-ante workers are willing to join the firm for compensation which gives them the utility z which they can earn outside the firm. Ex-post, however, workers who have received good signals will opportunistically leave to pursue their inside projects independently unless their compensation is raised to given them utility equal to p. If the firm does raise the compensation of good signal workers, it may be unable to recover its training costs.

As discussed in the introduction, there are two possible ways in which the firm can deal with this problem – legal and organizational. We wish to focus on an organizational approach, the practice of redundancy, in which two researchers are assigned to the same inside research project. Thus we assume that legal restraints are not available to the firm. In the context of our

[2]One can generalize slightly by assuming that a bad signal indicates that the probability of success is r, where r is less than z, but this leads to the same results.

model, this amounts to disallowing the imposition of fines on those workers who leave the firm at date 1.[3]

We model redundancy as a random variable Q: $Q=0$ means that the two researchers have been assigned to the same project, while $Q=1$ means that they have been assigned to different projects. At date 0, the firm chooses the expected value of Q, $q=EQ$, where q represents the probability that the two researchers will be assigned to different projects. Thus, q ranges between 0 and 1: a q of 0 indicates certain redundancy, and a q of 1 indicates certain uniqueness of projects. There are a number of ways to interpret q. The firm might give each worker a list of possible projects to pursue, and allow the worker to randomly select a project from the list. Here q measures the extent to which the two lists contain overlapping projects. Alternatively, the firm could pursue a mixed strategy in which it knowingly assigns the two workers to different projects a fraction q of the time, and to the same project $1-q$ of the time.[4]

If the two researchers are assigned to different projects ($Q=1$) their activities are completely independently of one another, so that whether or not one of the research projects generates a successful product has no effect on whether or not the other project generates a successful product. However, when the two researchers are assigned to the same project ($Q=0$), they always receive the same signal (good or bad), and either both develop a successful product, in which case the products are identical, or neither develop a product. Hence in our formulation, redundancy has no beneficial effects on the production of successful projects, so that if opportunism was not a problem, productive efficiency would lead the firm to choose q equal to one.[5]

Redundancy discourages opportunism because employees who leave at date 1 face the possibility that someone else in the firm is also working on the same project. When the project does turn out to be redundant, which

[3]It is possible to rule out such fines endogenously. If the courts cannot distinguish whether departing workers leave to pursue their inside or outside project, any fines would have to be applied to all workers who leave the firm. Such fines would discourage opportunism, but would also deter bad signal workers from leaving to pursue their outside opportunities. Since the firm would then have to compensate such bad signal workers, fines would impose an efficiency cost. If z is relatively large, or g, the probability of a good signal is small, such costs are large and firms will prefer not to use fines even if they have the option to do so. In a separate appendix (available on request) we have explicitly calculated the regimes under which fines will or will not be imposed under certain simplifying assumptions.

[4]In the client connections case, q can be thought of as a deterministic measure of the extent to which there is overlap in partner-client relations, or, in a hierarchical setting, of supervisor contact with clients. The more overlap (lower q), the less likely it is that a client will follow a partner out of the firm. Q is then the realization of whether or not a client actually follows a departing partner.

[5]We are abstracting from situations in which some redundancy is actually beneficial to production. This would occur when research workers' results are not perfectly correlated – so that increasing the number of workers increases the chances of a successful outcome.

happens with probability $1-q$, the most that the employee can hope to earn is $\frac{1}{2}$. And it is likely that he will earn considerably less, because whereas the firm always has a monopoly over its products when its employees do not opportunistically leave, an employee who has left and develops a redundant project must compete against someone else who is marketing an identical product. Competition in the product market will drive aggregate profits below 1, and in the extreme case (pure competition) which we assume, all the way to 0. All our results continue to apply in the more general case where two competitors each receive an amount c, with $0<c<\frac{1}{2}$, if they both wind up trying to market the same product.

At date 0, the firm hires a large number of employees, and organizes them into research pairs. q then represents the average degree of redundancy amongst these pairs; researchers in different pairs are always pursuing different projects. Workers may know the identity of their partners; however, we assume that the courts cannot verify who has been paired with them. This assumption simplifies the analysis by eliminating schemes in which one worker's wages depend on the actions of another.

The firm's choice of q will depend on the information it has about its researchers' activities. We assume that the firm observes whether or not those workers who stay on through date 2 realize a success. However, it will not always be able to monitor its researchers' activities closely enough to decipher whether a researcher has received a good or bad signal at date 1.

We distinguish two cases. In the first case, which we call symmetric information, the firm directly observes the signal which the researcher receives at date 1. In the second case, which we call asymmetric information, the firm never gains direct access to researchers' signals. In this situation, firms face the further complication that bad signal workers, whom it cannot separate from good signal workers, will be tempted to stay on, thereby earning the rents (utility in excess of z) intended solely for good signal workers.

3. Contractual arrangements

At date 0, the firm signs a contract with each researcher it hires. Since all researchers are ex-ante identical, each researcher will sign the same contract. In this section, we examine the variables which this contract will depend upon, and the consistency requirements which it must satisfy. We leave the formal determination of the optimal contract to the next section.

Based on the technology we have specified, each inside project can generate one of the following three outcomes:

(1) good signal, project succeeds, probability $=gp$,
(2) good signal, project fails, probability $=g(1-p)$,

(3) bad signal, project fails, probability $=(1-g)$.

A completely contingent contract must allow payments to the researcher to depend on which of these three outcomes arises. We denote by w_s the wage the firm pays to a worker who obtains a good signal and whose project succeeds. Similarly, w_f represents the wage to a worker who obtains a good signal, but whose project fails. Note that, in equilibrium, a bad signal worker does not receive a wage, because he will leave the firm at date 1 to pursue his outside opportunity, and wage payments occur at date 2. Still, to allow for every possible contingency, we must consider the fact that firms may want to pay an exit bonus to workers who leave the firm at date 1. Such a bonus is only of use in the asymmetric information case, when it may help induce bad signal workers to leave the firm – in the symmetric information case, the firm can identify and dismiss these workers directly. We denote such an exit bonus by b, and remark that because firms cannot distinguish between good and bad signal employees in this case, such a bonus will have to be paid uniformly to all leaving employees.

Thus, a complete contract specifies the outcome contingent wages w_s and w_f for those workers who stay with the firm, and in the asymmetric information case, the exit bonus b for those workers who leave at date 1.

We now discuss the constraints which a contract must satisfy to be viable. Consider first the difficulties the firm faces in trying to prevent good signal workers from leaving the firm. These difficulties arise in both the symmetric and asymmetric information cases. On the one hand, a good signal worker must be deterred from leaving to pursue his outside project. Hence, we require

$$pU(w_s)+(1-p)U(w_f)\geqq zU(1+b)+(1-z)U(b). \tag{1}$$

The left-hand side of (1) refers to the expected utility of a good signal worker who remains with the firm, while the right-hand side refers to the expected utility of a worker who leaves the firm to pursue his outside project. (Under symmetric information, $b=0$, and the right-hand side is simply equal to z.) As long as the inequality in (1) is satisfied, a good signal worker will never leave to pursue his outside project.

On the other hand, a good signal worker must also be deterred from opportunistically leaving the firm to pursue his inside project independently; hence, we require

$$pU(w_s)+(1-p)U(w_f)\geqq pqU(1+b)+(1-pq)U(b). \tag{2}$$

In (2), pq represents the probability (as of date 1) of the good signal worker producing a nonredundant marketable product as of date 2, in which case he earns $1+b$ units of income; $(1-pq)$ represents the probability that either his inside project fails, or he produces a redundant product, in either of which cases he earns only b units of income. (Again, $b=0$ under symmetric information, and the right-hand side is just pq.)

In the asymmetric information case, the contract must satisfy a further incentive compatibility constraint. In particular, a worker who receives a bad signal must be encouraged to leave the firm, and not to stay. We can write this requirement as

$$zU(1+b)+(1-z)U(b)\geqq U(w_f). \tag{3}$$

In (3), the right-hand side refers to the worker's utility if he remains with the firm, and takes into account the fact that his project is certain to fail, in which case he receives income of w_f; the left-hand side refers to the worker's expected utility from leaving to pursue his outside project. Constraint (3) illustrates why an exit bonus may be desirable in the asymmetric information case – it makes it more attractive to bad signal workers to admit they have received a bad signal and leave the firm, rather than masquerading as good signal workers.

The contract must also guarantee its workers an ex-ante expected utility of at least z, since this is the expected utility of the 'competing offer' as of date 0, the outside project which each worker may pursue independently. This constraint is

$$g[pU(w_s)+(1-p)U(w_f)]+(1-g)[zU(1+b)+(1-z)U(b)]\geqq z. \tag{4}$$

Finally, we note that the bonus b is constrained to be $\geqq 0$, q is constrained to lie between 0 and 1, and w_s and w_f must be nonnegative.

Several simplifications of (1)–(4) can be deduced. First, manipulation demonstrates the (1) implies (4) directly; hence, we can disregard (4) in what follows. Second, (1) and (2) are equivalent to (2) combined with the following:

$$q\geqq z/p. \tag{1'}$$

To summarize: a feasible contract consists of values of b, q, w_s, and w_f, which satisfy (1'), (2), and (3) in the asymmetric information case, and of values of q, w_s, and w_f which satisfy (1') and (2) in the symmetric information case.

4. Results

For each pair of researchers which the firm hires, its expected profits are given by

$$(1+q)gp-2gpw_s-2g(1-p)w_f-2(1-g)b. \tag{5}$$

The first term in the expression represents expected revenues from projects developed, while the last three terms represent expected payments of wages and bonuses. With probability qgp, the firm will realize two unique successful projects, and thus a profit of 2, and with probability $(1-q)gp$, the firm will realize only one successful project and a profit of 1. So expected revenue is $(1+q)gp$. Clearly, with more internal redundancy (a lower q), expected revenues are lower. On the other hand, greater redundancy lowers the wages the firm has to pay in order to deter good signal workers from leaving and pursuing their inside project independently.

With symmetric information, the firm maximizes (5) subject to constraints (1′) and (2), over the control variables q, w_s, and w_f. ($b=0$ under symmetric information.) The problem is a simple one, and it is easy to verify the following proposition (formal proofs are contained in the appendix).

Proposition 1. In the symmetric information case:

(*i*) *(2) is met with equality; (1′) is met with equality only at the 'corner' solution $q=z/p$.*
(*ii*) *$w_s=w_f=U^{-1}(pq)$: there is complete risk-sharing for good signal workers.*
(*iii*) *The optimal q (henceforth denoted q_s^* where the subscript s refers to the 'symmetric' case) ranges from 1 to z/p, depending on the parameters.*

The reasoning for (ii) is this: once the good signal has been observed, it is optimal for the risk-neutral firm to provide complete insurance to its workers regarding the final outcome. By (2), the firm must guarantee its workers an expected utility of at least pq in the good signal case, or they will leave the firm. From the firm's point of view, this constraint is most cheaply met when wages are riskless. If wages were risky, the firm would have to pay a higher dollar amount to give the risk-averse workers the same expected utility. The firm does not, on the other hand, provide complete ex-ante insurance: good workers get an expected utility of pq, which is generally higher than the expected utility of z that bad signal workers get at date 1.

From (ii), we can see exactly how a lower q can help the firm: it lowers the rents that workers can extract by threatening to leave with an inside project. The basic effect at work here is something that may be termed 'the disciplinary benefit of threatened competition.' If $Q=0$, so that the two projects turn out to be the same thing, the project is worth more inside the firm than it is to the two workers if they left and competed (so long as c, the amount competitors receive when marketing indentical products, is less than $\frac{1}{2}$). Firms can take advantage of this fact by making the event $Q=0$ relatively likely, thereby forcing worker rents down faster than revenues.

According to constraint (1′), there is a limit beyond which q is no longer effective, namely the 'corner' solution $q=z/p$. There is no point in using redundancy to try to lower workers' expected utility below z, since they can always ensure themselves this amount by leaving to their outside opportunities.

We can examine the firm's choice of q more fully by focusing on the family of utility functions $U(x)=x^{\alpha}$, with $0\leq\alpha\leq 1$. We then obtain the following formula (substituting (2) in the objective function (5) and maximizing):

$$q_s^{*}=(1/p)(\alpha/2)^{(\alpha/(1-\alpha))}. \tag{6}$$

(Note: this formula is valid for interior solutions only. If the formula yields values of q_s^* greater than 1 or less than z/p, they should be interpreted as corner solutions at these points.)

It is apparent from the formula (6) that a higher value of p leads to q_s^* being lower: redundancy is more important when the good signal is a stronger indication that the inside project will be successful, so that workers are more tempted to behave opportunistically. It can also be verified that q_s^* is decreasing in α – there is more redundancy when workers are less risk-averse. As we approach complete risk neutrality, q_s^* is forced to its lower bound corner solution z/p. The intuition behind this is as follows: increased redundancy always lowers revenues linearly. Under risk neutrality, it also lowers wages linearly, but at a greater rate than it lowers revenues. Thus, the optimal solution is to push redundancy to its polar extreme and pay good signal workers the lowest possible wage, $U^{-1}(z)$.

With risk aversion, increased redundancy still lowers wages, but at a diminishing rate. Therefore, redundancy is not used as much. The more risk-averse are workers, the faster these diminishing returns set in, and the less redundancy is employed as a rent-reducing mechanism.

In the asymmetric information case, the firm still seeks to maximize profits as given by (5). However, in addition to the constraints (1′) and (2), it also faces the incentive constraint (3). As the following proposition tells us, this extra constraint changes the nature of the solution somewhat:

Proposition 2. In the assymetric information case:

(*i*) (2) *and* (3) *are met with equality;* (1′) *is only met with equality at the corner* $q=z/p$.

(*ii*) $w_s > w_f$ – *there is incomplete risk-sharing for good signal workers after date 1. Those whose projects are successful earn more than those whose projects fail.*

(iii) *An exit bonus is still never used.*

(iv) *Redundancy is higher than in the symmetric case: $q_a^* < q_s^*$ except when the latter was already at the corner $q_s^* = z/p$, in which case $q_a^* = q_s^* = z/p$.*

While complete wage insurance was feasible for good signal workers in the symmetric information case, it no longer is under asymmetric information. If we had $w_s = w_f$, with both providing a utility of $pq > z$, a bad signal worker would always wish to stay with the firm, rather than leaving to pursue his outside opportunity. By 'spreading' w_s and w_f, the firm can induce bad signal workers to leave. When the signal is good, a workers knows that it is relatively likely that the project will succeed. He prefers a gamble with a probability p of getting w_s and $1-p$ of getting w_f to his outside opportunity. When the signal is bad, however, and the worker knows with certainty that staying in the firm means getting w_f, he will prefer the outside opportunity.

Inducing the desired behavior is costly to the firm. Recall that in order to prevent good signal workers from leaving with the inside project, firms must ensure them a utility level of at least pq. Under symmetric information, this was accomplished with a fixed wage. Now the good signal wage is risky. In order for expected utility to remain at pq, the dollar expected value of wages must rise (for a given q), which is a cost to the firm. (Note that in the polar case of risk neutrality for incomes above zero, inducing truth-telling is costless, and the solution does not differ from that of the symmetric case.)

At first glance, it would appear that exit bonuses might be useful to the firm under asymmetric information. Incentive compatibility requires making the outside opportunity more attractive than a wage of w_f when the signal is bad. One can imagine two ways that this might be accomplished. The first, already discussed, is to lower w_f by spreading good signal wages. The second possibility is to pay an exit bonus, which also makes leaving the firm for an outside project a more appealing proposition.

While an exit bonus has the beneficial effect of encouraging bad signal workers to go to their outside opportunities, it also has two negative aspects: first, there is the direct cost of bonus payments, and second, there is the detrimental effect of encouraging opportunism by good signal workers, since any exit bonus must be paid to all workers who leave the firm. This second part of the trade-off is illustrated in a comparison of constraints (2) and (3) – it can be seen that increases in b loosen the latter, but tighten the former. As it turns out (see the Appendix for a proof), the tightening of the opportunism constraint (2) is always more significant in magnitude than the loosening of (3), so that even under asymmetric information, a bonus is never used.

Our final result is that redundancy is used more under asymmetric information than under symmetric information. Having shown that the exit bonus is zero allows us to calculate the optimal q under asymmetric information as

$$q_a^* = pq_s^* + (1-p)z/p. \tag{7}$$

Since q_s^* is always $\geqq z/p$, it follows immediately that $q_a^* \leqq q_s^*$ with equality holding only when q_s^* is already at the corner of z/p. Given the preceding elaboration of the costs involved in inducing the desired behavior under asymmetric information (in terms of wage spreading), this last fact should come as no surprise. The problem arises because good signal workers are guaranteed a higher utility than bad signal workers (pq, as opposed to z). Consequently, without wage spreading, bad signal workers would be tempted to misrepresent themselves as good signal workers, and stay inside the firm. In a sense $(pq-z)$ measures the extent of the temptation. The greater is this temptation, the more costs the firm has to bear, in the form of wage spreading, to induce bad signal workers to leave.

By lowering q (increasing redundancy), the firm forces the utilities of good and bad signal workers closer together, so that there is less temptation for bad signal workers to misrepresent themselves. This allows the firm to save on the costs of inducing the behavior it wants from bad signal workers. Thus, there is a second benefit to redundancy above and beyond that discussed in the symmetric information case, and more redundancy is used in equilibrium.

5. Conclusions

We have suggested that firms can overcome the problem of employee opportunism through the practice of internal redundancy, in which workers are assigned to overlapping tasks. Our analysis shows that the optimal degree of internal redundancy in a firm will depend on several factors, including the relative likelihood that projects will be successful, the monetary income workers can achieve by pursuing opportunities outside the firm, and worker risk aversion. Internal redundancy is also likely to be higher when firms possess less information about the progress of their employees' activities.

Although the model we have presented does not include supervisors or other vertical structure, it can readily be interpreted in a hierarchical framework. In this context, redundancy measures the resources devoted to supervision of worker projects, supervision which aims to keep management abreast of workers' progress and specialized project knowledge.

Appendix

In the symmetric information case, the firm's problem is

$$\text{Max}(1+q)gp - 2pgw_s - 2(1-p)gw_f \tag{A.1}$$

subject to

$$pU(w_s)+(1-p)U(w_f)\geqq pq \quad \text{and} \tag{A.2}$$

$$pq\geqq z, \tag{A.3}$$

where we have implicitly assumed that workers who receive a bad signal leave the firm to pursue their outside opportunity, and that the firm pays a 0 exit bonus. Both of these facts are straightforward to verify.

The first order conditions for this problem imply that $w_s=w_f$, and that (A.2) holds with equality, whereas (A.3) is slack except at the corner $q=z/p$. Substituting for w $(=w_s=w_f)$ from (A.2) into (A.1) leads to an unconstrained maximization over q. The first order condition for this constrained maximization is

$$q_s^*=(1/p)W'^{-1}(\tfrac{1}{2}), \tag{A.4}$$

where the function W ( ) refers to U^{-1}( ), W' refers to the derivative of W, and W'^{-1}( ) refers to the inverse of W'. Formula (6) in the text is a specialization of (A.4) to utility functions of the constant relative risk-aversion type, $U(x)=x^{\alpha}$.

We now turn to the asymmetric information case. First, we prove that the exit bonus is always 0. Allowing for an exit bonus, firm profits are given by

$$(1+q)gp-2gpw_s-2g(1-p)w_f-2(1-g)b, \tag{A.5}$$

and the three constraints facing the firm are

$$pU(w_s)+(1-p)U(w_f)\geqq pqU(1+b)+(1-pq)U(b), \tag{A.6}$$

$$pU(w_s)+(1-p)U(w_f)\geqq zU(1+b)+(1-z)U(b), \tag{A.7}$$

$$zU(1+b)+(1-z)U(b)\geqq U(w_f). \tag{A.8}$$

(A.6) and (A.8) hold with equality. Therefore, (A.8) can be used to solve for w_f in terms of b, and (A.6) can then be used to solve for w_s in terms of b and q. (A.5) is then reduced to a maximization over the two variables q and b. To determine whether or not b can ever be positive, we differentiate (A.5) with respect to b:

$$\mathrm{d}(\mathit{profits})/\mathrm{d}b=-2gp\,\mathrm{d}w_s/\mathrm{d}b-2g(1-p)\,\mathrm{d}w_f/\mathrm{d}b-2(1-g). \tag{A.9}$$

The right-hand side of (A.9) has three terms. The last term is negative.

From (A.8), the second term is also negative. Therefore, to show that d(profits)/db is negative, it is sufficient to show that dw_s/db is positive. In fact,

$$w_s = W\{(1/p)[pqU(1+b)+(1-pq)U(b)-(1-p)(zU(1+b)+(1-z)U(b))]\}, \tag{A.10}$$

Therefore, dw_s/db equals

$$W'\{\ \}(1/p)[U'(1+b)(pq-(1-p)z)+U'(b)(1-pq-(1-p)(1-z))],$$

which is positive for all q and for all b. This demonstrates that b always equals 0.

Substituting $b=0$ into the two binding constraints (A.6) and (A.8) reduces the firm's choice of optimal q to an unconstrained maximization of (A.5). The first order condition for this problem is

$$q_a^* = W'^{-1}(\tfrac{1}{2})+(1-p)z/p, \tag{A.11}$$

which is the result presented in the text as eq. (7). Notice that when W'^{-1} equals z (q_s^* at the corner z/p), q_a^* is also at the corner z/p.

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